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- ⇒ Microsystems and micromechanisms;
- ⇒ Electronic and microelectronic;
- ⇒ Optoelectronic and holography;
- ⇒ Precision Micromechanisms;
- ⇒ Instruments engineering;
- ⇒ Measurement technique;
- ⇒ Sensors and transducers;
- ⇒ Actuators, drives and microdrives;
- ⇒ Computer aided design;
- ⇒ Dimensional control automats;
- ⇒ Measurement apparatus and systems;
- ⇒ Environment quality control apparatus;
- ⇒ Industrial informatics;
- ⇒ Robotics and microrobotics;

SUMMARY

INDUSTRIAL ROBOT AUTOMATION

Conf. dr. ing. Paul Ciprian Patic
Valahia Univesity of Târgovişte

Abstract - Europe has achieved a leading position in manufacturing and use of robotics, with an annual turnover in robot sales estimated at about €3.5bn, which corresponds to some 33% on a global scale. When taking into account robot automation systems and related services, the annual turnover of some 225 European companies having robotic activities exceeds €13bn and is expanding at current growth rates of 7%.

Today, robotics affects a broad sector of economic activities from automotive and electronics industries to food, recycling, logistics, etc. Up to now however, robot automation technologies have mainly been deployed in capital-intensive large-volume manufacturing, resulting in relatively costly and complex robot systems, which often cannot be used in small and medium sized manufacturing. New branches of robot automation that emerge nowadays such as food, logistics, recycling etc. require radical new designs of robot systems.

Research and development efforts in robotics will strongly contribute to the creation of new opportunities towards European employment and growth. These opportunities are even more pronounced when taking into consideration apparent socio-economic factors such as the overhanging of our society, increasing the productivity of European industries or the need towards a knowledge-based society as formulated in the Lisbon strategy. Robotics is able to address sustainable perspectives to all of these factors.

Keywords – robot, *Installations,* Automotive Industries

1. INTRODUCTION

In the last 30-40 years, large enterprises in high-volume markets have managed to remain competitive and maintain qualified jobs by increasing their productivity, through, among others, the incremental adoption and use of advanced ICT and robotics technologies. In the 70s, robots have been introduced for the automation of a wide spectrum of tasks such as: assembly of cars, white goods, electronic devices, machining of metal and plastic parts, and handling of work pieces and objects of all kinds. Robotics has thus soon become a synonym for competitive manufacturing and a key contributing technology for strengthening the economic base of Europe.

So far, the automotive and electronics industries and their supply chains are the main users of robot systems and are accounting for more than 60% of the total annual robot sales. Robotic technologies have thus mainly been driven by the needs of these high-volume market industries.

In these global key markets where relatively few robot manufacturers can compete, European robot manufacturers face today a fierce competition.

To remain competitive in the global arena, future manufacturing scenarios throughout all industrial branches will have to combine highest productivity and flexibility with minimal lifecycle-cost of manufacturing equipment. This is particularly valid for today's small and medium sized productions as these are particularly prone to relocation due to high labor costs.

As mentioned above, so far, robot automation technologies have been developed specifically for capital-intensive large-volume manufacturing, resulting in relatively costly and complex systems, which often cannot be used in small and medium sized manufacturing. Furthermore new branches of robot automation such as food, logistics, recycling etc. require radical new designs of robot systems.

Future robot systems cannot be a mere extrapolation of today's technology but rather follow new design principles required in a wide range of new application areas (application pull). At the same time, novel technologies, particularly coming from the IT world and the mass markets will have an increasing impact on the design, performance and cost of future industrial robot automation (technology push). From the current trends, it is evident that the operation of robots will increasingly depend on information generated by sensors, worker instructions or CAD product data. Thus it can be expected that manufacturing competence will be further concentrated on robot systems which are expected to become a key component in the digital factory of the future.

In this report, the future of manufacturing automation has been depicted in five scenarios in order to formulate challenging requirements for future robotic systems, identify main obstacles to progress and deduce relevant research directions. The culminating long-term vision (year 2025) in robot automation is that of ***"A robot assistant serving the worker(s) at the manual workplace and being fully integrated as an agent in symbiotic manufacturing systems".***

Related key technology challenges for pursuing successful long-term industrial robot automation are introduced at three levels: (1) basic technologies, (2) robot components and (3) systems integration:

1. *Basic technologies*: RTD challenges related to the development of robot assistants concern mainly their required intelligent system behavior and its underlying functionalities like perception, decision making, real time physical action, system architecture, learning, and use of natural language and dialogues.

2. *Robot components*: Industrial robots have always been depending on the availability of key-components such as actuators, sensors, materials and human-computer-interfaces as enablers for novel systems and applications. Besides component functionality and performance, aspects of mechanical, electrical and informational integration within standard system architectures are of increasing importance. Microsystems have entered as sensors, actuators and switches robotics. Further potential lies in creating robot structures which embed micro-systems (sensors, actuators, circuits) into materials (so called smart matter systems) helping to create new light-weight, low inertia material for new actuation devices.

3. On a *systems integration* level, the main challenges lie in the development of methods and tools for instructing and synchronizing the operation of a group of cooperative robots at the shop-floor.

Furthermore, the development of the concept of hyper flexible manufacturing systems implies soon the availability of: consistent middleware for automation modules to seamlessly connect robots, peripheral devices and industrial IT systems without reprogramming everything ("plug-and-play"); the introduction of wireless techniques on the shop-floor; mobile work-cells involving mobile robots and manufacturing equipment for a swift change-over of manufacturing lines to new production needs; and, the establishment of a life-cycle-oriented approach of production equipment (procurement, financing, planning).

Competitive manufacturing of the future will increasingly depend on the progress of robotics technologies and the availability of safe and cost-effective robotic products and related services.

We expect significant socio-economic impact in the following four categories of industrial stakeholders: end-user industries, existing robot automation manufacturers and system integrators, new start-ups in robotics and product-related service-industries.

2. CURRENT SITUATION OF ROBOT AUTOMATION IN EUROPE

Today, Europe has achieved a leading position in manufacturing and use of robotics equipment. The annual sales volume of robots is estimated at about € 3.1 billion, which corresponds to some 33% on a global scale, see Figure 1.

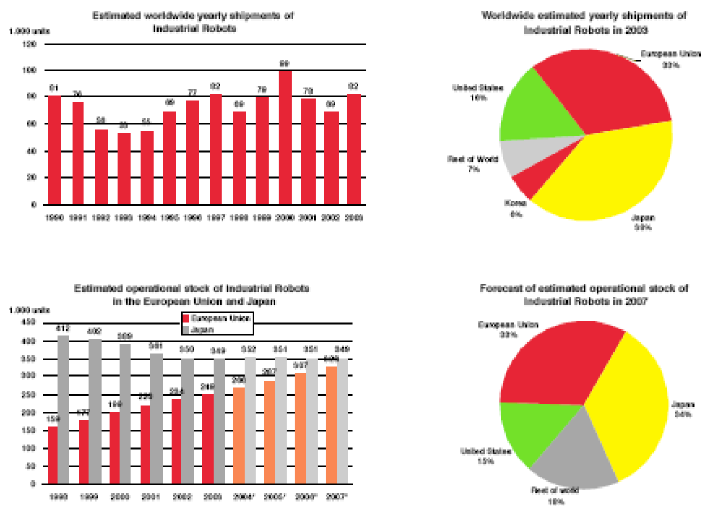

Figure 1: Installations and shipments of industrial robots worldwide

When taking into account sales of robot components, system integration and other services, the total revenues add up to some € 13 billion.

Robots are special in that they both enable flexible knowledge-based production and are a complex knowledge-based product by themselves. The relatively few European robot industries and component manufacturers have a pivotal role in the manufacturing supply chain, but they are directly exposed to stiff competition, particularly from Japan and Korea.

A comparison of robotic usage is indicated by the robot density, i.e., the number of robots per 10,000 workers, see Figures 2. Despite the differing character and structure of national industries, from this robot density number it can be seen that European robot density lags behind Japan. Another factor is the dominant number of robots being used in non-automotive applications with respect to automotive sector which is obvious for Finland and Sweden.

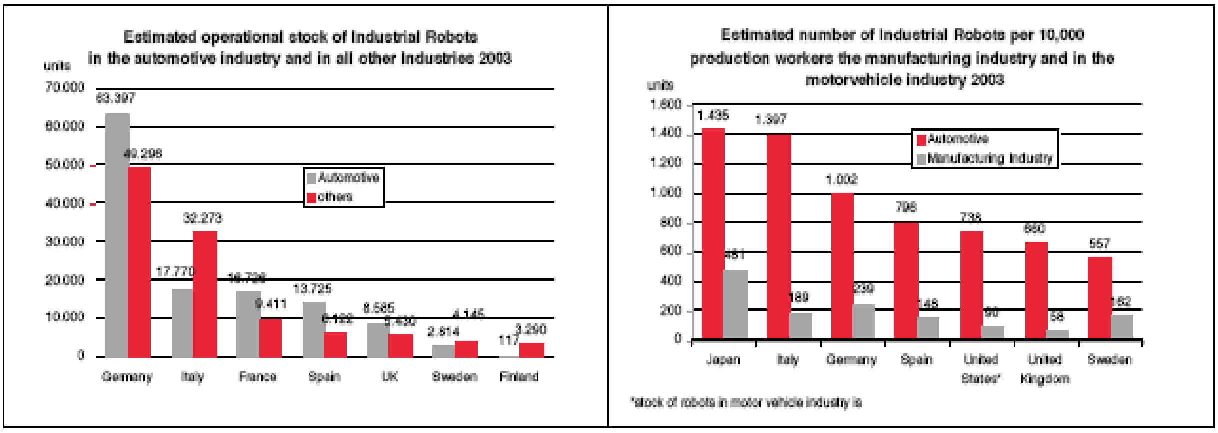

Figure 2: Robot density in automotive

However international efforts are just as pronounced:

• The Japanese Robot Association (JARA) has launched robotics initiatives worth €300m;

• Korean research and industry is in the progress of a strategic robotics research programme worth €400m.

Both programmes are embedded into large national roadmaps towards gaining competitive edges in a critical key technology for future manufacturing across all industries.

3. CURRENT AND FUTURE KEY-BUSINESS DRIVERS

So far, industrial robot technology and products have largely been driven by the requirements of the automotive and the electronics (light assembly) industry. It is foreseen that future manufacturing paradigms in these industries will still be largely depending on future robotic products, solutions and services. However, the emergence of other applications from non-automotive industries opens up new technological horizons and market opportunities for robotic technologies.

3.1 Automotive Industries

So far, robots have been mainly used in the automotive industries, including their supply chains, accounting for more than 60% of total robot sales. Typically prime targets for robot automation in car manufacturing are welding, assembly of body, motor and gear-box, and painting and coating. Automotive industries as the key application driver in terms of cost, technology and services robotics industry are subject to fierce global competition (see Figure 3).

Robots in the automotive sector			
Make	Japan	Europe	Other
Honda	100 %		
Toyota	100 %		
Nissan	100 %		
Mazda	100 %		
VW	10 %	90 %	
BMW	20 %	80 %	
DC	20 %	80 %	
Renault	50 %	50 %	
PSA	50 %	50 %	
Ford	50 %	50 %	
GM	80 %	20 %	
Korean	60 %	20 %	20 %

Increasing investment portion of robotics by car industry and 1st tier suppliers.

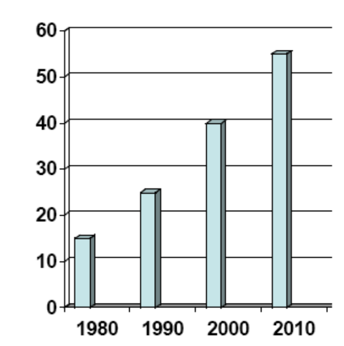

Figure 3: Origin of robot supplier in the automotive industry

Furthermore robot systems increasingly become the central portion of investments in automotive manufacturing which may reach 60 % of the total manufacturing equipment investment in the year 2010 (for car and 1st tier suppliers). Generally it is estimated that the cost of a robot automation investment in these industries accounts to 4 times the unit prize of a robot.

The degree of automation in the automotive industries is expected to increase in the future as robots will push the limits towards flexibility regarding faster change-over-times of different product types (through rapid programming generation schemes), capabilities to deal with tolerances (through an extensive use of sensors) and costs (by reducing customized work-cell installations and reuse of manufacturing equipment). These immediate challenges lead to the following current RTD trends in robotics:

• Expensive single-purpose transport and fixing equipment is replaced by standard robots thus allowing continuous production flows. Remaining fixtures may be adjusted by the robot itself.

• Cooperative robots in a work-cell coordinate handling, fixing and process tasks so that robots may be easily adjusted to varying work piece geometries, process parameters and task sequences. Short change-over times are reached by automated program generation which takes into account necessary synchronization, collision avoidance and robot-to-robot calibration.

• Measuring devices mounted on robots and increased use of sensor systems and RFID-tagged parts carrying individual information contributes to better dealing with tolerances in automated processes.

• Human-robot-cooperation bridges the gap between fully manual and fully automated task execution. People and robots will share sensing, cognitive and physical capabilities.

3.2 Electronics Industries

Electronics industries have reached most important advances in the use of robot automation planning and operation responding to highest requirements in flexibility (uncertain product lifetimes and variants, throughput, lot sizes) and cost by:

• Consistent modularization of equipment and control in order to adapt to varying degrees of automation, to allow the reuse of equipment, and to add capacity on demand (extension of manufacturing work-cells);

• Lean and structured manufacturing layouts to minimize transport and to effectively combine manual and automated work-cells;

• IT-based engineering tools for concurrent product/production planning and design, programming and servicing of the equipment;

• Automated testing of electronic components (computer vision, electronic test equipments) for a 100% quality control;

• Advanced manufacturing processes (joining, wiring, coating, gluing) which are at the same time suitable for mass products and robot guidance and control. Here, laser based processes will play an increasing role in terms of joining, coating, cutting, and finishing.

3.3 Current and Future Industries Acting as Application Drivers

There are numerous new fields of applications in which robot technology is not widespread today due to its lack of flexibility and high costs involved when dealing with varying lot sizes and variable product geometries. New robotic applications will soon emerge from new industries and from SME's, which cannot use today's inflexible robot technology or which still require a lot of manual operations under strenuous, unhealthy and hazardous conditions.

Relieving people from bad working conditions (e.g., operation of hazardous machines, handling poisonous or heavy material, working in dangerous or unpleasant environments) leads to many new opportunities for applying robotics technology. Examples of bad working conditions can be found in foundries or the metal working industry. Besides the need of handling objects at very high temperatures, work under unhealthy conditions takes place in manual fettling operations, which contribute to about 40% of the total production cost in a foundry. Manual fettling means heavy lifts, strong vibrations, metal dust and high noise levels, resulting in annual hospitalization costs of more than €150m in Europe. Bad working conditions can also be found in slaughterhouses, fisheries and cold stores where beside low temperatures also the handling of sharp tools makes the work unhealthy and hazardous. Other examples where robots can improve the working environment are painter workshops, glazier workshops and garbage handling plants.

4. A EUROPEAN VISION FOR LONG-TERM INDUSTRIAL ROBOT APPLICATIONS

Long-term visions toward industrial robots of the future have been depicted in five scenarios which are given in the following as examples:

A. Robot assistants as a versatile tool at the workplace;

B. Robot assistants in crafts;

C. Robots for empowering humans;

D. Multi-robot cooperation;

E. Hyper-modular Work-cell Designs.

A long-range vision (15 years) has been formulated towards the development and use of industrial robotics in manufacturing scenarios of the future.

A robot assistant serves the worker(s) at the manual workplace and is fully integrated as an agent in symbiotic manufacturing systems.

The robot assistant should have the following features:

• Displaceable (with very little effort) or mobile (possibly with autonomous navigation capability);

• Its arm is inherently safe so that its impacts are harmless;

• Capable of understanding human-like instructions (in end-user terms);

• Coordination with other robot assistants to perform larger cooperative tasks;

• Have access to CAD or digital factory data bases for generating programs and for parameterizing manufacturing processes;

• Possesses sensing capabilities to identify and locate objects and to control forces and torques;

• Deployable in existing manufacturing environments through plug and play functionality;

• Be able to learn skills and optimize them during process execution.

5. MAIN OBSTACLES TO PROGRESS

The realization of the described long-term vision is subject to overcoming the following barriers:

• Man-machine-interaction: Today, manufacturing tasks cannot be expressed in intuitive end-user terms as would be typically required for instructions by voice. Multimodal dialogues based on voice, graphics, and texts should be initiated to quickly resolve insufficient or ambiguous information;

• Mechanical limitations: Still, robot mechanics account for some 80% of the system price.

For some components, particularly gears, there exists a painful dependency on Japanese suppliers. In order to decrease this dependency, new drive lines should be developed where high density motors and compliant compact gears (e.g. on the basis of mechanical wave generators) with integrated torque and position sensors are used. Advanced control of such sensor based drive systems will make it possible to decrease weight and cost without reducing the robot performance. Furthermore a cooperative space-sharing robot (“no fences”) requires harmless motions. This can be achieved by intrinsically safe designs or suitable sensor equipment.

• Sensors: A dependable, full 3D recognition is required for work piece and worker localization in less structured environments (e.g. a craftsman’s shop). Inexpensive sensors do not exist yet but high volume entertainment and supervision applications will make this technology affordable;

• Robot automation life-cycle costs. Especially for investments into cooperating (assistive) robots productivity gains are probably less pronounced than quality gains, which in some cases will result in severe cost limits of such systems to achieve cost-effectiveness;

• Socio-economic factors. Especially in areas with little or no automation a strong conservative attitude in industry towards advanced mechatronic systems may slow down investments in novel robot systems. The introduction of robotics into industries characterized by bad working conditions and low status can contribute to changing their attractiveness to employ young people;

• Standards. First standards towards cooperative robots and intelligent assist devices (e.g. “smart balancers”) are about to emerge. New standards for robot assistants allowing physical interaction at normal working speeds will be required. Setting new standards needs committed industries to support the high cost and time involved.

6. KEY TECHNOLOGY CHALLENGES TO PROGRESS

Key technology challenges for pursuing successful long-term industrial robot automation are introduced on three levels: basic technologies, robot components and systems.

6.1 Basic Technologies

RTD challenges related to the development of robot assistants concern the required intelligent system behavior. Underlying relevant functionalities to address are perception, decision making, real time physical action, system architecture, learning, use of natural language and dialogues.

• Perception. All major functions of a robot assistant are based on “a priori” knowledge about its environment, work pieces and skills (perception, manipulation, and interaction). Therefore knowledge has to be acquired through interaction with the environment, with people or possibly through databases or other repositories (e.g. the www). For this, appropriate models and ontology of the environment, task and interaction spaces have to be found and adequate representations of world model data and skills have to be formulated.

• Decision making. Today task generation is performed offline by geometric or even symbolic planners on the basis of consistent a priori world knowledge. Future aspects will require on-line task generation based on stochastic information thus leading to higher degrees of reactivity and interaction.

• Real time physical action. Especially in the presence of people, physical actions by the robot have to be perceived as goal-driven, socially acceptable and expressive. In this context, aspects of ergonomics and behavioral psychology need to be adopted to arrive at methods for motion planning and generation.

• System architectures. Future robot assistants require the implementation of learning mechanisms which impose additional requirements on the robot’s system architecture. Furthermore aspects contributing to the system’s dependability such as advanced abilities to cope with disturbances, exceptions or failures (“graceful degradation”) require adequate system architectures.

• Learning. A robot assistant should continuously improve its capabilities by acquiring new knowledge and skills. Besides the necessary functions for sensing, moving and acting, such a robot should exhibit cognitive abilities enabling it to focus its attention, to understand the spatial and dynamic structure of its environment, to interact with it, and to communicate with other agents and with humans at the appropriate level of abstraction.

• Language and dialogues. Human-robot interaction will have to be based on multi-modal communication with natural language as the most versatile and intuitive means of instruction. Dialogues should help extract the user intent or interactively resolve ambiguous situations and should be perceived as intuitive, efficient and goal driven. For robustness and performance, domain-specific (welding, handling, machining …) syntax and data is needed.

Therefore methods have to be sought which control and permit dialogues depending on situation, environment and machine state.

6.2 Robot Components

Industrial robots have always depended on the availability of typical key-components such as actuators, sensors, materials and human-computer-interfaces. Besides component functionality and performance data, aspects of physical and logical integration within standard system architectures in hardware and software are of increasing importance. It should be noted here that there is a clear trend to share both components and architectural aspects at least in parts with other complex mechatronic systems such as service robots or even automobiles (“convergence of technologies”).

• Actuators: Today electro-magnetic servo-drives are the governing actuator for robots. However with the advent of assistive robots electro-hydraulic motors may come into play. Even though robot gears are considered mature components with few open research questions they represent a major bottleneck towards high-precision, light-weight and low-cost robot arms. Research should aim at alternative gear designs both for servo drives as well as for novel actuator principles to be taken up by European manufacturers. New sensor types such as magneto-strictive torque sensors and capacitive low-cost high precision encoders can provide critical benefits to the drives in terms of hybrid force/torque control.

• Sensors: So far, current sensor systems have not displayed enough robustness and accuracy at appropriate costs to be widely utilized in both industrial and everyday environments. A major breakthrough towards flexibility and robustness would emerge from the commercial availability of low-cost 3D sensors (at some €100). Furthermore embedding sensors in robot structures as tactile and non-tactile sensing (e.g. artificial skins) will be necessary for robots in human space sharing environments. The tool is a most important interface by itself which the worker can use to intuitively calibrate and program the robot relative its environment and work object. However, this requires as 6 degrees of freedom force/torque sensor to be mounted between tool and robot flange. These sensors are very expensive today and an important task is to develop a new concept for low cost and moderate accuracy 6 DOF force sensing.

• Materials. Currently novel materials which embed actuation and sensing properties are under research (“adaptronics”), particularly in the aerospace and automotive field. A significant potential lies in creating robot structures which follow these new principles: To “grow” structures instead of removing material for manufacturing robots, to embed micro-systems (sensors, actuators, circuits) into materials and to create new light-weight, low inertia material for new robot arms.

• Robot Arms: Today, the weight/payload ratio for robot manipulators is typically of the order of 10 to 50, mainly due to heavy drives which account for some 60% of the arm weight. Large masses result in a significant inertia, which makes it difficult to increase speed and at the same time such systems are not well suited for operation in the presence of humans. Thus the need for new designs of systems with a low weight to payload ratio and possible intrinsic safety arises. This requires an entire new approach to design and the use of new types of advanced materials and new actuators. Optimized weight to payload ratio will generally be more efficient and in some cases the added mechanical flexibility is desirable (e.g. to allow operation in cooperation with people). Such mechanically flexible robots can only have repeatability and performance similar to existing robots through use of sensory feedback in combination with new methods for control.

• Intuitive human-robot interfaces should support an efficient transfer of knowledge and skills between user and machine. While multi-modal interfaces will be very much driven and thus provided by the IT industries, typical interfaces for robot instruction will have to be developed within the robotics community, such as robust gesture recognition, hap tic displays.

▪ Microsystems and mechatronics. Microsystems typically embed transducers, actuators and circuits on millimeter scale and are make up valves, optical or mechanical sensor-systems, miniature servo-drives and micro-switches. Currently novel materials which embed actuation and sensing properties are under research, particularly in the aerospace and automotive field.

A significant potential lies in creating robot structures which embed micro-systems (sensors, actuators, circuits) into materials (so called smart matter systems) helping to create new lightweight, low inertia material for new actuation devices.

6.3 System Integration

The main R&D challenges of future industrial robot systems are as follows:

• Fine manipulation/high precision. Installation and change-over times of robot work-cells are highly dependent on negotiating tolerances in processes, product geometries and product position/presentation. This aspect is even more emphasized as product components decrease in size (micro, nano...). A goal is to account for required precision on the basis of existing (non-precision) machines by use of increased numbers of sensors and improved sensor data processing.

• Human-robot-collaborative work-cells. A cooperative task execution between robot and worker can increase the overall productivity through a perfect split of capabilities (“worker is better at/robot is better at”). This idea also extends to the vision of making robots a commodity in manufacturing and crafts.

• Cooperating robots. As unit prices drop at increasing rates, the cost of typical robot peripherals (conveyors, feeders, positioning devices, fixtures ...) can be drastically reduced and at the same time provide more flexibility. The result would be a network of interlinked robots which cooperatively transport, machine, handle and assemble work-pieces. A typical, simple scenario is a robot presenting a work-piece and positioning it so that a second robot can work on that piece. RTD tasks especially comprise scalable/distributed architectures for multiple robots, so that synchronization, sensor data processing, programming, task allocation, decision making and diagnosis can be organized and managed in a distributed system.

• Hyper flexible manufacturing systems. Product volumes and life-times are especially uncertain for consumer goods (electrical appliances, mobile communication, articles of infotainment). An immediate change-over may give additional opportunities to react to market developments and receptivity. The adaptation to new batches, product variants or new products should be shortened by typically one order of magnitude compared to today. This should result in a consistent modularization of manufacturing systems both in terms of software (components, interfaces) and hardware (interfaces, signal, energy transmission):

o A consistent middleware of automation modules to connect robots, peripheral devices and industrial IT systems (in a mechanical, electrical and especially logical way) without reprogramming ("Plug and Play")

o The "wireless shop floor". Signal transmission should be detached from wiring and switching cabinets. Closely associated to this challenge are aspects of data security.

o Mobile work-cells should facilitate the change-over of manufacturing lines to new compositions or, in a more advanced way to "abandon" the robot work-cell in favor of installing robots temporarily at the workplace/workbench.

o Establishment of a life-cycle oriented consideration of production equipment (procurement, financing, planning)

• Micro-and nano-manufacturing. As products become smaller manufacturing technology has to be scaled. However, as materials, manufacturing, processes and design principles for micro-systems differ from traditional products and manufacturing, the development of low-cost, dependable micro manufacturing equipment constitutes a major challenges. These systems generally incorporate rich sensor capabilities for optimized process control, robotic devices for automated handling, assembly and machining of micro-parts. It is expected that the manufacturing of nano-systems will follow radically new and fully automated processes (from solid state physics, generative processes from biology) requiring new robotics devices, possible based on completely different motion generating principles (controlled electrical, magnetic fields, atomic forces …).

7. EUROPE'S COMPETITIVE POSITION IN INDUSTRIAL AUTOMATION

From the broad sector of economic activities which are affected by robotics, it is obvious that research and development in this field will contribute to creating new opportunities towards European employment and growth. These opportunities are even more pronounced when taking into consideration apparent socio-economic factors such as the over-aging of our society, the need for increasing the productivity and competitiveness of European manufacturing industries or the need towards a knowledge-based society as formulated in the Lisbon strategy. With regard to the major societal challenges identified in the Kok report (i.e., the graying Europe, the EC enlargement, economic growth, productivity and employment), the role of robotic can be summarized as follows:

• The graying Europe: Over the next two decades the industrialized world is going to experience a significant growth in the number of people above 65 so that the dependency ratio is going to grow from about 22% to more than 45% in almost all EU countries. Contrary to this trend the employment rate is even declining for physically demanding jobs.

