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APPLIED RESEARCH PROGRAM OF MECHANICAL ENGINEERING AUTOMATION

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1. INTRODUCTION

On the present, the inter-enterprise cooperation through all product lifecycle stages is becoming cardinal importance. In consequence of globalization and technological progress the industrial cooperation and integration are essential, especially for small and medium sized enterprises (SME) to keep their own position and progress continuity. Costumer requires new products of high quality according to exact specifications and delivered right on time. Sometimes smaller companies using traditional methods of industrial control are unable to satisfy these exacting requirements. Moreover they must face to competitive pressures of great and even multinational companies. Concepts of virtual organisation (VO) and product lifecycle management (PLM) bring new opportunities in this sense. Some Slovak enterprises, within the incorporation into European structures, begin to accept changes leading to the virtual cooperation. On the part of university there is possible to enter into intense collaboration in the form of research, applied research, education and training. Various institutions all over the world are engaged in these tasks including many important European universities. Applied research in Slovakia still does not meet all needs of the industrial establishment. Research team at Department of Manufacturing Engineering, STU in Bratislava seeks to build Laboratory of PLM and Innovation. By doing so the technological and personal conditions will be reached, comparable to foreign workplaces, that is necessary requirement for continuous advance in engineering automation. The paper presents activities of the laboratory and achieved results with emphasis on collaboration between academic and industry community.

2. LABORATORY OF PLM AND INNOVATION

In the past 10 ÷ 15 years many research and developmental projects were solved in the field of virtual cooperation. This effort have brought wide-ranging academic and empiric knowledge that was particularly supported in European Union by the programs ESPRIT, IST, INCO, IMS also in USA and other countries. Professional teams created a theoretical concept with the pursuit of start-up the first practical application of VO. However the results reached until now are not coordinated. Poor level of definitions, formal theories, modelling methodologies and suitable reference models belong to evident deficits. This naturally reflects in an absence of the appropriate supporting ICT.
In next steps there is necessary to summarize and organize all existing information and create the base of knowledge of the industrial integration. The research team headed by professor Štefan Valčuha actively deals with problems in this area. The Laboratory of PLM and Innovation established for engineering industry belongs to concrete outputs of current activities. Installed hardware and software equipment supports work in CAx/PLM environment (CATIA V5, SmarTeam, AutoCAD, Mechanical Desktop, Sysklass, MS office,

communication devices and others). Nowadays four projects of the long-lasting integrated research program are in working-out phase. Considering solutionists' potential, conditions and possibilities of academic research five work areas were established:

1. **Permanent analysis** – mapping the current status and trends of the virtual cooperation according to accessible reports and individual research (suppliers, products, situation of SME in Slovakia, results of implementation, etc.),
2. **Information system** – development of a software application based on internet technologies as the support for communication and cooperation on PLM principles,
3. **Operation processes** – creation of knowledge and experience associated with implementation and operation of systems to support the virtual organization and PLM conception (evaluation processes, implementation models, process analyses, reference models, manuals for managers, etc.),
4. **Education program** – diffusion of accumulated knowledge through seminars and courses (learning plans, prospects, presentations, scientific conference, the PLM monograph, sources for e-learning, etc.)
5. **Engineering support** – direct integration of the laboratory sources into the processes in industrial sphere (support of the product lifecycle oriented on the manufacturing planning and methodical support in the ICT area).

3. PERMANENT ANALYSIS

The analytical process is important for composition of current and exact information that represent a foundation for tasks solving in other work areas. In respect of continued progress of virtual cooperation a specification of information is expected via our questionnaires, research labours and studies of practical realization. Cooperation with the enterprises is generally oriented into three directions:

- **With industrial partners of projects**, one of which currently implements a PLM system, will bring real information about process of implementation.
- **Cooperation with SMEs** will support a mapping of current situation with regard to their awareness, exploitation of ICT and ability to implement necessary changes.
- **With PDM/PLM providers** will bring us the information about market segmentation, available systems, their structure and functionality.

