Research Methodology for the National Knowledge Network INPRO- ROMANIA

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Abstract: - The paper presents the systemic structure of the Romanian knowledge network in the area of integrated engineering of products and processes – INPRO. The systemic structure of the network is presented using IDEF0 functional modelling language. Such a structure underlines the possibilities of continuous improvement of the network. Teamcenter software and a complex database are the main elements of network functioning. A specific research methodology for projects carried out in the network system is presented. A research example (done in network frame) from cutting tool area shows the possibilities and advantages of the methodology. The research activity in the network frame can be done by students, PhD students and/or specialists.

Key-Words: - knowledge, network, research, design, project, integrated engineering

1 Introduction

The spectacular development of information technology, computer science and globalization influence all economic, research, educational and administrative areas of the society.

European production systems have been subject to a permanent change lately as they have to adapt to globalization and the need for industrial innovation. In any case, many traditional manufacturing processes are now outside actual European countries (especially Asian countries that manufacture products with low costs) and the knowledge of the associated technologies will be lost in Europe in a near future if nothing is done. The industrial innovation of products needs technology transfer, (generally by using non usual materials or the non usual manufacturing processes) [11]. In order to use new, innovative processes, large companies must seek co-partners, by using the competences of the latter in specific manufacturing processes to integrate these competences during the design process. In order to keep production competences the VRL-KCiP network was created in Europe (http://www.vrl-kcip.org/). Specialists from different areas are associated in a network allowing them to share without retained the competences and knowledge which they still possess, and to integrate these competences into new design systems. The network offers joint research, tools, consulting and training for manufacturing techniques, requirements engineering, risk management, collaborative engineering, knowledge capture and management [10].

2 INPRO Research Network

In Romania, a new member of the European Union, the main research centres of technical universities participate in a research network in the area of integrated engineering of products and processes – INPRO (http://www.eng.upt.ro/inpro). The research activities are integrated in the Product Lifecycle Management concept and focused on conception stage [7].

The network mission is to bring together the specialists in production process research in order to share their knowledge in a common structure.

The strategic objectives of the INPRO network are:

- Developing a knowledge database in the area of integrated engineering of products and processes;
- Improving the performances of research activities, building up research teams specialized in priority areas in order to facilitate their access to the EU research programs;
- Improving and stimulating human resources development;
- Enhancing the connection between the Romanian network partners and the European research network VRL – KCiP;

