ANALYSIS OF THE PROCESS OF INJECTION MOLD PROJECT FOCUSED ON THE KNOWLEDGE MANAGEMENT

Kelly Patricia Dias
UFSC – Universidade Federal de Santa Catarina. GEPP – Grupo de Engenharia do Produto e Processo. Departamento de Engenharia de Produção. C.P. 476, Campus Universitário, CEP: 88040-900, Florianópolis, SC – Brasil. Tel.: +55 48 3331-7063
e-mail: kellypatriciadias@ibest.com.br

Fernando Antonio Forcellini
UFSC – Universidade Federal de Santa Catarina. GEPP – Grupo de Engenharia do Produto e Processo. Departamento de Engenharia de Produção. C.P. 476, Campus Universitário, CEP: 88040-900, Florianópolis, SC – Brasil. Tel.: +55 48 3331-7041
e-mail: forcellini@deps.ufsc.br

Régis Kovacs Scalice
UDESC – Universidade do Estado de Santa Catarina. Departamento de Produção e Sistemas. Campus Universitário Prof. Avelino Marcante, CEP: 89223-100, Joinville, SC – Brasil. Tel.: +55 47 4009-7830
e-mail: rkscalice@joinville.udesc.br

Abstract. *The intense demand for injected plastic products with a more guided design, less costs and higher quality exigencies, rendered necessary the development of more efficient injection molds, with more precise dimensions, in the shortest possible time and able to produce parts without defects. However, there is a strong dissatisfaction from the companies related with the cycle of development of plastic parts in Brazil and with the injection molds industry when talking about delivery times and the quantity of needed adjusts until getting a good operation of the mold. Inside this context, the mold project activity plays a large importance, as it influences on the characteristics and the quality of the produced mold and consequently on the molded products. The main aim of the present article is to identify the main practices during the process of projecting an injection mold. Many injection mold toolmakers companies were researched and beside others aspects, it was verified that a big part of the mold project development cycle is done based on the experience and knowledge of the projectists, what may create an accentuated dependence from the company to the professional. So, it will be proposed a set of rules and actions to contribute to the quality enhancement and reduction of the mold development time, and also to transform the knowledge tacit and explicit.*

Keywords*: Design, Injection Mold, Knowledge Management.*

1. INTRODUCTION

In the last twenty five years (MDIC, 2002) the Plastic Industry was one of the sectors with the highest rate of growth in the world, since it is present in many sectors, mainly in the automotive industry. The reason why plastic is so widespread and has advanced so rapidly is due to several advantages: in the automotive industry occurs weight reduction and, therefore, lower fuel consumption, thus allowing modern design which, due to its higher flexibility, reduces costs, immunizes corrosion, etc.

Amongst plastic transformation processes, injection is the leading one (MDIC, 2002). The great success of this technology is due to a series of advantages, of which it is pointed out: large production, large reproducibility and dimensional precision, great flexibility in terms of geometry and molding dimensions, since the production range goes from micro-moldings, inferior to 1mg, till pieces over 100 kgs. (Cunha, 2003).

Resulting from the extensive application of thermoplastics in all industrial sectors there was a great demand for plastic transformers, for tools (molds) as used in injection machines. Under the circumstances it is noticed a fair increase in the number of toolmakers, which are companies responsible for molds fabrication. In Brazil alone there are approximately 1.200 companies of this type, the vast majority being concentrated in three poles: São Paulo (SP), Joinville (SC) and Caxias do Sul (RS) (Ferro, 2001).

However, according to MDIC (2002), internal development of molds for the sector of transformed plastics it has always been considered one of the sector's bottlenecks. Owing to final cost of the piece the internal production of molds is still not totally viable, though it has evolved in technical capacity and quality.

The great demand for products of different design, lower costs and better quality requirements makes it necessary to develop, in the shortest possible time, more efficient molds which are capable of producing faultless pieces with exact dimensions.

In this scenery, where quality with reduction in manufacturing costs is a pre-requirement and where the great differential is delivery time, Brazilian mold companies have, of late, turned to modernization of their factories with the acquisition of tooling machines CNC (Computer Numerical Control) and computerized systems of support to project and fabrication CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing), as well as CAE tools (Computer Aided Engineering), in order to support projects of plastic components and corresponding molds through simulation, being of advantage its use in projects of molds for complex components or of rigorous specifications or when tight tolerances are required (Cunha, 2003; Gomes e Vallejos, 2005; Resende, 2002).

