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MANUFACTURING INNOVATION AND HORIZON 2020 – DEVELOPING AND IMPLEMENT „NEW MANUFACTURING“

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Abstract: *Manufuture developed the Vision 2020, the Strategic Research Agenda and Road Maps as basics for the European Research in FP8. The vision was mainly influenced by the challenges toward competition and sustainability by transformation from cost orientation to adding value with technical and organizational innovations. Manufuture developed a strategic research Agenda "2020-2030" and Roadmaps to support the process of structural changes and orientation to higher efficiency and changeability. Technology development was driven by the activation of technological potentials in the process chains from basic materials to finished products and from customer's orders to the end of life to increase adding value. Manufuture proposed fields of proactive actions for cooperative research in Europe across the 40 industrial sectors. Core fields of the strategic research agenda are part of the Factory of the Future (FOF) and Digital Manufacturing program and on the way now for implementation. Also in this analysis are include one example from Serbia about digital manufacturing concept.*

Key words: *manufature program, factory of the future, digital manufacturing, innovations.*

1. INTRODUCTION REMARKS

Manufacturing demonstrates a huge potential to generate wealth and create high quality, value-adding jobs [1] [1)]**.** In 2007, the total number of manufacturing enterprises in the EU-27 non-financial business economy was estimated to be 2.3 million, representing a little over one in every ten (11%) enterprises within the EU-27 non-financial business economy. Manufacturing enterprises provided employment for 34.5 million persons. This was equivalent to 26 % of the employment in the EU-27 non-financial business economy. In 2008, manufacturing jobs and jobs directly depending on manufacturing represented 36.7% of the overall employment in Germany.

The EU-27 manufacturing sector generated EUR 7.274 billion of turnover in 2007, of which EUR 1.813 billion was value added. This was equivalent to 29% of the value added in the EU-27 non-financial business economy. On average, EUR 52,551 of value added in manufacturing was generated by each person employed. Total investment by the EU-27 manufacturing sector was valued at EUR 262 billion in 2006, equivalent to almost 14% of the manufacturing sector's value added.

Manufacturing activity is important for SMEs [2]**.** SMEs are the backbone of the manufacturing industry in Europe. Micro, small and medium enterprises provide around 45% of the value added by manufacturing while they provide around 59% of manufacturing employment.
Manufacturing is an R&D&I intensive activity [3]. In 2006, the R&D expenditure just in the Mechanical Engineering sector in EU-10 was $ 8,323 million. In 2007, the 'manufacturing' sector received the greatest share of business enterprise R&D expenditure in most of the EU-27 countries. This was notably the case in Germany, Slovenia and Finland, where 88.7 %, 88.2 % and 80.0 % respectively of R&D expenditure by the BES went on manufacturing. Across all industries R&D intensity (R&D expenditure as % of GDP) was 3.5 % in 2009 worldwide. At the same time, R&D intensity of Mechanical Engineering in Europe was 3.6 whereas in USA and Japan it was 3.2 and 3.0 respectively. This indicates that in the EU, Mechanical Engineering is of higher importance for overall technological performance than in US and Japan where the sectoral figure was below total industries. Also, in the business enterprise sector, manufacturing accounted for the highest shares of researchers in most EU Member States. In 2008, 14.1% of all tertiary students (EU-27) were participating in engineering, manufacturing and construction education. In 2008, 39.8 % of 6 enterprises in the EU-27 were considered innovative in terms of technological innovation. In most countries, the proportion of innovative enterprises was generally higher in manufacturing than in services. In 2009, 2.4 million people were employed in the high-tech manufacturing sector in the EU-27.