Slovak companies and also foreign rival firms feel the impacts of economic and technical changes. Factors of globalization, outsourcing and customization change character of the inter-enterprise cooperation that must be now based on the direct and fast communication, support synchronization of processes, bridge any geographical, time and cultural gaps. These are relevant facts for decentralized clusters built on the principles of the VO (figure 1). More details about present organisations are available in literature [2], [3], [4]. In the Slovak area no organisation exists comparable with European or world's virtual organisations. The reasons are in the conservativeness, low level of ICT and poor awareness. SMEs still prefer partnerships in traditional supply chains at the local and regional level. This approach can be rational, but in comparison with potential of VO less ambitious. Participation in VO proposes business process reengineering, widening of market share, acquisition of new technologies and opportunities. Some progress is evident in case of horizontal integrating infrastructure with the support of PLM. Summary analysis about the current situation including position of SMEs is available at department. [10]

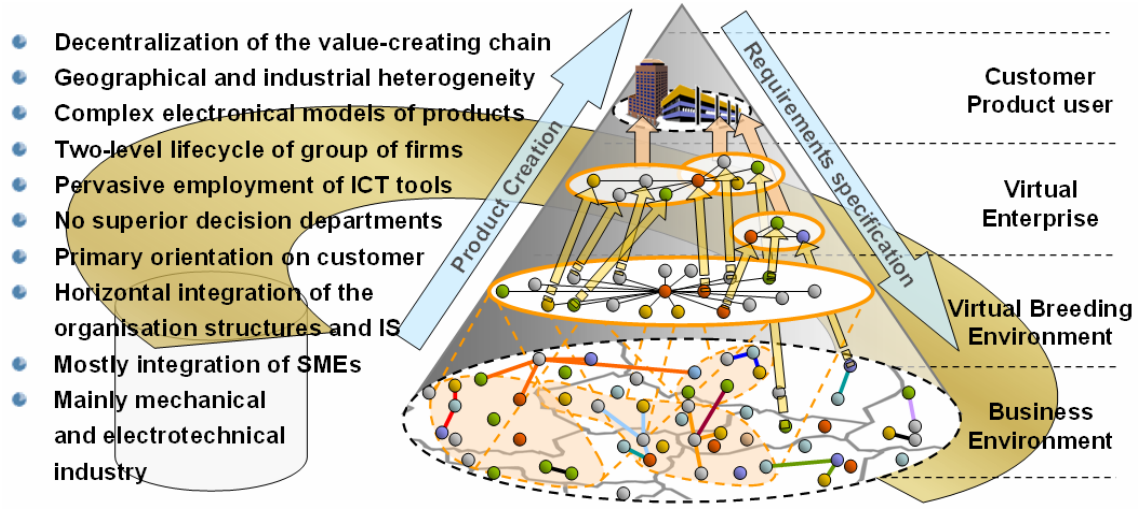

Figure 1: Concept and principles of virtual organisation

4. INFORMATION SYSTEM

Virtual enterprise is a form of collaborative network, in which the recombination of value-creating chain, horizontal integration of organization structures and information systems take place. This type of cooperation incites development and use of sophisticated supporting ICT tools. In comparison with large companies, SMEs are oriented on narrow range of products, and usually they are more flexible and agile. However large companies dispose stronger technical and personal basement. Communication and internet technology offer an opportunity for enterprises to become an equivalent partner to large companies.

Information system for small and medium enterprises ISSME (figure 2), being developed within the research programme, is based on the web-interface platform with the possibility of new technologies implementation. This system offers tools for project management, cooperation and outsourcing. The purpose is to support execution of projects, which would be impossible or too difficult by individual approach. Company is allowed to enter ISSME through extranet, search for partners and establish mutual relationships. Company becomes one of the co-operating partners and can create temporal virtual enterprises with others. On the other hand a company situated in the system doesn't have to be incorporated into the project-oriented virtual enterprise. This information system is just in the development stage, but implementation of model variants in industrial environment is on plan. The target of ISSME is to present the partner's business activities, create digital communication channel, and improve relationships with customers and business partners. The ISSME provides functions called e-business:

- Actual presentation of company through the Internet
- On-line registration system
- Searching for partners, customers and subcontractors
- Catalogue of services and products
- Communication with partners, customers and subcontractors
- Forums for registered users of information system
- Outsourcing of machines, tools, fixtures, working forces, and services
- Access to contact information

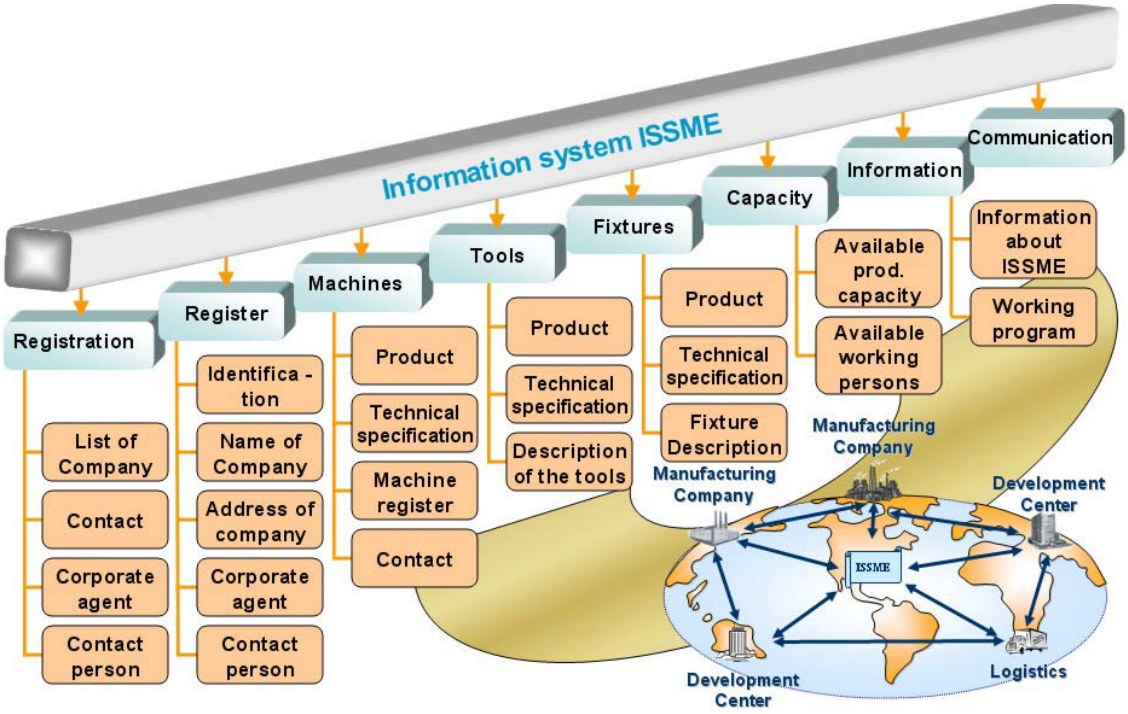

Figure 2: Structure of information system ISSME for small and medium enterprises

5. OPERATION PROCESSES

Despite many advantages the new conception brings an “overturn” in its initial phase. It is required to adjust the information system, organizational structure, working methods, reorganize the business processes, workflow, corporate culture and management strategy. Implementation of the PLM beside the software installation includes the enterprise analysis, requirements definition, system design and development, training of personal and other subsidiary activities. With technical point of view there is important to consider also economic, juridical and social aspects. These tasks require a holistic approach based on appropriate modelling method and use of reference models. The objective of solutionists is to develop methodical processes usable within the implementation of PLM and building of VO. At the present there are solved two tasks:

1. Methodology for **selection of suitable PLM system** by user’s requirements,
2. Methodology for **design and development of VO reference models**.

5.1. METHODOLOGY FOR SELECTION OF PLM SYSTEM

Today no universal PLM system exists on the market which would by usable for each type of company. Variously software products have different properties and not always cover all initial requirements. Implementation costs are relatively high with expecting of long-time usage, permanent maintenance and actualization. Many enterprises use incompatible applications, especially CAD/CAM, database systems, PDM systems, office applications. In light of functionality these are only partial parts of the complex solution for product lifecycle management. So the selection methodology is important and actual. Some consulting companies and also software providers are engaged in this question.