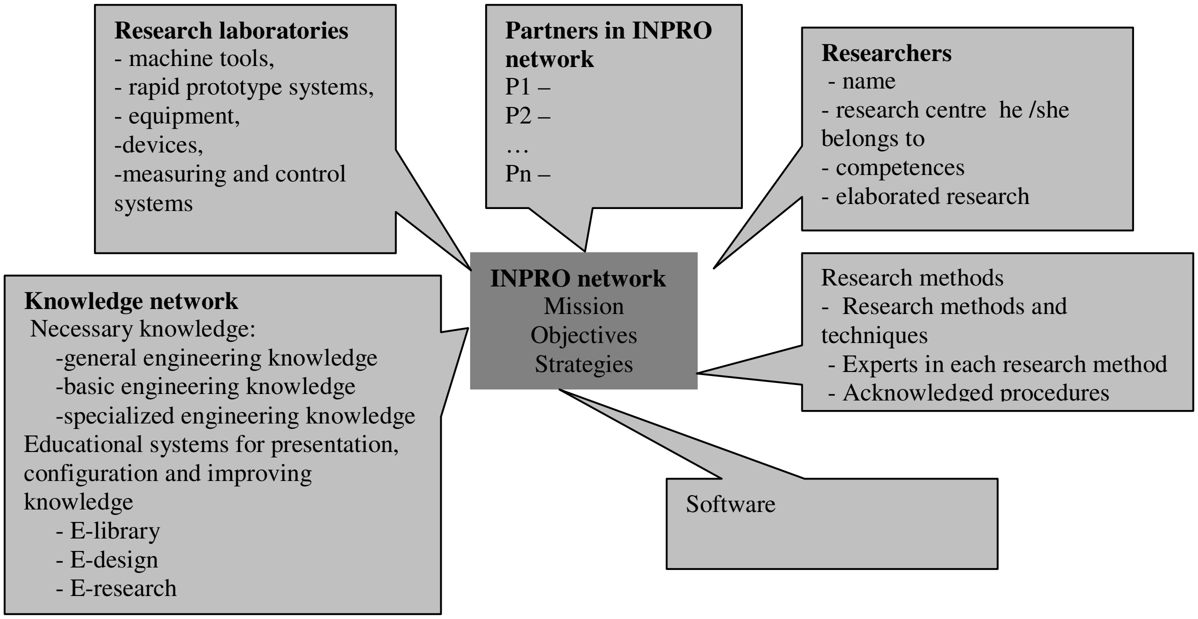

Fig.1. INPRO network components

- More efficient use of material resources and the reduction of research costs;
- Developing managerial abilities in the research area.

The viability and efficiency of such a network is based on its systematic and systemic structure which allows continuous improvement [8].

The network includes a number of eight universities and research centres and is open to a future extension.

The research laboratories are used in common and the specialists from different engineering areas have the possibility of collaborating and working together. The network allows knowledge dissemination through the database system and through the e-learning products. The most important aspects of the INPRO network are presented in figure 1.

The main stages of the INPRO network developing are:

- Developing the network infrastructure and elaborating the functioning methodology;
- Shared research and design activities;
  - Create, develop and provide maintenance to the common research platform;
  - Studying and developing models for products and manufacturing processes;
  - Knowledge management;
  - Shared research and design activities;
- Result dissemination and knowledge transfer through the industry.

The systemic structure of the network is presented in figure 2 (the IDEF0 functional modelling language is used).

The universities, research centres, specialists, knowledge and material resources are the input data in the network. The information from the market is of great importance too. The network output obtained from the research and design activities includes products offered to the industry, knowledge that increases the network database and, last but not least, a feedback for continuous improvement of network activity.

The network needs specialized system software (The TEAMCENTER system was selected and implemented) and a complex and complete database that allows the development of research projects in common.

2.1 TEAM CENTER Software

Teamcenter Engineering is a *Product Data Management* (PDM) system. PDM is a tool that helps manage all the processes, applications, and information required to design, manufacture, and support a product throughout its life cycle. The goal of a PDM system is to provide a single, common interface for managing and accessing all data within an organization. PDM systems interface with Enterprise Resource Planning (ERP) systems. With PDM, ERP systems and the web interface, the network has all the ingredients for a true collaborative environment.