2. SUSTAINABLE AND COMPETITIVE EUROPEAN MANUFACTURING

It is envisaged that the continuation of the joint EC-industry investments on cross-disciplinary manufacturing research would allow the contribution to major social-driven targets for European manufacturing [4]:

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- Employment: maintain and create new jobs in manufacturing,
- Value added: increase value added by manufacturing, and
- Environmental impact:
  - reduce emissions of green house gases from manufacturing activities,
  - reduce energy consumption in manufacturing activities, and
  - reduce waste generation by manufacturing activities,
- Research & Development: increase business enterprise R&D expenditure in manufacturing,
- Innovation: increase the number of manufacturing enterprises engaged in innovation activities, and
- Education: bring all manufacturing engineering graduates & doctorate holders into manufacturing employment.

2.1. Towards a manufacturing knowledge-value chain

On the basis of previous achievements, a coordination and integration of activities related to [4]:

- research,
- valorization (innovation),
- education & training,
- standards, IPRs, infrastructures and international cooperation,

is needed to promote a sustainable & competitive European manufacturing. This is to be supported on the basis of private and national / European funding. A multi-disciplinary approach involving all relevant actors from the public and private sector is required.

Within this context, a number of cross-disciplinary implementation "vehicles" (existing or envisioned) are to be employed, such as [4,13].

- Manufacturing research addressing industrial competitiveness − Factories of the Future PPP (H2020 – Pillar II),
- Manufacturing research addressing societal challenges (H2020 Pillar III),
- Manufacturing research at the frontiers of knowledge − ERC (H2020 Pillar I),
- Manufuture Industry Cluster – EUREKA,
- Manufacturing education / research-innovation-education, pilot projects & KIC on manufacturing − Education, EIT,
- New Industry European Innovation Partnership – Innovation,
- Advanced Manufacturing Systems (KET) − Industrial Policy.

In collaboration with all relevant actors, Manufuture ETP, together with its sub-platforms and national / regional platforms, will provide the integration framework catalyzing the synergies among these "vehicles" [7,10].

2.2. Factories of the Future Roadmap beyond 2013

The manufacturing research and innovation community has been working on a strategic innovation agenda and a roadmap2 for the future, applying in a broad range of manufacturing sectors [5,7].

In response to the megatrends, following the Europe 2020 strategy and focusing on future market demands, it is foreseen that European Manufacturing sectors will undergo structural transformations towards [5]:

- Factory and Nature -> green / sustainable,
- Factory as a good neighbour -> close to the customer,
- Factories in the value chain -> collaborative, and
- Factory and Humans -> human centered.

Achieving these transformations requires a coordinated research and innovation effort, where manufacturing challenges and opportunities are addressed by deploying successively a set of technologies and enablers providing the decisive answers to the manufacturing challenges as well.

2.3. Research priorities in FoF

The suggested priorities are organized under the following clusters [4,5,13]:

- Cluster 1: Advanced Manufacturing processes
- Cluster 2: Adaptive and smart manufacturing systems
- Cluster 3: Digital, virtual and resource-efficient factories
- Cluster 4: Manufacturing eco-systems
- Cluster 5: Human-centric manufacturing
- Cluster 6: Customer-focused manufacturing

For the research and innovation actions to have the desired impact, specific consideration is given to the fact that R&D&I (research, development and innovation) need to be associated to dissemination and demonstration activities, addressing market readiness (industrial implementation) at an early stage.

3. MANUFACTURING RESEARCH IN HORIZON 2020

The manufacturing research and innovation community has been already working on a strategic innovation agenda and roadmap for the future. It also has in place the appropriate instruments, i.e. a Technology Platform – Manufuture and a Research Association – EFFRA. This is a sound basis for having implementation vehicles in the context of Horizon 2020 quickly in place [5,13].

With respect to Horizon 2020 structure, manufacturing is clearly an enabling cross pillar activity with major relevance to several research and innovation themes in all three pillars. Thus, on the basis of the successful implementation of the FoF PPP so far, a continuation and expansion of the community's thinking and implementation to all three pillars of Horizon 2020 would bring added value to the Programme [1,6-10,13].