However, these tools of analysis do not replace any fundamental knowledge in respect of plastic materials properties, molding projects or processing. In fact, computerized techniques only allow the complementation of the project designer's knowledge, by making him more productive and more specific in forecasting. Final results are the reflection of the designer's good evaluation and experience (Cunha, 2003).

According to Costa and Luciano (2002), in spite of many advances in CAD/CAE/CAM areas a great part of the reasoning and of the decisions taken during project stages still continues restricted to the designer's knowledge, which may cause a marked dependence of the company in relation to him.

Under these circumstances, companies who manufacture injection molds need an expert when projecting them. This is so because in spite of actions taken to modernize factories as well as research done in order to improve the development process of injected components, injection molds are still projected in an empirical manner.

Harada (2006) describes that a good performance of an injection tool is also directly associated to the care taken in project development. As per Blanchard and Fabrycky (1990) cost of project in relation to the total production cost of a product is 5%. However it exerts an influence of 70% over total cost of production since decisions are taken during the execution of the project which, in turn, will influence functional conception as well as process definition and materials to be used. As such, the activity of mold projecting plays an important part in the development of injected plastic components, thus greatly influencing characteristics, quality and properties of the molded piece.

Therefore, one of the greatest problems encountered in the project process it is how to do it in order to recuperate and value such dispersed knowledge. Nonaka & Takeuchi (1997) describe that knowledge is only created by individuals and to them it belongs. An organization is unable to create and manage knowledge without people. In fact what the organization can do is to support creative employees and supply them with contexts, so that they may be able to manage and administer knowledge. However besides the generation and acquisition of knowledge, it is necessary to be sure that it is registered, transferred efficiently, assimilated and used through stocks and knowledge content.

Accordingly, the objective of this study is to submit an outlook on knowledge management in respect of injection molds development having in mind the reality of companies installed in the region of Joinville (state of Santa Catarina). This survey was prepared through structured questionnaires which tried to identify main practices in project development of injection molds (its phases and necessary information to project a mold), characteristics of the respondent and of the company's profiles, identifying the environment of injection mold's conception, as well as to characterize organizational management process of this area.

For such effect, concepts of knowledge management (KM) and also development process of injected components are initially presented. After that we run over the characterization of environment development of molds' projects. Last of all it is proposed a set of directives for the conception of a KM model in the project of molds.

2. KNOWLEDGE MANAGEMENT

Knowledge Management may be defined as a set of techniques, methods and philosophies which can be applied in an organization in order to guaranty that knowledge is continually created, disseminated and converted into practical actions within the organization (Rozenfeld at al, 2006).

Knowledge is divided in two types: the explicit and the tacit. According to Nonaka and Takeuchi (1997) tacit knowledge is highly personal and difficult to formalize, which makes it difficult for its transmission and sharing. On the other hand explicit knowledge is well structured and therefore easily verbalized.

Regarding Carvalho (2000) the difference between tacit and explicit knowledge is that the former has a subjective and intuitive nature which makes difficult its identification, its mapping out, its processing or transmission of acquired knowledge by means of any systematical or logical method, whereas explicit knowledge may be easily identified, mapped out, "processed" by a computer, transmitted electronically or stored in data base centres.

In this context Nonaka and Takeuchi (1997) suggest four patterns of basic conversions for knowledge creation in the organization, as shown in Picture 1.

Socialization (from tacit knowledge to tacit knowledge) is the formation of more tacit knowledge, i.e., a sharing process of experiences, as for instance, a "master-learner" type of job, observation and imitation.

In externalization (from tacit knowledge to explicit knowledge) tacit knowledge may be converted into explicit knowledge through oral or visual reports, via metaphors, analogies, models, texts, images, figures, rules, etc.

Combination (from explicit knowledge to explicit knowledge) it is a systematic process of concepts in a knowledge system. It occurs through meetings, documents, etc. An example of it is the manner as per which knowledge conversion happens in schooling institutions.