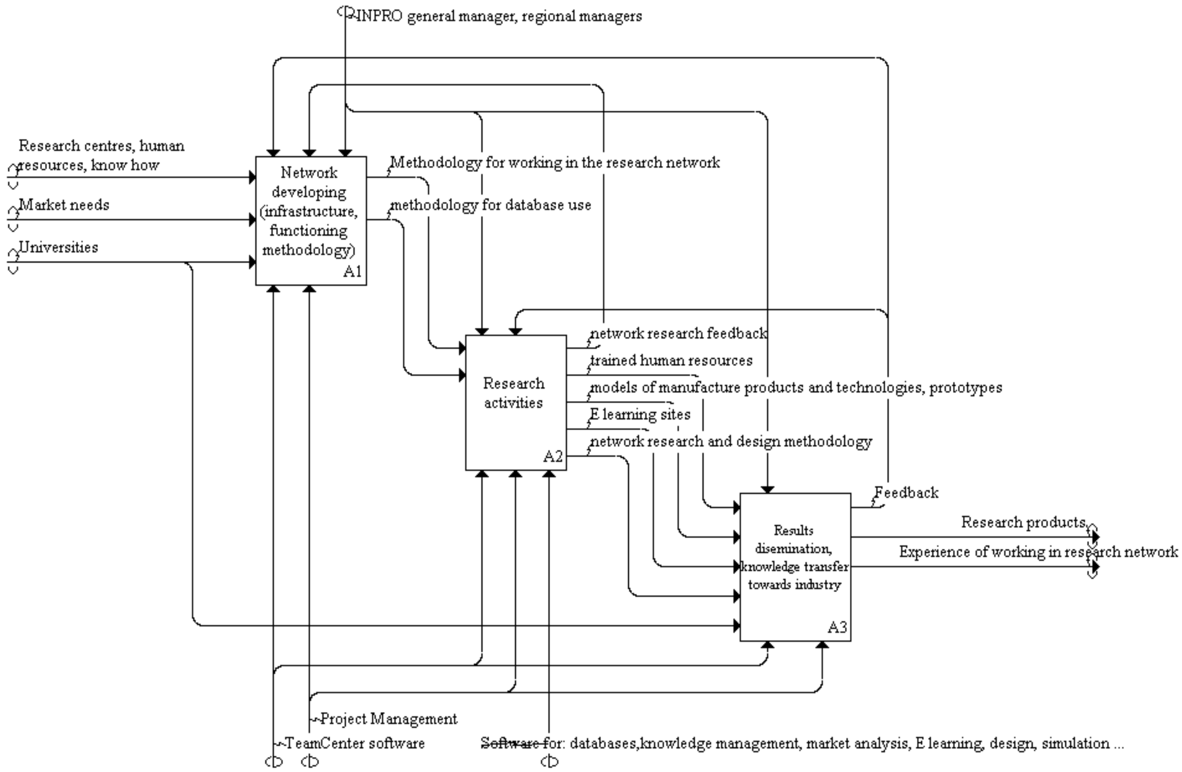

Fig.2. Systemic structure of INPRO network

Benefits of using the Teamcenter Engineering PDM system include:

- Reduces duplicate data which reduces storage requirements.
- Simplifies finding data and distributing data to those who need it.
- Allows quick interaction with digital product data to view 3D models and 2D images of drawings and documents in a single visual environment.
- Provides revision control and assurance of latest data.
- Manages assemblies and relationships between parts.
- Easily builds and modifies Bills of Material (BOM).
- Maintains history of a product's development evolution.
- Establishes relationships between requirements, specifications, and parts.
- Provides access control and vaulting to assure integrity of data.

Teamcenter enables customers to maximize the power of their product knowledge and leverage it to increase the profitability and productivity of every stage in their product lifecycle.

2.2 Database necessary to be developed in the INPRO network in order to plan and track the research projects (using Project Management Methodology)

In order to plan a research project correctly and efficiently in the INPRO network it is necessary to have access to a database which must contain [2, 3]:

- Engineering knowledge (general, basically and specific knowledge) and the specialists for each area;
- Human resource information: name, institution where he/she works, contact address, scientific abilities, managerial abilities, human resource costs;
- Research methods and techniques, experts in each research method, acknowledged procedures;
- Research laboratories: machine tools, rapid prototype systems, equipment, devices measuring and control systems and research possibilities;
- Equipment characteristics: input parameters, output parameters, precision level, necessary knowledge and instruction for equipment use, using costs, necessary materials (characteristics, costs);

- Existing software.

This information can be used during the planning stage of a research project (the Project Management methodology is used) in order to establish the resource needs for each activity. An integrated system for technological equipments (cutting tools) structured on relational objectual data base.

3. Research Methodology for INPRO Network

Because the research activities are performed in teams and the researchers are located in different places, there is an absolute need for a precise communication methodology supported by TEAM CENTER software and a research methodology that describes the research activities step by step.

The research methodology begins with the description of the problem as clearly as possible, the establishing of the kind of research that must be done, research planning using Project Management methodology, the development and tracking of the research, the design and manufacturing of prototypes, if necessary, experiments on the product and finally analysis, interpretation and dissemination of the results, audit of the project, learned lessons and offering of the research product to the beneficiary.

3.1. Problem definition

In management and engineering, a problem is the difference between the actual situation and the desired one. Generally, the true causes are not known and an attentive analysis of the root causes is necessary in order to establish the true nature of the problem. The correct and complete understanding of the problem is very important and necessary in each situation, more in the situation of the network collaboration where the information exchange is made in a synchronous or asynchronous way. The problem must be explained in a textual and/or graphical way and communicated in the network.

