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Recent advances on key technologies for innovative manufacturing

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Abstract Through the I*PROMS Network of Excellence which originated during the sixth Framework Programme of the European Commission, this paper introduces a European vision of the essential research areas to deliver future innovations in manufacturing. In particular, these areas are identified as Advanced Production Machines, Production Automation and Control, Innovative Design Technologies and Production Organisation and Management. Then, special attention is given to the main findings from the authors' research programme since the start of I*PROMS in October 2004 for a number of technologies belonging to these four generic research streams.

Keywords Advanced production machines · Micro and nano manufacturing · Rapid prototyping · Production automation and control · Optimisation algorithms · Innovative design technologies · Conceptual design · Automatic feature recognition · Production organisation and management · Fit manufacturing

Introduction

Throughout history the ability of a civilisation to manufacture new devices has been closely linked to its successful development. Nowadays, manufacturing is acknowledged as an important driver for a nation to generate wealth. For instance, in the European Union, it accounts for 20% of the Gross Domestic Product (Manufuture Strategic Research Agenda 2006). However, in order to stay competitive in the global market and thus to keep ahead of fast growing industries in emerging economies, manufacturing companies in developed countries must constantly find the means to generate innovative production systems and manufactured goods. In particular, such systems should react rapidly to changing customer requirements, design inputs, and material/process/labour availability to manufacture high quality and cost-effective products.

In order to help European manufacturing industry to achieve long term sustainability, the European Commission has launched an important number of projects supported by various funding schemes through its Framework Programmes. One of such initiatives is the Innovative Production Machines and Systems (I*PROMS) Network of Excellence (NoE) coordinated by the Manufacturing Engineering Centre (MEC) to which the authors belong (Pham et al. 2004). In particular, I*PROMS integrates the production research activities of 30 research centres from 14 countries in Europe. Its goal is to address the area of production research in an integrated manner in order to help shape the area and overcome its fragmentation at the European level. The Network acts as the main research hub within the European Union (EU) for the whole area of production machines and systems by creating an EU-wide research community concentrating on future manufacturing concepts, processes and systems. Thus, through the adoption of advanced information and communication technologies, I*PROMS promotes the development of common concepts, tools and techniques enabling the creation and operation of flexible, re-configurable, sustainable, fault-tolerant and eco- and user-friendly production systems.

I*PROMS has defined its main research streams around four clusters which are Advanced Production Machines (APM), Production Automation and Control (PAC), Innovative Design Technology (IDT) and Production Organisation and Management (POM). APM is concerned with devel-

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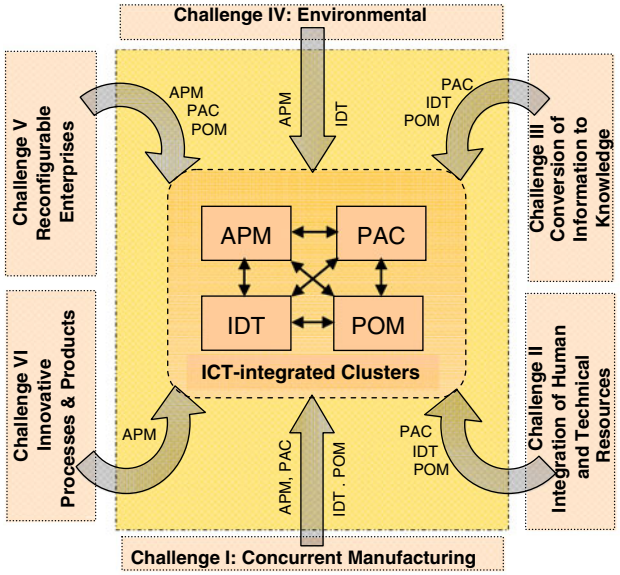

Fig. 1 I*PROMS and the Six manufacturing challenges

oping novel manufacturing machines and processes such as those required for the production of new miniaturised devices integrating a multiplicity of functions and high-performance materials; PAC covers the technology for making these advanced manufacturing machines more intelligent, flexible and reconfigurable; IDT relates to the tools for designing the innovative, customisable, value-added products of the future and the machines and systems required to produce them; POM deals with the management of factories of the future, including those for manufacturing innovative products with micro components. The combination of these interconnected clusters aims simultaneously to address the six "Visionary Manufacturing Challenges for 2020" (National Academy of Sciences 1998) that were identified by a study conducted in the United States of America (Fig. 1). The establishment of these four research areas follows the Network's strategy detailed in the roadmaps drawn up by the research clusters. Research synergy is achieved through complementary nature of the human and physical resources of I*PROMS partners who collaborate both on their existing projects and on new research programmes.

This paper reviews the main research findings that have emerged from the studies carried out at the MEC since the establishment of I*PROMS in October 2004. In particular, special attention is given to investigations into the technologies covered by the Network's closely integrated research clusters. They include technologies for: micro and nano fabrication, new material processing, rapid prototyping, intelligent control, automated product innovation and advanced modelling and simulation. These technologies are developed concurrently with research into new manufacturing management paradigms such as "Fit" Manufacturing.

These technologies are keys to attaining the EU's goal of becoming the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion (http://www.europa.eu.int/comm/lisbon_strategy/index_en.html). Furthermore, by dealing holistically with the entire field of Production Machines and Systems, I*PROMS has the flexibility to choose and modify its priority research topics, dropping old subjects and embracing new areas according to changing industrial needs. This ability to adapt leads to sustainability of operation, by eliminating the risk of the Network becoming prematurely obsolescent when a particular research topic is no longer current or relevant.

The remainder of this paper presents the MEC's research work related to I*PROMS themes as follows. The next section covers advanced production machines. Then, production automation and control and innovative design technologies are respectively discussed in the subsequent sections. This is followed by the production organisation and management theme before giving some generic conclusions in the last section.

Advanced production machines

Micro and nano manufacturing

In the last decade, manufacturing industry has witnessed a rapid increase in demand for micro products and micro components in diverse sectors such as electronics, optics, medicine, biotechnology and automotive. Examples of applications include medical implants, diagnostic devices, micro fluidic systems, micro nozzles and micro moulds. These microsystem-based products are an important contributor to a sustainable economy as they represent key value-adding elements for many sectors of industry (Dimov et al. 2006). However, this current trend for product miniaturisation can only be met to some extend by the lithography-based micro electromechanical systems (MEMS) fabrication technologies that followed the silicon-based microelectronics revolution of the late twentieth century. In particular, such processes have limitations for developing new and emerging micro devices with enhanced functionalities that require the use of a variety of materials and complex three-dimensional (3D) structures with high aspect ratios. For this reason, there is a need for new complementary micro manufacturing technologies that enable the cost effective production of components from a wide range of materials and incorporating micro features having complex geometries.

In order to contribute to the development of such complementary technologies, the MEC in collaboration with other partners has engaged significant efforts in a micro and nano