Internalization (from explicit knowledge to tacit knowledge) is directly related to apprenticeship by practical tuition. In order to occur internalization it is necessary to verbalize and to document.

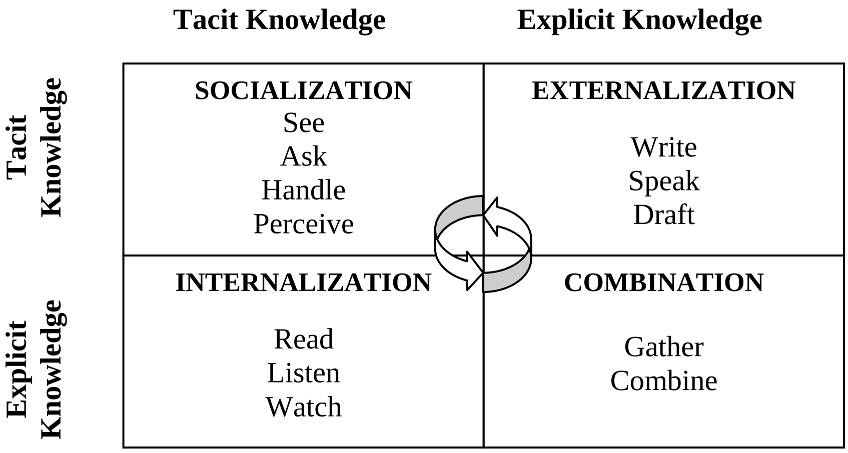

Figure 1. Knowledge conversion manners (Nonaka and Takeuchi, 1997)

Therefore, so that knowledge may be transformed into a valuable resource for the Company, it is necessary that the organization's knowledge, experiments and specialties are formalized, distributed, shared and applied (Ferreira, 2003).

3. INJECTED PLASTIC COMPONENTS DEVELOPMENT

Injected plastic components are a special category of industrial products which, considering the development process, present peculiar characteristics (Gomes at al, 2003).

Companies in this line of business act in an independent manner. Usually it is performed by more than one company, where one of them develops the component and forwards it to the Company responsible for the mold project and fabrication. A third company is responsible for the component's injection. However, in some cases the project of the injection mold is prepared by a third party responsible for the project and fabrication.

Under the circumstances, in order to guaranty good quality, less development time and less cost for the injected product, it is required harmony in all stages of its development cycle.

3.1. Injection Molds

A mold may be considered as a structure (machined steel plates, pins, bushings and many other items) where, according to the elaborated project, functional systems are set up, thus allowing the mold to fulfill its functions. Figure 2 shows a general representation of an injection mold and its main functional systems: cavity and core, centering and alignment, feeding, cooling and ejection. The table 1 points out the functions of these major functional systems.

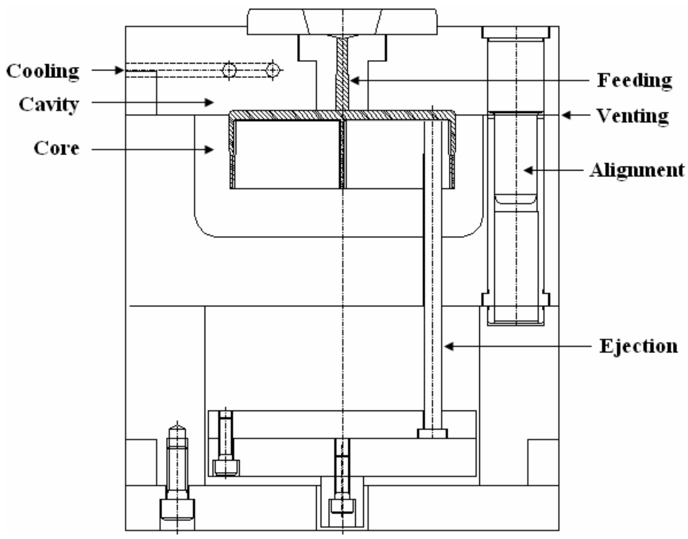

Figure 2. Elements of an injection mold.