The main steps that must be followed for a problem definition in the situation of network communication are the following:

- Establishing of a virtual team for the problem definition;
- Individual studies or E-sessions in order to determine the analyzed areas or perspectives (technical, managerial, economic, ecological, legislative, etc.) to identify the key parameters or indicators, behaviors for short and long periods, possible feedback loops caused by different parameters, contradictions, risks and uncertainty.
- E-session for establishing the problem and the research- design topic.

In order to communicate information in the network in the best way, the methods of root cause analysis are very useful. These are 5Whys, Failure mode and effects analysis, Pareto Analysis, Fault tree analysis, Bayesian inference and Ishikawa diagram. Some other useful methods for problem definition are specified by TRIZ methodology. These are: 9 box solutions map (used to accurately capture the history of each problem and the problem context, to set the system context, to define its environment (super-system) and all the details (subsystems)) and Eight Trends of Technical Evolution (show how to predict new markets and new products, how all products and industries develop).

Taking into account the importance of a correct and complete problem definition is useful to organize more E-sessions with this aim.

TRIZ methodology underlines the characteristics of a clear problem definition. These are: the end point, the purpose, the main function we are seeking, all functionality / benefits (everything we want and everything we don’t want), where and when we want our functionality, conflicts identification in time and space, real functionality checking (Why do we want this?), ideal outcome, everyone’s ideal outcome.

The problem that we wanted to solve in the network frame was the design of a boring head that can manufacture holes of different diameters and a chamfer at the end of the hole (chamfer has different diameters depending on the hole diameter). The material we want to manufacture has high characteristics and the production series are low.

3.2. Establish the research type that must be done

After the precise defining of the research theme, is important to establish the types of research activities that must be carried out. Each research activity comes to an end with a model [1, 6, 9]. The main possible research models are:

- Mathematical (analytical) model. A formal theory is developed and the results of the theory can be compared with the empirical ones.

- Experimental models. These models need an experimental design, phenomenon observation, data collecting, data processing, model validation. There are three types of experimental models depending on the level of phenomenon understanding.
  - For the scientific model the phenomenon is deeply observed, the model proposes a theory that explains the phenomenon, measures and analyzes for model validation.
  - In the case of engineering models, the existing solutions are studied, measured, improved and developed until no more improvement is necessary.
  - For the empirical model there is no need of a theory or an explanation for the phenomenon. It works as a black box with input and output. Generally it includes experimental, statistical research, analysis and validation of the model.

In the case of experimental models it is important to pass through some steps, which are:

- Preliminary experimental design. Select the variable factors and their investigation level. Establish the parameters that are measured, their characteristics, measured units, format etc.
- Choose the best experimental model for the research model. The main experimental research methods are Complete Factorial Design, Fractional Factorial Design, Latin Square, Taguchi Method.
- Do the experiments and obtain the model
- Verify the model. Does the model reflect the studied system in an acceptable way? For input data, does the simulation offer correct output data? Statistical methods (variance analysis methods) allow the verification of an experimental model. The most useful one is ANOVA method.

For our problem we choose to build an analytical model, a representative tool for all the boring manufacturing possibilities. This model consists of an ideal tool body with several stages that can present multiple movements and regulation possibilities, as well as active elements with different shapes and positions.

By particularization, a specific cutting tool can be obtained. The reason of the representative tool is not only the obtaining of a specific solution but also to do a synthesis of the knowledge in this area and to improve the knowledge database of the network.

3.3. Research planning using Project Management methodology

After the description of the problem and the establishing of the kind of research that must be done, the next step is the research planning using Project Management methodology [4]. The most used software is Microsoft Project. The main stages are:

- Choose a project manager;
- Define the project aim, objectives, deliverables, deadlines, technical requirements, limits and exclusion;
- Choose a project team
- Create the work breakdown structure (activity name, duration, estimation costs, responsibilities);
- Develop a network plan
- Risk analysis
- Resources allocation (human resources, materials, equipment)
- Cost computing and analysis

The planning of a research project is presented in figure 3.

Besides the research or optimization part, the project can contain some modules for product design, or technologies design, prototype design and/or prototype manufacturing.

In order to do a good and realistic plan is very important to have a data base with complete information about researchers, laboratories, knowledge, costs available in the network (chapter 2.2).

