PERSPECTIVES OF MOULD MAKING INDUSTRY FOR DIGITAL GLOBAL MANUFACTURING

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In production engineering radical changes are taking place supported in new manufacturing paradigms and in technological developments. The increasing demand for meeting customer requirements and technological innovations have influenced the degree of flexibility built in the manufacturing system and its ability to respond in terms of cost, volume and time delivery. Taking the example of Portuguese mould making industry, this paper will analysed the main changes that have occurred in this industry and its ability to adapt to the availability of higher level of digital technologies and how they support new business models, extending their value adding chain.

1. INTRODUCTION

During the past years significant changes have taken place in the industrial world. Mould making companies have to face an increasing pressure to improve quality and to meet stricter delivery times. Competition is marked with a strong pressure on price reduction to satisfy tailored orders, volatile and global demand, shorter product life cycles, increased product customisation and reduced time to market (Henriques, 2004). To meet these challenges, companies are moving away from traditional organisations and structures into simultaneous engineering activities where product and processes are designed and developed in a more integrated manner. Sohlenius (1992) describes very clearly how concurrent or simultaneous engineering could be viewed as an approach to increase the competitiveness by decreasing the lead-time and still improving quality and cost, supported in the technology developed to promote it. These trends and drivers, as well the new approaches to product and process engineering have had a profound impact in mould manufacturing companies.

As an industrial sector, mould making industry has a particular relevance in Portuguese economy and many companies have emerged, showing a good level of competitiveness. These companies have a common ability to adopt organizational and technological changes, acting as important contributors in the supply chain of several OEMs, from different industrial sectors (e.g household appliances, electric/electronic and automotive sector). These companies are mainly small and medium enterprises (SMEs) with a strong investment in technical skills and manufacturing technologies and with high quality based culture. The dependence on technical tacit knowledge, acquired within long experience years, has been felt as a critical factor in most mould-makers [Henriques, 2005].

The objective of this paper is to present a discussion regarding the use of digital technologies in the mould making industry, based on our own perspective about the challenges and opportunities foreseen for Portuguese mould making companies.

Taking into account the companies' size and the global market the authors discuss the strategy that should be designed, competences that should be developed and, finally, what should be the role of digital technologies, as a differentiation factor for their competition in global market.

2. THE PRESENCE OF DIGITAL TECHNOLOGIES IN MOULDMAKING: ACTUAL STATE AND EVOLUTION

In the global mould making industry *quality*, *cost* and *delivery-time* form the essential basis of competition. For many OEMs time is the winning criteria, however in order to compete on time (i.e. lead time) and cost, mould making companies must have a clear technology strategy, based on the most modern generation of processing machines and deploy work, from the mould design to its delivery and in-production setting-up, in an around the clock concept.

As far as moulds manufacturing chain is typified by one-of-a-kind production systems, being each mould a unique device involving specific and tailored solutions, the engineering knowledge and manufacturing skills had and will maintain a central role in the business (Henriques, 2004, 2005). As illustrated in Figure 1 the diversity of technologies used in mould manufacturing has increased significantly over the last decades.

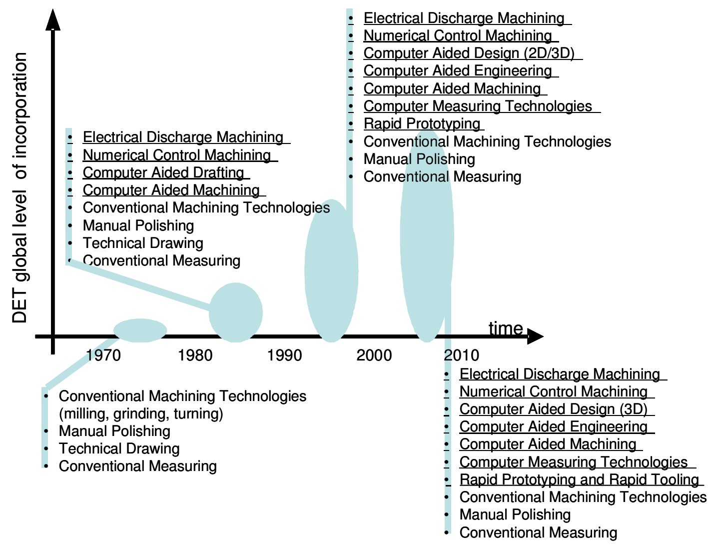

Figure 1 – Time evolution of most relevant moulds manufacturing technologies.
(The technologies based on DET are underlined).

After the 90's, most of the introduced manufacturing technologies are deeply based on microprocessors or digital technologies able to support the programming and control tasks. Thus, nowadays it is difficult or even impossible to detach mould design & manufacturing technologies from DET. The computer plays a central role in this sector at different individual and interrelated tasks. Digital based technologies can be found from the design to the manufacturing processes, where five-axis machining, coordinate measuring or rapid prototyping are only few examples. Automation has shifted the focus of technological expertise from shop-floor to the office, e.g. mould design, process and production planning, and CNC part programming.