Table 1. Functional system of an injection mold

Injection Mold Functions	Sistema do Molde de Injeção
Gives shape, size and final touch to molded piece.	Cavity and Core
Maintains alignment between the two halves of the mold, thus assuring dimensional reproduction of the piece.	Centering and Guiding
Guides cast polymer from injection machine's cylinder up to molding cavity, thus allowing its filling.	Feeding
Allows the existing air and gases in molding cavities to escape, thus enabling its filling with cast polymer.	Venting
Controls mold temperature in order to solidify the material	Cooling
Allows extraction of pieces.	Extracting

3.2. Injection molds project

According to Tonolli (2003), a mold's project is a task that requires great effort and competence in doing it, since it involves the knowledge of several technical areas. As before mentioned, the development cycle of injected plastic components is made up of phases which involves more than one group of responsibilities. In the case of an injection mold project that is also applicable. Usually, after conclusion of the component's project, it is prepared a selection of toolmakers that will be responsible for the mold's project and fabrication.

The toolmaker receives the drawing or a physical sample of the product and may elaborate the mold project or, alternatively, to subcontract any specialized company in projects.

From this moment onwards an exchange of information is initiated, firstly to quote prices and to evaluate viability for the fabrication of the component.

In this manner the selected company starts reviewing the component's project and making, thereafter, suggestions regarding modifications related to mold fabrication and injection. Only after the updating of the component's project it is started the mold's project process and its fabrication. After this stage the mold is then sent to the company or sector responsible for production of the component.

Under these circumstances the project designer, when projecting the mold, should interact with the component's project designer as well as with the party responsible for the molding process who, as it happens, has much information on plastic materials' behavior. Accordingly, the mold project's process is based in information that is associated to knowledge experts in distinct fields, as for instance, customer's needs, list of requirements and mold project's rules, solution rudiments for the project, information regarding the injecting machine and component's material to be injected, amongst others.

Harada (2006) draws attention to the fact that it is very important that the project designer should deeply know mold fabrication processes and the availability of equipments in the tool room in order to obtain a better utilization of the factory thus allowing a reduction in fabrication costs. The acquisition of components from other sources will, therefore, be minimized.

In the beginning of an injection mold project's process it is necessary that certain information is defined, such as: information related to the product (geometrical shape, utilization, foreseen production, finishing after molding and weighing), to plastic material (type, contraction, molding characteristics and specific molding pressure) and the injection machine to be used (free gap between columns, injection capacity, injecting surface, mold's minimum and maximum height, machine's opening course, handler to extract pieces, closing strength, centering hole, mold's fixation system, cooling system and extraction system).

Considering the above mentioned aspects the project designer should assemble all necessary information for mold project development and define its main systems.

Various writers have proposed models for the injection molds project, however, according to Sachelli (2005) does not exist convergence in respect of phases that should be followed up in the development of injection molds.

Since does not exist a unique and absolute standard model for the project process neither a step sequence universally accepted, surveys have been conducted with several mold manufacturers in order to identify main practices in the injection mold project process.

Within the conducted surveys, injection molds project designers of the interviewed companies have enumerated by order of importance which are the phases to be followed up in the development of the injection mold project. In fact, it is noticed, literature on the subject also does not register which phases should be followed up in the injection mold project development.

As per Sachelli et al (2005) does not exist a rule to be followed up when projecting a mold. Each project designer based on his own knowledge, skill and experience is the one to define the adequate sequence of activities for projecting.

Daré (2001) also describes that it is very difficult to establish any systematic for the mold project, due to many existing interactions amongst activities, which require that many countless decisions have to be taken in an interactive and simultaneous mode. In this manner it becomes difficult to define the exact moment and sequence as per which activities have to be performed.

In this context Figure 3 represents the development phases of the injection mold, where first phase refers to an analysis on information about the product, plastic material and injection machine. During the second phase the number and layout of cavities are defined. On third phase line(s) of mold partition is(are) located. In the following phase (fourth) the set of core, cavities and slide is developed. In the projecting phases of the feeding system, mechanical system, extraction system, cooling system and guides and alignment system it is proposed an interactive and simultaneous manner, since, as submitted, it is difficult to establish a follow up order for the mold project. Last of all the ventilation system is projected.