3.4. Project development

Development and monitoring of the project must be done in accordance with the project schedule. Creativity meetings in INPRO network, synchronic or asynchronic communication between the research team members, experimental activities, model elaboration, design activities and manufacturing activities can be done in one or several locations. The actual software possibilities allow network meeting with the participation of specialists located in different geographical areas. Software such as Teamviewer allows visualization, modifications and additions to the drawings made by all participants at a network meeting. The final variant of the model (drawing) can be discussed by all participants and accepted by consensus or voting [5].

In order to elaborate new solutions, it is necessary to establish a virtual team. The methodology of choosing the team members is presented next::

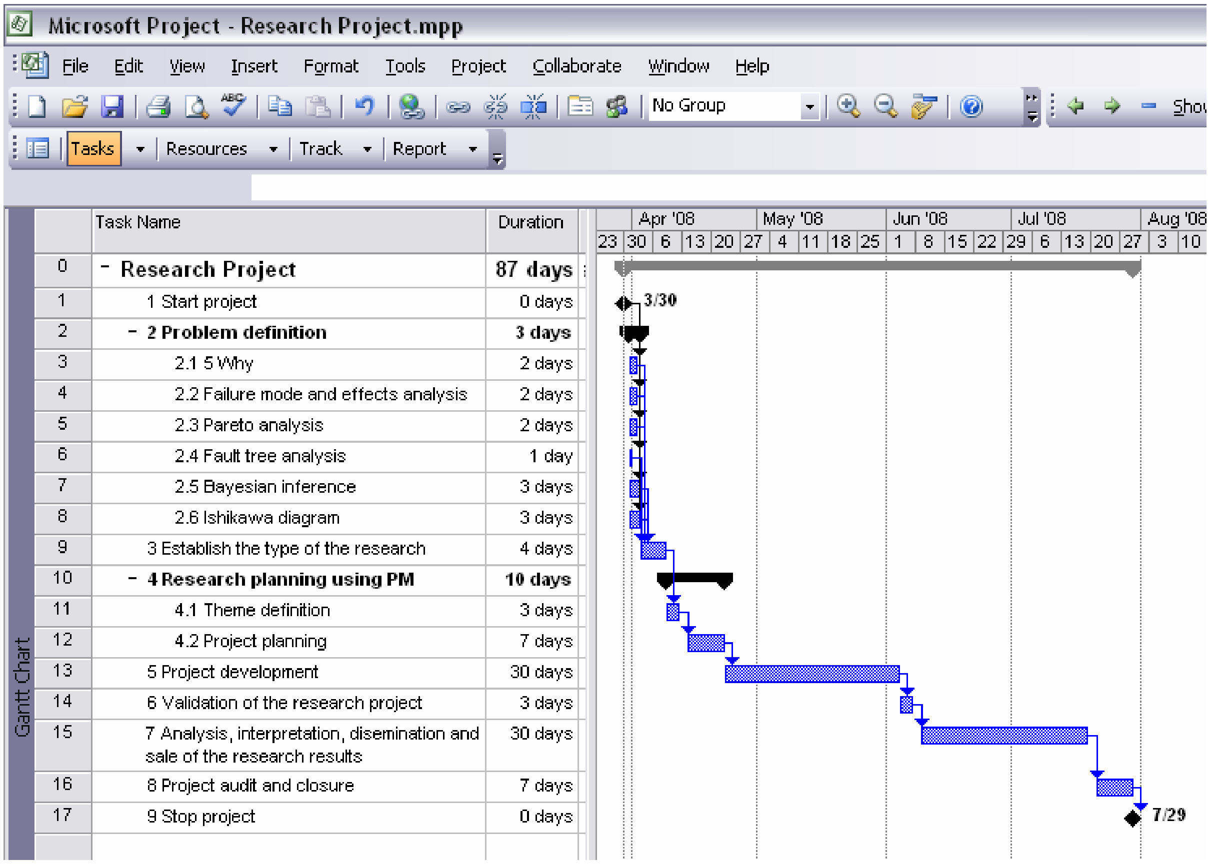

Fig.3.Generic research project

ESTABLISH the E-research virtual group members;
DO WHILE the E-research group members is complete
CONTACT the E-research virtual group member;
IF the person accepts to participate
THEN
EXPLAIN the working principles;
IF the knowledge level must be verified
THEN
The person COMPLETE a test;
IF the test is good
THEN
ACCEPT the person as a E-design group member;
ENDIF
ELSE
ACCEPT the person as a E-design group member;
ENDIF
ENDIF
ENDDO

The next research sessions can be done in a synchronous or asynchronous way.