Taking the example of evolution observed in the EDM process, it can be considered as a paradigm of the impact of DET in the performance improvement of the manufacturing technology. In the early days, it was slow and difficult to control machining process. Currently it is a highly reliable manufacturing process incorporating the most advanced DET found among the mould manufacturing technologies. The impact of sinking EDM on mould making industry, with all its developments, has been especially profound and vice-versa: more than 40% of sinking EDM equipment is set up in moulds & dies companies. The first equipments launched in 1950s were based in a simple resistance-capacitance power supply and were used in simple sinking operations on difficult-to-machine metals. A single electronic circuit promoted the discharge and actuated the servo system clutched to the electrode. The effort pursued during the following decade originated the innovation seeds at the automation level: the electrode orbital movement, the improvement of the discharging process through more sophisticated electronic circuits based on transistor and capacitors and the piloting of the spark generator. In the 1980s, the advent of computer numerical control (CNC) brought tremendous advances in the efficiency of the EDM machining operations. CNC facilitated an automatic and unattended machining, from inserting the electrodes in the tool changer to a finished polished cavity or cavities, and allow a complete integration with CAD/CAM systems. The interactive communication between the operator and the machine was possible, the programming became a real computer assistant task and the tool changer device allowed the management of multiple electrodes for unattended operation.

The spread of artificial intelligence took place during the 1990s and the EDM technology was improved. Predictive learning systems, adaptive process control and optimisation, intelligent lift-off movements, constant monitoring of all machine operations, intelligent adaptation of the machining current to the electrode area, automatic eliminations of abnormal discharges and the use of "expert-programs" that optimize programs for specific application are examples of developments which contribute for inexperienced operators to use the machine at (or at least near) full capacity.

In this century, the connectivity era for EDM, the equipments start to include complementary communication devices, allowing their integration in intranet/internet networks, the remote monitoring and even the remote control. These EDM systems can be programmed to send SMS messages to facilitate a 24 hour usage. The inclusion of webcams is becoming a standard for remote maintenance and problem solving assistance. The current software in EDM equipment offers a total package for managing and producing specific data for EDM machining. Increased process security can be achieved through the implementation of a chip-based identification system, ensuring that jobs consistently run with the correct CNC program, electrode off-set values and magazine position.

The EDM technology has a history of being "ahead of the curve" in adopting innovative concepts in metalworking technology. The concept of *autonomatisation* is a more recent approach in which the equipment can be fully automated, for the performance of consecutive jobs, and the process can be fully autonomous with artificial intelligent-based adaptive control systems supporting the operation without human assistance. If assistance is need the equipment can call the operator by SMS/email/etc.. The development of *autonomatisation* concept was only possible due to a strong presence of advanced DET.

Besides its importance in the manufacturing processes, digital technologies were fundamental to allow the communication among entities and individuals all along the mould making value chain. It is clear the importance of a continuous interaction with the clients, to create the trustfulness foundations for responsive and long-term partnerships on a world wide basis. During the last 25 years 80% to 90% (depending on the years) of the Portuguese moulds production has been delivered to foreign countries. Thus, digital technologies were and are the means to overcome the physical (and even cultural) barriers and to continuously communicate and exchange different types of data. The recent advances in digital communication infrastructures and tools (Figure 2) culminates in the virtual facilities, such as meeting rooms where work-teams at distance can meet in a virtual space, performing engineering collaborative work supported in video, voice and even software applications which allow the sharing of data in real time.

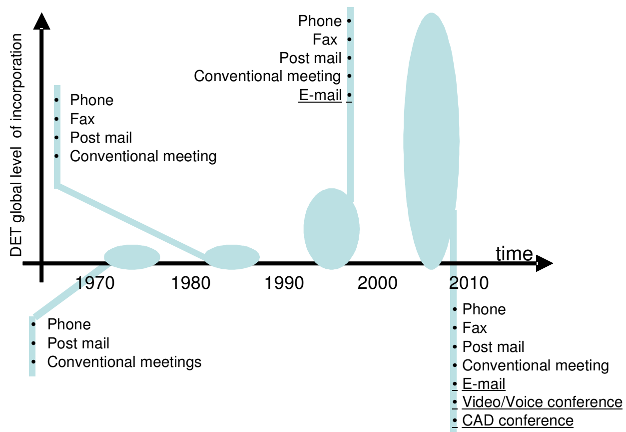

Figure – 2 – Evolution of communication technologies in mould making companies.
(technologies based on DET are underlined).