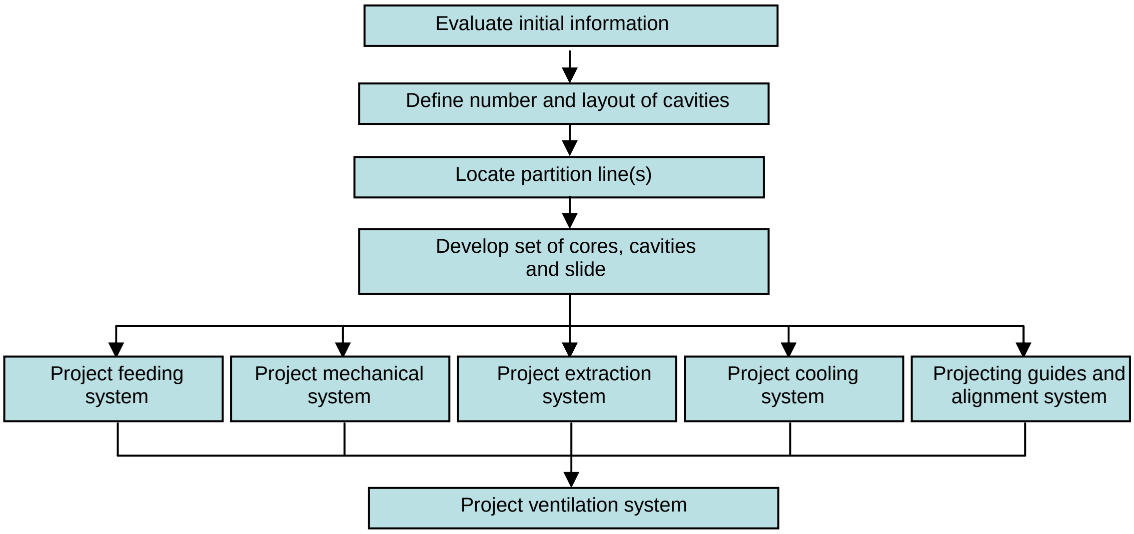

Figure 3. Development phases for injection molds project

4. CHARACTERIZATION OF ENVIRONMENT DEVELOPMENT FOR MOLD PROJECTS

For this survey, 18 companies representing the region of Joinville more significantly in mold production were chosen. This selection is composed of 16 toolmakers and two project offices.

Main line of business of these companies is connected to the automotive industry (41%). The average of manufactured molds per year varies from 21 to 40 (35% of toolmakers) of which 96% of those manufactured molds are for the Brazilian market and the balance for export.

Having in mind to characterize the environment and identify main practices in the process of mold projecting the following points were raised:

a) *Detect project designer's experience and formation* - for a good performance of a toolmaker it is expected that employees have skills and knowledge obtained in the basis of several years of experience in the field (Gomes e Vallejos (2005). In the surveyed companies it has been perceived that the majority of professionals work with mold projects for more than 10 years (61% of the interviewed). As for qualifications of project designers, which is considered a fundamental element in obtaining competitive differentials, it still is undesirable since 56% of them only have technical courses. Differently to what happens in developed countries many of the Brazilian project designers are not engineers, thus reducing not only conception capacity but also adaptation to changes in national tool rooms (Gomes at al, 2003).

b) *Identifying which criterion to use in order to define who will execute the mold project* - it has been noticed that project designer's knowledge level is the main involving factor for the purpose of defining who will execute the mold project. According to the surveyed companies 72% of them use such criterion.

c) *Checking if project designers re-use information of prior projects in new ones* - in order to help companies in new projects or decision taking, all interviewed project designers re-use prior project information. Main information used is CAD geometry. Following a national trend since according to Vallejos et al (1998), in Brazil, mold projects are effected with a basis on prior well succeeded experiences and the adopted solutions are usually simple with little technical innovations and, many times, not so efficiently.

d) *Checking if project designers use CAE* - usage of CAE simulation provides the necessary information for the project of pieces, molds and in the injection molding process. Without this tool there is a need for great previous experience, insight, creation of prototypes or molding trials in order to obtain information on practically all parameters of process observation in the injection practice (Gondak et al, 2005). Nowadays, in countries which are main producers of molds, CAE tools are largely used, thus greatly increasing its potential in piece development and processing (Gomes at al, 2003). However, according to this survey, CAE systems are not greatly used here. According to 56% of the interviewed they use this system just for more complex projects of pieces, mainly due to high costs.

e) *Checking if after delivery of the mold project there is a return due to possible problems and how this is managed* - development of the injected plastic material involves several phases, as presented in 2.2 above. Any problems which may occur with the product or the mold's project (like project errors or no adaptation to the fabrication process) will have serious implications in cost and development time. Still according to this survey, when the mold project is being manufactured, there is always a return possibly due to problems, mainly of mold modification (for 85% of the interviewed companies). After delivery of the mold and the beginning of plastic products production, there are also returns with the request, mainly, of mold improvements.