Employment aspects require elderly workers to remain in their jobs which calls for machines, tools or especially robot assistants to enable the worker make use of their skills and experience without the full physical strain.

• Growth, productivity and employment: The European growth gap to the US and Asia has widened which can be attributed to a lower investment per employee and to a slow-down of the technical progress in the mid-1990s. Increasingly newly created jobs tend to be low-wage jobs, which is in contrast to required investments in R&D, training and education. Also it is remarked that Europe's industrial structure is based on more low- and medium-tech industries. Manufacturing employment continues to be on the decline, currently representing about 18% of employment in Europe. Manufacturing and application of novel robot systems strongly contributes to shift resource-intensive industrial activities to a knowledge-based economy. This has a positive effect on employee skills and on job satisfaction. As robotic automation in Japan is seen as a strategically important enabling technology, and consequently is strongly supported by the Japanese government, it is important to realize here that a lead of Japanese suppliers of robot automation will be detrimental to the still healthy European robot industry.

• EC enlargement: Current and future enlargement of the EC will, besides an increase in population, add significant, mostly low-cost, manufacturing capacities. The transformation process from a low-cost to a knowledge and skill-driven manufacturing is critical as it implies significant investments in manufacturing equipment, new processes, high-added value products and trained personnel. New robot technologies may play a key role in transforming these industries and protecting them against increasing competition from low-wage countries.

• Standardization is particularly important for complex systems such as robotics to reduce manufacturing costs of the robot units themselves, to ensure exchangeability between components from different manufacturers and to reduce dependence on specialized robot experts. These factors affect, among others, training efforts for personnel from robot manufacturers, system integrators and end users. From a European point of view, standardization will also help to further improve the competitive position of the European robot industry vis-à-vis Japan in particular. Lack of standardization will shatter European resources and will make it easier for non-European robot manufacturers to penetrate the European market.

8. BUSINESS CASES

A broad manufacturing base is vital for Europe as it spurs demand for everything from raw materials to intermediate components, from software, financial, health, accounting, and transportation services in the course of doing business. Industrial robotics will increasingly gain importance as a cornerstone technology in future manufacturing scenarios. The automotive sector provides a good example. The production of automobiles stimulates the demand for everything from raw materials (in the form of coal and iron) to manufactured goods (in the form of robots) and to the purchase of services (in the form health insurance for the companies' employees). Competitive manufacturing of the future will increasingly depend on the progress of robotic technologies and the availability of robotic products and related services. We expect significant business and socio-economic impact in four categories of industrial stakeholder: end-user industries, existing robot automation manufacturers and system integrators, new start-ups in robotics and product-related service industries. The objective regarding end-user industries is to maintain competitiveness and create high quality jobs. Even in relatively slow economies the manufacturing industries are having difficulty finding skilled workers as was revealed in recent US-based studies. Innovations as highlighted in this report can contribute to this transformation through:

• Seamless robot automation concepts: from manual workplaces with robot assistants to automated systems capable of managing manufacturing uncertainties;

• Automated robot configuration and radically new programming through intuitive instruction and skill-based task specification;

• Life-cycle oriented reusable robotic and work-cell components that can be configured with a minimal set-up time;

• Increasing robot penetration in manufacturing: today, only 15% of possible robot automation potential is being exploited; further exploitation improvement will very likely contribute to less unemployment as more manufacturing capacity will remain in Europe. This particularly relates to industries which have only used little automation;

• Interactive industrial robots free the workforce from physical work. Therefore, equal opportunities on the shop floor in terms of gender and age could be promoted;

• Less physically demanding jobs in manufacturing through assistive robot systems.

Concerning existing robot manufacturers and system integrators, robots will remain a growth market for the next years to come, as manufacturing will depend on further productivity gains both in the automotive and particularly in the non-automotive industries. The creation of novel products, solutions and services in non-automotive sectors is vital for robot manufacturers and system integrators, since it will permit them to break with potentially dangerous dependencies they now have on robotic technologies tailored only for automotive applications. Technological advances may open-up important benefits and options for both robot manufacturers and system integrators:

• Increasing productivity in labor-intensive industries through a scalable robot automation approach, thus providing competitive solutions for new manufacturing paradigms, new products and innovative business models;

• Penetration in flexible small-scale manufacturing and in crafts, especially by introducing new assistive robots.

• Some new and very specific robotic products, especially cooperative robots, which address the needs of specific applications, may be outside the product portfolios of existing robot manufacturers. Such new technologies may be offered by innovative spin-offs;

• Life-cycle-oriented approaches in the planning, implementation and operation of robot systems offer chances for new services and businesses in a growing market.

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INSTRUMENTS FOR MEASUREMENT & CONTROL OF PRESSURE AND TEMPERATURE, DEDICATED TO THE INCREASE OF CONFORT AND SAFETY OF RAILWAY CARS

Dr. Eng. Dumitru VLAD- INCD Fine Mechanical Bucharest
Ph.Eng. Eugeniu CONDURATEANU- INCD Fine Mechanical Bucharest

Abstract - The project of a modernisation for 100 pcs. railway cars is a part of an assembly of projects reffering the rehabilitation of Romanian Railways, inter-conditonally financed by BIRD, BERD and EU-PHARE.

The aim of this project is to modernise a lot of 100 pcs. railway cars from the serial-type no.19-50 and no.20-50, builded-up by the German company DWA and having at this time more than 15-20 years of activity; more , to increase the level of confort offered to passengers at the level ascked by the actual European standerds ; and more, to decrease the exploitation costs and expenditure.

The main objectiv of INCDMF is to realise and to developpe new systems to increase the confort of passengers and to increase the safety of railway cars, by creating and by putting into production of new types of pressure and/or temperature measuring and controlling instruments.In the same time, to induce into the manufacturing process of this instruments of new methods, able to insure the increase of accuracy, of productivity and able to offer a rapid rithm of the transfer of the information to the producer.

In this way, this new products will need a very short time to be introduced in the production process, without preliminary steps for experimental models a.s.o., so, the result will be the realisation of new products in a very short time and with high perfomances, at the actual level of the market.

Keywords –pressure, temperature, instruments for measurement

1. TEMPERATURE SWITCH, TYPE BOYLER.

This temperature switch is used on the principal tank for hot water existing inside the railway car.

Like components, this temperature switch is realised with a thermosensibil sub-assembly, metallic case, some fixing parts and one inversing electrical contact.

Like fonctinement: this temperature switch is based on the cubic dilatation of a special liquid existing inside the thermosensibil system. Under the increasing/ decreasing of the temperature, this special liquid will modify his own volum, acting on an elastic element. This elastic element will act (thru a levier) on the inversing electrical contact, modifying his position .

The technical characteristics of the product are the following:

- Temperature range: +20ºC….+100ºC;
- Stting points: +30ºC; + 70 ºC;
- Fixed differential: max.4ºC;
- Contact error: ± 2ºC;
- Working media : normal;
- Electrical current (nominal): 1,5 A; 1,0 A;
- Electrical current (nominal): 250V; 380V.

2. BIMETAL TEMPERATURE SWITCH

This product can be offered in two variants: one, covering the range of temeperature 50ºC…60ºC, to be used to command the heating resistances inside the ventilation system of hot air, the other, covering the range of temperature 5ºC…10ºC, to be used in the retention tank of the railway car.

Like components, this temperature swith is realised with a metallic case, an assembly of elastic lamella, snap-action bimetallic diaphragm and a superior cover.

Like functionement: the product is based on the changement of the shape of a dedicated bimetallic disk (diaphragm) under the variation of the temperature. The temperature switch has a NC (normally closed) or NO (normally open) electrical contact. Like effect of the increasing temperature, this elastic disk will change the initial position , and in this way will produce the changement into the electrical circuit. Decreasing the temperature will generate the changement of the position of the disk, to his initial position, with a same effect inside the electrical circuit.

The technical characteristiques of the bimetal temperature switch:

- Contacting temeperature range:
  + 5ºC±3ºC….+10ºC±3º;
  +50ºC±3ºC…..+60ºC±3ºC;
- Working media: normal;
- Electrical current (nominal) : 6A;

- Electrical current (nominal): 250 V;
- Electrical resistance on contacts:10mΩ;
- Electrical connection : 2,8mm; 6,3mm.

3. TEMPERATURE SWITCH FOR HOT AIR

This temperature switch is used in the heating circuit of the railway car during the cold wether.

Like components: fixing flange;metallic case;thermosensibil assembly; acting lever assembly; electrical contact assembly.

Like functionement: the temperature switch is based on the cubic dilatation of a special liquid existing inside the thermosensibil assembly. At the increasing or decresing the temperature, this liquid modify his own volum, acting on an elastic element type capsule. This capsule act, via the lever, on the electrical contact (type inversor), modifying his initial stage.

Technical characteristiques:

- Temperature range: +80ºC….+126ºC;
- Setting point: 118ºC±5ºC; 90º±5ºC;
- Electrical contacts : NC +NO with common point;
- Electrical current (nominal):1,5A (16A);
- Electrical current (nominal): 220V;
- cosφ = 0,8 ;
- electrical connection: 6,3 mm.

4. DIFFERENTIAL PRESSURE SWITCH FOR AIR

This product is designed for the hot air turbine.

Like components: elastic element type diaphragm; electrical contacts assembly; metalic case.

The differential pressure is the result of the different two pressures, p1 and p2 (with p1>p2). This two pressure act under the elastic element of the gauge (rubber ondulated diaphragm). At the setted value for the differential pressure, the rigid center of the diaphragm act on the electrical contact, generating his changement. At the value Δpu (rising), the NC contact will open, and at the value Δpc (decreasing), the NO contact will close (Δpu>Δpc). The difference between Δpu and Δpc represent the fixed differential of the gauge.

Technical characteristiques :

- Pressure range: 0,3…2 mbar;
- Electrical contacts: NC+NO with common point, 220V,5A, cosφ=0,8;
- Working media: normal;
- Sensibil element: rubber diaphragm;
- Process connection:G ¼" (G1/2");
- Maximum admisibil pressure: 600 mbar;
- Fixxed differential: 0,5 mbar;
- Contacting error: ± 0,2 mbar;
- Overpressure: 800 mbar.

5. PRESSURE CONNECTOR

The product is dedicated to be used inside the braking system of the railway car.

Like components: pressure connector with giaphragm assembly; electrical switch assembly; electrical cable output assembly; case.

Like functionement: the pressure connector is based on the pressure variation acting on the effective surface of an elastic element type diaphragm. This generate a displacement who, thru a lever and a spring is transmitted to an electrical microswitch, modifying his position from "normal closed" to "normal open" and vice – versa , depending of the increasing or the decreasing of the pressure.

Technical characteristiques:

- Pressure range: 0,4…4 bar;
- Setting point: 3 bar;
- Fixes differential: 0,4 bar;
- Contacting error: ± 0,2 bar ;
- Switch contact: NC + NO with common point; 220V; 50 Hz;cosφ=0,8;
- Process connection: M16x1,5.

MODELING, SIMULATION AND TECHNOLOGY OF A RESONANT MICROCANTILEVER BEAM FOR A GAS SENSOR

*Prof.Dr.Eng. Georgeta **Ionascu***, Assist.Prof.Dr.Eng. Lucian **Bogatu***, Prof.Dr.Eng. Adriana **Sandu*****
*Dr.Physicist Elena **Manea*****, Dr.Eng. Ileana **Cernica*****,*
*M.Eng.Stud. Valentina **Nicolae***, M.Eng.Stud. Ana-Maria **Porojnicu****

** POLITEHNICA University of Bucharest, Precision Engineering Department*
*** POLITEHNICA University of Bucharest, Department of Strength of Materials*
**** National Institute for Research & Development in Microtechnology of Bucharest*

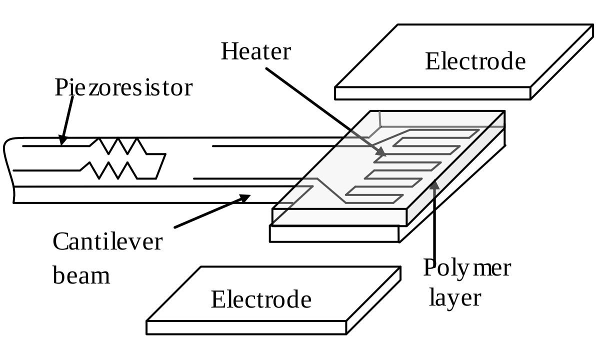
Abstract - The modeling, simulation and fabrication of a resonant microcantilever beam for a gas sensor, in complementary metal oxide semiconductor (CMOS) technology are presented in this paper. The composite beam, with multi-layered structure (Al, SiO_2 and poly-Si layers) is obtained by using a conventional CMOS process combined with subsequent micromachining steps. The analytic computation an numerical simulation performed to determine the resonant frequency of the cantilever beam offer a good agreement between the obtained results. As was expected, the resonance frequencies are high, advantageous for a high sensitivity of the sensor.

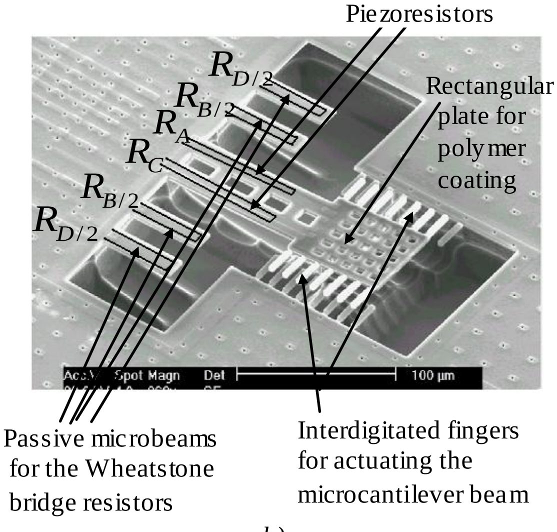
Keywords – modeling, beam vibration simulation

1. Introduction

The microelectromechanical systems (MEMS) – intelligent or micromechatronic devices, among which the analyzed product is, are obtained by the integration of mechanical elements, sensors, actuators and electronic components on the same substrate (of silicon) processed by micro fabrication technologies. The components of the electronic scheme are made by process specific to the integrated circuits (CMOS, in this case), while the micromechanical components are performed by micromachining processes – substractive methods, by which pieces of the silicon wafer are selectively removed (etched) and/or additive methods, by which new structural layers are added. So, complete systems can be obtained on one silicon chip of only a few millimeters [1].

A gas sensor is a device that converts analytic chemical information into a useful signal. This type of sensors has important industrial and environmental applications, including the detection of hazardous chemicals, quality control in the food, perfume and beverage industries, and medical applications too. The gas sensor with a microcantilever beam works as a resonant microbalance (a picogram microbalance), at which the mass increases, due to the gas sorption into the polymer layer (fig. 1a) deposited on the microbeam surface, yield the variation of its resonance frequency.





a) *b)*

Fig. 1 *Microcantilever beam gas sensor: a) – design of cantilever beam (electrodes are used for electrostatic actuation); b) – SEM (Scanning Electron Microscope) image of cantilever beam.*

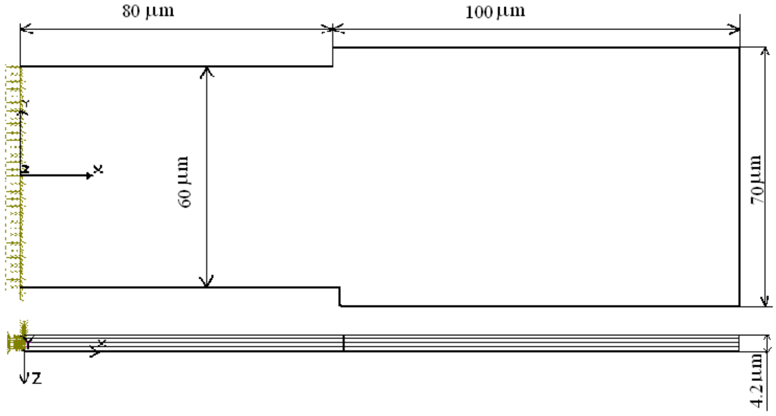


Fig. 2 *Form and sizes of microcantilever beam*

The microbeam is electrostatically actuated and the resonance frequency is measured by means of a set of piezoresistors connected in a Wheatstone bridge configuration: two piezoresitors (R_A and R_C) positioned on the active cantilever beam, and the other two – reference resistors (R_B and R_D) situated on the neighboring shorter, auxiliary cantilever beams (fig. 1b).

The composite cantilever beam, with a multi-layered structure (Al, SiO_2 and poly-Si layers) of form and sizes shown in fig. 2, is obtained by using a CMOS-MEMS process developed at Carnegie Mellon University (CMU) and combined with subsequent micromachining steps (anisotropic and isotropic plasma etching) in order to release the microbeam from the silicon substrate, which acts as a sacrificial material [2, 3].

2. ANALYTIC COMPUTATION OF FUNDAMENTAL RESONANT FREQUENCY

The resonant frequency computation is performed considering an approximate model. The resonant frequency corresponding to the first vibration mode (the excited one) for a cantilever beam is equal to [4, 5]:

$$f_1 = \frac{\omega}{2\pi} = \frac{1.875^2}{2\pi L^2}\sqrt{\frac{EI}{\rho A}} \qquad (1)$$

The natural frequency for the free undamped vibration of a composite cantilever beam can be approximately determined by replacing in equation (1), the bending stiffness *EI* and density ρ, with the composite bending stiffness $\overline{EI}$ and composite density $\overline{\rho}$ [5]:

$$\overline{EI} = \sum_{i=1}^{N} E_i I_i \qquad (2)$$

$$\overline{\rho} = \frac{\sum_{i=1}^{N} \rho_i t_i}{\sum_{i=1}^{N} t_i} \qquad (3)$$

where: N – is the number of layers in the composite cantilever beam,

$E_i I_i$ – the bending stiffness of the individual layers,

ρ_i – is density of the individual layers,

t_i – is the thickness of the individual layers.

The transformed-section method is used to obtain an imaginary beam (fig. 3 b) equivalent to the original beam (fig. 3 a).

This imaginary beam has the neutral axis located in the same place as for the original one and it is made from only one material, with Young's modulus corresponding to the top (Al) layer.

The principle of the transformed-section method lies in the normalization of each layer with respect to the Young's modulus of the top layer. The width of each composite layer is given by the formula:

$$b_i = \frac{Ei}{E_N} b \qquad (4)$$

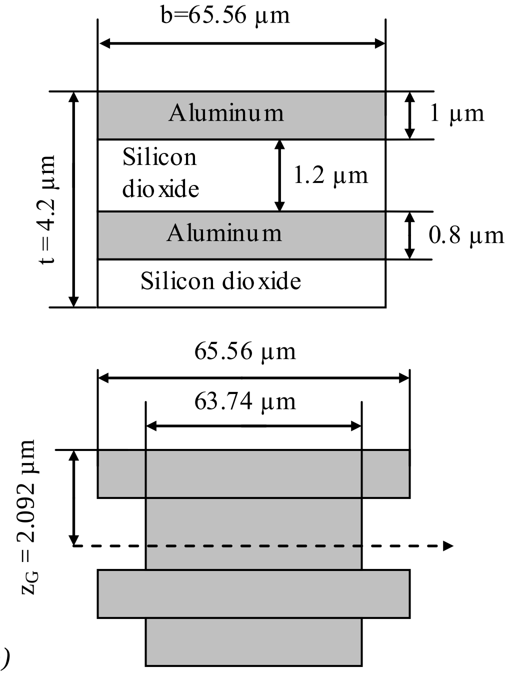
where: b_i – is the width of each normalized layer,

E_i – is the Young's modulus of each layer,

E_N – is the Young's modulus of the top (Al) layer.

An equivalent (constant) width of the cantilever beam, b = 65.56 μm (fig. 3a), was considered, from the condition of equal mass of the real beam and the equivalent one.

a)



b)

Fig. 3 *Cross-section of the microcantilever beam: a) - the original (composite) beam, which shows the combination of CMOS layers; b) - the imaginary beam of the same material (Al) obtained by the transformed-section method. The centroidal axis of the composite beam is marked.*

The considered values of elastic and physical constants of the layer materials are given in table 1.

Table 1 *Material properties of thin layers which form the composite cantilever beam*

Material	ν	E [GPa]	ρ [kg/m^3]
Silicon	0.17	150	2330
SiO_2	0.17	70	2200
Al	0.3	72	2700

There were obtained: b_1 = b_3 = 65.56 μm and $b_2 = b_4$ = 63.74 μm (fig. 3b).

The centroid coordinate (the location z_G of the neutral plane) of the composite beam is found by:

$$z_G = \frac{\sum_{i=1}^{N} A_i z_i}{\sum_{i=1}^{N} A_i} \qquad (5)$$

where z_i - is the distance from the reference layer, which in this case is considered the top (Al) layer, to the neutral axis of each individual layer,

A_i – is the cross-sectional area of each individual layer, as shown in fig. 3b.

It results that z_G = 2.092 μm.

The individual moments of inertia I_i of each layer are computed with the following equation:

$$I_i = \frac{b_i t_i^3}{12} + A_i d_i^2 \qquad (6)$$

where d_i – is the distance between the centroidal axis of the beam and the neutral axis of each individual layer.

One can computation the bending stiffness of the beam with equivalent section,

$$\overline{EI} = 2.829 \cdot 10^{-11}\ Nm^2 \qquad (7)$$

and the density of the equivalent beam,

$$\overline{\rho} = 2414.28\ kg/m^3 \qquad (8)$$

Replacing (7) and (8) in equation (1), the fundamental resonant frequency of the composite cantilever beam is obtained:

$$f_1 = 113.5\ kHz \qquad (9)$$

3. BEAM VIBRATION SIMULATION

The analytic model of computation is validated by numerical computation by using FEM (Finite Element Method). The analysis was performed with COSMOS.

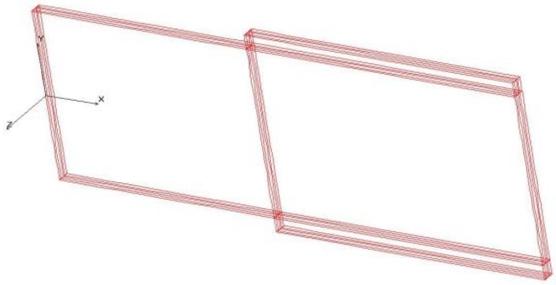


Fig. 4 *Model of numerical computation*

The structure meshing was made in 23200 elements of three-dimensional solid with 8 nodes/element (SOLID 3D), which interact 27225 nodes. In fig. 4, there are presented the volumes that were meshed in two categories of elements corresponding to the layer materials (Al and SiO_2). The structure is fixed at the end from the left side (x=0).

The first natural vibration mode (the excited one for the gas sensor) is shown in fig. 5. The fundamental (natural) resonant frequency obtained by numerical computation is equal to 107.23 kHz.

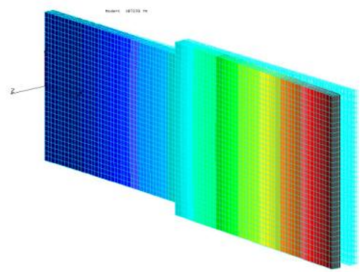
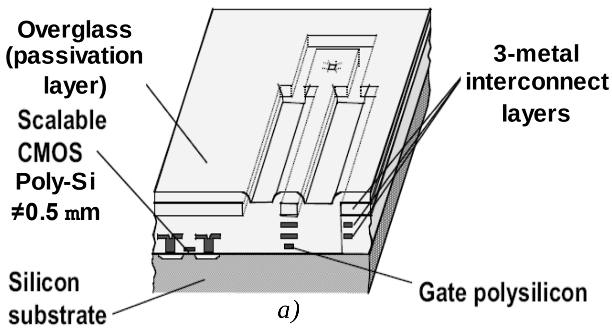


Fig.5 *COSMOS simulation of the microcantilever beam resonant frequency. First natural vibration mode.*

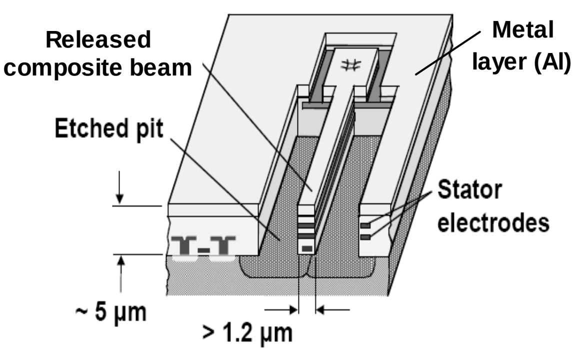
4. FABRICATION OF MICROCANTILEVER BEAM IN COMPLEMENTARY METAL OXIDE SEMICONDUCTOR (CMOS) TECHNOLOGY

Carnegie Mellon has developed an integrated CMOS-MEMS process in which microstructures with high aspect-ratio composite beam suspensions are fabricated using conventional CMOS processing along with the sequence of maskless dry etching steps. The etching masks are provided by the interconnect metal layers in the standard CMOS processes. Advantages of this process include the ability to integrate low-noise sensor interface circuitry, feedback control, signal amplification and processing alongside microstructures.

The standard CMOS technology illustrated in fig. 6a is followed by two maskless dry (plasma) etch steps to release the microstructures that are protected by the top-most metal layer. An anisotropic RIE (Reactive Ion Etching) with CHF_3 and O_2 is first performed to remove silicon oxide not covered by any of the aluminum metal layers. The RIE also removes the top-most layer of silicon oxide. The top metal layer is uncovered and acts as an etch resistant mask. This step is followed by an isotropic RIE process using SF_6 and O_2 to etch the bulk silicon and release the microbeam structures. The RIE process produces high aspect-ratio vertical sidewalls. Fig. 6b illustrates the released beam after these three post-CMOS processing steps. Typically, the silicon is etched about 25 μm vertically, which undercuts structures up to 16 μm wide. Larger structures must have etch holes for proper release.



a)



b)

Fig. 6 *Cross section of CMOS micromachining process: a) – chip shown as received from CMOS foundry, b) – released structures after combined anisotropic and isotropic plasma etching.*

5. Conclusions

A composite microcantilever beam fabricated in CMOS technology was analyzed by analytic and numerical computation. The values obtained for the fundamental (natural) resonant frequency are not much different. (a difference of about 6%). The analytic model, although approximate, offers values enough precise for the fundamental resonant frequency and presents the following advantages:

- it is relatively simple and allows data introduction in a usual programming medium;
- parameters modification(number of layers, material properties, sizes of the microbeam/layers) can be easily made, while in the FEM case any modifications leads to a new computation model.

The numerical computation is recommended to be used in the final phase, after structure form and sizes establishing, for verifying and visualization of other natural vibration modes. The parametric modeling allows an easy adaptation of the model of numerical computation at the constructive changes of the structure.