For synchronous sessions the steps can be:

- *ESTABLISH the E-design virtual group members;*
- *COMMUNICATE the research-design topic to the E-design group members- mail;*
- *ORGANIZE an E-session for establishing the analyzing criteria. Each member can propose one or more criteria. Each member will note all criteria. A specific soft will determine the most important criteria and their weight;*
- *ORGANIZE an E- creative session in order to develop new constructive solutions from the design topic and in concordance with the criteria established before – use a specific E-creative method;*
- *ORGANIZE an E-session in order to analyze the existing constructive solutions from the design topic and in concordance with the criteria established before; analyze all combination variants – Morphological Analysis Method;*
- *New creativity E-session.*

Of course, these E-sessions can have different characteristics depending on hardware equipments and software. The synchronous E-sessions can be done on Messenger, Skype or more sophisticated video systems. Software packages such as Teamviewer allow visualization, modifications and additions to the drawings made by all participants at a network meeting. When Teamcenter Engineering is used, the participants have accesses to more information. Team Center is a *Product Data Management (PDM)* system that helps the managing of all the processes, applications, and information required to research, design, manufacture, and support a product throughout its life cycle. The goal of a PDM system is to provide a single, common interface for managing and accessing all data within an organization (this can be a research network).

For asynchronous E-sessions, the problem definition, research topic and the other necessary documents are sending to the team members after an algorithm presented next.

- Each participant will receive a code (P1, P2, P3, P4, P5, P6);
- Knowing the problem, each participant will write three proposal for the problem solving on the computer;
- Send the file to the participant with the following code;
- Complete, improve, establish details, change or write the opinion about the first three ideas until all the ideas are discussed by all the participants (Table 1);
- Analyze, group, compare the proposals (value analysis by giving notes to each solution, for all the criteria, by all the team members);
- Establish the best solution;
- Preliminary design of the best solution;
- Analyze these solution by all the team members;

Establish the final, optimum solution. All the participants note again the solution. In order to adopt it, generally, five from the six-team members must give the maxim note. If not, the process begins again until the best solution is obtained. The E-brainstorming sessions can be organized in a classical way or using some Creativity Methods for breaking Psychological Inertia. These are creativity, intuitive and heuristic techniques: consonants association, analogy and extrapolation, inversion, empathy, combination, modifying, improving, developing, input-output techniques, interrogative lists. TRIZ methodology uses a list of 40 Inventive Principles which must be followed step by step or/and the 9 box solution map. These creativity E-sessions are organized depending on the research topic, importance, team skills etc.