Our objective is to create a methodology fit to small and medium enterprises. Designed methodological process is based on the scoring of evaluation criteria and algorithmic elaboration of results using multi-attribute utility method (figure 5). Valuable information for this task is experience of enterprise that is in process of the PLM system implementation – Konštrukta Industry a.s., Trenčín. During decision-making managers considered mainly stability of provider, its experience with implementation, license politics, integrations with own systems, implementation duration, price, and maintenance fees.
Based on knowledge of PLM systems two types of criteria have been defined in technical and management area. Evaluation with multi-attribute utility method allows assign the order to each product. Decision Matrix Method is right for our purpose. In this case the weights of criteria importance are determined with scale from 1 till 10 (1 to lowest weight and 10 to highest weight). Using the same scale all individual alternatives are evaluated based on the satisfaction of each criterion (1 – unsuitable, 10 – suitable). That averaged total represents the value of that alternative, and can be compared to the same calculation for the others.

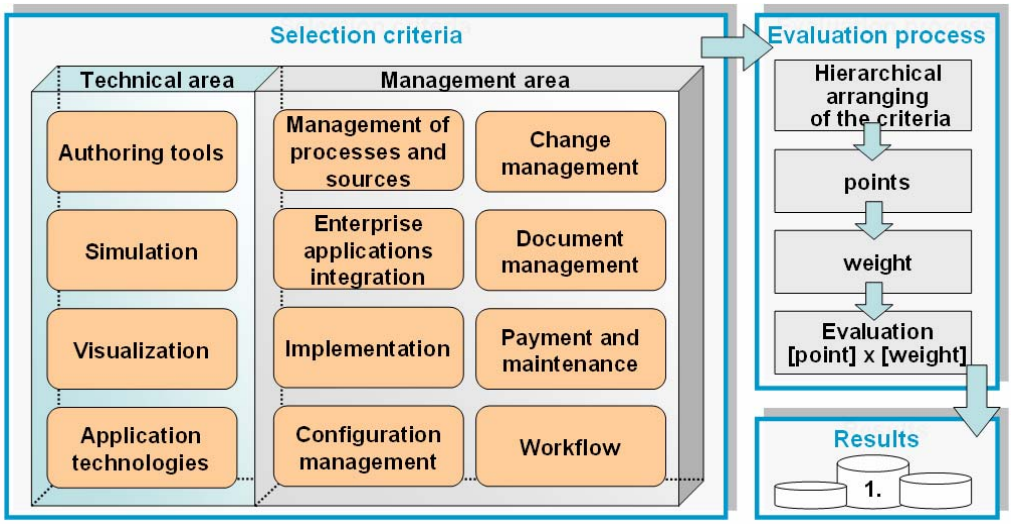

Figure 3: Methodology for selection of suitable PLM system

5.2. MODELLING METHODOLOGY VO-PLM

Many supporting systems coming out of leading R&D projects still require massive configuration and customization effort. Modelling as a research and development method may simplify analysis, specification, design and development of adequate supporting infrastructure. Reference models will contribute to mistakes elimination, setup time reduction and total costs decreasing. Such approach requires unified methodology. This question is answered by the **Frame modelling systems VO-PLM** which describes theoretical background, formalization methodology and application areas of reference models in term of VO building and PLM implementation. The frame system was created following state of the art of business modelling and virtual organization modelling, after analysis of many publications, studies and reports of research projects. The figure 4 shows also cooperation between research group (Laboratory of PLM and Innovation) and Slovak industrial establishment (SMEs engaged in applied research program). Such approach will allow creating models in line with requirements and needs of industrial enterprises.