As concerns the CMU CMOS-MEMS process used to fabricate the composite microcantilever beam, the simplicity of this process must be pointed out. By removing the CMOS component and limiting the process to one metal and one oxide layer, a designer can focus on the mechanical aspects of a microstructure with the capability to layout multiple device variations of arbitrary size onto a four inch wafer. The process (a) starts from pre-processed wafers and requires only one photolithography step, (b) provides a conductor material for actuating electrostatic and thermal devices, (c) avoids electrical shorting between metal microstructures or to the silicon substrate by using silicon dioxide as an insulator, and (d) allows quick prototyping of MEMS structures.

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THE STRATEGIC, PERFORMANCE AND PROCESS BENCHMARKING USING FOR THE ECONOMIC SUPPORT HAVING IN VIEW THE UE ADERATION

Diana Mura Badea, Vasile Finat (INCDMF), Angela Voicila, Gheorghe Stefanescu (CER), Dinu Comanescu, Mihai Avram, Despina Duminica (UPB-CCDM), Gabriela Matache, Petrin Drumea (INOE 200-IHP); Gabriel Vladut, (IPA-CIFATT)

Abstract - The benchmark concept is not sufficiently known in Romania. By using the bibliographical data presentation [1] one may say for a good understanding that the word "benchmark" is a term taken from the geometry and refers to a mark used as a reference point for elevation direction comparison. Further, the benchmarking may be defined as "the methodology consists in a permanent search of the best practices in the aim to adopt and to fit their positive aspects and to apply them in order to become the best from the best ones".
Keywords - benchmark concept

The benchmark concept is not sufficiently known in Romania. By using the bibliographical data presentation [1] one may say for a good understanding that the word "benchmark" is a term taken from the geometry and refers to a mark used as a reference point for elevation direction comparison. Further, the benchmarking may be defined as "the methodology consists in a permanent search of the best practices in the aim to adopt and to fit their positive aspects and to apply them in order to become the best from the best ones". There are 4 types of benchmarking, as follows:

- the intern benchmarking: the comparison between the same type of operations and the similar ones from the same organization;
- the concurrent benchmarking: the specific comparison with the competitors on the product, method, processes;
- the functional benchmarking: the comparison of the similar functions between the organizations, which are not concurrent in the same activity sector in order to find the innovative techniques;
- the generic benchmarking: the comparison between organizations of various sectors on processes and working methods.

By using the benchmarking [2] it is possible to be evaluated

- products and services delivered to the internal and external costumers;
- operations, operational strategies, procedures, processes developed at all departments level and organization functions;
- business and quality culture.

In order to develop a benchmarking process the understanding of the own organization is the most important. It starts by defining and by understanding of all existing situation aspects in the organization in which a benchmark is developed. They may be obtained by searching the answer of such question series as the following:

- which are the needs of the internal and external costumers;
- which is the own system of the quality management;
- the existent system is capable to deliver the necessary funds and resources.

The time and the quality are included through the comparison criteria surveyed by a benchmarking.

The time is directly implied in different processes and for this reason automatically determines that the participants focus their attention on them and the relations between them.

To reduce the time dedicated to different activities implies the productivity increasing, which leads as well an increase of a qualitative perception of costumers as the costs reduction.

As well one may mention a benchmarking for all total quality costs of the organization. The quality benchmarking may be divided as follows:

- external quality benchmarking
- internal quality benchmarking.

The certification organizations may be assimilated to the benchmarking organizations and by extension RENAR may be considered a benchmarking network.

The data bases of such organizations are not enough structured and cannot be used for benchmarking services.

The organizations are not encouraged to initiate and to develop the benchmarking projects, the techniques of this management discipline being insufficiently known.

The systematical approach of benchmarking projects implies the knowledge and the using of the benchmarking tools in all four achieving stages:

- the planning:

1. missions, goals, objectives, flux diagram

Processes: priority analysis, critical processes selection, measures definition.

Outputs: goal project description, motivation, applying field, advantages, measures/methods, necessary times.

2. project description

Processes: to establish the comparison with internal and external partners.

Outputs: the identification of 3-4 potential partners.

3. the identification of 3-4 potential partners.

Processes: priorities establishment, validity of the information collection plan.

- the analysis:

Inputs:

1. the information report

Processes: the definition of differences between performances and processes.

Outputs: the analysis of differences.

2. the analysis of differences

Processes: the reserves calculus, the determination of tendencies with or without transformation.

Outputs: the design of future performances.

- the integration:

Inputs:

1. the design of future performances.

Processes: the establishment of communication tools.

Outputs: the report on the best practices.

2. the report on the best practices.

Processes: the development of new objectives and their impact on the staff.

Outputs: the reviewed objectives, the impact on the staff.

- the action:

Inputs:

1. the reviewed objectives, the impact on the staff.

Processes: the development of the management action plan.

Outputs: the action plan agreed by management.

2. the action plan agreed by management.

Processes: the establishment of comparison with internal and external partners.

Outputs: the implementation stage.

3. the implementation.

Processes: the project reevaluation.

Outputs: the reevaluation.

The benchmarking tools must be combined with the quality tools, in every stage being used one or several tools.

The up-today standards are used as a guide during the benchmarking development. ISO 2000 is a basic documentation for a high level benchmarking.

The benchmarking may be also applied to the scientific research, technological development and innovation.

The wrong use of these tools as their un-use determines the alteration of the benchmarking project results.

The present situation of the problem may be resumed as:

- the lack of a systematical approach of benchmarking projects;
- the non-applying and/or the un-knowledge of the benchmarking tools and of the quality tools;
- the un-existing of the benchmarking organizations prepared to deliver services in the field;
- the lack of specialized staff;
- the lack of contacts with European and international organizations, clubs and networks.

Having in view the integration perspective of Romania the approach and the development of the organization, process benchmarking projects or the benchmarking of the human component creative reliability in a organized frame (benchmarking organizations, benchmarking clubs or networks) allow the connection to the European benchmarking networks.

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EQUIPMENT FOR TESTING & CHECKING THE TECHNICAL CHARACTERISTIQUES OF PRESSURE TRANSDUCERS IN A NON-STEADY REGIME

Ph. Eng. Valentina Bajenaru
Dr. Eng. Vlad Dumitru

Abstract - In the last time, the very fast development of communication and IT technologies generate new opportunities for the creation of new, modern equipments for testing & checking the pressure measurement instruments.

Keywords - IT technologies

1. GENERAL PRESENTATION

The nopvelty degree consist in the integration in the proposed stand of some new elements for generating the pressure and for the surveillance of the created conditions, this surveillance being possible thru the computer aid, who offer too the possibility of monitoring and stcking the infos,and permiting too the following-up comparison of the results of realised measurements by stcking this in a data-base, and , in the same time, a comparison between the technical characteristiqus of an etalon with the checked instrument, in the same conditions.

The dificulty consist in coupling together the elements defining the complex mecatronical system, like follows:

- An electro – mechanical part, able to generate all the conditions for the variation of the pressure, based on a very precise electromechanical mouving assembly;
- A pneumatical part, offering conditions for generate the pressure and to be very tight, creating all the needed conditions for good measurements;
- A computed monitoring & stocking part,strictly imposed in such processus of following – up the characteristiques of different pressure tranducers in non-steady regim; the classical methods of observation (dial + indicator or electronical display) are not enough precise, inducing big aproximations and errors, due to the time – factor.

The novelty of this presented work consist in the solving of all this important problems.

2. DESTINATION OF THE PRODUCT

The realised equipment is dedicated to all users having in operation automation installations containing pressure measuring aguges in non-steady regim.

In the same time, potentially users can be the producers of instruments for measuring- controlling for pressure, and too the specialised laboratories inside research-development institutions, universities and companies, as in Bucharest, Ploiesti, Vaslui, Pascani, Craiova, Constanta, Galati, Cluj-Napoca a.s.o.

The presence of the computer system inside the equipment offer a high level of novelty and respect the international standards & inquiries.

3. SCIENTIFICAL AND TECHNICAL PRESENTATION

The novelty consist in the use of the remote technique for checking - controlling – monitoring like a frequently used technique at international level.This kind of approach permit a better knewledge of functional parameters of pressure transducers in a non-steady regim.

More, the possible changements in the good functionement of the transducer, like the extention of the measuring range,can be very easily realised, by modifying the software or by adding, with minimal hardware connections needed, new programmable software moduls.

The equipment will realise the acquisition of data from the two resistive transducers and their transmission to the computer, for the comparison of the response-characteristiques in a non-steady regim of the tested pressure transducers. This will facilitate a concrete presentation of the functionement by representing different graphics and registrations and data resulting from the test maded on this equipment.

The practical functional analise started by the indentifying the conditions regarding the limits of the proposed equipment;the desired inputs and ouputs offered a list of functions to be fullfilled. As it is well=known, every function of the system has his own inputs and outputs. This functions are putted together , and define the necessary sequences or informational flux. In the end of this functional analise, result a principle sketch.

Following is presented the equipment and his modus-operandi.

The principal components of the equipment are:

1. PC;
2. Printer;
3. Os – Oscilloscope TDS 2012;
4. Rp – Pressure regulator LR-1/4-D-MIDI;
5. S1- Valve;
6. Md- Digital Manometer DPI- 103;
7. Amplifier AED 9101 B;
8. Rez – Pressure tank of 5 l. volume;
9. S2 – Valve;
10. Power supply for the Amplifier (12 V);
11. T2- Pressure transducer under test;
12. T1 – Etalon pressure transducer P8AP;
13. D3/2 – electro-valve (power supply 220V AC);
14. Switch.

Working mode:
The transmission of pressure is like this: pressure source (compressor) – pressure regulator Rp - Ball valve S1 – pressure tank Rez – ball valve S2 – digital manometer Md – electrovalve D3/2 – etalon pressure transducer T1 – pressure tyransducer under test T2.
The followings are the steps of work:

Step 1 – S1 and S2 are in position “open“; the pressure from the compressor will be setted with Rp thru the tank and in the all circuit, till the electrovalve.

Step 2 - when the desired for test pressure will be realised (readed on Md), close S1;

Step 3 - with manual switch pos.27, act on D3/2, switching from the preferential position 0 to the working position 1.The pressure existing in tank will détente instantly in both pressure transducers, realising a “step of pressure “.

Step 4 - the signals obtained from both pressure transducers (2mV/V)are ampliofied and sended to Os, pos.12. Thru RS232 interface, the signals from Os are transmitted to PC. This data are processed, memorised and stocked in the data base with the specialised software.

Step 5 - With the same manual switch pos.27, act on the D3/2 electrovalve, putiing it from position 1 (work) to the position 0 (out of work), in this way both pressure transducers are free of pressure .

Step 6 – after finishing the test, the all equipment will be free of pressure acting the needle like part of the assembly pos.6.

Using the specialised software, the signals from the Os are processed and sended to the computer, where they are processed, dispalyed and memoratedfor every sequence of work. More, for stockage of data and for a better visualisation and comparison of graphics resulted from both pressure transducers, it can be used the printer .

4. TECHNICAL CHARACTERISTIQUES.

- media used for pressure generation: air;
- range of pressure tranducers to be checked: 0….10 bar;
- range of pressure possible to be generated by the stand: 0…15 bar (possible reglage);
- acuuracy of the comparison element: 0,4
- posibilities to indicate the response-parameters in non-steady regim:
  - ♣ maximum pressure (peak value);
  - ♣ accuracy of measurement;
  - ♣ response in amplitude;
  - ♣ response in phase;
  - ♣ resonancy frequence;
  - ♣ amortisation period;
  - ♣ amplitude for super-oscillation.
- working temperature 5…40 °C.

CONCLUSION

The project is relevant for the re-startof the industrial sector, offering new thermotechnical products and trying to eliminate the difference between romanian producers and the similar europeans.More, the project offer the alignement to the European Market, thru this modern method for realisation of an equipment dedicated to the testing and checking of technical characteristiques of pressure measuring instruments working in non-steady regim.

THE BARRETTHAND GRASPER – PROGRAMMABLY FLEXIBLE PART HANDLING AND ASSEMBLY

Conf. dr. ing. Paul Ciprian PATIC
Valahia Univesity of Târgovişte

Abstract - This paper details the design and operation of the BarrettHand BH8-250, an intelligent, highly flexible eight-axis gripper that reconfigures itself in real time to conform securely to a wide variety of part shapes without tool-change interruptions. The grasper brings enormous value to factory automation because it: reduces the required number and size of robotic work cells (which average US$90,000 each – not including the high cost of footprint) while boosting factory throughput; consolidates the hodgepodge proliferation of customized gripper-jaw shapes onto a common programmable platform; and enables incremental process improvement and accommodates frequent new-product introductions, capabilities deployed instantly via software across international networks of factories.
Keywords – barretthand grasper, *articulated fingers*

1. INTRODUCTION

This paper introduces a new approach to material handling, part sorting, and component assembly called "grasping", in which a single reconfigurable grasper with embedded intelligence replaces an entire bank of unique, fixed-shape grippers and tool changers. To appreciate the motivations that guided the design of Barrett's grasper, we must explore what is wrong with robotics today, the enormous potential for robotics in the future, and the dead-end legacy of gripper solutions.

For the benefits of a robotic solution to be realized, programmable flexibility is required along the entire length of the robot, from its base, all the way to the target workpiece. A robot arm enables programmable flexibility from the base only up to the toolplate, a few centimeters short of the target workpiece. But these last few centimeters of a robot must adapt to the complexities of securing a new object on each robot cycle, capabilities where embedded intelligence and software excel. Like the weakest link in a serial chain, an inflexible gripper limits the productivity of the entire robot workcell.

Grippers have individually-customized, but fixed jaw shapes. The trial-and-error customization process is design intensive, generally drives cost and schedule, and is difficult to scope in advance. In general, each anticipated variation in shape, orientation, and robot approach angle requires another custom-but-fixed gripper, a place to store the additional gripper, and a mechanism to exchange grippers. An unanticipated variation or incremental improvement is simply not allowable.

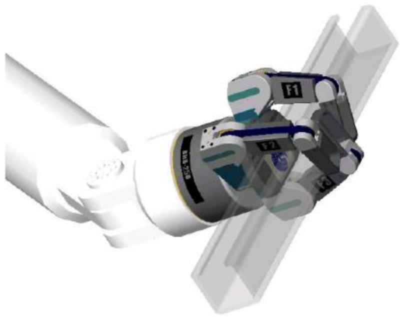

Figure 1 Graspers automatically conform to any part shape in any orientation

By contrast, the mechanical structure of Barrett's patented grasper, illustrated in Figure 1, is automatically reconfigurable and highly programmable, matching the functionality of virtually any gripper shape or fixture function in less than a second without pausing the work-cell throughput to exchange grippers. For tasks requiring a high degree of flexibility such as handling variably shaped payloads presented in multiple orientations, a grasper is more secure, quicker to install, and more cost effective than an entire bank of custom-machined grippers with tool changers and storage racks.

For uninterrupted operation, just one or two spare graspers can serve as emergency backups for several work-cells, whereas one or two spare grippers are required for each gripper variation – potentially dozens per workcell. And, it's catastrophic if both gripper backups fail in a gripper system, since it may be days before replacements can be
identified, custom shaped from scratch, shipped, and physically replaced to bring the affected line back into operation. By contrast, since graspers are physically identical, they are always available in unlimited quantity, with all customization provided instantly in software.

2. GRIPPER LEGACY

Most of today's robotic part handling and assembling is done with grippers. If surface conditions allow, vacuum suction and electromagnets can also be used, for example in handling automobile windshields and body panels. As part sizes begin to exceed the order of 100gms, a gripper's jaws are custom shaped to ensure a secure hold.

As the durable mainstay of handling and assembly, these tools have changed little since the beginning of robotics three decades ago. Grippers, which act as simple pincers, have two or three unarticulated fingers, called "jaws", which either pivot or remain parallel during open/close motions as illustrated in Figure 2. Well organized catalogs are available from manufacturers that guide the integrator or customer in matching various gripper components (except naturally for the custom jaw shape) to the task and part parameters.

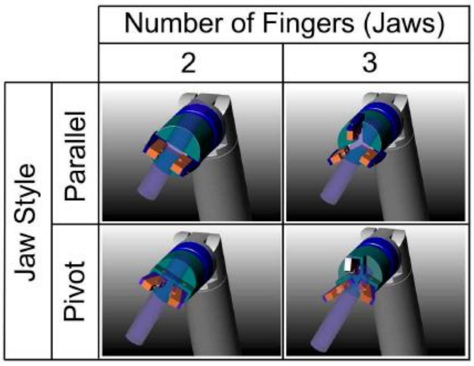

Figure 2 Gripper variations are limited

Payload sizes range from grams for tiny pneumatic grippers to 100+ kilograms for massive hydraulic grippers. The power source is typically pneumatic or hydraulic with simple on/off valve control switching between full-open and full-close states. The jaws typically move 1cm from full-open to full-close. These hands have two or three fingers, called "jaws". The part of the jaw that contacts the target part is made of a removable and machinably soft steel or aluminum, called a "soft jaw".

Based on the unique circumstances, an expert tool designer determines the custom shapes to be machined into the rectangular soft-jaw pieces. Once machined to shape, the soft-jaw sets are attached to their respective gripper bodies and tested. This process can take any number of iterations and adjustments until the system works properly. Tool designers repeat the entire process each time a new shape is introduced.

As consumers demand a wider variety of product choices and ever more frequent product introductions, the need for flexible automation has never been greater. However, rather than make grippers more versatile, the robotics industry over the past few years has followed the example of the automatic tool exchange technique used to exchange CNCmill cutting tools. But applying the tool-changer model to serial-link robots is proving expensive and ineffective. Unlike the standardized off-the-shelf cutting tools used by milling machines, a robot tool designer must customize the shape of every set of gripper jaws - a time-consuming, expensive, and difficult-to-scope task. Although grippers may seem cheap at only US$500 each, the labor-intensive effort to shape the soft jaws may cost several times that. If you multiply that cost times a dozen grippers as in the example above and throw in a tool-changer and tool-storage rack for an additional US$10,000, the real cost of the "few-hundred-dollar" gripper solution balloons to US$20,000 to US$60,000.

To aggravate matters, unknowns in the customization process confound accurate cost projections. So the customer must commit a purchase order to the initial installation fee on a time and materials basis without guarantee of success or a cost ceiling. While priced at US$30,000, intelligent graspers are not cheap. However, one can "customize" and validate the process in software in a matter of hours at the factory in a single day. If the system does not meet performance targets, then only a day's labor is wasted. If the system succeeds, then there are not any hidden expenses following the original purchase order.

Beyond cost, the physical weight of tool changer mechanisms, located at the extreme outer end of a serial-link robotic arm, limits the useful payload and dynamic response of the entire system. The additional length of the tool changer increases the critical distance between the wrist center and payload center, degrading cinematic flexibility, dynamic response, and safety.

3. DESCRIPTION OF THE BARRETT HAND

Flexibility and durability in a compact package

The flexibility of the BarrettHand is based on the articulation of the eight joint axes identified in Figure 3. Only four brushless DC servomotors, shown in Figure 4, are needed to control all eight joints, augmented by intelligent mechanical coupling. The resulting 1.18kg grasper is completely self-contained with only an 8mm diameter umbilical cable supplying DC power and establishing a two-way serial communication link to the main robot controller of the workcell. The grasper's communications electronics, five microprocessors, sensors, signal processing electronics, electronic commutation, current amplifiers, and brushless servomotors are all packed neatly inside the palm body of the grasper.

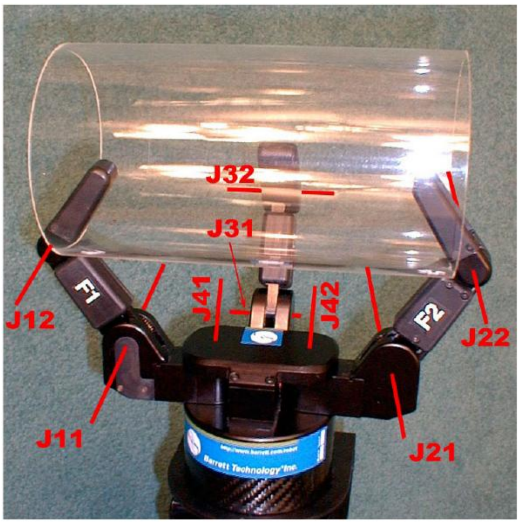

Figure 3 Eight axes of the BarrettHand

The BarrettHand has three articulated fingers and a palm as illustrated in Figure 5 which act in concert to trap the target object firmly and securely within a grasp consisting of seven coordinated contact vectors — one from the palm plate and one from each link of each finger.

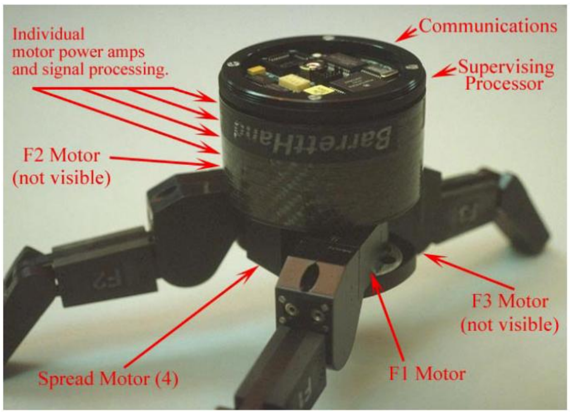

Figure 4 Motor locations in the BarrettHand

Each of the BarrettHand's three fingers is independently controlled by one of three servomotors as shown in Figure 6. Except for the spread action of fingers Fl and F2, which is driven by the fourth and last servomotor, the three fingers, Fl, F2, and F3, have inner and outer articulated links with identical mechanical structure.

Each of the three finger motors must drive two joint axes. The torque is channeled to these joints through a patented, TorqueSwitch mechanism (Figure 7), whose function is optimized for maximum grasp security. When a fingertip, not the inner link, makes first contact with an object as illustrated in Figure 8, it simply reaches its required torque, locks both joints, switches off motor currents, and awaits further instructions from the microprocessors inside the hand or a command arriving across the communications link.

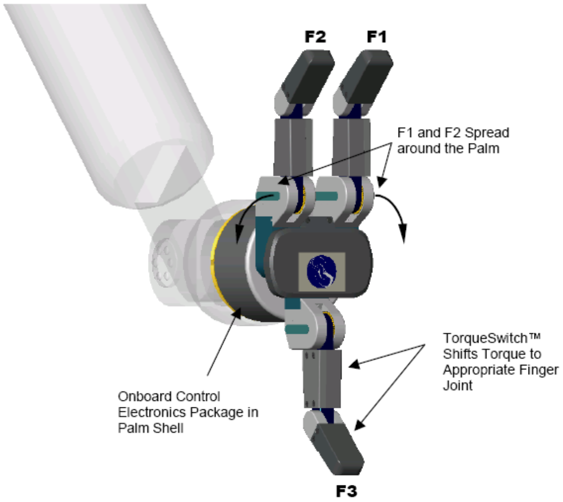

Figure 5 Three articulated fingers of the BarrettHand spread and conform to various shapes

But when the inner link, makes first contact with an object for a secure grasp, the TorqueSwitch, reaches a preset threshold torque, locks that joint against the object with a shallow-pitch worm, and redirects all torque to the fingertip to make a second, enclosing contact against the object within milliseconds of the first contact. The sequence of contacts is so rapid that you cannot visualize the process without the aid of high-speed photography. After the grasper releases the object, it sets the TorqueSwitch threshold torque for each finger in anticipation of the next grasp by opening each finger against its mechanical stop with a controlled torque. The higher the opening torque, the higher the subsequent threshold torque. In this way, the grasper can accommodate a wide range of objects from delicate, to compliant, to heavy.

The finger articulations, not available on conventional grippers, allow each digit to conform uniquely and securely to the shape of the object surface with two independent contact points per finger. The position, velocity, acceleration, and even torque can all be processor controlled over the full range of 17,500 encoder positions. At maximum velocity and acceleration settings, each finger can travel full range in either direction in less than one second. The maximum force that can be actively produced is 2kg, measured at the tip of each finger. Once the grasp is secure, the links automatically lock in place allowing the motor currents to be switched off to conserve power until commanded to readjust or release their grasp.

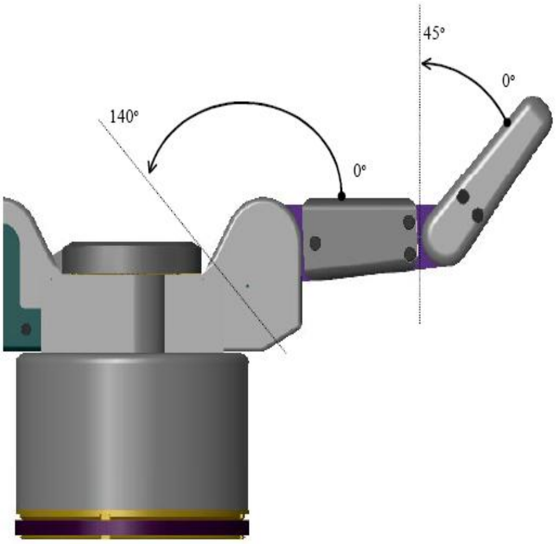

Figure 6 The inner and outer joints close in a 3-to-4 ratio with respect to the robot toolplate until the inner link strikes an obstacle, activating the TorqueSwitch

While the inner and outer finger-link motions curl anthropomorphically, the spread motion is distinctly non-anthropomorphic. The spread motion is closest in function to a primate's opposable (thumb) finger, but instead of one opposable finger, the BarrettHand has twin, symmetrically opposable fingers centered on parallel joint axes rotating 180 degrees around the entire palm to form a limitless variety of gripper-shapes and fixture functions.

The spread can be controlled to any of [3,000] positions over its full range in either direction within 1/2 second. Unlike the mechanically lockable finger-curl motions, the spread motion is fully back-drivable, allowing its servos to provide active stiffness control in addition to control over position, velocity, acceleration, and torque. By allowing the spread motion to be compliant while the fingers close around an object, the grasper seeks maximum grasp stability as the spread accommodates its position, permitting the fingers to find their lowest energy states in the most concave surface features.

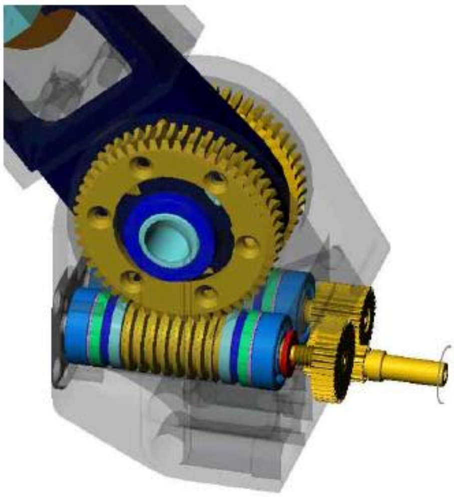

Figure 7 The TorqueSwitch mechanism

4. ELECTRONIC AND MECHANICAL OPTIMISATION

Intelligent, dexterous control is key to the success of any programmable robot, whether it is an arm, automatically guided vehicle, or dexterous hand. While robotic intelligence is usually associated with processor-driven motor control, many biological systems, including human hands, integrate some degree of specialized reflex control independent of explicit motor-control signals from the brain. In fact, the BarrettHand combines reflexive mechanical intelligence and programmable microprocessor intelligence for a high degree of practical dexterity in real-world applications.

