PRODUCTIVITY CENTERED PRODUCT DESIGN

Marcelo Grijó Vilarouca, M.Eng.
NEDIP - Mechanical Engineering/UFSC
mgrijo@nedip.ufsc.br

Acires Dias, Dr. Eng.
NEDIP - Mechanical Engineering/UFSC
acires@emc.ufsc.br

Abstract. *The production process demands a satisfactory productivity level which must be adequate to these enterprise goals. However, several times the production system performance is affected due to design process is not properly oriented to the manufacture needs, among others factors.Product development environment in the industrial sector of plastic transformation is fragmented due to inherent characteristics of the sector which raises objections to employ design methodology and tools and to the communication between the several interfaces.From this context, a formal and effective integration between the product design and product manufacture becomes necessary for the plant productivity ("design for productivity"). In this sense, this paper aims to present a methodology to systematize (survey, formalize and organize) available knowledge on manufacturing in order to make it further available for the decision process in the product design (component of plastic) and injection mold processes.This methodology is based on the link between the production line and product design through product attributes unfolded from productivity: manufacturability of the plastic component, maintainability and reliability of the injection mold. From these attributes the next tools are used in a integrated way with the project and manufacture agents (designers, process technicians, toolmakers and manutentores = maintenance technicians): functional analysis system technique (FAST), failure mode and effects analysis (FMEA) and Ishikawa's diagram. The methodology was applied in the processes of product production and molds maintenance and injection machines in a company of the electro-electronic sector.*

Keywords*: Interface design - manufacture, manufacture knowledge systematization, FMEA, FAST, productivity.*

1. Introduction

Intense competition in the globalized market created new challenges to several business-oriented processes of enterprises. Productive process demands for productivity, in other words, efficient utilization of the plant, low production costs, reduced production time, low stock levels and quality product production. However, from all interfaces between productive process and other organizational functions product development has become decisive to reach productivity.

In this context, this paper aims to present a proposal that effectively design the product towards productivity applied to plastic components domain in a electro-electronic industry. Two important aspects are considered:

- Provide a formal systematic which integrates the product design and the productive process of inject plastic component. This assures that all designs will be properly oriented to manufacture needs (operation and maintenance) which will guarantee productivity, quality and competitive cost.
- Development of plastic component and injection mold represents 50 to 70% of total investment to design an electro-electronic product, thus it becomes totally dependent from an optimized design process.

2. Production context

Contador (1997) explains productivity as the capacity of producing or condition in which production occurs, and it is measured by the relation between the results of the executed production results and the productive resources. However, Campos (1994) establishes productivity as "making more with less". According to Contador (1997), it was observed a strong existing correlation between productivity and competitive advantage obtainment at well-succeed Japanese companies. Under this perspective, the author established the (strategic) productivity concept that focuses on those capacity resources which help the company to obtain a competitive differential.

Adequate production performance in the industrial sector of plastic transformation strategically establishes that the utilization of process injection plant should be more than 85% (based on the author's professional experience). Process inefficiency is related to: waste generation (scraps); unplanned maintenance interventions in the injection machines and molds; and molds set-up, as represented in Fig. 1. The reason of these prejudicial occurrences can be related to inherent situations of operation itself, as well as design of mold and component of plastic.

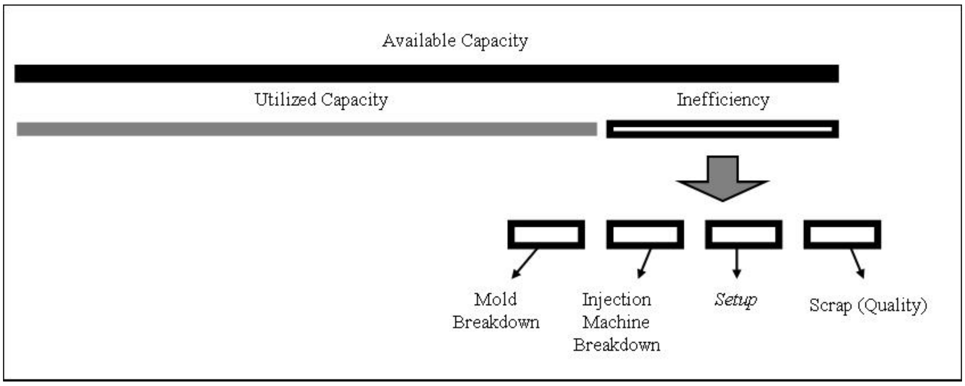

Figure 1. Production capacity utilization view

Thus, operation improvement implementation in order to decrease inefficiency, should not be exclusively the only one to be taken. New products introduction can result on productivity lost without considering factory characteristics and needs.