3.1. Manufacturing in Pillar I − Excellent Science [4,7,13]

A1. ERC − *In order to stimulate substantial advances at the frontiers of knowledge, the ERC will support individual teams to carry out research in any field of basic scientific and technological research which falls within the scope of Horizon 2020, including engineering, social sciences and the humanities.* Basic research for manufacturing.

A2. Future & Emerging Technologies − A2.1. FET Open: fostering novel ideas − *By being explicitly non–topical and non-prescriptive, this activity allows for new ideas, whenever they arise and wherever they come from,* *within the broadest spectrum of themes and disciplines.* This topic is general and could foster highly innovative ideas for manufacturing.

A3. Marie Curie Actions − A3.1. Fostering new skills by means of excellent initial training of researchers − *Typically, successful partnerships will take the form of research training networks or industrial doctorates, while single institutions will usually be involved in innovative doctoral programmes.* Among others, this topic is expected to train researchers in an industrial perspective .

A4. Research Infrastructures − 4.1. Developing the European research infrastructures for 2020 and beyond − Mainly related to subtopic 4.1.3. Development, deployment and operation of ICT-based e-infrastructures − *Grid and cloud infrastructures providing virtually unlimited computational and data processing capacity; an ecosystem of supercomputing facilities, advancing towards exa-scale; a software and service infrastructure, e.g. for simulation and visualisation; real-time collaborative tools; and an interoperable, open and trusted scientific data infrastructure.* Such facilities and infrastructure may also be exploited for manufacturing related research activities.

3.2. Manufacturing in Pillar II − Industrial Leadership [4,7,13]

B1. Leadership in Enabling and Industrual Technologies.

B1.1. Information and Communication Technologies (ICT) − *A number of activity lines will target ICT industrial and technological leadership challenges and cover generic ICT research and innovation agendas.*
Mainly related to subtopics:
1.1.3. Future Internet: infrastructures, technologies and services
1.1.4 Content technologies and information management: ICT for digital content and creativity
1.1.5. Advanced interfaces and robots: robotics and smart spaces
1.1.6. Micro- and nanoelectronics and photonics.

ICT for Manufacturing is a critical enabler for the future sustainable competitiveness of manufacturing industry. In the context of this theme, a number of key ICT for manufacturing research areas should be addressed, such as agile manufacturing systems & processes, seamless factory life-cycle management, human-centricity in manufacturing, collaborative supply networks, customer-centric design & manufacturing.

B1.2. Nanotechnologies − Mainly related to subtopic 1.2.4. Efficient synthesis and manufacturing of nanomaterials, components and systems − *Focusing on new flexible, scalable and repeatable unit operations, smart integration of new and existing processes, as well as up-scaling to achieve mass production of products and multi-purpose plants that ensures the efficient transfer of knowledge into industrial innovation.* The achievement of mass production of products is a very interesting and demanding topic for manufacturing.

B1.3. Advanced materials − Mainly related to subtopics:

1.3.4. Materials for a sustainable industry -- *Developing new products and applications and consumer behaviour that reduce energy demand and facilitate low-carbon production, as well as process intensification, recycling, depollution and high added-value materials from waste and remanufacture.*
1.3.7. Optimisation of the use of materials -- *Research and development to investigate alternatives to the use of materials and innovative business model approaches.*

Topics such as alternative use of materials, use of alternative materials, energy demand, remanufacture and innovative business models will have to be examined in relation to current manufacturing activities.

B1.5. Advanced Manufacturing and Processing − Mainly related to subtopics:
1.5.1. Technologies for Factories of the Future -- *Promoting sustainable, industrial growth by facilitating a strategic shift in Europe from cost-based manufacturing to an approach based on the creation of high added value.*
1.5.4. New, sustainable business models -- *Cross-sectoral cooperation in concepts and methodologies for "knowledge-based", specialised*
production can boost creativity and innovation with a focus on business models in customized approaches that can adapt to the requirements of globalised value chains and networks,
changing markets, and emerging and future industries.