5. DIRECTIVES FOR THE CONCEPTION OF A GC MODEL IN A PROJECT OF INJECTION MOLDS

Figure 4 presents a structure that could be assumed as a set of directives for the conception of a mold for Knowledge Management (KM) in the injection molds project.

The model foresees existence of three categories involved in the process of knowledge management, as follows: the project designer, the technologies and the factory.

It is for the project designer to perform the process of mold projecting by interacting with the factory, with the technologies and with the customer.

Technology refers to available tools in the Company (substructure) as for example with CAD/CAE/CAM systems.

The mold is conceived in the factory. The following activities are performed: project management, machining and thermal treatment processes, selection of machinery, equipments and tools for mold fabrication, modeling of CN geometry, assembling and adjustments.

The proposed model focalizes flux of information and knowledge where same would be stored and recuperated by the three involved categories in the process of mold project. Functions in respect of each category are:

Project designer: Defines main functional systems of the mold, taking into consideration technologies, factory and customer's information (responsible for requesting mold fabrication and for supplying data for the product to be produced).

Technology: as submitted, technology refers to available tools in the Company. More utilized systems for the injection mold project are CAD and CAE. 3D Modeling of the component to be injected, cavity and male connector and also other functional systems of the mold are performed in CAD. System CAE helps the project designer with information for the project, such as: Flux analysis of plastic material, contraction, cooling and distortions amongst others.

Factory: where mold components are machined and assembled and where professionals with many years of experience use their knowledge and skill to supply information in respect of the fabrication process cycle.

KM system structure as proposed in Figure 4 contains the model, the development phases of the project for injection molds (Figure 3), models of standard documents (budget and process index cards, etc.) and historical data. The last one may be divided in:

Projects: Records of mold projects that were prepared in the Company. Although each product is different it is common for project designers to analyze earlier mold projects in order to find similarities, be it either in geometry, or in the solution principles used or even in the attained performance.

Better practices: the historical of learned lessons and good practices (acquired experience) during project execution.

Actions against hazards: hazards in a project are events or uncertain conditions that, should they occur, will threaten the project's objectives (negative effect) or, otherwise, will create opportunities for improvement of those objectives (positive effect). These hazards are originated from existing uncertainty in all projects. It is important to identify hazards that could affect the project and to register characteristics of such hazards as well as to develop actions that enhance opportunities and reduce threats to project objectives, as for example, to effect corrective actions and request alterations to the project amongst others.

Such historical data should, at any time, be recuperated by the professionals involved in the project, having in mind the capture of useful knowledge during project activities.

6. CONCLUSION

The characteristics of plastic transformation sector through the both process of modeling by injection and process of project and manufacture of injection molds demand more efficient proceedings to mold project in relation to increasing market requirements. In this sense, one expects matters more effective on mold project development to drive better quality and even reducing delivery time. Through this research, where the development environment of mold projects was studied, it was proposed a set of guidelines to the conception of a knowledge management model as being the major condition to improve quality, reduce mold development time, as well as formalizing the knowledge of the projectists (from empirical projects to formalized ones).

The necessity of projectists interact with clients, company members and technologies, was noted as one the most further factor for elaboration of projects, once the mold project process is based on information coming from several areas. Hence, projectists are immerse into a set of dispersed information which needs to be gathered and organized, and thus, develop the project process with their skill and knowledge.

It is even important to cite which those information and knowledge be filed, organized and recovered by professionals evolved on project process. In this sense, such information may be employed in future projects, as well as decreasing the impact when such projectists, if for any reason, leave the company and take with them all the knowledge and experience appropriated on the process with no registry to the company.