By strict mathematical definition, dexterity requires independent, intelligent motor control over each and every articulated joint axis. For a robot to be dexterous, at least n independent servomotors, and sometimes as many as $n + 1$ or $2n$, are required to drive n joint axes. Unfortunately, servomotors constitute the bulkiest, costliest, and most complex components of any dexterous robotic hand. So, while the strict definition of dexterity may be mathematically elegant, it leads to impractical designs for any real application.

According to the definition, neither your hand nor the BarrettHand is dexterous. Naturally, their superior versatility challenges the definition itself. If the BarrettHand followed the strict definition for dexterity, it would require between eight and 16 motors, making it far too bulky, complex, and unreliable for any practical application outside the

mathematical analysis of hand dexterity. But, by exploiting four intelligent, joint-coupling mechanisms, the almost-dexterous BarrettHand requires only four servomotors.

In some instances reflex control is even better than deliberate control. Two examples based on your own body illustrate this point. Suppose your hand accidentally touches a dangerously hot surface. It begins retracting itself instantly, relying on local reflex to override any ongoing cognitive commands. Without this reflex behavior, your hand would burn while waiting for the sensations of pain to travel from your hand to your brain via relatively slow nerve fibers and then for your brain, through the same slow nerve fibers, to command your arm, wrist, and finger muscles to retract.

As the second example, try to move the outer joint of your index finger without moving the adjacent joint on the same finger. If you are like most people, you cannot move these joints independently because the design of your hand is optimized for grasping. Your muscles and tendons are as streamlined and lightweight as possible without forfeiting functionality.

The design of the BarrettHand recognizes that intelligent control of functional dexterity requires the integration of microprocessor and mechanical intelligence.

5. CONTROL ELECTRONICS

Inside its compact palm, the BarrettHand contains its central supervisory microprocessor that coordinates four dedicated motion-control microprocessors and controls I/O via the RS232 line. The control electronics, partially visible in Figure 4 are built on a parallel 70-pin backplane bus. Associated with each motion-control microprocessor are the related sensor electronics, motor commutation electronics, and motor-power current-amplifier electronics for that finger or spread action.

The supervisory microprocessor directs I/O communication via a high-speed, industry-standard RS232 serial communications link to the work-cell PC or controller.

RS232 allows compatibility with any robot controller while limiting umbilical cable diameter for all power and communications to only 8mm. It is important to recognize that graspers generally remain inactive during most of the work-cell cycle, while the arm is performing its gross motions, and are only active for short bursts at the ends of an arm's trajectories.

While the robotic arm requires high control bandwidth during the entire cycle, the grasper has plenty of time to receive a large amount of setup information as it approaches its target. Then, with precision timing, the work-cell controller releases a "trigger" command, such as the ASCII character "C" for close, that begins grasp execution within a couple milliseconds.

6. GRASPER CONTROL LANGUAGE (GCL)

The grasper can communicate and accept commands from any robot-work- cell controller, PC, Mac, UNIX box, or even a Palmpilot via standard ASCII RS232-C serial communication — the common denominator of communications protocols. Though robust, RS232 has a reputation for slow bandwidth compared to USB or FireWire standards, but its simplicity leads to small latencies for short bursts of data. By streamlining the GCL, we have achieved time of flight to execute and acknowledge a command (from the work-cell controller to the grasper and then back again to the work-cell controller) of the order of milliseconds. The initial effort to develop a highly optimized grasper language based on such a standard protocol means that the GCL is upwardly compliant with any future industry-standard protocol.

The grasper has two control modes: supervisory and real time. Supervisory is the normal mode used to control the grasper. It is made up of a simple command structure, designed for optimal performance and minimized learning curve.

Supervisory mode has the following grammatical structure:

Object (prefix) — Verb (command) — Subject (parameters) — Qualifiers (values)

The prefix refers to motors 1 through 4 with the ASCII values for 1, 2, 3, and 4 corresponding to the fingers Fl, F2, F3, and the spread motion. Any number of prefixes may be used in any order. If the prefix is omitted, then the grasper applies the command to all available axes.

As an example, the ASCII character "C" represents the command which drives the associated motor(s) at its individual default (or user defined) velocity and acceleration profile(s) until the motor(s) stops for the default (or user defined) number of milliseconds. As each motor reaches this state its position is locked mechanically in place.

• 1C closes finger Fl.
• 2C closes finger F2.
• 12C closes fingers Fl and F2.
• C is equivalent to 1234C and closes all three fingers and the spread motion.

We also have defined "S" (derived from "spread") as a shortcut for "4" and "G" (from "grasp") as a short cut for "123", so that:

• GC is equivalent to 123C
• SC is equivalent to 4C

There are similar commands for opening fingers, moving any combination of the four axes to an array of positions, incremental opening and closing by default or user defined distances, reading and setting user-defined parameter values, and reading the (optional) strain gages on the three fingers. The latest version of the BH8-250 firmware has 21 commands and 28 parameter settings, giving it almost unlimited flexibility.

The real time mode is reserved for

advanced uses such as real time tele-operation control and is frequently accessed through Barrett's user-friendly GUI for PCs running Windows95/98/NT. In real time mode, the user specifies a tailored packet-structure in supervisory mode. Barrett's PC software gives the user a histogram of 20 successive time-of-flight tests so that the user can refine the packet structure by quantitatively balancing information content with latency.

The GUI accelerates the prototyping of tasks and includes a pictorial of the grasper with sliders for position and rate control. The GUI also has a novel "Generate C++ Code" button which enables anyone to save and later recall successful algorithms without any knowledge of C or C++ programming. But, with C++ programming familiarity, you can also edit the code as desired.

Once real time mode is initiated, packets are exchanged in full duplex until an ASCII control character is issued to break out of real time mode and return to supervisory mode. The system has proven effective and robust in a variety of customer applications.

7. CONCLUSION

Although the BarrettHand BH8-250 was only introduced commercially in 1999, 30 units have been put into service around the globe at a price of US$30,000 each. The largest concentration of graspers is among automotive manufacturers and suppliers in Japan, including Honda, Yamaha Motorcycles, and NGK (ceramic substrates for catalytic converters). At this time, these manufacturers are only beginning to explore the capabilities of this versatile device, while some customers, such as Fanuc Robotics and the US and Japanese space programs have become repeat customers.

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CARING OUT THE BENCHMARKING NATIONAL NET FOR COMPANIES

Dr.ing. Diana Mura Badea, INCDMF Bucuresti, Romania
Auditor sef SRAC,Vasile Finat, INCDMF Bucuresti, Romania
Ing.Angela Voicila, consilier CER Bucuresti, Romania
Dr.ing. Gabriel Vladut, IPA CIFATT Craiova, Romania
Dr.ing. Dinu Comanescu, UPB-CCDM, Romania
Dr.ing. Petrin Drumea, INOE 2000 IHP Bucuresti, Romania

Abstract - Caring out the Benchmarking National Net for Companies is based on the Benchmarking Europeen Net model and has as an objective the encouragement off all interested parts to concentrate their efforts in order to create a favorable environment where:

- The Romanian Companies must be based on reliable, coherent and equal services.
- The SMEs must have access and be initiated in the benchmarking concepts add services as stimulus for the on going improvement.
- To provide better identification posibilities of the point of comparation and using of the best practices.

Thus, the European benchmarking model and frame has been taken over.

Keywords – SMEs, Benchmarking

INTRODUCTION

Caring out the Benchmarking National Net for Companies is based on the Benchmarking Europeen Net model and has as an objective the encouragement off all interested parts to concentrate their efforts in order to create a favorable environment where:

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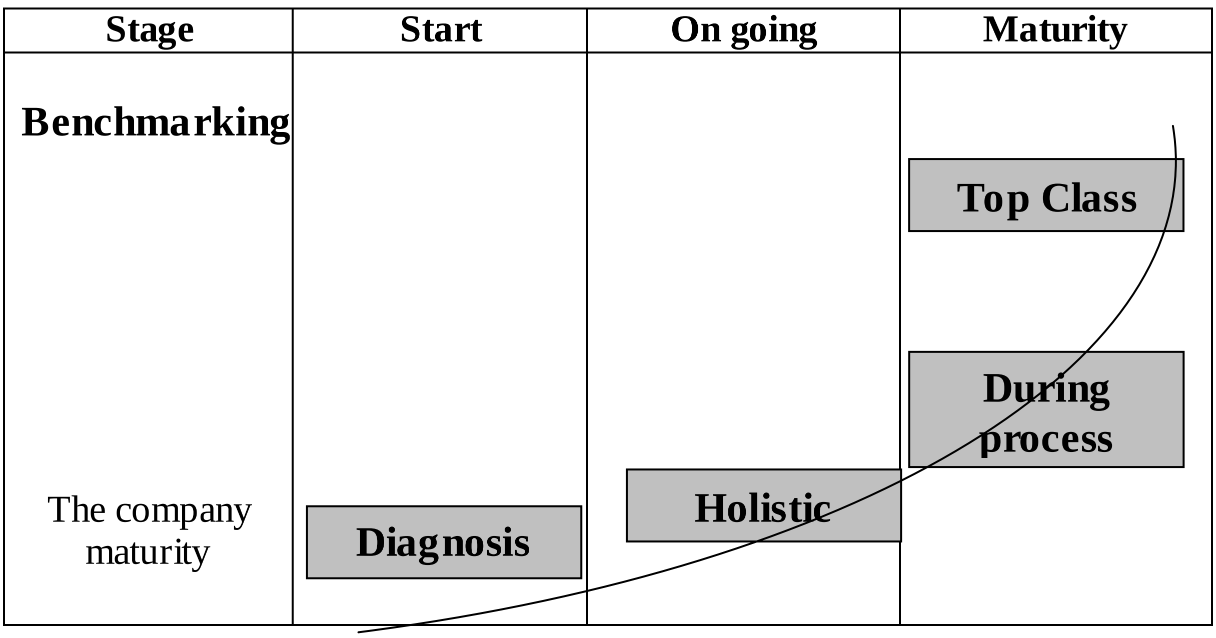
Thus, the European benchmarking model and frame has been taken over.

So the benchmarking chart with its 3 maturity levels has been taken over.

- The early stage – the company has the first contact with this instrument (Diagnosis Benchmarking).
- Holistic Benchmarking – a business in its whole is tasted and the key zones to be improved are identified.
- Process Benchmarking – an already tested company is countered on the specific process and has in view the performance at worldwide level.



THE BENCHMARKING AS A PART OF THE QUALITY MOVEMENT

In order to overpass the rising competition, the organization must over take new skills and practice, new ideas.

This means they must change and improve the performance. The changing and the improvement are direct connected by know-how.

If another organization has found a better solution, why should it be refuzed its experience ?

By comparing the own solution with a better one, we can learn how to improve our own solution.

The Benchmarking role is: “To learn from the others”.

Benchmarking is a part of the quality management concept, comparing the practices even in different fields, may bring important improvements.

A sugestive example is that some governmental agencies, schools, hospitals, etc find out concepts applied by companies as being good for them, too.

Taking into consideration benchmarking direction is mainly to proceses, comparing them is not so important if the organization has 100 or 10.000 employees.

THE TOP MANAGEMENT SUPPORT IS AN ESSENTIAL CONDITION IN BENCHMARKING

Without an opened and sincere support of the top management in projecting benchmarking may not achieve the wanted results. The top management is able and can support the team.

In adition, the top management must accept less flettering analizes of their capacities and must provide the frame conditions for the change.

Having as a base the excellence business EFQM model where an organization trys to describe itself on the basis of 9 performance cryteries:

<table>
<tr><td rowspan="3">Management
10%</td><td>Employees
9%</td><td rowspan="3">Processes
14%</td><td>Employees satisfaction
9%</td><td rowspan="3">The business results
15%</td></tr>
<tr><td>Policy and strategy
8%</td><td>Clients satisfaction
20%</td></tr>
<tr><td>Resources
9%</td><td>Impact on the society
6%</td></tr>
</table>

Important factors 50% | Results 50%

when improvement posibilities are taken into consideration, cames out an issue connected to the fact that an organization prefers already known ways to find solutions.

Here the Benchmarking has to interfere. Are compared the own process - which were identified as needing improvement – with a similar process from another organization in order to have a different view and in order to cary out a real improvement.

THE DEVELOPING STAGES OF THE BENCHMARKING CONCEPT

The development of the benchmarking concept may be devided in 5 stages:

1. *The analize of the products in competition*

The Benchmarking concept in this stage meant the comparation between products features, functionality and performance, in competition. At the beginning it is perfomed only at the technical level and then on a larger scale, including the products in competition evaluation from the market prospective.

2. The competition Benchmarking

First was performed by Rank Xerox when they started to analize their own manufacturing expences and to verify if there were as expensive as the competition selling prices. Now the accent is on the processes effciency and not only comparing the products.

3 The process Benchmarking

Has appeared during the '80 when the managers started to understand that they may learn from other enterprises, from other fields experience (Benchmarking taken from the box). The information quantity and the existing knowleadges in the companies that are not in competition is apriori higher than to the competition.

4. The strategy Benchmarking

It is a systemic process of evaluating the alternative scenaries of implementing strategies and improving performances by understanding and adopting the partners succesfull strategies (either in competition or not).

This is different from the process benchmarking because its area is larger and dipper.

5. The global Benchmarking

It is the next generation concept. It is a global concept because it includes and analyses the cultural differences between the companies at the worldwide level. It takes into consideration the conditions (laws, administration, education, social and environment) influencing the companies location.

PRESENTATION OF THE PROJECT CARRYING OUT THE BENCHMARKING NATIONAL NET

The project title: Carrying out a benchmarking net in order to use the strategic benchmarking, performance and the process to support the economical reforms, trade for SME's.

The project objective is to carry out the net, to train the experts and to set up the benchmarking organizations in order to promote in Romania the benchmarking techniques and concept and the connection to the European and international nets.

Preparation to attend the future RTD FP7 of the EU for the period 2007-2013 (FP7). The FP7 future project shows clearely the main options of the European policy in the RTD field, knowing that science and technology are considered real key instruments for the European future (the essay "Science and technology, the key to Europe's future – Guidelines for future European Union policy to support research").

The essential part of the scientific research and technological development in order to improve the European economical competition was recognized and stated by the strategy set up by the European Council in Lisabona in 2000.

In order to answer these requirements are needed:

- to provide and develop domestically the institutions nets and organizations that may become interne sorces of scientific competence and reference technique;

- both in the high technology fields and for the general development of the society based on knowledges.

The project is financed by the Excellence Research Programme meant to:

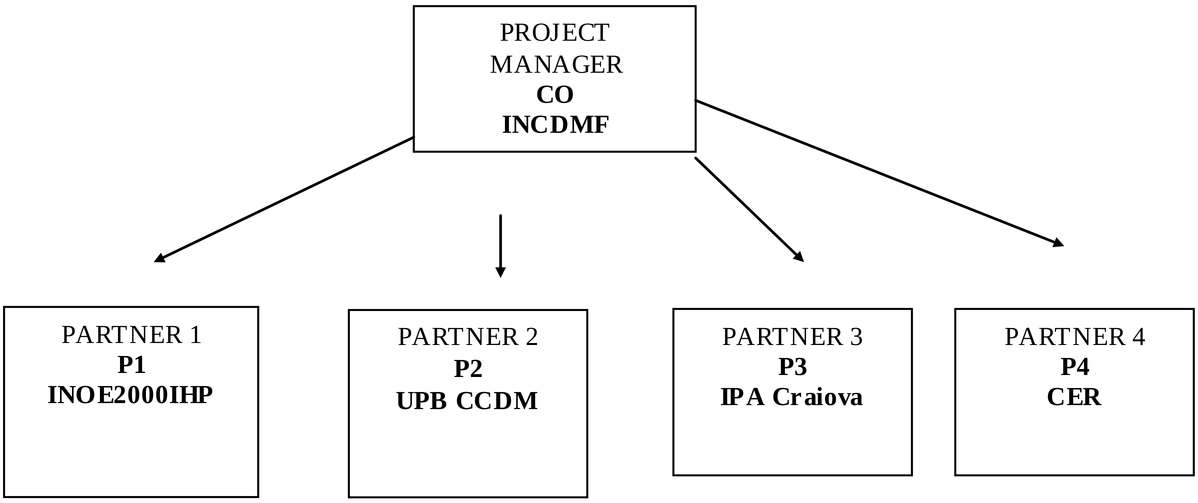
- improve, the RTD system capacity in Romania of taking over knowledges, results and high level experience in top scientific and technologies field, spreading and sending them to the economical and social domestic environment in order to improve its competitivity;
- support setting up, development, integration and strengthening in the envisaged fields of some research nets whose activity touches the excellence level, recognized according to the international standards;

- accelerate the alignment and technological integration of the economical agents, according the EU requirements and standards;
- integrate and strengthen the RTD institutional nets in the envisaged fields.

It is included in the module 1: „Complex Research and Development Projects" having as specific objectives:

- to improve the national economical competition;
- to cary out some integrated technological nets in the specific fields, that may allow the integration in the corresponding technological platform at the European level;
- to develop RD activities and infrastructures at regional level having social impact.

The partnership structure in the project:



RESEARCH REGARDING THE CONSTRUCTION OF A NEW TYPE OF PROFILED ROTOR

Abulghanam ***Zaid***[1)]*, Nicolae* ***Băran***[2)]*, Despina* ***Duminică***[2)]
[1)] *Al-Balqa; Applied University Tafila Applied University College P.O. Box 179 Jordan*
[2)] *POLITEHNICA University, Splaiul Independentei 313, Sector 6 ,060042, Bucharest, Romania*

Abstract - The paper presents the sketch and the functioning principle for a new type of fan with profiled rotors. Each profiled rotor includes two rotating pistons which enter the cavities of the adjacent rotor. The outline of the rotating piston is described by mathematical relations; a computer program was used in order to establish the numerical coordinates (x_i, y_i) of the outline.
Based on these coordinates, two identical rotors for the new type of fan were machined on a CNC centre

Keywords – profiled rotors, piston profile

1. SKETCH AND CONSTRUCTIVE PRINCIPLE OF A FAN WITH PROFILED ROTORS

The constructive solution and the functioning principle of the fan result from Figure 1.

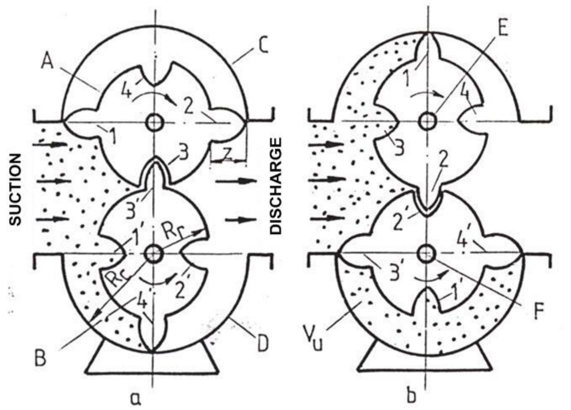


Fig. 1. *Sketch of fan with profiled rotors. A,B – rotors; C, D – half-cylinders; E, F – shafts; 1, 2, 3', 4' – rotating pistons; 1', 2', 3, 4 – cavities in which penetrate the pistons of the adjacent rotor.*

The two rotors A and B are tangent and rotate synchronously. There are two ways of guaranteeing the synchronous rotation:

- manufacturing of a number of teeth on the lateral surface of the rotors;
- using two gears placed outside the fan and fixed on the shafts E and F (Fig. 1 b).

The rotating pistons (1, 2, 3', 4' – Fig. 1) enter the cavities of the adjacent rotor.

The suctioned fluid (Fig. 1 a) is transported to the discharge and, after a 90º rotation of both rotors, the system arrives in the position shown in Figure 1 b.

The fluid contained in the available volume Vu (Fig. 1, b), that is the space between the pistons 3' and 4', will be transported to the discharge after a 180º rotation.

Two such volumes will be transported from intake to discharge during a complete rotation.

Computing relations for the volumetric flow rate ($\dot{V}$)and for the fan driving power (P) are established in [1] and [2].

$$\dot{V} = \pi l z (z + 2R_r) \cdot \frac{n}{30} \text{ [m}^3\text{/s]} \quad (1)$$

$$P = \dot{V} \cdot \Delta p = \dot{V} \cdot \rho_{H_2O} \cdot g \cdot \Delta h \text{ [W]} \quad (2)$$

where: R_r – rotor radius [m]; l – rotor length [m]; n – rotating speed [rot/min]; Δp – increase of pressure achieved by the fan, which can be expressed in [N/m^2] or in Δh [m H_2O].

2. ESTABLISHING COMPUTING RELATIONS IN ORDER TO DEDUCE THE OUTLINE COORDINATES OF THE ROTATING PISTON PROFILE

Each cylindrical rotor is endowed with two special-shaped cavities and with two rotating pistons.

The computation method for the cavity outline is presented in [3] and [4].

The shape of the rotating piston can be:

a) triangular; in this case there is only one tightening zone between the intake (the low pressure zone) and the discharge (the high pressure zone); this zone appears as a result of the mobile contact between the top of the piston and the inside surface of the casing, respectively of the cavity of the adjacent rotor.

b) a parabole symmetric to the piston axis;

c) a curve with a relatively complex equation; the paper establishes the equations from which the coordinates of the curve points can be deduced; the coordinates are obtained using computation software and are presented below.

The previously presented constructed solution is considered. The rotor radius was chosen $R_r = 50\,\text{mm}$ and the casing radius $R_c = 80\,\text{mm}$.

If the upper rotor (O_2) is fixed, the point E, placed on the mobile lower rotor (O_1) will arrive to the point A (Fig. 2).

Which will be the trajectory of the point E on the annular surface ($R_r \div R_c$) if the two rotors are mobile ?

A rotating coordinate system xO_2y is chosen in order to solve the problem. The coordinates of the point A (x_A, y_A) are established relatively to this system.

The coordinates of point A will be:

I) $x_A = - O_2B = - CD = - AC\cos\alpha$ (3)

It is obtained from $\Delta\ O_1EC$ that:

$$\cos\theta = \frac{O_1E}{O_1C} = \frac{R_r}{R_r + AC} \quad . \tag{4}$$

It results that

$$AC = \frac{R_r(1-\cos\theta)}{\cos\theta} \, . \tag{5}$$

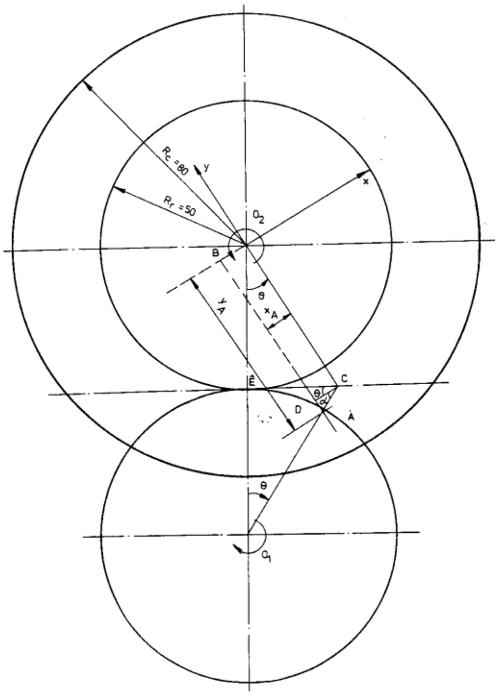


Fig. 2. *Notations for computing.*

Because in $\Delta\ O_1EC$

$$\theta + 90^0 + \theta + \alpha = 180^0 \tag{6}$$

it results:

$$\alpha = 90^0 - 2\theta \tag{7}$$

If (5) and (7) are introduced in (3), it is obtained that:

$$x_A = -\frac{R_r(1-\cos\theta)}{\cos\theta} \cdot \cos(90^0 - 2\theta), \tag{8}$$

or:

$$x_A = -\frac{R_r(1-\cos\theta)}{\cos\theta} \cdot \sin 2\theta \, .$$

II) $y_A = - AB = - (BD+DA) = - (O_2C+DA)$ (9)

It is obtained from $\Delta\ O_2EC$ that:

$$\cos\theta = \frac{O_2E}{O_2C} = \frac{R_r}{O_2C}; \; O_2C = \frac{R_r}{\cos\theta} \tag{10}$$

$$y_A = -\left(\frac{R_r}{\cos\theta} + AC\sin\alpha\right) = -\left[\frac{R_r}{\cos\theta} + \frac{R_r(1-\cos\theta)}{\cos\theta} \cdot \sin(90^0 - 2\theta)\right] \tag{11}$$

or $y_A = -\left[\dfrac{R_r}{\cos\theta} + \dfrac{R_r(1-\cos\theta)}{\cos\theta} \cdot \cos 2\theta\right]$.

The coordinates of the point A will be:

$$\begin{cases} x_A = -\dfrac{R_r(1-\cos\theta)}{\cos\theta} \cdot \sin 2\theta; \\ y_A = -\left[\dfrac{R_r}{\cos\theta} + \dfrac{R_r(1-\cos\theta)}{\cos\theta} \cdot \cos 2\theta\right] \end{cases} \tag{12}$$

If the angle θ is eliminated from the system of equations (12), the equation of the curve that establishes the outline of the rotating piston is obtained. This equation is difficult to solve.

3. COMPUTING EXAMPLE

The values in Table 1 are obtained if values R_r=50 mm, R_c=80 mm and $\theta = 0^0, 1^0, 2^0, \ldots 52^0$ are introduced in Equation (12).