This is the core for cross –sectorial manufacturing research. This is where manufacturing research & innovation activities will be routed

Key Enabling Technologies (KETs) will be also supported within the Pillar II framework. Advanced manufacturing systems and processes are a “sine qua non” for the KETs. They are an indispensable and essential condition without which KETs will never realize their potential. Thus, advanced manufacturing systems and processes are considered as the Grand Key Enabler for the KETs.

3.3. Manufacturing in Pillar III- Societal challenges [4, 7, 13]

C2. Food Security, Sustanble Agruculture, Marine and Martime Research and the Bio-Economy.

C2.2. Sustainable and competitive agri-food sector − *Mainly related to sub-topic 2.2.3. A sustainable and competitive agri-food industry. The needs for the food and feed industry to cope with social, environmental, climate and economic change from local to global will be addressed at all stages of the food and feed production chain, including food design, processing, packaging, process control, waste reduction.* Manufacturing is important for the entire food sector and there is big potential for advanced manufacturing technology, i.e. food processing and manufacturing, food machinery, etc.

C4. Smart, Green and Integrated Transport.

C4.1. Resource efficient transport that respects the environment − Mainly related to subtopic 4.1.1. Making aircraft, vehicles and vessels cleaner and quieter will improve environmental performance and reduce perceived noise and vibration − *Reducing the weight of aircraft, vessels and vehicles and lowering their aerodynamic, hydrodynamic or rolling resistance by using lighter materials, leaner structures and innovative design, will contribute to lower fuel consumption.* Advanced materials and consequently new processes will play an important role in accomplishing these objectives.

C5. Climate Action, Resource Efficiency and Raw Materials.

C5.4. Enabling the transition towards a green economy through eco-innovation − *Mainly related to: 5.4.1. Strengthen eco-innovative technologies, processes, services and products and boost their market uptake, and 5.4.4. Foster resource efficiency through digital systems.* Research in manufacturing is needed in order to decrease resource consumption by exploiting eco-innovative processes and processes as well as digital services and modern business models.

4. INDUSTRY 4.0 − THE FUTURE OF GERMAN MANUFACTURING INDUSTRY [11, 12]

If German industry is to survive and prosper, it will need to play an active role in shaping this fourth industrial revolution. It will be necessary to draw on the traditional strengths of German industry and the German research community:

- Market leadership in machinery and plant;
- Manufacturing;
- A globally significant cluster of IT competencies;
- A leading innovator in embedded systems and automation engineering;
- A highly-skilled and highly-motivated workforce;
- Proximity to and in some cases close cooperation between suppliers and users;
- Outstanding research and training facilities.

In implementing Industrie 4.0, the aim is to create an optimal overall package by leveraging existing technological and economic potential through a systematic innovation process drawing on the skills, performance and know-how of Germany's workforce. Industrie 4.0 will focus on the following overarching aspects:

- Horizontal integration through value networks
- End-to-end digital integration of engineering across the entire value chain
- Vertical integration and networked manufacturing systems

The following aspects characterise the vision for Industrie 4.0:

- It will be characterised by a new level of sociotechnical interaction between all the actors and resources involved in manufacturing. This will revolve around networks of manufacturing resources (manufacturing machinery, robots, conveyorand warehousing systems and production facilities) that are autonomous, capable of controlling themselves in response to different situations, self-configuring, knowledge-based, sensorequipped and spatially dispersed and that also incorporate the relevant planning and management systems. As a key component of this vision, smart factories will be embedded into inter-company value networks and will be characterised by end-to-end engineering that encompasses both the manufacturing process and the manufactured product, achieving seamless convergence of the digital and physical worlds. Smart factories will make the increasing complexity of manufacturing processes manageable for the people who work there and will ensure that production can be simultaneously attractive, sustainable in an urban environment and profitable.
- The smart products in Industrie 4.0 are uniquely identifiable and may be located at all times. Even while they are being made, they will know the details of their own manufacturing process. This means that, in certain sectors, smart products will be able to control the individual stages of their production semi-autonomously. Moreover, it will be possible to ensure that finished goods know the parameters within which they can function optimally and are able to recognise signs of wear and tear throughout their life cycle. This information can be pooled in order to optimise the smart factory in terms of logistics, deployment and maintenance and for integration with business management applications.
- In the future under Industrie 4.0, it will be possible to incorporate individual customer- and productspecific features into the design, configuration, ordering, planning, production, operation and recycling phases. It will even be possible to incorporate last-minute requests for changes immediately before or even during manufacturing and potentially also during operation. This will make it possible to manufacture one-off items and very small quantities of goods profitably.
- Implementation of the Industrie 4.0 vision will enable employees to control, regulate and configure smart manufacturing resource networks and manufacturing steps based on situation- and context-sensitive targets. Employees will be freed up from having to perform routine tasks, enabling them to focus on creative, value-added activities. They will thus retain a key role, particularly in terms of quality assurance. At the same time, flexible working conditions will enable greater compatibility between their work and their personal needs.
- Implementation of the vision for Industrie 4.0 will require further expansion of the relevant network infrastructure and specification of network service quality through service level agreements. This will make it possible to meet the need for high bandwidths for data-intensive applications and for service providers to guarantee run times for time-critical applications.

Industrie 4.0 is focused on creating smart products, procedures and processes. Smart factories constitute a key feature of Industrie 4.0. Smart factories are capable of managing complexity, are less prone to disruption and are able to manufacture goods more efficiently.

In the smart factory, human beings, machines and resources communicate with each other as naturally as in a social network. Smart products know the details of how they were manufactured and how they are intended to be used. They actively support the manufacturing process, answering questions such as “when was I made?”, “which parameters should be used to process me?”, “where should I be delivered to?”, etc. Its interfaces with smart mobility, smart logistics and smart grids will make the smart factory a key component of tomorrow’s smart infrastructures. This will result in the transformation of conventional value chains and the emergence of new business models.

Industrie 4.0 should therefore not be approached in isolation but should be seen as one of a number of key areas where action is needed. Consequently, Industrie 4.0 should be implemented in an interdisciplinary manner and in close cooperation with the other key areas.

5. DIGITAL MANUFACTURING IN SERBIA – ONE APPROACH [14–16]

Digital manufacturing, within digital factory, has become the main manufacturing concept in the twenty-first century and highly important for companies to enhance their competitiveness. One of the main research priorities in Strategic Research Roadmap 2013-2020 of European public-private partnership for Factories of Future (PPP FoF), is ICT-enabled intelligent manufacturing. ICT is a key enabler for improving manufacturing systems at three levels: smart factories, virtual factories and digital factories. In this context, digital factories are defined with the ultimate goal to improve design productivity using software for the digital representation and test of products and processes prior to their manufacture and use. This also implies better understanding and design of manufacturing systems for better product life cycle management (PLM) involving simulation, modelling and knowledge management from the product conception to manufacturing, maintenance and disassembly/recycling. The major sub-topics are: knowledge and analysis; enhanced, interoperable models for products and processes; design environments; and lifecycle management.

Some of the future challenges in digital manufacturing are: definition of design inputs in terms of adding value by increasing the level of customisation and integrating the customer needs into manufacturing design; definition of simultaneous product and process design in terms of development of a standardised set of core metadata that could be inherited by any relevant software tool (CAM, CAD, CAPP, etc.) without the need for translators; development of models to deal with large quantities of production data available in real-time and from multiple sources; bridging the gap between the digital and the real world in terms of data management, cost of data acquisition and modelling, integration of sensor/actuator data, human interfaces suitability, etc.; development of long-term tracing systems for product life cycle management.