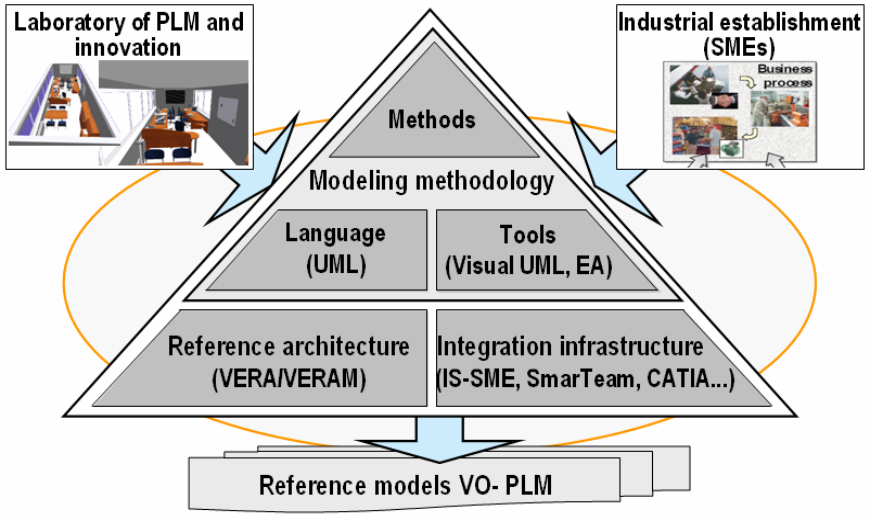

Figure 4: Modelling methodology VO-PLM

The **reference architecture** provides an area to discussion about problems, and also facilitates analysis, specification and problem understanding. Many reference architectures have arisen in parallel with development of business modelling concepts. In point of inter-enterprise integration modelling the **Virtual enterprise reference architecture** (VERA) developed by the project Globemen is significant contribution. Authors have been operating with this reference conception within modelling.
Routine operation of VO is associated with interactive data processing, sharing and exchange. Structure of the information flow is variable with constantly increasing volume of diverse data (design, technological, production, business and organizational). For modelling purpose there is useful to group three key elements of information flow (hardware, software and personnel) to one system called **integration infrastructure of virtual organization**. Specific tools can vary from cluster to cluster.
Modelling methodology provides mechanisms (language, tool and methods) which should be used for transformation of first requirements into reference models of the integrating infrastructure. Proposed methodology is based on principles of the object-oriented language **UML** in its current version UML 2.0. According to the company OMG (Object Management Group) this language is usable for specification, visualization, design, development and documentation of systems, mainly for software systems but also for systems of un-software and corporate nature as well. This language in conjunction with its tools supports work effectiveness of all persons participated in systems creation.

6. EDUCATION PROGRAMME

Complexity of the PLM causes that enterprises are not looking for supplier of CAx applications no longer, but partner that helps them to build complex solution. Technical schools should take up this challenge. School-leavers must have knowledge not only in CAD/CAM but also in PDM/PLM technologies. University graduate should be able to define system properties in respect of production character and enterprise strategy what is needed for selection and implementation of software tools.
Direct transfer of results to educational process belongs to advantages of the academic research. The Output of successful project is a knowledge basis in form of publications, research reports, dissertation and diploma thesis, studies, scripts etc. This knowledge is

used by researchers in teaching process within seminars, lectures and qualification thesis. Nowadays lessons are focused on the work with CATIA V5 and the PLM system SmarTeam is supposed to be incorporated in the next year. Every student has to elaborate its own assignment called **Design of tooling system for cutting technology**, which consists from (figure 5):

- Task analysis and proposal of solution
- 3D models of construction elements
- Parametric configuration model
- Strength control by cutting force
- Entire drawing documentation
- Summary progress report