Tab. 1. *Computed values.*

θ	x_i [m]	y_i [m]
0	0	-0,05
1	-0,2658909	-0,0500152
2	-0,2125980	-0,0500609
3	-0,7172460	-0,0501369
4	-0,0000170	-0,0502430
5	-0,0000332	-0,0503791

θ	x_i [m]	y_i [m]
6	-0,0000573	-0,0505448
7	-0,0000908	-0,0507398
8	-0,0001354	-0,0509637
9	-0,0001926	-0,0512160
10	-0,0002638	-0,0514961
11	-0,0003506	-0,0518035
12	-0,0004543	-0,0521375
13	-0,0005765	-0,0524973
14	-0,0007186	-0,0528822
15	-0,0008819	-0,0532913
16	-0,0010678	-0,0537238
17	-0,0012775	-0,0541786
18	-0,0015124	-0,0546548
19	-0,0017737	-0,0551513
20	-0,0020626	-0,0556670
21	-0,0023803	-0,0562008
22	-0,0027277	-0,0567514
23	-0,0031061	-0,0573176
24	-0,0033072	-0,0576061
25	-0,0039596	-0,0584914
26	-0,0044366	-0,0590963
27	-0,0049482	-0,0597114
28	-0,0054953	-0,0603351
29	-0,0060786	-0,0609660
30	-0,0066987	-0,0616025
31	-0,0073564	-0,0622432
32	-0,0080522	-0,0628863
33	-0,0087866	-0,0635302
34	-0,0095601	-0,0641734
35	-0,0103730	-0,0648142
36	-0,0112257	-0,0654509
37	-0,0121184	-0,0660817
38	-0,0130514	-0,0667050
39	-0,0140247	-0,0673190
40	-0,0150384	-0,0679220
41	-0,0160925	-0,0685123
42	-0,0171870	-0,0690881
43	-0,0183216	-0,0696475
44	-0,0194963	-0,0701890
45	-0,0207107	-0,0707107
46	-0,0219644	-0,0712108
47	-0,0232572	-0,0716877
48	-0,0245884	-0,0721395
49	-0,0259576	-0,0725646
50	-0,0273641	-0,0729612
51	-0,0288072	-0,0733276
52	-0,0302863	-0,0736622

Data from Table 1 allow constructing the curve AC, which establishes the shape of the profile of the rotating piston (Fig. 3).

The curve BC is constructed symmetrical to AC, as shown in Figure 3.

The shape of the rotating piston (curve ACB) is thus established. A better tightening between intake and discharge is obtained, because of the existence of two contact zones:

- between the piston top and the inside surface of the casing, respectively the cavity of the adjacent rotor (O_1);
- between the cavity edge (point A placed on the rotor O_1) and the lateral surface of the rotating piston (ACB) placed on the rotor (O_2).

The data presented in the computing example allowed constructing the profiled rotor presented in Figures 4 and 5.

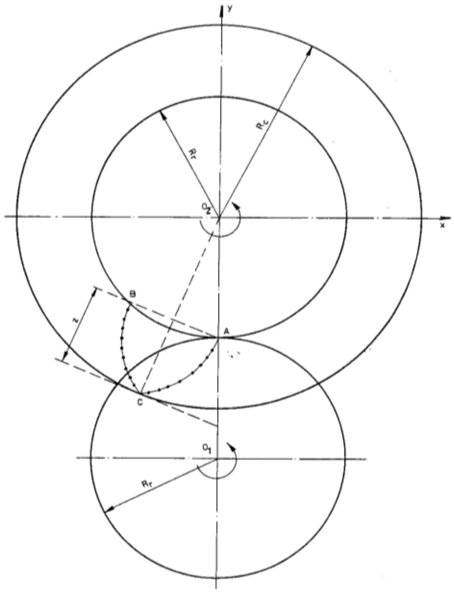


Fig. 3. *The outline of the rotating piston, obtained using numerical data (x_i,y_i) from Table 1.*

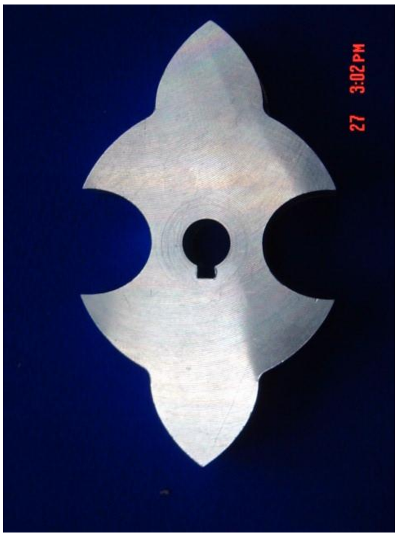


Fig. 4. *Image of the profiled rotor***.**

The machining of the rotor was achieved using a high precision CNC machining centre.

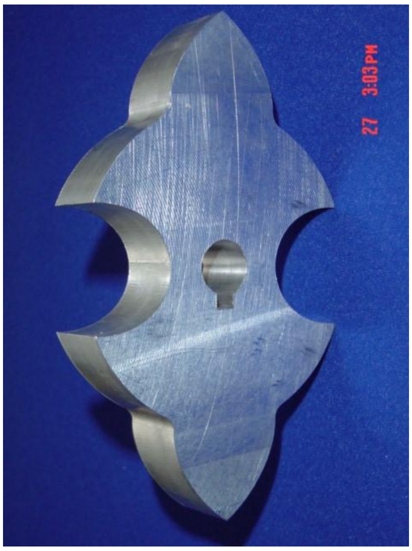


Fig. 5. *Axonometric image of the profiled rotor*

Figure 6 presents both rotors positioned inside the casing; it can be noticed that the rotating piston of the upper rotor enters the cavity of the lower one.

Fig. 6. *The rotors positioned in the casing*

CONCLUSIONS

a) The constructive solution presented in Figure 1 can be used as working machine in the following variants: fan, pump or compressor.

b) Because a solution of rotating machine with alternating rectilinear movement of the pistons was proposed, the energy conversion inside the machine is achieved with minimum loss of energy.

c) The fan can be easily achieved because the manufacturing technology of the rotors and casing is based on a CNC program; the parts are manufactured on a CNC centre.

d) This type of rotating machine has real advantages compared to other types of profiled rotor machines.

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STRATEGY AND INDUSTRIAL POLICY ON MECATRONICS AND MEASUREMENT TECHNIQUE FIELD

Conf.Ph.D., Eng Gheorghe Gheorghe
General Manager INCDMF – Bucharest

Abstract - The paper presents the basic and esential aspects of the strategic tendences of compared evolution of the Precision Mechanics and Mecatronic Integration Industry.
All strategical considerations are bilateral and included in a structural matricx corresponding to : the strategic considered type, objective, initiatives, responsible institutions, alocated resources, implementation period, targets, impact evaluation.

Keywords – mecatronics, high – tech, strategical tendences

Basic and esential aspects of the strategic tendences of compared evolution of the Precision Mechanics and Mecatronic Integration Industry.

➢ **STRATEGICAL TENDENCES OF COMPARED EVOLUTION BASED ON:**

1 **Important changes in the HIGH-TECH products domain with high added value:**

1.1 **The "changing"** becomes on esential factor of developing and innovation, of economical grow the of competitivness and productivity based on raising the new know ledges volume "in order to generate" results with scientific and economical impact, sustaining/supporting the Research programs needing more founds to be allocated according the Lisabona strategy (1% PIB public founds and 2% PIB private founds) and with a better use of the human and material resources, setting up the European research aria and for "changing the scientific results in new products, processes and services".

Thus, the changing in the specific industry made possible the products growth processes and **HIGH-TECH and MED-HIGH-TECH** services, obtained by appling the research results and technological development.

1.2 These new **products/process** with high added value are characterized by new characteristics and performances of the included inteligence and informatization, of the new specialized and decizional functions for the industrial processes from the other branches of the economy and having great variety mainly from the destination point of view – as goods and means for industries, investments and for consume.

An exemple, are the mecatronic inteligent equipments for measurement, adjustment and controling the industrial processes in the processing industry.

1.3 Precision mechanics and mecatronic integration industry has a major contribution to the accomplishment and the development, horizontally and vertically of the informational infrastructure, of the communication infrastructure in industrial an economical processes, of the energetically infrastructure of the health modern infrastructure and lost but not least of the processing industry infrastructure.

1.4 Coven at present, the precision mechanics and mecatronic integration industry, is as the other industries in a difficult position, trying to adopt but mainly to become flexible to the realities of a globalizes /worldwide market it has the tendency towards a renewing, extending and developing strategy under certain forces and competitive phenomenon.

Thus precision mechanics, mecatronic and integrating industry, is by its potential, a new option of industrial development of the Romanian market, on medium and long term, by which, its viable fields at present may sustain the vevelopment of other industrial fields, of new generations in the future but mainly for developing the new generations of the other industrial strategic branches for Romania and for the new Romanian economy, in the context of its integration at 1st January 2007 in EU and in the European single market.

1.5 Thus, by Romania postad heration to EU process and by the financial support that will follow and by the supported/sustained efforts of the Romanian governmental industries, specialy the Ministry of Economy and Trade/Comerce, we may hose the gredients to overpass the obstacles and drive to realist and objective economic process of developing and industrial growing up of the precision mechanics and mecatronics integration field, mainly the HICH TECH products field with gread added value based on new mecatronic knowledges.

- **TRATEGIC TENDENCES OF COMPARED EVOLUTION, BAZED ON:**

2 **Important changes in the demond – offer on the market field :**

2.1 **Precision mechanics and mecatronics integrating industry is characterized at present by a valuable technique offer and by increasing evolution from the qualitative and less quantitative point of view, having a competitive positioning depending of its capability of adaptation to the markets demands and conditioned by the processing industry re launching and generaly by the Romanian industry.**

Thus, the precision mechanics and mecatronic industry in the future has a potential market on medium-long term, being on important source for direct and indirect export and representing in the Romanian industrial system, a competitive field with real chances of viability and providing profit.

2.2 **The field request, in all, shows a quasistationar position and for certain subfields is decreasing, because of the leck of investments in economy and because of population decreasing capacity of bugging.**

2.3 **The field ofert, in all, has a majour development and variety, because of:**

- **the invasion, on the Romanian market, of the products from specialized and worldwide wellknown companies both directy and by the representing Romanian companies;**
- **agresive invasion of some products made by companies out of EU, from forecast countries, and specialy China, using the dumping system.**

2.4 **The domestic market quota of the field in all, decreased mainly in some subfields that are not competitive .**

2.5 **The field external market** is characterized by a continious grow the specialy connected to EU countries because of the traditional market pathes and because of new companies with foreign capital comming with their own pathes.

2.6 **The weight of the precision mechanics and mecatronics integrating industry on the export market** CAEN percentage chass in all is differ between 2006-2008, as follows:

(a) **for CAEN 33:**

- production of medical devices and instruments/tools: 2,35%;
- production of devices and measurement, control and verification: 14,6%;
- production of measurement adjusting and control equipments: 5,38%;
- production of devices and optical and photographical tools/ instruments: 1,26%;
- clocks (orologery): 0,01%;

(b) **for CAEN 28:**

- production of hand tools: 2,79%;
- production cutting and home using devices: 0,33%;

(c) **for CAEN 29:**

- production of home electric devices and tools: 39,2%;
- production nonelectrical devices used at home: 5,1%;

2.7 **Supported development of the HIGH-**

TECH products for export from the precision mechanics and mecatronics integration field, means **initiation and participation with new specific strategies**, as follows:

(a) setting up and organizing a **sectorial pole for export**, specific to the precision mechanics and mecatronic integrating industry (see the anex);

(b) **setting up and monitoring the mix and multifield value chain** (see the anex);

(c) **applying and integration of the value chan in the precision mechanics and mecatronic integration industry** strategy (see the anex);

(d) **setting up and the strategy chart** integration for SMSEs for the **European calification** (see the anex);

(e) **setting up and applying indicators** for integral objective characterization of economical circuites appreciation of the precision mechanics and mecatronics integration filed;

(e_1) **composite index – economical thrust indicator;**

(e_2) **composite ICCS – GEA;**

➤ **STRATEGICAL TENDENCES OF COMPARED EVOLUTION, BASED ON :**

3 **Important relanchings in SUSTEINABLE DEVELOPMENT OBJECTIVE FIELD :**

3.1 **Precision mechanics and mecatronics integrating industry** is envolved at present and in the future in the following **main developing objectives**:

3.1.1 **providing the annual economic grow** the based on growing the investitions rate by the participation of the national capital and by atracting foreign investments;

3.1.2 **providing a certain stability** and a certain stabilization by approaching productive structure in the future high-tech and med-high-tech - mecatronic products with high great aded value on new knowledges, in relaunching and alignment at the European level/international level and financial discipline similar to the European one;

3.1.3 **promoting on alignment and integration policy coherent and compatible** with the EU mechanism and with the community acquis, on revitalization and retehnologiyation of the field with hightech competitive potential and based on informational and mecatronics technology.

3.1.4 **the development of the bussiness enviroment** on the basis of modernizing the economical financial frome the legislative frome, according to competitiveness capacity growth similar to the European one.

3.1.5 **identification and actualization**, based on the strategy, the monoindustrial arias and setting up an action plan and also harmonizing the complementarity and the competivity of the field;

3.1.6 **supporting the reinforcement of the precision mechanics and mecatronics integrated field** in addition to electronics and electrotechnics industrial sectors/fields, for developing the economical agents with competitive and complementar reorientation potential.

3.2 **Precision mechanics and mecatronics integration industry** is deeply involved at present and in the future in the following **derived** development **objectives**:

3.2.1 **impels and development of the national demand as the main outlet of the industrial production by developing the market competition, on going the prices liberalization process by improving the local operators acces to the** public aquisitions etc.;

3.2.2 **stimulating the national/local production in order to improve the export by mentaining** the market on the traditional pathways and on the actual market pathways and by penetrating with new high-tech and med-high-tech mecatronic products with great aded value;

3.2.3 **stimulating the investitional process** of the productive and inovative companies and high-tech companies caring out sustenable investments that should provided **technological and important quality grow in the mecatronic informatics, robotic and informatized products**;

3.2.4 **accelerating finalization of the specific legislative harmonization** for the precision mechanics and mecatronic integrated field, with the European reglementations / regulations, mainly for the competitive fields with chances at export;

3.2.5 **setting up the eficient functioning conditions** of the economical agents from the industrial profile sector and an atractive environment for bussiness and cooperation at domestic and external level.

3.2.6 **suporting applicative R-D with finality and technological transfer in the production field** to industry, economy and society, by themes of interest for the profile industry fields;

3.2.7 **supporting the economical agents** in the field for redimensioning the capacities and modernizing the clean equipments and technologies, for suporting the investments necessary to improve the quality and to reduce the quality improvement and the polution level;

3.2.8 **setting up and organinizind industrial technological and scientifical local / regional clusters** by atraqcting industrial companies, research-development institutions, universities innovative and productive SMSEs and profesional asociations.

➢ **STRATEGICAL TENDENCES OF COMPARATE EVOLUTION, BASED ON:**

4 **Modernizations and developments in THE PRODUCTION CAPACITIES FIELD:**

4.1 **Modernizations and developments in the production capacities field** in the precision mechanics and mecatronics industry are relevant because of the retechnologization evolution at the companies level, from a very low level-becouse of the leck of the investments founds (the great majority of the companies have only Romanian capital) to a medium level-where the companies distribution investment founds for technological renewal (joint venture companies) for new production capacities for test laboratories;

4.2 For the short and medium term **strategy** 2006÷2008 the great majority of modernized technologies are dedicated for improving the products quality by adequate tgechnological procedures similar to those European / International [**automatized technologies** for termic treatments for galvanic coatings, for metalic material moulds (Aluminium Alloy, Coper Alloy etc.) and nonmetalic materials (termorigid plastic materials, teflonic materials etc.)];

4.3 To the great majority of the **productive companies and innovative SMSEs** are majore modernizind tendences and conex and auxiliary fabrications on tools and portable tools, moulds and technological devices, packages etc.

These industrial productions in the own structure context of the industrial production represents in, different way, enough semnificative proportions from the total production volume.

4.4 **Global costs**, on restructing / retehnologizing and modernizing the production capacities are estimated for the period 2006÷2008, as follows:

- **Total global costs,** 2006÷2008: aprox. 160 mil. €, divided in:
  - **own** sources: ~ 38 mil. €;
  - **atracted** sources: ~ 122 mil. €;

4.5 **Actions** carried out by industrial companies and innovative and productive SMSEs, together with the governmental institutions and NGOs are **identified** in order to provide human and financial resources.

Thas are necessary:

(a) **actions to join** the main actors in order to increase the capacity of representing their interests;

(b) **public-privat partnership**, by involving the economical agents, employers, profesional asociations CCIR and CCIB, special national organizations – for standardization, accreditation etc. in order to involve human and financial resoruces for informative actions etc.

➢ **STRATEGICAL TENDENCES OF COMPORATE EVOLUTION, BASED ON:**

5 Important changes in SMSEs streightensing consolidation and development:

5.1 The important changes imluded in the SMSEs consolidation and developing strategyestablish and define, the action direction for the 2006÷2008 period,as follows**:**

(a) **strategic direction "diminishing fiscality over the SMSEs ":**

- *providing fiscal facilities for SMSEs developing intelogent mecatronic fields and high-tecch products ;*

(b) **strategic direction "stimulating setting up new working places, the export and high-tech techniques and technologies implementation":**

- *support to organizing „the export Po " for the precision mechanics and mecatronic Industry;*

(c) **strategic direction "intensifing setting up new SMS Es and reimforming the existing ones":**

- *setting up* ***SMS Es*** *an Intelogent and Informational Engineering, Information and Systems Engineering for products with very great added value;*

(d) **strategic direction "acceleration and amplification acces of the private SMS Es by buging , renting and leasing for the spaces and production and comercial equipment which were not used in the public and state national companies":**

- *the SMS Es within the precision mecchanics and mecatronics profile to the existing capacities in someprecision mechanics entreprises and metal products from OBOR – Bucharest platform;*

(e) **strategic direction „setting up of a founds system to garantee and cogarante at the national and regional level the financing":**

- *setting up "The Loans Garantee Found for precision mechanics and mecatronics industry";*

(f) **strategic direction "setting up a national data / information basis/ bank specialised in the SMS Es issues":**

- *setting up and organizing an Informational bank for SMSEs next to the Romanian goverment and monitorized by the Parliament through its specialised comisions;*

(g) **strategic direction "setting up a strong national consulting and managerial training antreprenorial for SMS Es ":**

- *setting up and organizing a „consulting center" and a bussiness shool for precision mechanics and mecatronics fields in a UPB partnership.*

(h) **strategic direction "developing a national bussiness incubators and scientific parts net":**

- *bussiness incubator for* **SMSEs** *and investors in precision mechanics and mecatronic: instrumentation engineering, robotics and nanorobotics, mecatronics and integronics;*

- *scientific park „Tehnological platform for mecatronics senzorics, robotics and integronics", for European development of know how in* *the fied. ;*

(i) **strategic direction, , setting up a complete rigurous a national strategy for SMS Es , according the management science requirements":**

- *setting up "**a sectorial program** to elaborate national strategies and European integration of the SMS Es from Romania for the curent dimensioning/**sizing of the SMS Es strategie develoment sector** / field for fundamenting its participation basis to Romania development and participation in the prospective development of EU - 27 (according to **the SMS Es strategy scheme for European calification**).*

5.2 MIX Methods and tehniques for dimensioning/ sizing the SMS Es strategies from precision mechanics and mecatronics integrating industry apreciating the competitivity evaluation in the field :

5.2.1 Market Survey

Market Survey –for the specific field is based on the following **analysis /issues/topics :**

(a) **the market structure,**with indicators reffering to products, subfields and entreprises

(b) **the main products market** ;

(c) **the supply net with indicators** reffering to the structure;

(d) **world comerce,** trade with indicators reffering to production, export, import;

(e) **international comerce/** trade with products from industry ;

(f) **industry perfomance indicators**;

(g) **benchmarking** towards other industries;

(h) **benchmarking** towards other countries.

5.2.2 Compozite indicator for evaluating the competitiviness :

Evaluating the competitiviness of the profile industry for the stage of predictional/ predictive and prognosis strategies, will be based on the evaluation composite indicator, finalized by the Word wide Economy Institute under the Romanian Academy (according to the sectorial project on evaluating the sectorial competitiveness).

The Structure of the composite indicator – nominated compozite evaluating indicator of the sectorial competitiveness **– ICCS and calculated as a weighted average of the indicators** on main topics / issues of the competitive performance / including parts as production, technology, structure, exports – will basicaly include the following indicatorrs :

(a) for the **production part:** work productivity (**VAB/emplyee**), using the production capacities (**C_{prd}/$C_{prod.optinal}$**) and unitar expences (**C_{Fm}xF_{mn}**);

(b) for the **tehnology part: expences with** R&D per working person;capital intensity **(invetments/ working person)** ;

(c) for the **structural part : sortimental diversification (diversifity Indicator**); geografical concentration (**concentration Indicator**);

(d) for the exports part: market quota (sails/worldwile sails) dynamics; exchange report (medium export price/medium import).

We must notice that this indicator ICCS will dimensioned by both present and future characterization.

5.2.3 Indicator for economical thrus for evaluating the competitivness:

The evaluation of the economical-financial performances for the industrial brench will be based the thrust **indicator projection** – agrtegated indicator used bu EU and which will include the following indicators:

(1) industrial production;

(2) production price;

(3) ordered novelties;

(4) working force;

(5) working activities ;

(6) constructions licences provided;

(7) the overal orders for the commerce;

(8) registered cars number;

This agregate thrus indicator is actualy a composite indicator evaluating the economical cicles by joining the thrust indicators for industry, services users constructions and commerce identifying and confirming the evaluation or damiging the main thrust indicators for the economical fields analizing this composite indicator tendency – agregat showing the aria, the country the analized industry economical situation.

➢ **STRATEGICAL TENDENCES FOR COMPARATE EVOLUTION BASED ON:**

6 Changes on CONSOLIDATION THE SMSEs FIELD FOR THE EU

6.1 Romania will join the EU at 1.01.2007 and thus **elaborating an consolidation policy for the SMSEs position** in order to be integrated in EU is based on the following premises :

(a) **action modalities:** for accelerating the SMSEs development by respecting and applying „the European Cart for Small Enterprises adopted by the European Council at Fiera-Portugal, 19-20 June 2002 Romania thas given the the aproval/agrement;

(b) **strategical development program for private fields;**

(c) **prioritizing and programing the** Phare PC7 other programs resources;

(d) setting up and organizing at world wide level a **"Task Force";**

(e) **encreasing the support and asistance/consultancy** by the IMMC, Ministry DP, Ministry FP, The Council for National Strategy and Export and the National Nucleus for Export (of the Precision Mechanics and mecatronics industry);

(f) the permanent coordination of the intensive development programs and policies;

(g) **cooperation and permanent buiding** by MEC;

(h) **focusing the activity of IMMC Ministry** on accomplishing objectives of strategical importance**;**

(i) **SMSEs** involving and participation, in setting up national consortium (a high percentage);

➢ **STRATEGICAL TENDENCES OF COMPARED EVOLUTION, BASED ON:**

7 Changes on denomizing the HIGH-TECH PRODUCTS EXPORT FIELD:

7.1 **The target change** on denomizing the HIGH-TECH products export field is sinterized as follows:

(a) **concentrating the field specific activities** mecatronic field promoting the products exports on the functional market pathways;

(b) **concentrating** the financial available resources;

(c) **avoiding the market parts without favorable development prospectives**;

(d) starting/**initiating the necesary steps** by the governmental institutions, to **inform the bussiness comunities** and **export ofices** within the Romania enbasies abroad (ex. to organize „**comercial activities**" on the „**target markets**" for high-tech products) by promoting and concentrating events meant to / for improving the eficiency and impact, by eficient using of the bilateral infrastructure in the export development activities);

(e) **impact seting up and evaluation actions** for the above mentioned changes at least 30%.