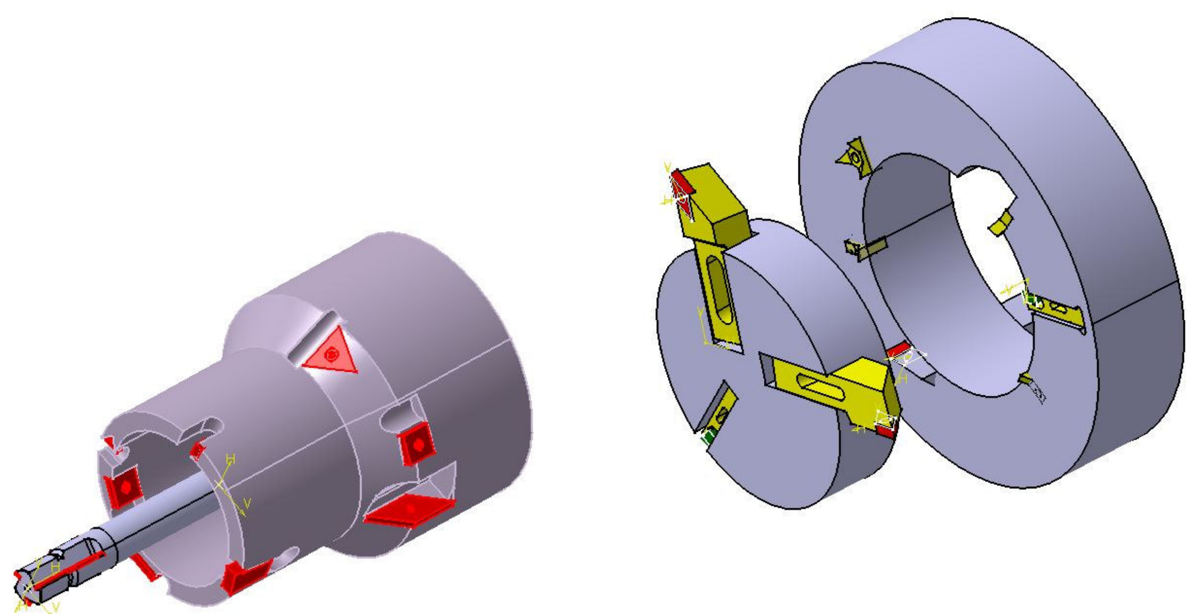

Fig.4. Representative model of boring heads with inserts

Table 1. Structure of the list that must be completed by each participant to asynchronous E-sessions

Partici-pant	Proposal1	Proposal2	Proposal3
Pi			
Pi+1			
Pi+2			
Pi+3			
…			

The selection of the best solution can be done only using Value Analysis principles. The analyzing criteria were established before. Each solution is marked by each team member for each analyzing criteria. The method is more useful if the members have no information about how the other members mark. Specific software for mark addition is very useful. The optimum solution can be improved if necessary.

In our case, in order to build the representative model of the boring head we organized first a synchronic meeting in which we used creativity methods.

Questions as:

- Imagine that you are instead of the boring head. How do you work much easier?
- What kind of material you need?
- How shall the coolant fluid come?
- How to put the edges (inserts)?
- What happens if you look from inside the process?

was done in order to break the psychological inertia of the participants.

He main ideas obtained in this session were the creation of several modules with cylindrical and toroidal shapes and the placement of the inserts the frontal and lateral side of the cylinder on radial and also tangential position.

After that, the final shape of the representative boring head was established during asynchronic communications (fig. 4). This representative model consists of several cylindrical and conical bodies placed on the same axis (z axis). The main shape of the tool body can be of either the axle type or the hole type. On the cylindrical and conical shapes, there are placed inserts with a cutting role and pads with the role of guiding the cutting tool into the hole. The cutting inserts can be placed on the cylindrical and conical shapes in radial position or in tangential positions (the tangential inserts can be placed on the frontal part or on the cylindrical and conical shapes).

Table 2. Analyzing criterion of the representative model of boring head

Criterion	**Constructive solution - examples**
Main shape type	Axle type, hole type
Edge position	On the cylindrical shape, on the frontal shape, on the conical shape, on multiple shapes
Component parts	Monoblock, with brazed inserts, with changeable inserts fixed on the tool body, with changeable inserts fixed on intermediate rigid elements, with changeable inserts fixed on intermediate adjustable elements.
Position of the active elements	Radial, tangential on the frontal shape, tangential on the cylindrical shape
Insert shape	Triangle, square, rhomb, special
Clamping system	Using tool body elasticity, with central screw, with wedge
Edge number	one, two,…

The body rotates around the z-axis (as main movement) in order to perform the chipping process and translates along the same z-axis with the aim of bringing new raw material in front of the inserts.

Analyzing the representative model of boring heads, we can underline the classification possibilities and the constructive solution related with each criteria (table 2).

Several particular solutions were obtained through particularization in another synchronic meeting. The best one was a modular tool built by a solid carbide helical drill or a drill with carbide inserts (for bigger diameters) and a chamfer with adjustable intermediate body and insert clamped by the elasticity of the tool body (fig.5).