Under this point of view, factory productivity is understood as consequence, a set of actions and established decision on design stages result. For the plastic component, Vilarouca (2004) explain a design that results on an inadequate rib dimension can originate a high level of waste due to sink marks on the component surface, endangering quality. Productivity can also be endanged by not taking into consideration, in design phase, good maintenance and operation practices in injection mold.

In general, costs related to maintenance and operation are frequently hidden. However, they are an expressive portion (up to 75%) of a product life cycle cost. In other study, Mobley (1990 *apud* BLANCHARD, VERMA and PETERSON, 1995) concludes that 15 to 40% of total product cost can be attributed to maintenance activities.

Another difficulty can be added in the plastic transformer industries: product development environment is fragmented due to inherent characteristics of the sector which raises objections to employ methodology and tools for design and to the communication between the several interfaces. Usually, several companies take part in the development and make integration between product development and manufacture more complex.

2. Productivity centered product design

Taken into consideration the characteristics previously mentioned and plant productivity two important aspects are established for integration between manufacture and design process, as shown in Fig. 2:

1. How to survey, formalize and organize the available knowledge and how to use it in the product design?
2. How and when this knowledge should be applied in the product development process of plastic component?

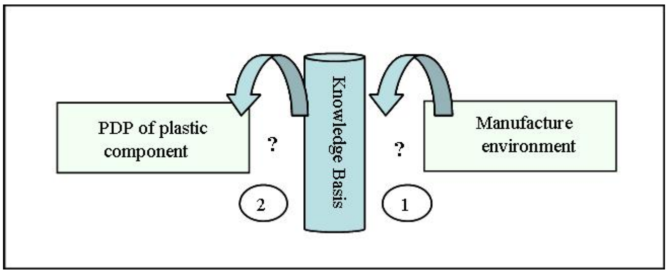

Figure 2. Integration between manufacture and design problem

Model of formal design review developed for this paper is shown in Fig. 3. This model answers questions (1) and (2) arisen from Figure 2. Question (1) is explained from the formal process to systematize the available knowledge of manufacture. Question (2) is elucidated by the definition and employment of review tools (which content is knowledge of manufacture) to support decision making process ("milestones") between the stages of product design process of plastic component.

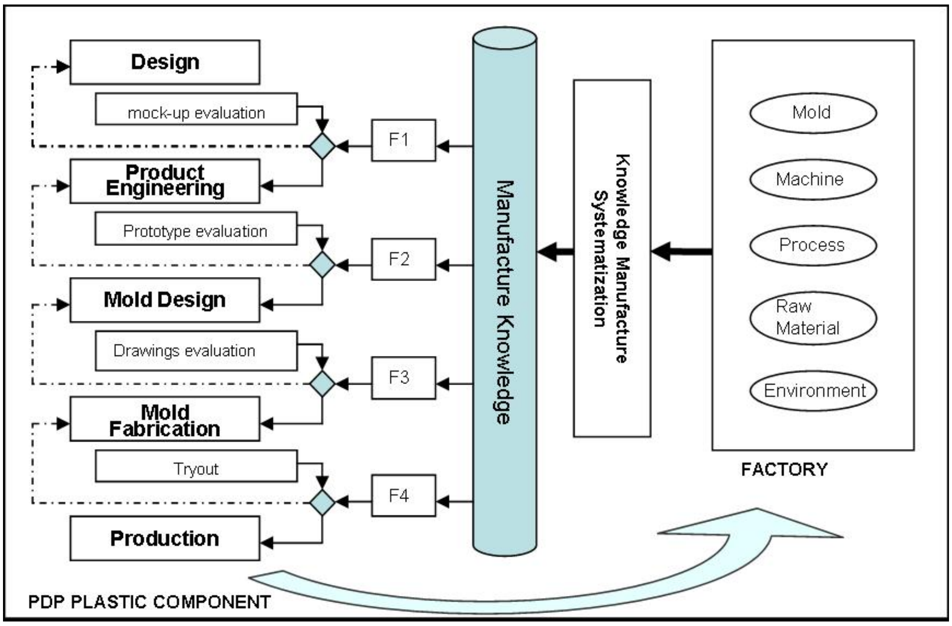

Figure 3. Model of formal design review from manufacture knowledge systematization

Detailed methodology to systematize this knowledge available in the production line will be presented hereunder. This systematization represents acquisition, organization, formalization and availability of manufacture knowledge for the design process.

Manufacture knowledge systematization is based on the design attribute of "productivity" and on the appliance of adequate tools. In this sense, there is a variety of tools, broadly available in literature, to be used in problems analysis and resolution in manufacure, like quality improvement tools: pareto analysis, root cause analysis, fishbone diagram, taguchi method, among others.