7.2 Imediate/operative **actions needed** to achieve the impact, **at least 30%** are the following :

(a) **special colective promotion** on the pathway markets;

(b) **modernizing and changing the technical skills** of the staff of the specialized in export, including programs for young persons by the training programs;

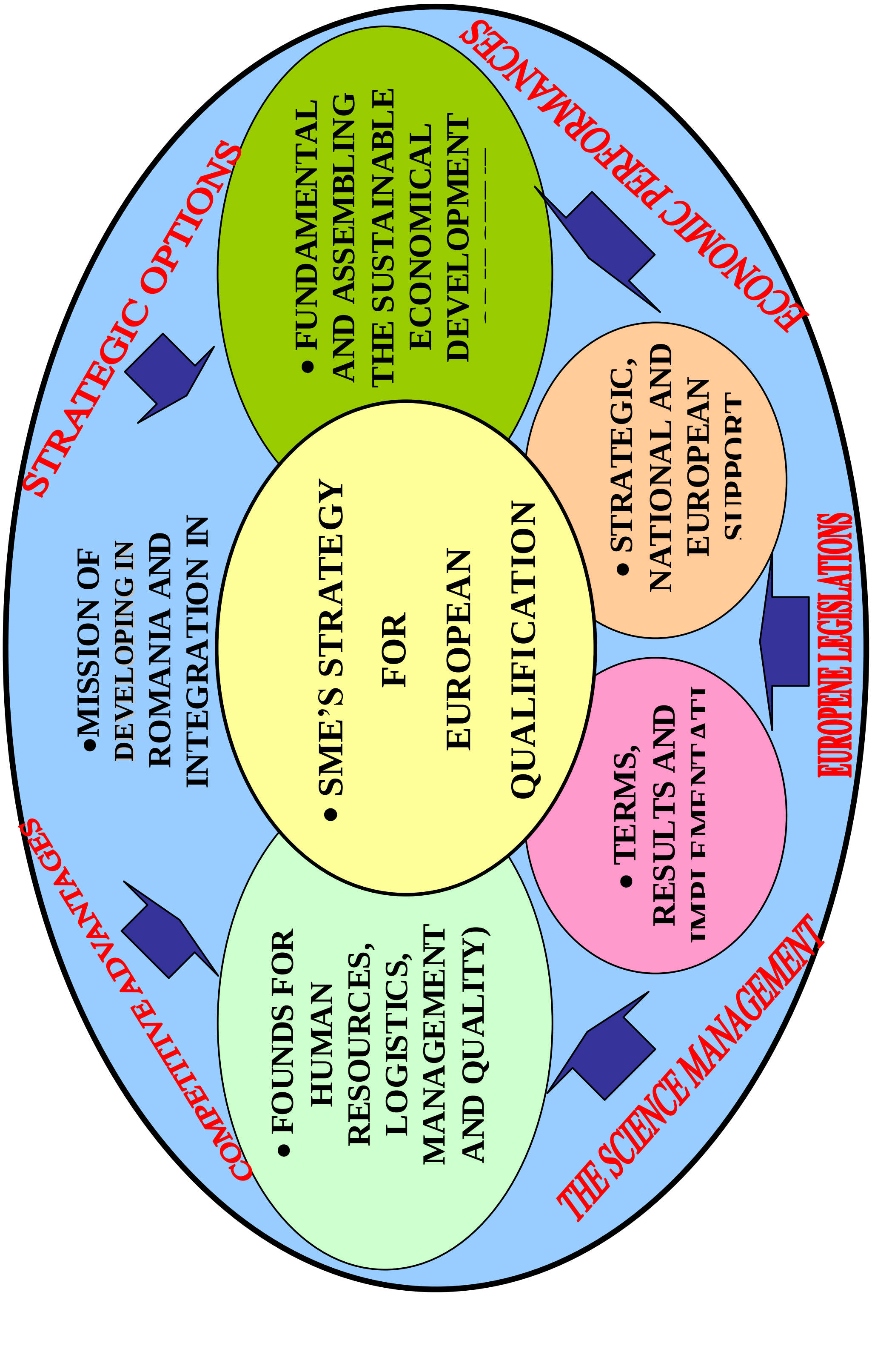
(c) **modernizing** the marketing activities on the foreign markets;

7.3 **The export dinamization prospectives and the export strategies** development for the precission mechanics and mecatronics industry are supported by the following **strategic considerations**:

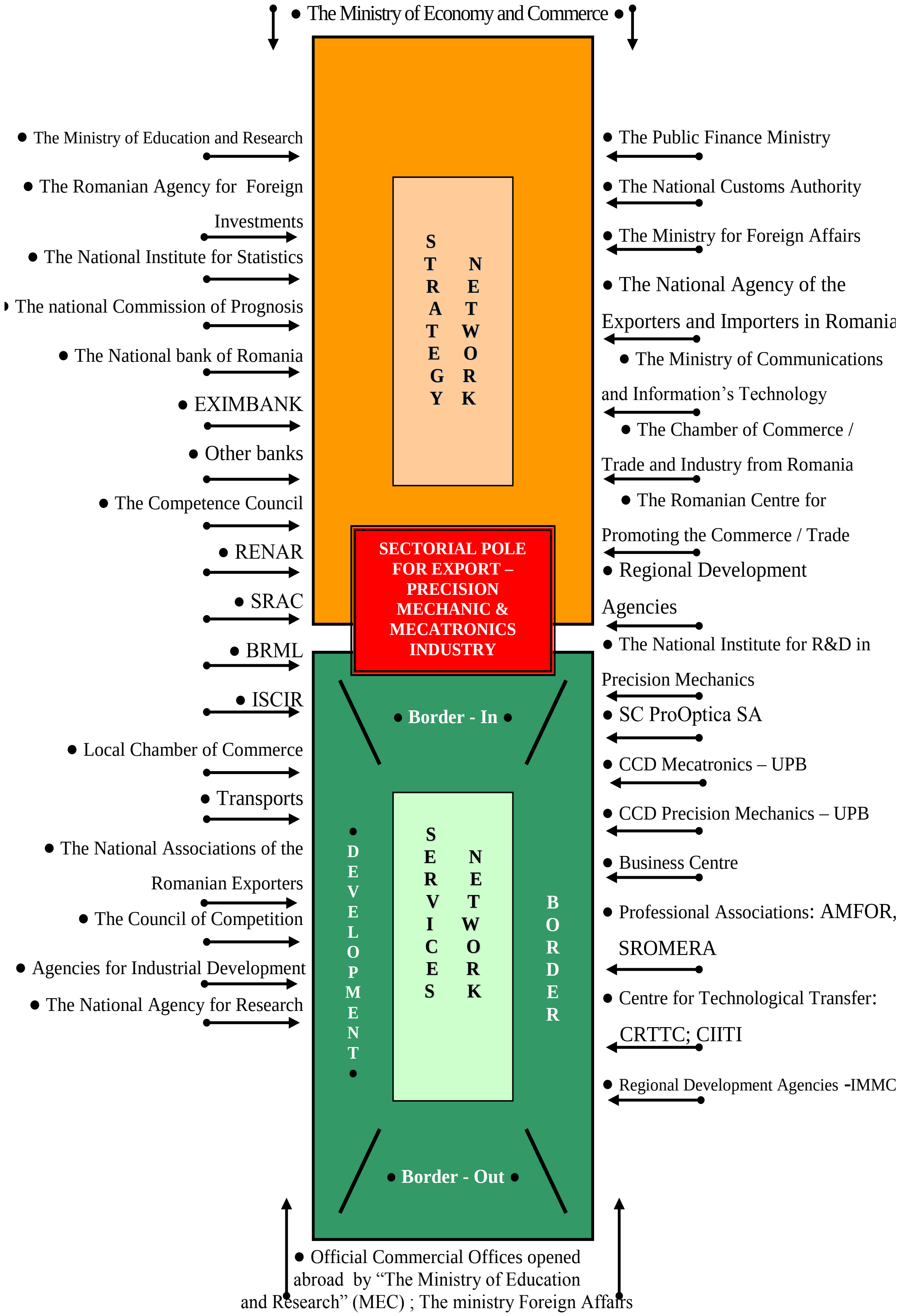
(a) strategic topic no.1: the strategy development components / parts: generated by working places, regional development, environment issues;

(b) strategic topic no.2 : export economic concentrations, clusters;

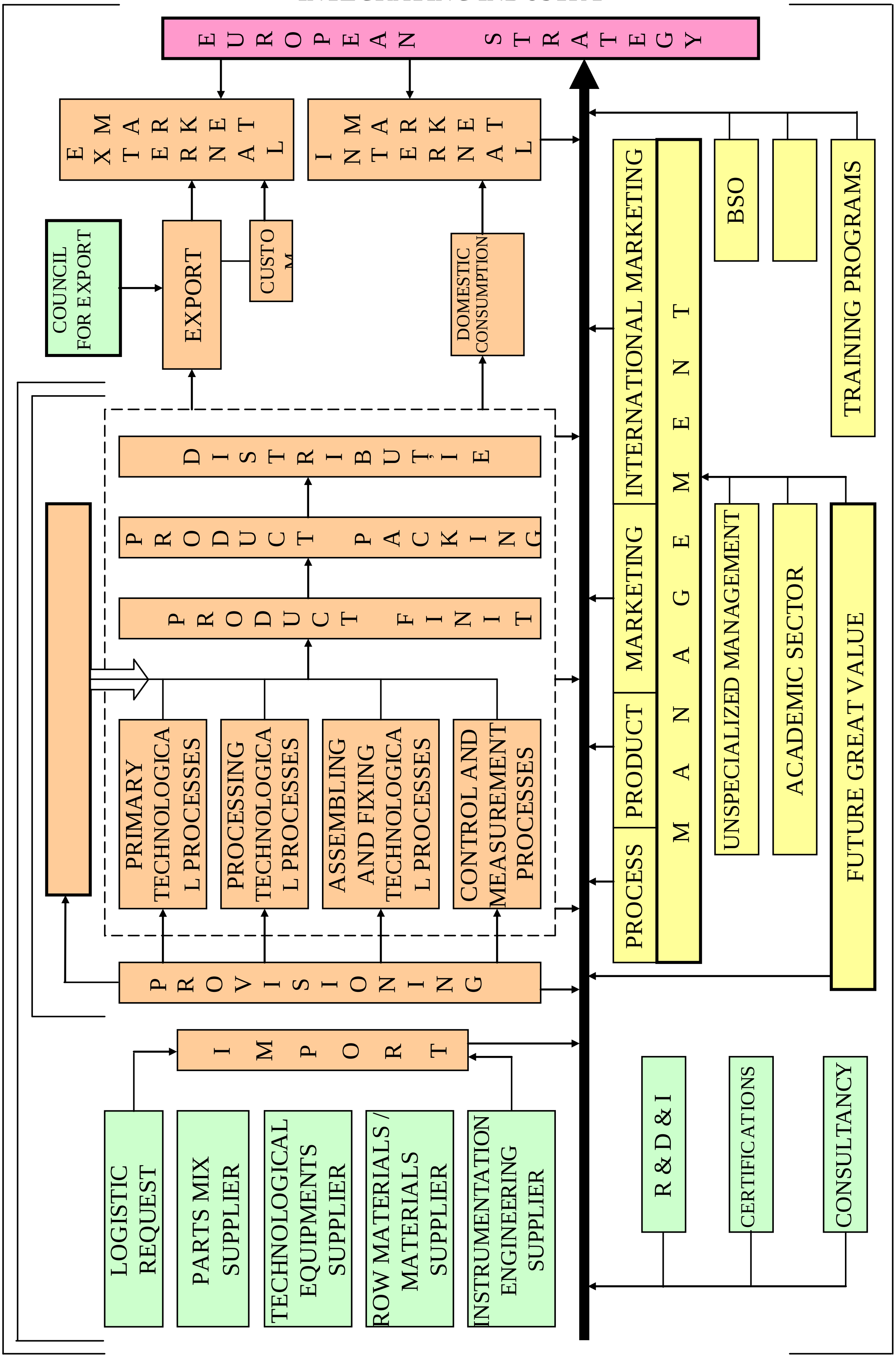
All these strategical considerations are bilateral and included in a structural matricx corresponding to : the strategic considered type, objective, initiatives, responsible institutions, alocated resources, implementation period, targets, impact evaluation.


STRATEGIC OPTIONS
ECONOMIC PERFORMANCES
EUROPENE LEGISLATIONS
THE SCIENCE MANAGEMENT
COMPETITIVE ADVANTAGES
• FUNDAMENTAL AND ASSEMBLING THE SUSTAINABLE ECONOMICAL DEVELOPMENT
•MISSION OF DEVELOPING IN ROMANIA AND INTEGRATION IN
• SME'S STRATEGY FOR EUROPEAN QUALIFICATION
• STRATEGIC, NATIONAL AND EUROPEAN SUPPORT
• TERMS, RESULTS AND
• FOUNDS FOR HUMAN RESOURCES, LOGISTICS, MANAGEMENT AND QUALITY)

● SECTORIAL POLE FOR EXPORT – PRECISION MECHANIC & MECATRONICS INTEGRATOR INDUSTRY ●



• THE MIX VALUE CHAIN – PRECISION MECHANICS AND MECATRONICS INTEGRATING INDUSTRY •



ASSESSMENT OF THE ACTIVITY CYCLE – LATEST TENDENCIES IN EU-25

- **TRUST INDICATOR DE IN ECONOMY • COMPOSITE INDICATOR •**

	Industrial production	Production price	New orders	Workforce	Work activities	Construction permit released	Orders volume in retail	Matriculated automobiles
EU-25	↘ 03-05	↗↗ 03-05	↘ 03-05	→ I-05	↗ IV-04	↗↗ IV-04	↗↗ 03-05	↘↘ 04-05
Zone euro	→ 03-05	↗↗ 03-05	↘↘ 03-05	↘ I-05	→ IV-04	↗↗ IV-04	↗↗ 03-05	↘↘ 04-05
BE	↘↘ 03-05	↗ 03-05	→ 03-05	↘↘ IV-04	↘↘ I-05	→ II-04	↘↘ 03-05	↘↘ 04-05
CZ	→ 03-05	→ 04-05	↘ 03-05	↗↗ II-04	↘↘ I-05	↘ I-05	↗↗ 03-05	
DK	↘ 03-05	↗ 04-05	↗ 03-05	→ IV-03	↗ IV-04	↗ I-05	↗ 03-05	→ 04-05
DE	↗↗ 03-05	↗↗ 04-05	→ 03-05	↘↘ I-05	↘↘ I-05	→ I-05	↗↗ 03-05	↘ 04-05
EE	↗ 03-05		↗ 03-05	↘↘ IV-04	↗ IV-04	→ IV-04	↗↗ 03-05	
EL	→ 03-05	↗ 03-05				↗↗ II-04	↘ 02-05	↘↘ 04-05
ES	↘↘ 03-05	↗↗ 03-05		↗↗ IV-04	→ IV-04	↗↗ IV-04	↗ 03-05	↘ 04-05
FR	↘ 03-05	↗↗ 03-05	↘↘ 03-05	↘ I-05	↘ I-05	↘↘ I-05	↗ 03-05	→ 04-05
IE	↘ 03-05	↗ 03-05		↘ IV-04	↗↗ IV-04	→ IV-04	↗↗ 03-05	↗↗ 04-05
IT	↘ 03-05	↗↗ 03-05	↘ 03-05		↘ IV-04		→ 02-05	↘ 04-05
CY	→ 02-05	↗ 03-05		↗↗ IV-04	↗↗ IV-04	↗↗ IV-04	↗ 02-05	
LV	→ 03-05		↗ 03-05	↗ IV-04	↗↗ IV-04		↗↗ 03-05	
LT	→ 03-05	↗ 04-05	↘ 03-05	→ IV-04	↗↗ I-05	↘ IV-04	↗ 03-05	
LU	↗ 03-05	↘↘ 03-05	↘↘ 02-05	→ IV-04	↘↘ IV-04	↘ IV-04	→ 03-05	↘↘ 04-05
HU	→ 03-05	↗ 03-05	↘ 03-05	↘ I-05	↗ I-05	→ IV-04	↗ 02-05	
MT			→ 03-05	→ IV-04	↗ III-04			
NL	↘↘ 03-05	↗ 03-05	↗ 03-05	↘↘ IV-04	↘↘ I-05	↗↗ IV-04	→ 02-05	↘ 04-05
AT	→ 02-05	↗↗ 03-05	↗ 02-05	→ IV-04	↗ IV-04	↗↗ IV-03	↘ 02-05	↘↘ 04-05
PL	→ 03-05	↘ 03-05	↗ 03-05	↗↗ I-05	↘ I-05	→ IV-04	→ 03-05	
PT	↘ 03-05	↗↗ 03-05	↗↗ 03-05	↘↘ I-05	→ I-05	→ I-05	↗↗ 03-05	↘ 04-05
SI	↘↘ 03-05	↗↗ 04-05		→ IV-04	→ I-05	↘ I-05	↘ 03-05	
SK	↗ 03-05	↘ 03-05	→ 03-05	↘↘ I-05	↘ I-05		↗↗ 03-05	
FI	↘ 03-05	↗↗ 04-05		↗ I-05		↘ IV-04	↗↗ 03-05	↗ 04-05
SE	↗↗ 03-05	↗↗ 03-05	↘ 03-05	↘ II-04	→ II-04	↘↘ I-05	↗↗ 03-05	↘ 04-05
UK	↘↘ 03-05	↗↗ 04-05		↘↘ I-05	↗ IV-04	→ III-03	↗ 03-05	↘ 04-05
NO		↗↗ 04-05		→ IV-04	↗↗ IV-04	↘↘ I-05	→ 03-05	↘↘ 04-05
CH				↘↘ IV-04		↗↗ IV-04		
BG			↗↗ 03-05		↗↗ IV-04		↗↗ 03-05	
RO	→ 03-05	↗ 03-05	↘↘ 03-05	↗ I-05	↗↗ IV-04	↘ IV-04	↗↗ 11-04	

Note:

- **TRUST INDICATOR DE IN ECONOMY** is **a composite indicator,** designated to evaluate the European economical cycles, constructions and commerce; This indicator identifies and confirms the estimation or the damaging of the main trust indicators for the analyzed economic domains; the composite indicator tendency shows the "economical situation" for EU-25 and for Euro Zone.

(Source: Eurostat, Industrie, commerce et services/Industrie, commerce et services - vue horizontale/Statistiques conjoncturelles sur les entreprises; ACEA)

▪ ASSESSMENT OF THE ACTIVITY CYCLE

● TENDENCIES IN PRECISION MECHANICS AND MECATRONICS IN ROMANIA

[THRUST INDICATOR IN ECONOMY (AGGREGATE/COMPOSITE INDICATOR)]

[01-02. 2006]

Indicators / INDUSTRY	Ind production	Production price	New orders	Work-force	Work activities	Construction permit released	Orders volume in retail	Matriculated automobiles	Obs.
0	1	2	3	4	5	6	7	8	9
PROCESSING INDUSTRY	↗ 01-02	↗ 01-02	↗ 01-02	→ 01-02	↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗ 01-02
CAEN 33	↗↗ 01-02	→ 01-02	↗↗ 01-02	↗ 01-02	↗↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗↗ 01-02
CAEN 3310	↗↗ 01-02	↗ 01-02	↗↗ 01-02	↗ 01-02	↗↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗↗ 01-02
CAEN 3320	↗↗ 01-02	→ 01-02	↗↗ 01-02	↗ 01-02	↗↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗↗ 01-02
CAEN 3330	↗↗ 01-02	→ 01-02	↗↗ 01-02	↗ 01-02	↗↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗↗ 01-02
CAEN 3340	→ 01-02	↗ 01-02	↗ 01-02	→ 01-02	→ 01-02	— 01-02	↘ 01-02	— 01-02	→ 01-02
CAEN 3350	↘ 01-02	→ 01-02	↘↘ 01-02	→ 01-02	↘ 01-02	— 01-02	↘ 01-02	— 01-02	↘ 01-02
CAEN 28	→ 01-02	→ 01-02	↘ 01-02	→ 01-02	→ 01-02	— 01-02	↘ 01-02	— 01-02	↘ 01-02
CAEN 2861	↗ 01-02	→ 01-02	↘ 01-02	→ 01-02	↗ 01-02	— 01-02	→ 01-02	— 01-02	↗ 01-02
CAEN 2862	↘ 01-02	→ 01-02	↘ 01-02	→ 01-02	↘ 01-02	— 01-02	↘ 01-02	— 01-02	↘↘ 01-02
CAEN 2875	→ 01-02	→ 01-02	↘ 01-02	→ 01-02	↘ 01-02	— 01-02	↘ 01-02	— 01-02	↘↘ 01-02
CAEN 29	↗↗ 01-02	↗ 01-02	→ 01-02	→ 01-02	↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗ 01-02
CAEN 2971	↗↗ 01-02	↗ 01-02	→ 01-02	↗ 01-02	↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗ 01-02
CAEN 2972	↗ 01-02	↗ 01-02	→ 01-02	↘ 01-02	↗ 01-02	— 01-02	→ 01-02	— 01-02	↗ 01-02
PRECISION MECHANICS AND MECATRONICS INTEGRATING INDUSTRY	↗↗ 01-02	→ 01-02	↗ 01-02	↗ 01-02	↗↗ 01-02	— 01-02	↗ 01-02	— 01-02	↗ 01-02

ROBUST DESIGN FOR SIX SIGMA

Despina ***Duminică***
POLITEHNICA University of Bucharest

Abstract - The paper presents the sketch and the functioning principle for a new type of fan with profiled rotors. Each profiled rotor includes two rotating pistons which enter the cavities of the adjacent rotor. The outline of the rotating piston is described by mathematical relations; a computer program was used in order to establish the numerical coordinates (x_i, y_i) of the outline.
Based on these coordinates, two identical rotors for the new type of fan were machined on a CNC centre.

Keywords – robust design,

INTRODUCTION

Design for Six Sigma (DFSS) is the application of Six Sigma principles to the design of products and their manufacturing and support processes. DFSS integrates marketing, engineering and production information into the design world, in order to optimize the translation of customer needs into feasible product specifications.

General Electric defines the principles of DFSS as: disciplined CTQ (Critical-to-Quality characteristics) flowdown; controlled design parameters; product performance modeled and simulated; designed for robust performance and producibility; functionally integrated product development; quality "designed in".

One or many methodologies can be used in order to design or re-design a new product or service on Six Sigma bases. A popular one, known as IDOV methodology, consists of Identifying customer and product requirements, Designing the product or service, Optimizing the design using process capability information and statistical approach of tolerancing and Validating the design.

Assessing and optimizing robustness performance becomes a crucial step in the optimization phase.

Robustness, as defined by Dr. Genichi Taguchi, represents the state where the technology, product or process performance is minimally sensitive to factors causing variability (either in the manufacturing or user environment), and aging at the lowest manufacturing cost.

Robust design can be obtained by minimizing the performance variability. This can be done by either minimizing the sensitivities (derivatives of process functions) or minimizing variability of design variables.

If the transfer functions between inputs and outputs are known, it is possible to simulate product or service performance without using prototypes. If the transfer functions are not known, approximations obtained using collected data can be used instead of it.

Non linear relationship between inputs and output suggest that, if the slope of the function varies, there are zones where a relative large variation of the inputs leads to a much less significant variation of the output. Robust design starts thus with the identification of such behavior, in order to take full advantage of it. This design stage is often finished with the choice of appropriate nominal values of the process parameters.

If the required performance has not been yet achieved, the designer has to tighten the tolerances of inputs that mostly affect output performance. If a variable has little influence on optimal performance, its tolerance can be loosen without affecting the robust behavior desired.

Monte Carlo simulation can be used to forecast the resulted performance of the re-designed product.

An example of robust design of a hydraulic product allows identifying the steps presented above.

EXAMPLE OF ROBUST DESIGN FOR A HYDRAULIC PRODUCT

Typical applications of the method are often found in the fields of hydraulics and pneumatics, due to strong non-linearity that characterize the behaviour of the magnitudes of interest.

An example is constituted by the speed of a hydraulic cylinder rod. If a symmetrical double-ended cylinder is supplied using a 4/3 valve and friction and losses in the distribution elements are neglected, the maximum speed of the cylinder rod v is equal to:

$$v = \frac{Q}{S_{cyl}} = \frac{s}{S_{cyl}} \cdot \sqrt{\frac{2P}{\xi\rho}} \quad (1)$$

where:

Q – flow rate;

S_{cyl} – useful area of the cylinder piston;

s - maximum distribution section of the valve;

P – supply pressure;

ρ - fluid density;

ξ - loss coefficient.

The external pressure is considered to be equal to zero.

If it is considered that the useful area of the piston is equal to $\pi(R^2 - rr^2)$, where R represents the piston radius and rr the radius of the rod, the expression of the maximum speed of the cylinder rod becomes:

$$v = \frac{s}{\pi \cdot (R^2 - rr^2)} \cdot \sqrt{\frac{2P}{\xi\rho}} \quad (2)$$

The constant k is introduced, equal to:

$$k = \frac{s}{\pi} \cdot \sqrt{\frac{2}{\xi\rho}} \quad (3)$$

Using this notation, the expression of the expression of the maximum speed of the cylinder rod can be written as (4):

$$v = \frac{k\sqrt{P}}{R^2 - rr^2} \quad (4)$$

The numerical values used in this application are:

- radius of the cylinder piston: R= 4 cm;

- radius of the cylinder rod: rr = 2 cm;

- maximum distribution section of the valve: s = 3 cm^2;

- supply pressure: P = 50 bar;

- fluid density: ρ = 800 kg/m3;

- loss coefficient: ξ= 1.6.

For this example, the maximum speed of the cylinder rod v is considered to be a CTQ (Critical-to-Quality parameter). It can be noticed that (4) constitutes the relation connecting the KPOV (Key Process Input Variable) v and the KPIV (Key Process Input Variables) P, R and rr. Using the presented methodology, a forecast of output variation in function of input variation will be exemplified.

As shown in Figure 1, the shape of the output v in function of each of the three input parameters, the other remaining constant, is different for each case. Due to the non-linearity of the relation (4) related to each analyzed input, different values of output distribution in function of input distributions are expected.

A normal distribution centered on the nominal value and with a 6σ of ±3% is imposed to each input. At the beginning, the other two inputs remain fixed. After that, all the three inputs vary in the limits of ±3%. The result is analyzed in each case.

It is supposed that the overall performance of the process must stay below ±5%.

Monte Carlo analysis is performed in order to forecast the output variation. Random variations of the inputs P, R and rr are generated and applied to relation (4) to predict the variation of the output v. A sample of N=1000 simulations is considered in each situation.

The resulted distributions of the output v are presented in the histograms shown in Figure 2.

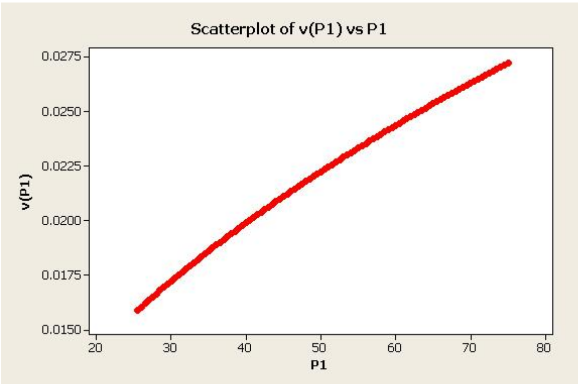
As shown in Figure 2, the main input that influences the output variation is the piston radius R, leading to variation of ±7.86% of the output v.

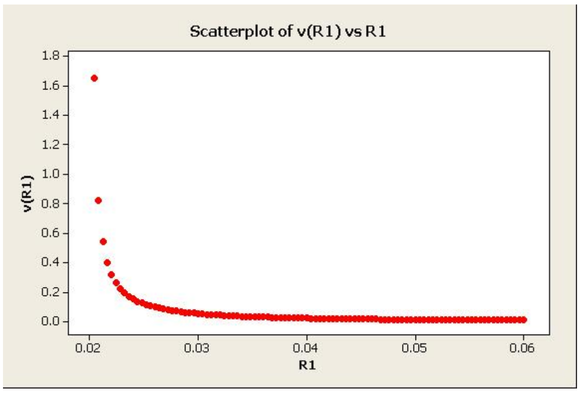
The obtained results are presented in Table 1 and reflect the current state of the process. The next stage to be achieved consists in process optimization.

Due to the non-linearity of the relation $v = v(R)$, the first optimization choice consists of finding a set of input parameters which lead to the same desired output, but with less variation. Tests performed using Monte Carlo simulation lead to the set P = 91.54 bar, R = 4.5 cm, rr = 2 cm. With these new values, the output distribution decreased from ± 8.22% to ± 7.62% without tightening any tolerance interval of the inputs (expressed as percents), as shown in Figure 3 and in Table 1 – the distribution *v_modif(P, R, rr)*.

Because the resulted output variation is far from satisfactory, tolerance interval is reduced only for the piston radius R, the input that has the most influence on the output.

The simulations showed that a tightening of the radius tolerance from ± 3% to ± 1.5% leaded to a resulted speed variation of ± 4.21%, value considered entirely satisfactory (Figure 4 and Table 1 - the distribution *v_modif_2(P, R, rr))*. For the other two inputs – supply pressure and radius of the rod – usual values of tolerance intervals can be used without affecting the overall performance of the system. A supplementary tightening (Figure 5 and Table 1 – the distribution *v_modif_1 (P, R, rr))* leaded to a resulted speed variation of ± 3.02%.