The optimization criteria were:

- material economy;
- uniformity of stress with minimal value of the stresses from different perspectives: cutting tool

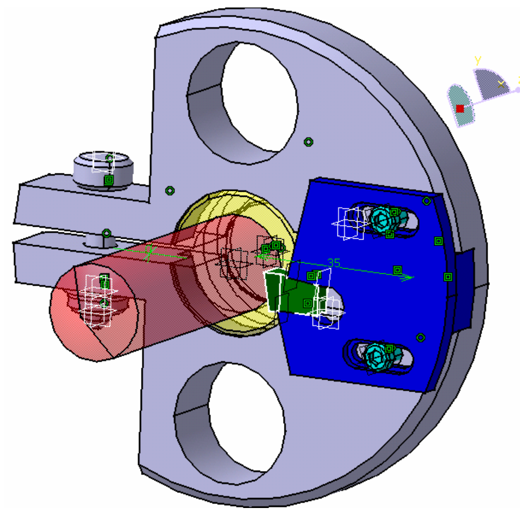

Fig.5. Chamfer with adjustable intermediate body and insert clamped by the elasticity of the tool body

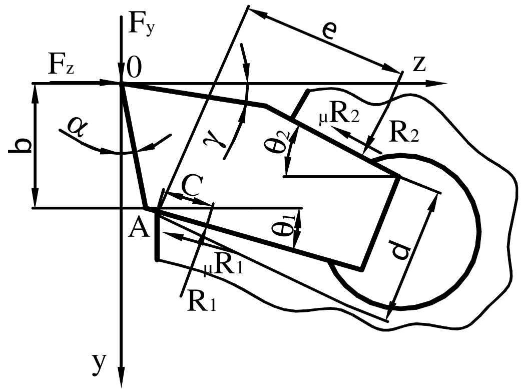

Fig.6. Equilibrium analysis of the clamping system realized due to the elasticity of the tool body

parameters, material with high performance, the type and form of the clamping system etc.
- minimum and uniform forces determined by insert position;
- modularity;
- ability to maintain cutting characteristics and power;
- different and large utilization area from the efficiency perspective.

There was several aspects that could be optimized: insert shape, clamping system and tool body. One of the optimization method started with the cutting force estimation. After that, the studies continued with the static or/and dynamic equilibrium analysis and the finite element method analysis.

The clamping system by the elasticity of the tool body is very economic from the space point of view. It requires precise shapes of the elements in order to assure the safe clamping and dynamic stability. Our purpose was to establish the optimal shape of the inserts and of the pocket [6]. The solving of the equilibrium equations (fig.6) indicated that the inserts and toolholders must have special gradients in order to assure a safe clamping. The best values are θ_1=2…15° and θ_2=2…6°.

3.5. Validation of the research project
The result of the research project must be debated by the team members of the research project, other specialists from INPRO network and customers.

3.6. Analysis, interpretation, dissemination and sale of the research results
Results analysis is made through an inferential process using the models data and experimental data. Results are graphics, tables, databases, synthesis information. These synthetic results are useful to be presented in reports, research papers, etc. The network (http://www.eng.upt.ro/inpro) contains secured sites where partners can see the needed information. Also, it allows knowledge dissemination through the database system and through the e-learning products.
Information is up-dated continuously as a result of the partners' feedback.

3.7. Project audit and closure
Making post project audit for each research analysis is very important for the future activity of the research network. The audit includes three major tasks:
- Assess whether the project was managed well and whether the customer was satisfied.
- Highlight what was wrong and what contributed to successes.
- Identify changes to improve the delivery of future projects.

The project audit and reports are instruments for supporting continuous improvement of the network organization.

4. Conclusions

Hardware and software systems allow a more and more easier connection between researchers located in different geographical areas. Research networks are viable solutions for economic, social educational and, last but not least, human development.

In order to reach its mission the INPRO research network developed an efficient infrastructure, adopted a functioning methodology that allows continuous improvement, established a research project methodology with specific features for working in networks and will develop a valuable knowledge database.

Creative methods (brainstorming, morphological analysis, San Francisco method, interrogative lists) adopted to network communication was used for the first time in order to do research and design activities for products and technological equipments.

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