The proposed structure represents a referential guide which will became the basis for future improvements through incorporation of technologies, as for example, the intranet. However, it is interesting to mention that the human factor is extremely important in KM, since technology only supplies the support and not the content.

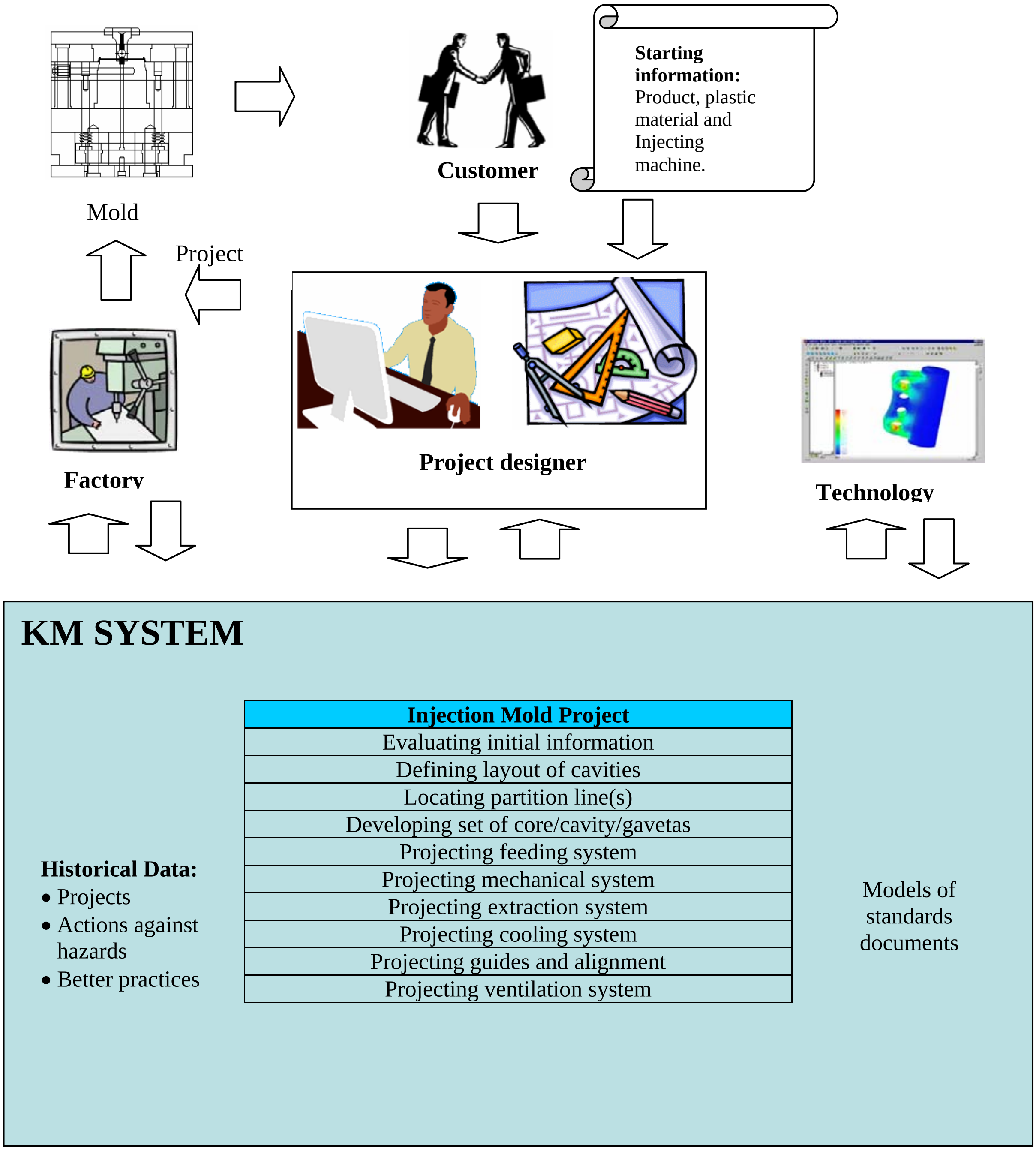

Figure 4. KM model in molds project

7. REFERENCES

Blanchard, B. and Fabrycky, W.J., 1990. Systems Engineering and Analysis. New Jersey: Prentice Hall International.