As it happens world wide, the Portuguese mould making companies are typically small and family owned firms with a high ability to manage technological changes. This capacity is recognized as the source for the observed innovations in the sector and the main driver for changing operational principles and for the development of new business strategies. As regards digital technologies they should support more consistent and effective work and promote the cooperation with clients which, according to Tang (2004), is still reduced to mere information exchange. The successful moulds factory will need to be agile and to extend their activity upstream and downstream in mould value chain. Beside this, the value perceived by clients will no longer be based strictly on moulds, but instead will derive from the capacity to provide integrated services along the value chain.

3. DET AS COMPETITIVE ENABLERS

DET have until now reinforced the current ways of working and strengthened the current sources of competitive advantage (deliver of cost effective moulds conforming to part/production specifications, in a reduced timeframe). Considering the companies' small size and the global market, the role of DET as competitive enablers to face the major expected (and even occurring) changes in the business strategies can be discussed.

In exploring new market opportunities, mould making companies have just started looking for an effective management of mould life cycle. Mould life cycle management can be considered as a holistic approach to mould development considering all aspects from its preliminary design to its retirement, involving the simultaneous engagement of cross functional teams and multi-disciplinary competences. It requires the integration of all the steps within the mould life cycle from part and mould design, in a design for manufacturing approach, moulds manufacturing and trail out, to mould in-production support (maintenance, repair, modifications in accordance to product updates) and finally to its dismantling or its recycling/reuse. Furthermore the success of such an embracement relies on companies' ability to evolve upstream and downstream in the mould value chain (Figure 3).

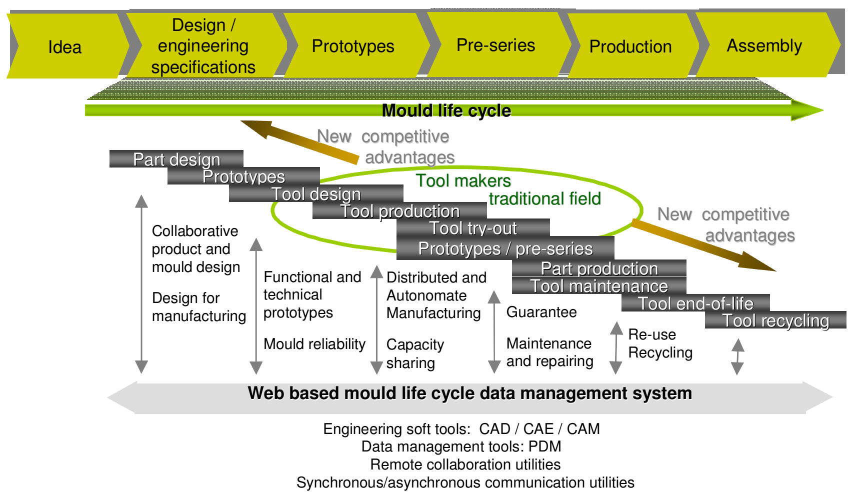

Figure 3 – Moulds life cycle management based on DET.

Going upstream means the involvement of mould makers in new product development process. Early interaction between mould makers and product developers encompasses mutual benefits. The latter incorporates process expertise within design decision making and the former gets involved in high value engineering tasks, valuing their competences through an economic service providing. To implement concurrently the product and mould design requires collaborative engineering abilities, targeting a distributed but improved streamlined value generation from the market perspective. Mould engineers depend on CAD/CAE/CAM software applications for drafting, design and manufacturing their moulds. Distributed engineering and manufacturing concepts include design, process and production planning, shop-floor control and numerical control manufacturing in disperse geographical locations. The advance of manufacturing technology, collaboration and communication tools, as well as in the infrastructure utilities, has driven to a manufacture framework in which a product designed in one side of the world has their moulds designed and produced simultaneously in the other side and is produced and assembled somewhere else. Future CAD/CAM/CAE systems will be fully integrated with real knowledge based engineering systems becoming highly effective tools to drive and assist the mould engineers in their decision making processes. Within a web based environment, they will become more collaborative, with applications integrating asynchronous and synchronous communication tools (voice/video conference, CAD conference with 3D geometry manipulation and sketch annotations facilities), data share and internet based Product Data

Management and work management tools to support an effective distributed design and manufacturing environment. Engineering services can be developed, emphasizing client driven innovation in a globalize business environment.

The upstream evolution to develop competences in product development is also pushing mould makers to dominate and explore the prototyping opportunities, particularly as regards functional and technical prototypes. The selection of the best prototyping process and parameters, and an effective control of each process performance is a difficult task since it requires a very wide technological background. The developed software applications, based eventually in artificial intelligence, will assure the success of prototyping process selection and parameter setting. Moreover, as far as the prototype field is in a fast evolution, in which technologies proliferate with specific application domains, the penetration of mould makers in this field as service providers must be supported in a well established network to guarantee the near to real time access to the most appropriate technologies, wherever they physically are based.