The objective of this research is to analyse process planning for prismatic parts in a digital manufacturing. After the introduction, the second section deals with a digital manufacturing concept and its main enabler – feature based technology. The third section presents the process planning model based on product features for prismatic parts. As an example, the existing feature based CAPP/CAM model for prismatic parts used in SME IVA-28 the advantages and limitations of the feature based process planning in a digital manufacturing.

It could be summarised that the main features of digital manufacturing are:

- Ambiguity of any knowledge must be eliminated, and knowledge must be presented in forms that can be processes/analysed/utilised by various IT tools and transformed into digital data. This is a basis for factory-wide knowledge integration in terms of widespread application of CAD/CAPP/CAM/CAI/CAx. This is an important issue for the cooperation: factory system – process - numerical control machining.
- Digital presentation and its multiple usage is one of the main issues, in terms of a synthesis of different formal presentations of different aspects/elements in digital manufacturing system.
- Simulation and prediction of product development is of essential importance, since it allows analysis and evaluation of manufacturability, product’s performance, and other related characteristics.
- All manufacturing-related activities supposed to be independent of distance, time and location of utilisation (i.e. collaboration in a networked environment).

Enabling technologies for digital manufacturing could be divided into following groups:

- for product design/development and simulation: CAD, VM (Virtual Manufacturing), CAPP, CAE (Computer Aided Engineering), CAM, etc.;
- for material processing (machining) and material flow control, such as NC (Numerical Control), CNC (Computer Numerical Control), DNC (Direct Numerical Control), FMS (Flexible Manufacturing System), control systems for material flow, etc.;
- for production management: IGES (Initial Graphics Exchange Specification), STEP (Standard for the exchange of product data), ERP (Enterprise Resource Planning), MES (Manufacturing Execution System), PDM (Product Data Management), database, Internet, Intranet, ...;
- for collaboration among enterprises: networked manufacturing, client relation management and supply chain management, etc.

The above process planning concept is partly integrated with IT infrastructure for manufacturing management: MES and ERP along with Bill of Material (BOM) module, where process planning considers products with the belonging elements and resources (e.g. machines with belonging elements).

Some of the proven, direct benefits obtained from the implementation of the above STEP-based manufacturing concept in “IVA-28” are:

- company-developed standards for machining typical forms/features and groups of typical features;
- proven strategies for machining the most important features which further assures high quality of the final products;
- independence of CNC machines with respect to distance, time and location of digital format utilisation in DNC networked environment;
- very fast and risk free production setup for new products in case of known features and materials;

- based on the digital product model, evaluation of product's performance development, manufacturability and related production activities flow allows price, cost and capacity predictability.

The future research direction for the improvement of the existing "IVA-28" manufacturing concept implies the following: (i) the unambiguous definition and further development of STEP manufacturing features and their full implementation in the practice, to fulfil the expected requirements regarding the complexity of future products; (ii) the enhancement of the existing digital manufacturing model by using artificial intelligence techniques for the design of a feature recognition model, the selection of machines, tolls, machining operations and optimal machining parameters, the generation of comprehensive process plans, and intelligent inspection; (iii) full integration of CAD/CAPP/CAM with IT infrastructure (ERP, MES, PLM software, etc..) in order to establish factory-wide knowledge integration across the entire life cycle management, presenting a step toward a digital factory.

6. CONCLUSIONS

In summary, the H2020 can provide added value and foster the manufacturing renaissance of Europe by [6-10] and also in Serbia:

- A systemic vision, connecting the production of goods and services with procurement and supply chain management, and connecting the different levels of responsibility, from private entities and public administration to the individual social and global needs of people involved in such new production approaches;
- New forms of entrepreneurship able to integrate new business models fostering added value in new combinations of goods production, services provision, value chains, procurement and global societal dimensions;
- Entrepreneurship and entrepreneurship education which are able to support the translation of the new business models into socially acceptable and welfare generating solutions.

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