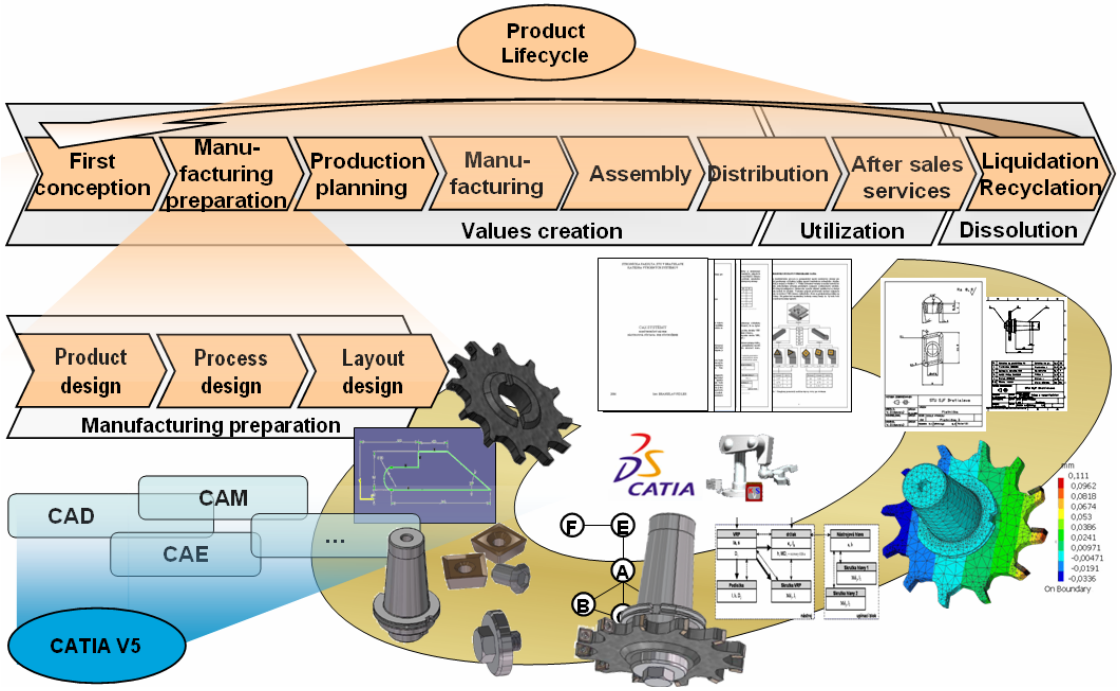

Figure 5: Exercises of CAx systems, SjF STU in Bratislava

7. ENGINEERING SUPPORT

The reason of technical support is in direct transformation of theoretical knowledge to the practical applications using personal and material resources of the laboratory. Following two tasks are solved in this work area:

1. **SmarTeam** – PLM system developed by the consortium of Dassault Systemes and IBM. It supports sharing and exchanging of information among work groups within enterprise and whole supply chain as well. It provides a modular solution for machine industry, automotive, electrical and construction industry, though due the universally adaptable data model it may be used for other industries. SmarTeam provides cooperation of workplaces (clients) through the web-interface and each of clients has assigned own authorization of the data access. Administrator is able to configure personal environment and authorization for every client. This system is suitable for building of the model virtual enterprise with industrial partners.

2. **Information and contact website**. For the project the partners' awareness about tasks and publishing of common results are very important. On the website of laboratory (http://projekty.kvs.sjf.stuba.sk) there are presented information about projects, objectives and solutions, publication activity, etc. On the website the questionnaire will be accessed as well with possibility of direct filling. The purpose of this questionnaire is to map of current situation of SME.

8. CONCLUSSIONS

Considering collaboration with industrial partners we expect that results of our programme, outputs of which are periodically presented in research publications, will help SMEs to increase their awareness and therefore to support their competitiveness. Such partnerships allow improving the education program in accordance with the latest available knowledge and trends.
Technological, social and expert conditions reached by building the laboratory are necessary requirement for continuous advance of the concept VO-PLM in Slovakia. At this time four mechanical manufacturing corporations are engaged in collaboration. We try to extend usability of the results for more small and medium enterprises. Communication strategy is based on direct addressing of chosen companies. For this purpose the database of small and medium enterprises and the questionnaire were created to find out actual information. First contact seminar with SMEs is intended to be.
Within next solution there is necessary to be concerned with tasks of the fields Operation processes and Engineering support (Analysis of PLM Implementation in the company Konštrukta Industry, Extension of collaboration with another companies, design and development of reference models, deployment of the ISSME in practical conditions). All outputs will become a part of complex methodology developed for realization of the PLM that should be verified in practical environment.

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