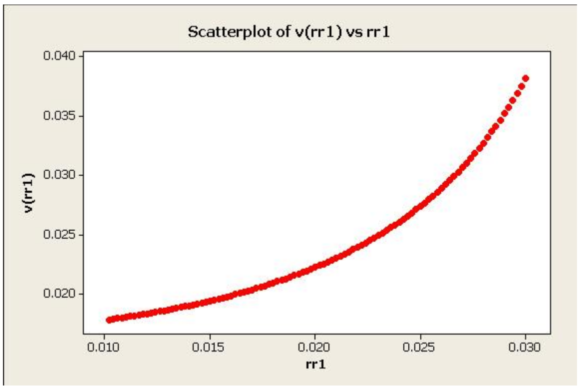


Fig. 1. *Variation of the piston speed obtained as result of the variation of one input in the limits of 50%-150% of the nominal value, the other inputs remaining constant: a) v=v(P); b) v=v(R); c) v=v(rr)*

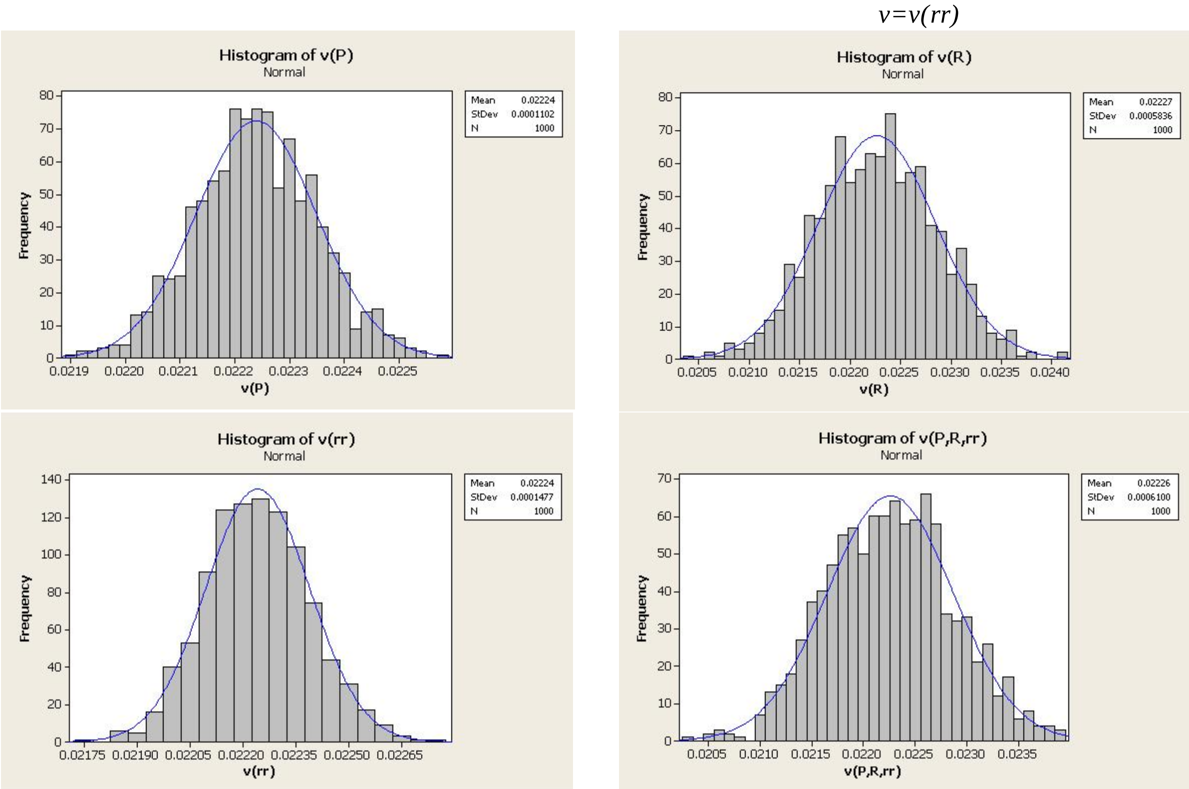


Fig. 2. *Resulted output distributions: a) P = P ±3%, R = ct, rr = ct; b) P = ct, R = R ±3%, rr = ct; c) P = ct, R = ct, rr = rr ±3%; d) P = P ±3%, R = R ±3%, rr = rr ±3%.*

Table 1. *Percentile variation of output as a result of input variation*

	v(P)	*v(R)*	*v(rr)*	*v(P,R,rr)*	*v_modif(P,R,rr)*	*v_modif_1(P,R,rr)*	*v_modif_2(P,R,rr)*
μ	0.02224	0.02227	0.2224	0.02226	0.02224	0.02222	0.02223
σ	0.0001102	0.000584	0.000148	0.00061	0.0005648	0.0002236	0.0003117
3σ	0.0003306	0.001751	0.000443	0.00183	0.0016944	0.0006708	0.0009351
$3\sigma/\mu$	1.49%	7.86%	0.20%	8.22%	7.62%	3.02%	4.21%
C_{pk}	3.75	0.69	2.86	0.67	0.71	1.84	1.3
C_{cpk}	3.78	0.7	2.87	0.67	0.72	1.88	1.33

The analysis was also performed in terms of capability indexes. Two such indexes were used:

- ✓ C_{pk} – a potential capability index defined as the minimum of CPU, the one-sided potential capability index defined as the ratio of (USL – Process mean) to (3 ∗ total standard deviation), and CPL, one-sided potential capability index defined as the ratio of (Process mean – LSL) to (3 ∗ within-subgroup standard deviation).
- ✓ *Ccpk* - a measure of potential capability, identical to the Cpk index except that, instead of being centered at the process mean all the time, it is centered at the target when given or the midpoint of the specification limits when the specification limits are given.

CONCLUSIONS

A crucial step in the application DFSS requires determining the critical parameters and optimizing their variability.

If the transfer functions between inputs and outputs are known, it is possible to simulate the performance of the product without the need of prototypes, using Monte Carlo methods.

The optimization has to start, when possible, with the adjustment of input parameters, in order to achieve a more robust behavior.

Tolerance intervals have to be tightened only for the inputs that produce the most significant variation of the outputs.

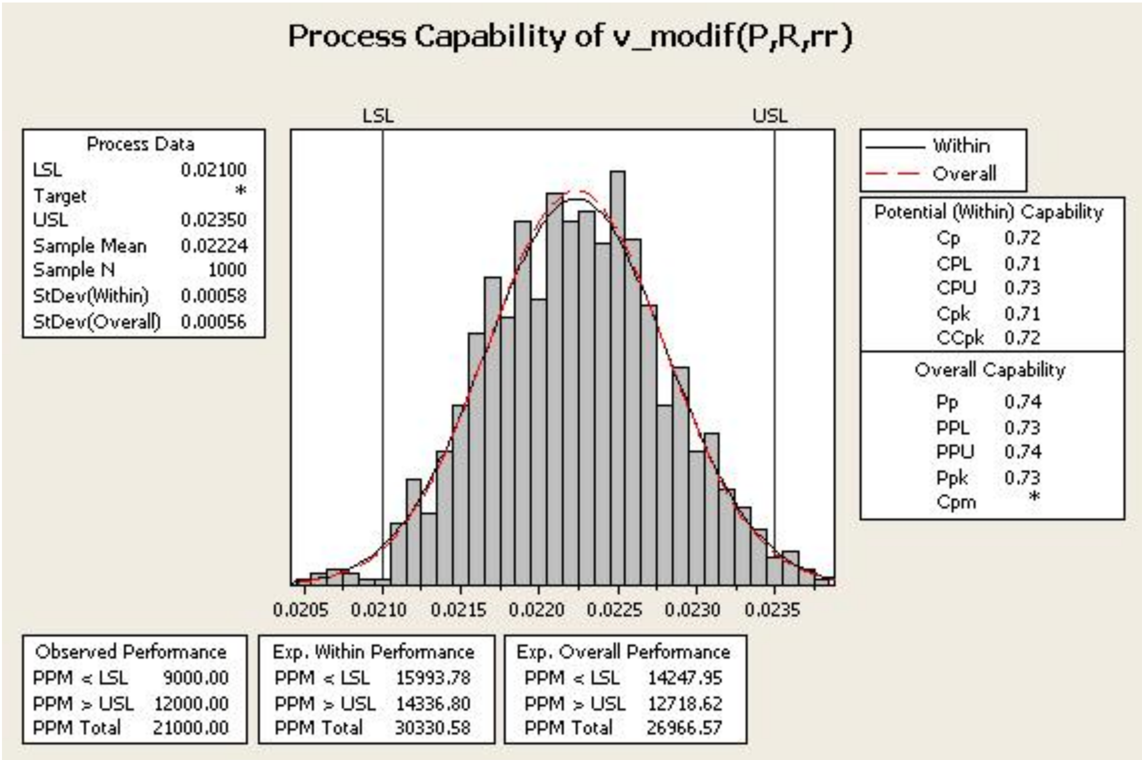


Fig. 3. *Output distribution for the modified set of inputs, without reducing percentile tolerance intervals.*

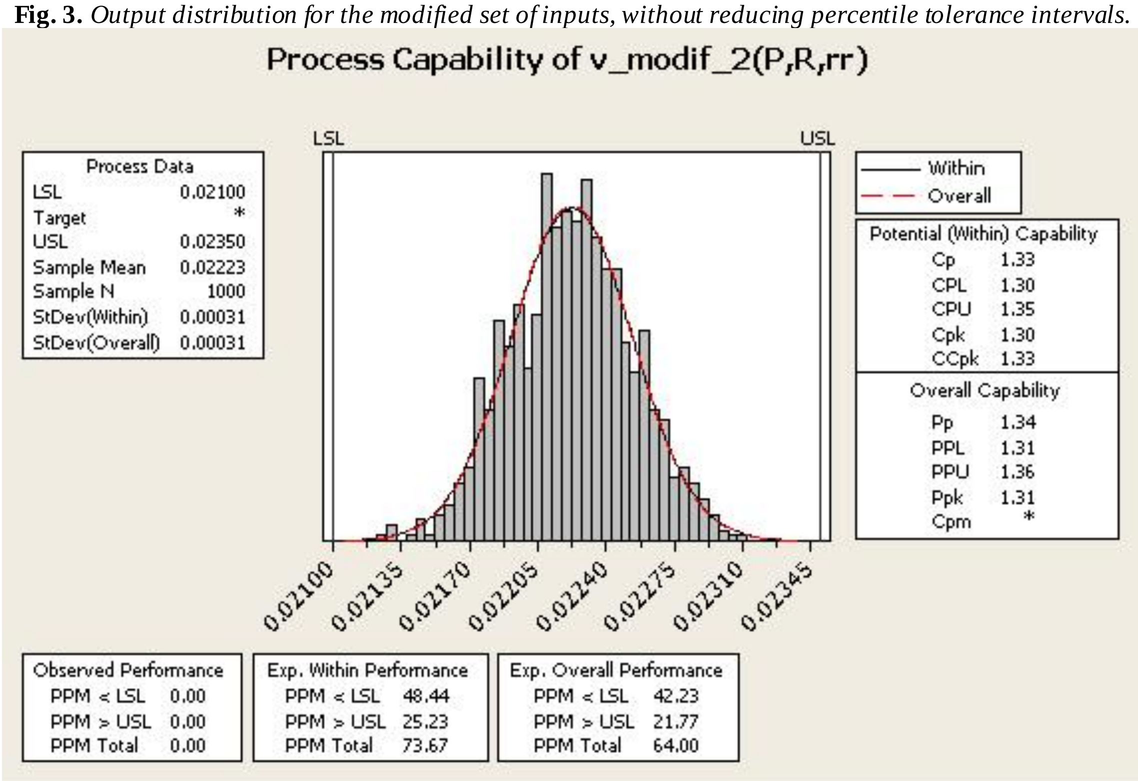


Fig. 4. *Output distribution for the modified set of inputs, reducing only the percentile tolerance of the piston radius from . ±3% to ± 1.5%*

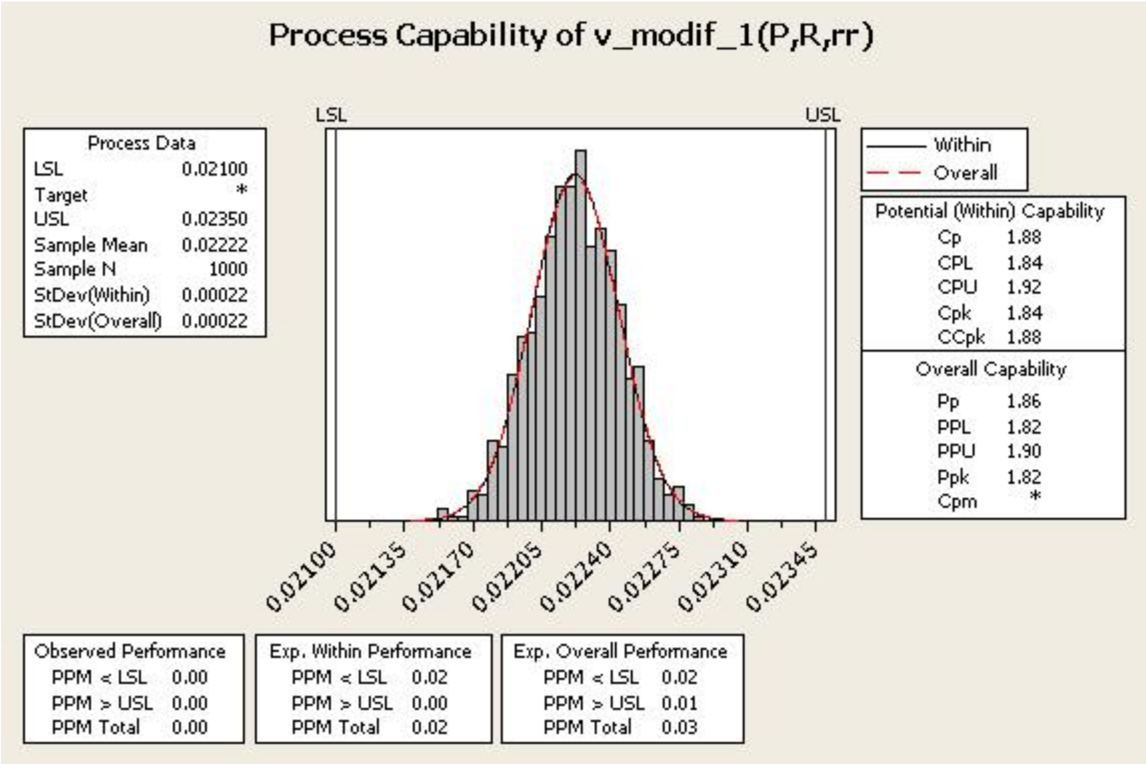


Fig. 5. *Output distribution for the modified set of inputs, reducing only the percentile tolerance of the piston radius from . ±3% to ± 1 %*

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ACED – B ADAPTIVE CONTROLLED ELASTICITY & DAMPING DEVICES

Mădălina Oana **STOICA**
"POLITEHNICA" *University of Bucharest*

Abstract - The paper presents the concept, design, manufacture and experimental tests of a new adaptive controlled elasticity & damping (ACED-B) mechanical devices.

Keywords –ACED-B, *Hysteretic diagram*

1. Introduction

The adaptive controlled elasticity & damping devices ACED-B can be used to control the structure behaviour under dynamic loads, in general, and seismic loads particularly. They provide the dissipation of the seismic energy even for very small load levels of the building structure.

ACED-B devices can be used both for efficiently and quickly strengthening of any type of existing buildings and building new constructions.

These mechanical devices are embedded in the building structure, usually into the bracings, in order to take-over and damp the loads generated by shocks, vibrations and seismic movements (Fig. 1).

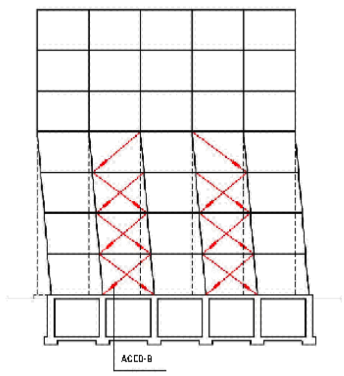

Fig.1 *Building isolation with ACED-B devices*

The ACED-B devices can be easily manufactured and their application will be reflected by an increase of the quality of the strengthening work, in a reduction of work amount on site, by the protection of the environment and by the efficient control of the behaviour of the new and existing building structures during earthquakes

The paper presents the concept, design, manufacture and experimental tests of the adaptive controlled elasticity & damping mechanical devices ACED-B capable to provide structural passive control of the building to seismic input.

2. ACED - B design

ACED-B devices include a new type of sandwich structure which is made up of elastic blade packages fabricated from high strength austenitic stainless steel thin plates. The device consists of several packages of elastic blades mounted in-series. Each package is composed of a variable number of blades acting in parallel (Fig. 2).

The elastic blade packages are subject to normal deflections on their contact surfaces by means of stiff deforming disks with an adequate geometry (spherical, parabolic etc.) required by the desired force – displacement ratio.

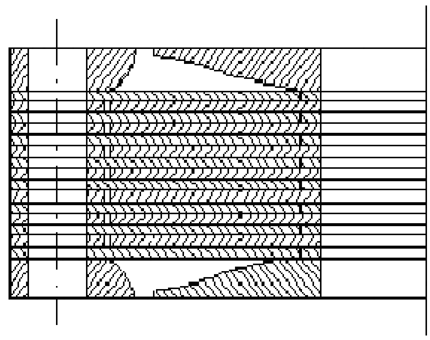

Fig.2 *Sandwich structure*

The damping characteristics are also adjustable depending on the static and/or dynamic loads applied to the device. Energy dissipation is mainly due to the radial friction between the elastic blade packages because of the normal forces developed on the contact surfaces.

ACED-B device is made up of two sets of sandwich structures symmetrically arranged and can be fabricated in two constructive alternatives:

- An adaptive ACED-B device, as shown in Figure 3, where the two sets of sandwich structures are pre-stressed by rods and spacers. In this case, the device can be pre-stressed after having been installed into the building in order to get an initial stress force.
- An encased ACED-B device, as shown in Figure 4, where the fastening of the two sets of sandwich structures is made from outside the building. In this case, the device is smaller in size and

weight, preserving the same characteristics of stiffness and damping.

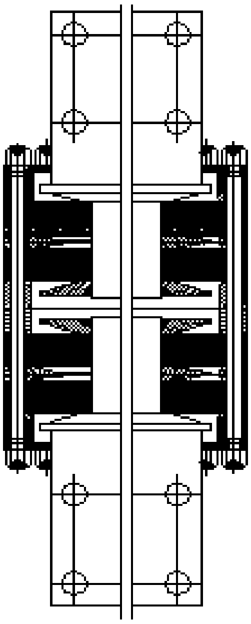

Fig. 3 *Adaptive ACED - B device*

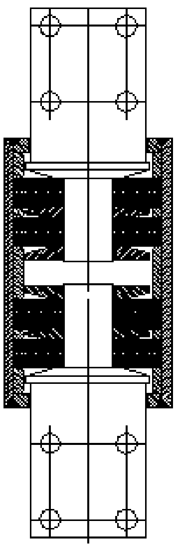

Fig. 4 *Encased ACED - B device*

These devices can be installed in the structure braces of new or existing buildings (Fig. 5).

Compared to the classic solutions, devices show the following advantages:

- the solution is much less expensive;
- the time required for the construction is shorter;
- there is no need to completely evacuate the inhabited areas for consolidation works, but only to provide a gradual access to certain rooms of the building for a short period of time;
- the architecture of a building is very little affected by the mounting operations of the devices.

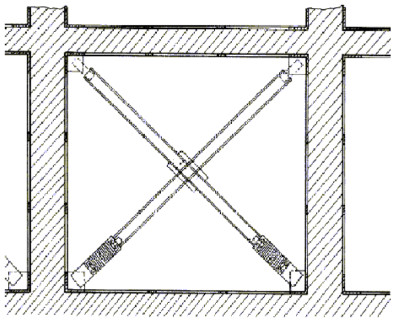

Fig. 5 *ACED - B installed*

The devices can be pre-stressed in order to be operational even when very small deformations occur in the structure. When the preset deflections corresponding to the displacement inter-story level required by the building type are reached, the stiffness of the devices increases very much according to a preset law, providing the necessary force to maintain the building stability.

3. Experimental results

ACED-B prototype was manufactured in order to evaluate the performances of the new devices.

Austenitic stainless spring steel strips made by SANDVIK (Sweden) were used for the device. These strips are also to be used for the industrial production of the devices.

Figure 6 and Figure 7 show the prototype ACED-B-200, a 200 mm diameter device.

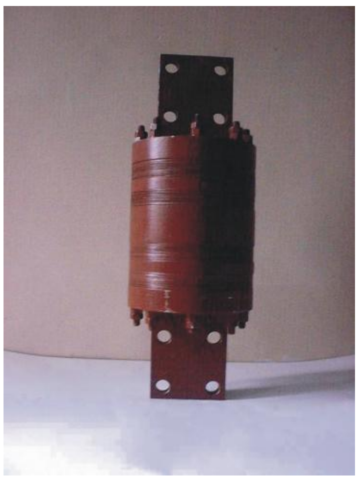

Fig. 6 *ACED - B prototype*

The elastic strips packages are made of stainless spring steel blades, 12R11 grade, 0.5 mm thickness, manufactured by SANDVIK, Sweden.

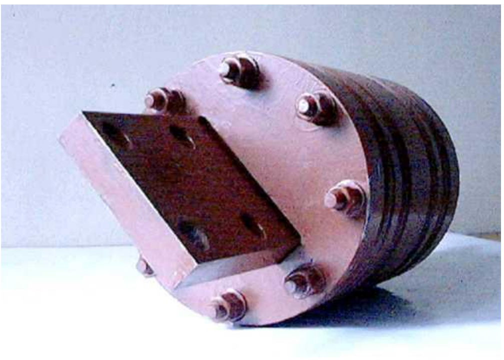

Fig. 7 *View of ACED - B prototype*

Spacers, elastic plates and deforming disks are shown in Figure 8.

Fig. 8 *Spacers, elastic plates and deforming disks*

Tests conducted in the "Institute for Solids Mechanics" within the Romanian Academy show that the new devices can be manufactured with the required stiffness and high damping capacity. The experimental research was performed on a Schopper compression test machine (Fig. 9).

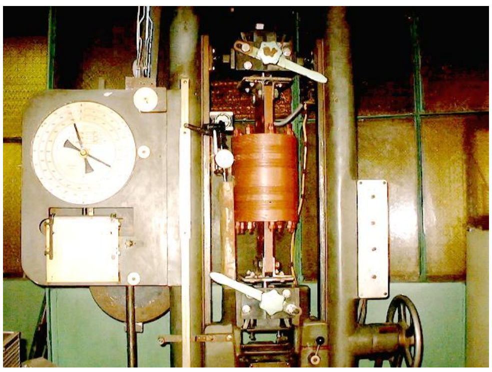

Fig. 9 *Experimental tests*

Fig. 10.1 - Fig. 10.3 present the hysteretic diagrams for ACED-B device compression tests with initial compression forces of: 0 N, 20000 N, 50000 N.

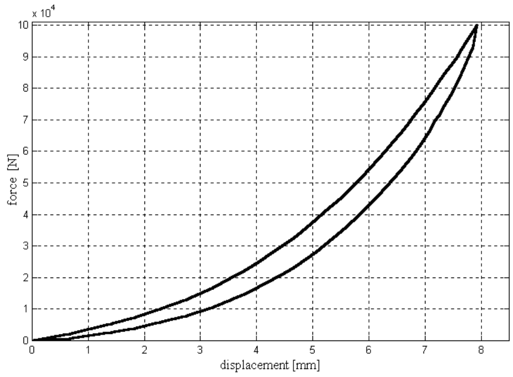

Fig. 10.1 *Hysteretic diagram for ACED - B device compression test with a compression force of 0 N*

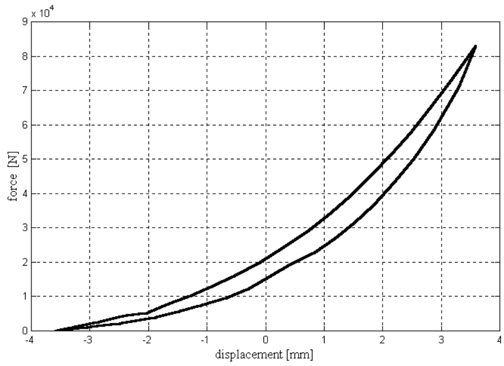

Fig. 10.2 *Hysteretic diagram for ACED - B device compression test with a compression force of 20000 N*

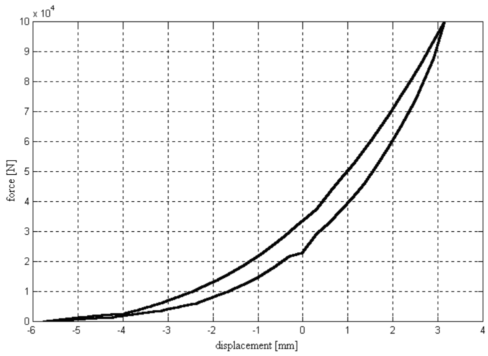

Fig. 10.3 *Hysteretic diagram for ACED - B device compression test with a compression force of 50000 N*

The relative damping provided by the ACED-B prototype, expressed by the dissipated energy per cycle, is shown in Table 1.

Table 1

No.	Initial compression force [N]	Relative damping
1	0	23.5%
2	20000	20.5%

3	50000	21.2%

Fig. 11.1 - Fig. 11.3 present the hysteretic diagrams for ACED-B device tensile tests with initial compression forces of: 0 N, 20000 N, 30000 N.

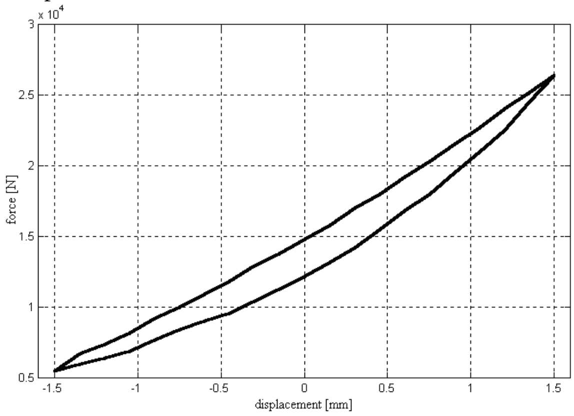

Fig. 11.1 *Hysteretic diagram for ACED - B device tensile test with a compression force of 0 N*

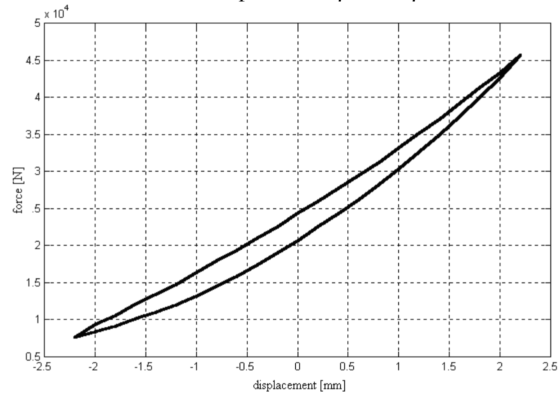

Fig. 11.2 *Hysteretic diagram for ACED - B device tensile test with a compression force of 20000 N*

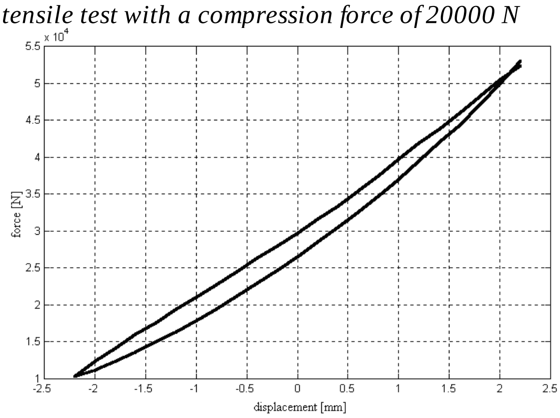

Fig. 11.3 *Hysteretic diagram for ACED - B device tensile test with a compression force of 30000 N*

The relative damping provided by the ACED-B prototype, is shown in Table 2.