Besides contributing to the focus on core competences, distributed manufacturing in mould making also facilitates the resolution of one significant problem: a rigid capacity in a highly variable demand context. As far as distributed manufacturing promotes the capacity sharing each company can enlarge their market assuming, through distribution, a flexible capacity. The correct use of digital technologies applied to manufacturing processes (e.g in process simulation and control) is becoming an advantage to be used by mould makers. Data gathering and treatment during mould manufacturing will allow mould makers to structure and explicit their tacit knowledge, facilitating its dissemination among collaborators. The overall process will be more efficient, less time consuming and more reliable. The widespread of the *autonomation* concept (i.e. autonomy + automation), the incorporation of the remote process/production monitoring, automated/computer-assisted process planning and virtual simulation into the mould manufacturing processes will improve their robustness and will contribute to the fully implementation of the internet-based manufacturing.

The life cycle costs of a mould remain a major penalty factor in any moulding process. Nevertheless, a subjective approach has been historically taken to measure mould life and mould reliability and in the definition of the mould end of life. If a mould is a production mean and represents a significant investment effort, its overall efficiency and its guarantee during a specified in-production phase must be considered as a mould design variable and should be presented as a marketing argument. Failure modes and reliability engineering of the mould are complex subjects, depending on design solutions and operative and maintenance conditions at client (mould user) site. Any analysis on that level requires data, which only can be retrieved from the mould in-production phase. The monitoring of the mould operative conditions (number of shots, cycle time, injection pressure, temperatures, clamping forces,…) allows the feedback of life data regarding mould performance to support reliability and failure mode analysis, the data collection for preventive maintenance and the certification used in accordance to the design specifications. The latter is indeed a necessary condition to put into practice the mould guarantee as a quality differentiation attribute. In this context, monitoring devices with the capability to process and archive digital signals in a secure way (mould digital black box concept) can be perceived as an innovative evolution to support the next step in mould business: to supply moulds guaranteeing its overall efficiency (involving the concepts of reliability, availability, and maintainability and performance) during a life time. If a guarantee service is foreseen, assistance, maintenance and repair services at a client site must be provided. In fact, and as mentioned by Cunha (2004), although a lot of effort is devoted to enhancing reliability and maintainability in the design phase, occurrences of malfunctions during the in-production phase are almost inevitable. At that level the distance issue between mould shop and client site is a geographical barrier that again can be overcome with remote engineering collaboration and communication utilities and portable diagnosis, maintenance and repair technologies. Digital technologies will be crucial for the development of a guarantee-based strategy as regards their definition and implementation, as well as to manage effectively the mould data and the knowledge generated along the mould life cycle.

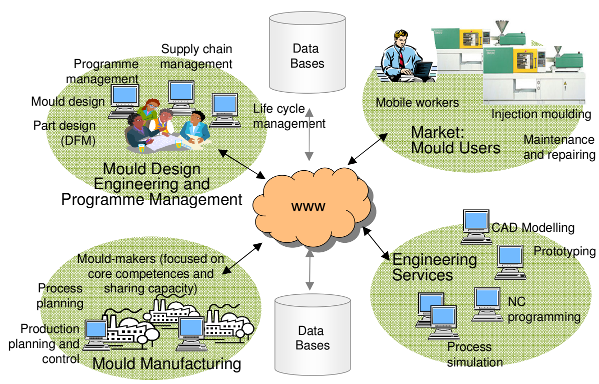

Figure 4 –Future DET-based mould making company.

In the near future mould making companies will become real Internet based virtual companies, concerned with the entire mould life cycle assurance, from the cooperative part and mould design engineering and distributed manufacturing to the mould programmes management involving supply chain resources planning and mould in-production monitoring at user site providing maintenance and repairing services (Figure 4). Increasingly mould making industry will be more information-oriented, knowledge driven and as far as much of the daily routine operations will be automated, resources will be shifted towards technological and business innovation and productivity improvement.

4. CONCLUSIONS

As in the past DET will create the conditions to face the new competition requirements, but will create by themselves new challenges. Now the new digital technologies involve new ways of thinking and new ways of working, supporting mould makers capability to answer to the new global market needs, defining new business attitude and corporate behaviour, which have strong implications in the strategic, organizational and technological domains.

This process began with CADrafting and NC equipments, but it is now much more intense as far as it deals with communication, collaborative engineering platforms, and information and knowledge management, which involves all companies and requires new work procedures.

New digital technologies are needed to stay competitive even in traditional SMEs highly focused on manufacturing competences. Though digital technologies are not only a base to do in a more efficient way the things companies are used to do, they must be perceived as extensive innovation enablers, particularly in the way companies design their business.

5. REFERENCES

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