Carvalho, F. C. A., 2000, “Gestão do Conhecimento: O Caso de uma Empresa de Alta Tecnologia”, Dissertation (Master of Production Engineering), Graduation Program in Production Engineering of UFSC, Florianópolis, Brazil.

Costa, C. A. and Luciano, M. A., 2002, “Tendências e desafios para sistemas computacionais de apoio ao projeto de moldes de injeção”, Plástico Sul, Porto Alegre, Ano 3, pp. 40-45.

Cunha, A., 2003, “Manual do Projectista para Moldes de Injeção de Plásticos: moldação por injeção e materiais plásticos” Centimfe.

Daré, G., 2001, “Proposta de um Modelo de Referência para o Desenvolvimento Integrado de Componentes de Plásticos”, ”, Dissertation (Master of Mechanical Engineering), Graduation Program in Mechanical Engineering of UFSC, Florianópolis, Brazil.

FERRO, S., 2001, “Setor tem tecnologia de ponta e preço coreano”, 1 Feb. 2006, <http://www.plastico.com.br/revista/pm321/moldes/setor_tem_tecnologia.htm>

Ferreira, M.G.G., 2003, “Gestão do Conhecimento no Processo de Desenvolvimento de Produtos”, Internal Publication of the Graduation Program in Mechanical Engineering of UFSC, Florianópolis, Brazil.

Gomes, J. O.and Ferreira, C. V.and Resende, M. F. C., 2003, “Uma Avaliação Tecnológica e Organizacional das Ferramentarias Nacionais”, Revista Plástico Industrial, Vol. 05, No.55., pp.278-287.

Gomes, J. O.and Vallejos, R. V., 2005, “Avaliação de desempenho técnico-administrativo: uma alternativa para a melhoria da competitividade”, Revista Ferramental, Joinville, Brazil, n.2.

Gondak, M de O. and Zluhan, G. P. and Santos, M. T., 2005, “Utilização da Simulação da Moldagem por Injeção no Desenvolvimento de Componentes Plásticos”, Curitiba-Pr, Brazil, V Congresso Brasileiro de Gestão de Desenvolvimento de Produto.

Harada, J., 2006, “A importância do projeto de moldes para injeção de termoplásticos”, Revista Ferramental, Joinville, n.6.

MDIC, 2002, “Estudo da Competitividade de cadeias Integradas no Brasil: impactos das zonas de livre comércio”, 1 Feb. 2006, <http://www.desenvolvimento.gov.br/sitio/sdp/estudos/estudos.php>

Nonaka, I.and Takeuchi, H., 1997, “Criação do Conhecimento na Empresa: como as empresas japonesas geram o conhecimento na empresa”, Rio de Janeiro, Brazil, Editora Campus.

Resende, M. F. C., 2002, “Estudo do Potencial dos Clusters do ABC de Joinville”, Report.

Rozenfeld, H. and Forcelline, F. A. and Amaral, D. C. and Toledo, J. C. and Silva, S. L. and Alliprandini, D. H. and Scalice, R. K., 2006, “Gestão de Desenvolvimento de Produtos: Uma referência para a melhoria do processo”, São Paulo, Brazil, Editora Saraiva.

Sacchelli, C. M., 2005, “Proposta de Sistematização do Processo de Desenvolvimento Integrado de Moldes de Injeção de Termoplásticos”, Qualification Exam of the Graduation Program in Mechanical Engineering of UFSC, Florianópolis, Brazil.

Sacchelli, C. M. and Dias, K. P. and Cambruzzi, J., 2005, “Estudo dos Princípios Projeto de Moldes de Injeção de Termoplásticos”, Joinville-SC, Brazil, 3º Congresso Brasileiro de Fabricação.

Tonolli, E. J. Jr., 2003, “Ambiente Colaborativo para o Apoio ao Desenvolvimento de Moldes para Injeção de Plásticos”, Dissertation (Master of Production Engineering), Graduation Program in Production Engineering of UFSC, Florianópolis, Brazil.

Vallejos, R.V.; Gomes, J.O.; Weingaertner, W., 1998, “Uma Reflexão sobre as Ferramentarias Nacionais”, Plástico Industrial, pp. 96-101.

8. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.