Table 2

No.	Initial compression force [N]	Relative damping
1	0	15.3%
2	20000	15.23%
3	30000	17.9%

Experimental results shows that:

- The force - displacement characteristic shows a nonlinearity controlled by the strips thickness and the deforming disk geometry;

- The relative damping provided by the ACED-B prototype, at compression tests, is more than 20%.

4. Conclusions

Usually, the devices are installed in the bracings which are currently mounted in the low part of the building, allowing their elongation or shortening controlled within the range of 10 - 12 mm. Thus, the relative horizontal displacements of the building floors are limited below the value at which cracks occur (i. e. below 4 ‰ of the floor height).

According to the Romanian Seismic Cod P100-92, [1], dissipation of seismic energy occurs only at high loads levels when the structure elements develop plastic hinges. According to the new consolidation procedure, the dissipation of the seismic energy occurs even at small and average loads. Moreover, at high loads, ACED-B devices "get stiffer" providing the elastic force required to withstand collapse and avoid the occurrence of plastic hinges.

Application of the proposed solutions leads to the following favorable phenomena during an earthquake:

- at small and average loads, a slight displacement of the building is allowed without affecting the structural and non-structural elements. The new devices operate like telescope dampers absorbing a large quantity of seismic energy and, consequently, minimizing the building seismic response;
- The greater the building deformation is, the higher the device stiffness becomes.

Acknowledgment

This work was supported by the Romanian Ministry of Education and Research through the Research Contract no. 1305/03.08.2001, in the framework of the Programme S1, Relansin - IMM.

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[1] Code for the seismic design of social - cultural, residential, agricultural & industrial buildings.

ACED – I ADAPTIVE CONTROLLED ELASTICITY & DAMPING MECHANICAL DEVICES

Mădălina Oana **STOICA**
"POLITEHNICA" *University of Bucharest*

1. Introduction

The adaptive controlled elasticity & damping devices ACED-I are compact mechanical devices meant for the adaptable control of buildings behaviour during dynamic and especially seismic loadings.

The devices have elasticity and damping properties that can be adjusted according to the load level due to the fact that the device dynamic behaviour is of hysteretic type with hardening non-linear elastic characteristic.

Parameters, such as stiffness, damping, deflection, can be set by an appropriate design at desired levels within a large range of values.

ACED-I devices (Fig. 1) are installed either between the buildings basement and foundation (a solution that is preferred in the rehabilitation of monuments as it does not impair their architecture) or between the consolidated under structure part of a building and its upper structure (a solution that is preferred when retrofitting or strengthening residential buildings).

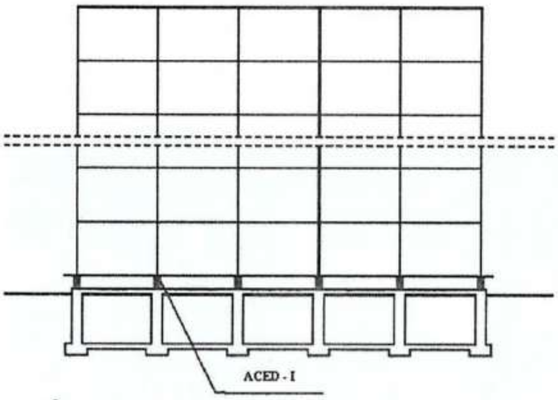


***Fig.1** Building isolation with ACED-I devices*

The new devices are capable to offer a good isolation on vertical direction as well, which is very important for old and monumental buildings, bridges (generally, large-span, low-height buildings).

The paper presents the concept, design, manufacture and experimental tests of the ACED-I adaptive controlled elasticity & damping mechanical devices capable to provide structural passive control of the building subjected to seismic loads.

2. ACED – I design

The ACED-I device shown in Figure 2 is made from up of seven ACED-I elements, symmetrically arranged.

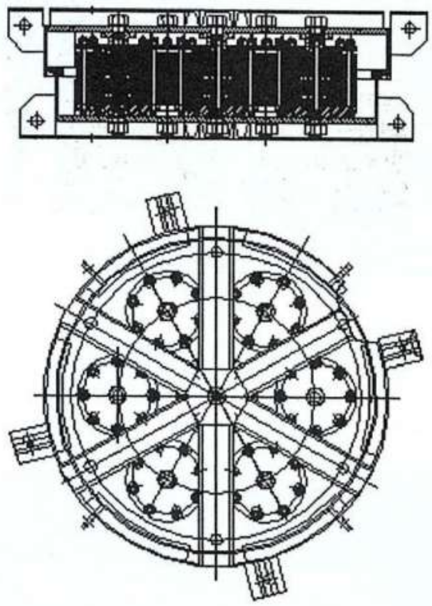


***Fig. 2** ACED – I device*

Each ACED-I element is designed from elastic blade packages fabricated from high strength austenitic stainless steel thin plates. The element device consists of several sandwich structures of elastic blades mounted in-series. Each package is composed of a variable number of blades acting in parallel (Fig. 3, 4).

The elastic blade packages are subject to normal deflections on their contact surfaces by means of stiff deforming disks with an adequate geometry (spherical, parabolic etc.) required by the desired force - displacement ratio.

ACED-I devices may be installed in series in order to obtain columns with the desired stiffness on all directions (Fig. 5).

The columns of ACED-I sets of devices are installed underneath the buildings in order to provide their isolation (Fig.1).

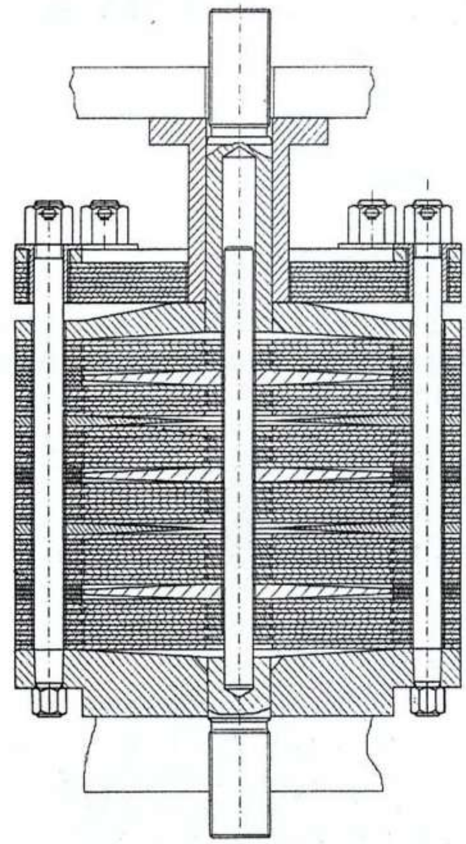


Fig. 3 *ACED – I element*

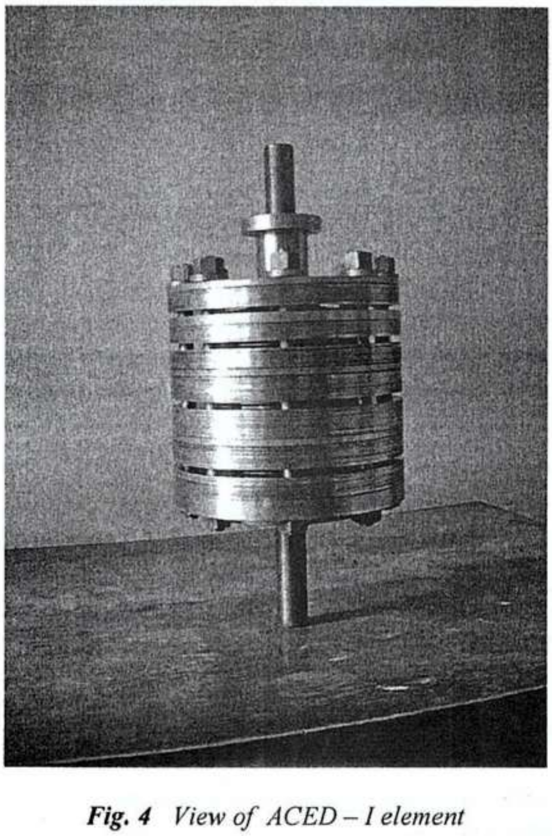


Fig. 4 *View of ACED – I element*

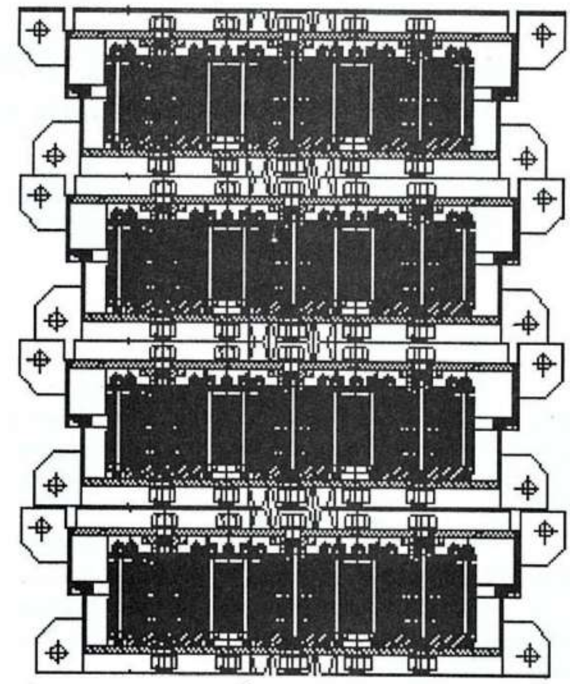


Fig. 5 *Column ACED – I devices*

3. Experimental results

For the ACED-I element several tests have been performed to assess the stiffness and damping characteristics using several configurations of sandwich structures which make-up the prototype element.

The tests were conducted in the "Institute for Solids Mechanics" within the Romanian Academy (Fig. 6) and in the "National Institute of Agricultural Machines" (Fig. 7). They show that the new devices can be manufactured with the required stiffness and high damping capacity.

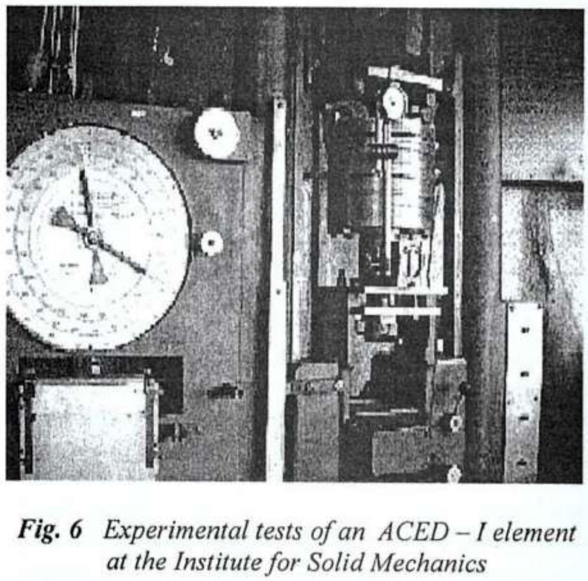


Fig. 6 *Experimental tests of an ACED – I element at the Institute for Solid Mechanics*

During all the tests, the thickness of the elastic elements the sandwich structure is made of, was kept constant at the value of 1 mm in order to point out the possibility to modify the hysteretic characteristic of ACED-I element only by modifying the geometry of the deforming parts and the set up of the elastic blades in the sandwich structure packages.

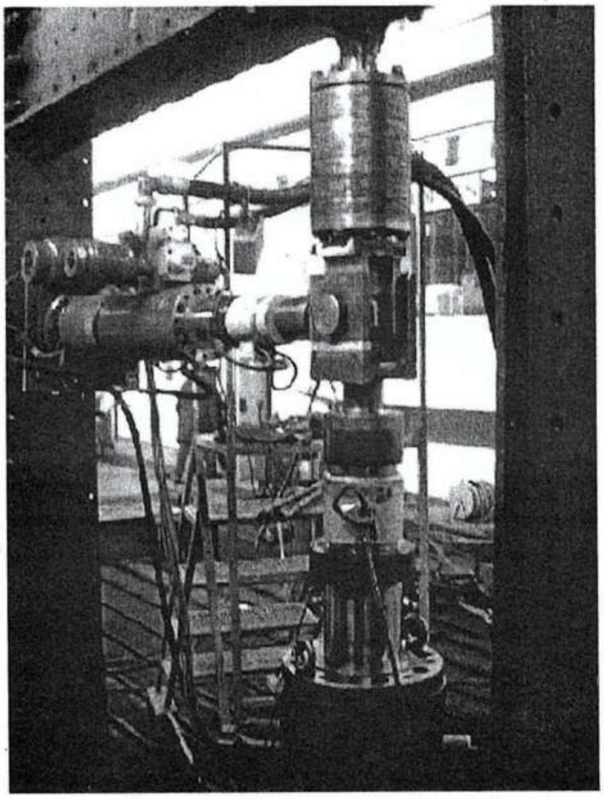
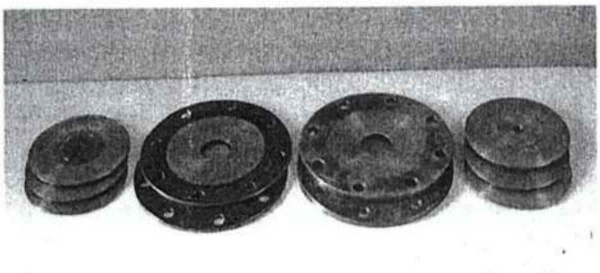


***Fig. 7** Experimental tests of an ACED – I element in the National Institute of Agricultural Machines (horizontal and vertical action)*

The ACED-I element prototype was made up of two pairs of deforming disks (Fig. 8 A, B), in different alternatives of sandwich structures mounted in series, each sandwich structure containing a different number of elastic blade pairs and spacers (Fig. 9).



Type A Type B

***Fig. 8** Deforming disks*

The sandwich structures (Fig. 3) are installed on seven elastic bars and they are in the contact with one central deforming part and one peripheral deforming part (upper and lower). The peripheral deforming parts have a convex-spherical shape.

The central deforming part is also convex-spherical in shape and its central area is in contact with the undistorted flat-circular (Φ 80 mm = Type A, Φ 90 mm = Type B) area of the sandwich structure (Fig. 10).

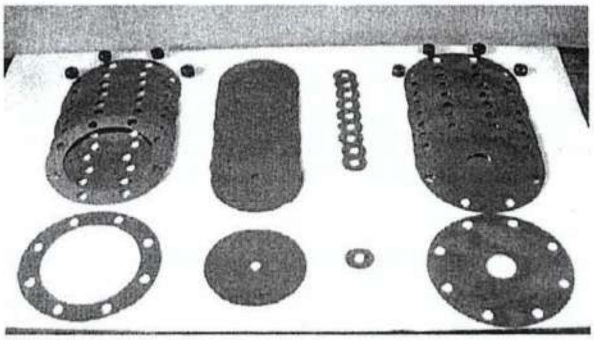


***Fig. 9** Spacers and elastic plates*

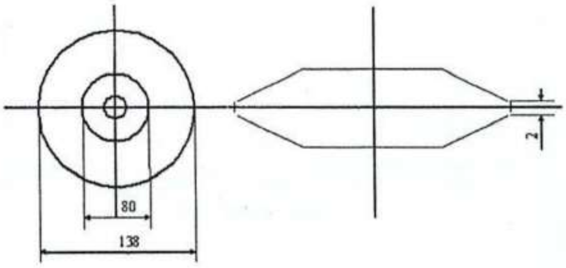


***Fig. 10** Type A deforming disk*

The first experimental tests were performed modifying the sandwich structure or the geometry of the rigid deforming disks, keeping constant the total number of the elastic plates, as following:

1) Alternative 1:

   Type A deforming disks;
   Number of elastic blades of the packages from bottom to top: 15, 15, 19, 17, 13, 11, 12;
   Compression pre-load force: 0 N, 20000N, 40000N;

2) Alternative 2:

   Type B deforming disks;

   Number of elastic blades of the packages from bottom to top: 15, 15, 19, 17, 13, 11, 12;
   Compression pre-load force: 0 N, 40000 N;

3) Alternative 3:

Type B deforming disks;
Number of elastic blades of the packages from bottom to top: 21, 19, 17, 13, 11, 9, 12;
Compression pre-load force: 0 N, 40000 N;

4) Alternative 4:

Type B deforming disks;
Number of elastic blades of the packages from bottom to top: 23, 21, 17, 11, 9, 9, 12;
Compression pre-load force: 0 N, 40000 N;

Figure 11 presents the stiffness characteristics of ACED-I element prototype for the four alternatives presented above.

The relative damping provided by the ACED-I element prototypes, expressed by the dissipated energy per cycle, is shown in Table 1.

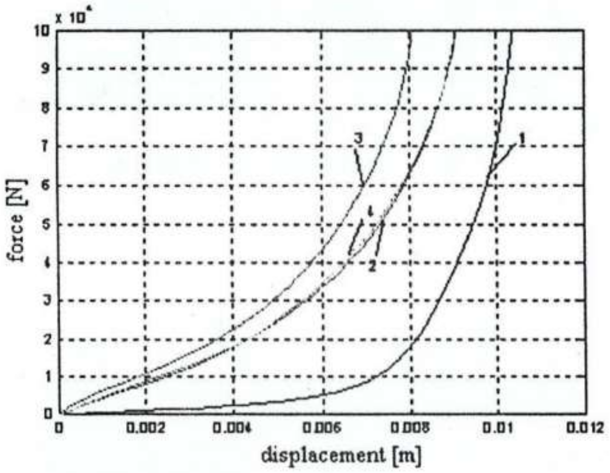


Fig. 11 ACED-I stiffness characteristics for the four set-ups

Table 1

Alternative	Initial compression force [N]	Relative damping
1	0	23%
	40000	33.5%
2	0	16%
	40000	35%%
3	0	19.5%
	40000	37.5%
4	0	17.5%
	40000	35%

In Figure 12.1 – 12.4 are shown the hysteretic loops obtained for the four alternatives with a static preloading of 40000 N.

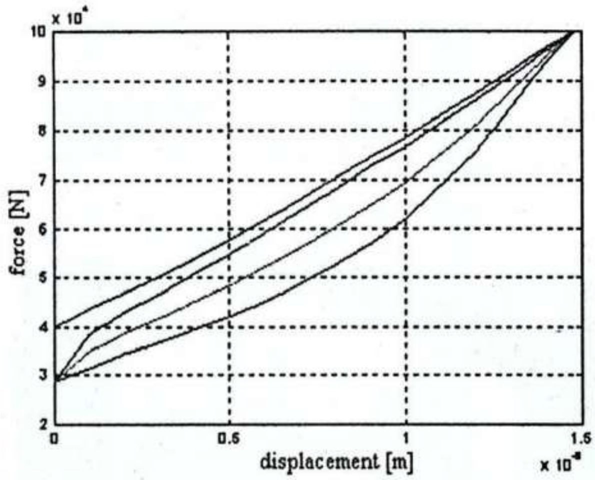


Fig. 12.1 ACED – I hysteretic loop for 40000 N static preloading (set up 1)

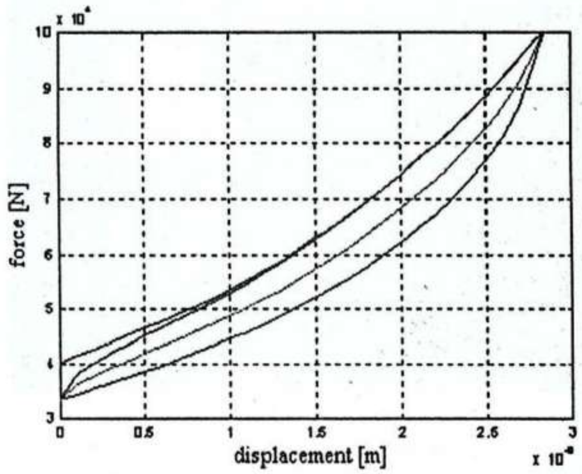


Fig. 12.2 ACED – I hysteretic loop for 40000 N static preloading (set up 2)

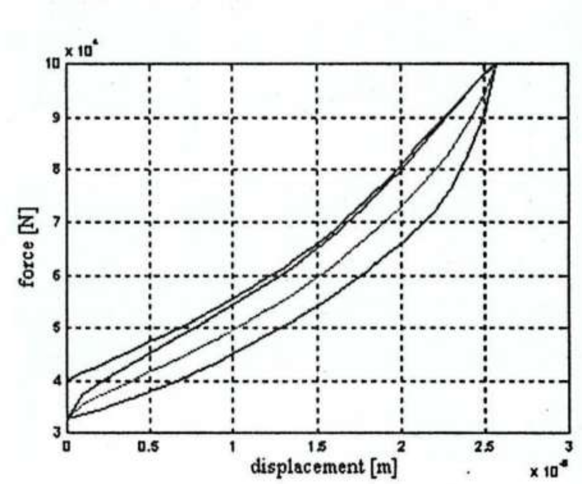


Fig. 12.3 ACED – I hysteretic loop for 40000 N static preloading (set up 3)

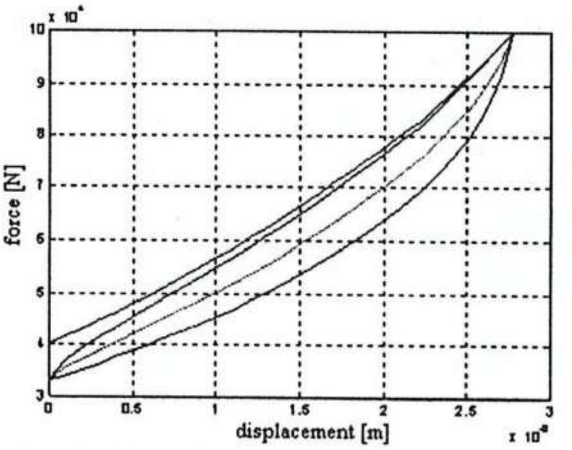


Fig. 12.4 *ACED – I hysteretic loop for 40000 N static preloading (set up 4)*

The final test was performed on a new ACED-I element prototype with a number of elastic blades of the packages from bottom to top: 29, 30, 30, 30, 30, 33 (set up 5).

Fig. 13.1 – 13.3 display the hysteretic loops of this new element device with more elastic elements, for different static preloading forces.

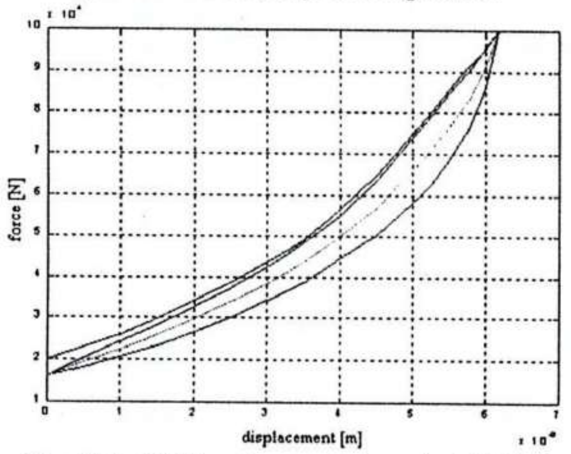


Fig. 13.1 *ACED – I hysteretic loop for 20000 N static preloading (set up 5)*

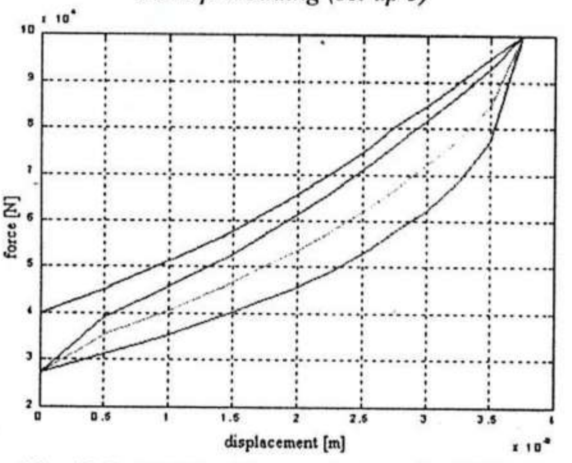


Fig. 13.2 *ACED – I hysteretic loop for 40000 N static preloading (set up 5)*

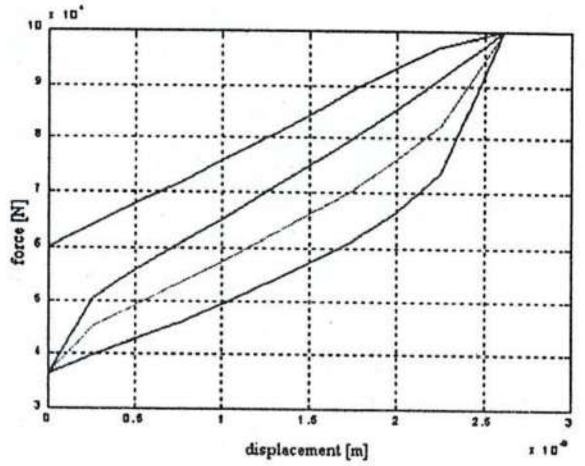


Fig. 13.3 *ACED – I hysteretic loop for 60000 N static preloading (set up 5)*

The relative damping provided by this new ACED-I element prototype is shown in Table 2.

Table 2

No.	Initial compression force [N]	Relative damping
1	20000	29.6%
2	40000	46.1%
3	60000	51%

4. Conclusions

The experimental results shows that:

1. The force - displacement characteristic has a nonlinearity controlled by the strips thickness and the deforming disk geometry;
2. In all the cases, ACED–I element prototypes displayed remarkable high damping ratio values (33% - 51%). The tests have shown that its damping capacity and stiffness characteristics can be easily adjusted according to the specific application requirements.

Application of the proposed solutions leads to the following favorable phenomena during an earthquake:

- The greater the building deformation is, the higher the device stiffness becomes and the devices operate like hardening springs with the following effects:

- stiffness of building – device assembly increases and consequently the eigenperiod of building vibration decreases getting farther from the resonance range and thus reducing the seismic response;
- damping due to the device increases (without the occurrence of the plastic hinge phenomenon in the building) resulting in a additional reduction of the seismic response;

- increase of the device stiffness allows the development of the elastic force required to maintain the building stability and avoid collapsing.

According to the proposed solution the protection effects are of "positive avalanche" type in the sense that any additional load produces , as a by-effect, the reduction of the seismic response both by increasing the damping and modifying the resonance range (i.e. the eigenperiod of building vibration is getting smaller due to the gradual raise of the device stiffness during a seismic event).

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NATIONAL INSTITUTE FOR RESEARCH & DEVELOPMENT
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Pantelimon Road 6-8, Bucharest - 021631, Sect. 2
Tel: 252 30 68 ; 252 20 96 Tel./ Fax: 252 34 37; 252 20 96
E-mail : cefin@cefin.ro ; revista@cefin.ro;
Web: centrutransfer.ro

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