Tools selected for systematization basically must identify, in a structured way, fault and failure during operation and maintenance due to erroneous decisions in the design stages. Then, from these identified problems, the select tools must allow to recommend corrective or preventive actions for the early design phases, according with the purpose of this research. In this context, FMEA (Failure Mode and Effects Analysis) was selected among others available tools because provide a systematic way, and its integrated uses with others complementary tools, of examining all the ways in which a failure can occur. To make a functional approach in the FMEA application another one has also been selected: FAST - Function Analysis System Technique, which provides a product or process functional deployment. Also, Ishikawa diagram was selected to systematize the identification of failure causes, associates with elementary cause is product design, during the FMEA application.

The merge of productivity in the design product as attribute is shown in Fig. 4. Thus, productivity attribute for the manufacture and design agents is seen in its unfolded form: manufacturability of the plastic component, maintainability and reliability of the injection mold.

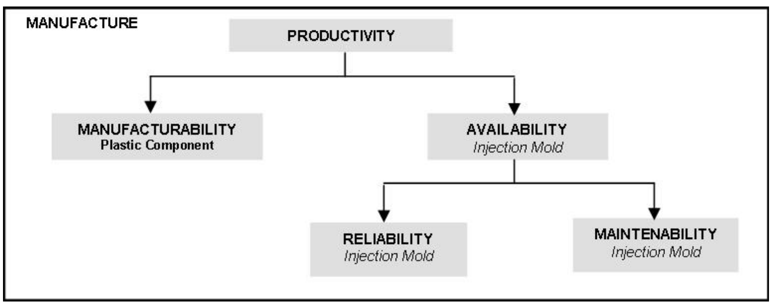

Figure 4. Productivity unfolded attributes

Parsaei, Usher and Roy (1998) describes manufacturability as the ability of manufacturing a product to obtain adequate quality and productivity, as long as it optimizes cost. The facility of manufacture is inherent to this definition since it affects all factors. It is understood that manufacturability has a direct relation with productive systems performance (quality, cost, productivity). According to Barkejian (1992), design stipulates the manufacturability; it is not established by the factory no matter how sophisticated it is.

To Blanchard, Verma and Peterson (1995), maintainability of a product or system is an inherent characteristic of design. Maintainability is the item ability to be sustained, where maintenance composes several needed actions to repair the effective operational condition of an item. Maintainability is a design parameter, maintenance is required as a consequence of design.

Dias (1996) states that reliability is the capacity of an item to fulfill a required function under stipulated conditions, during a given period. Therefore, it is understood that there are a relationship of 4 main factors: probability, adequate behavior, life period and operational conditions.

3. Manufacture knowledge systematization

Stages, tasks and tools required for making the manufacture knowledge systematization are represented in Fig. 5.

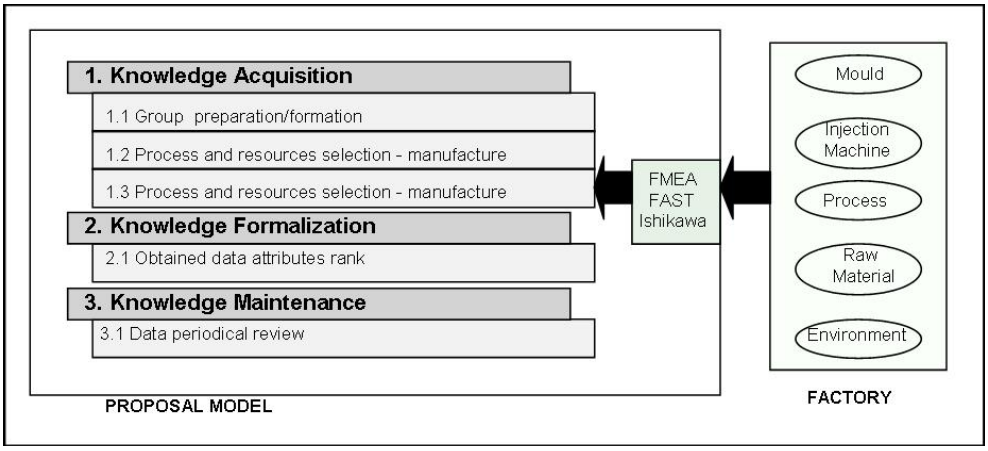

Figure 5. Proposal to manufacture knowledge systematization

Knowledge acquisition stage aims to capture knowledge from several specialists involved in the design and making of the plastic component and of the design, operation and maintenance of the injection mold through employment of tools. This stage establishes the necessity of selecting and preparing specialists to plan the work execution. Afterwards, manufacture processes and resources are identified and analyzed and then FMEA and FAST tools are applied. The final result of this stage is a set of recommended actions (recorded in FMEA forms) to the design of plastic component and injection mold.

In order to facilitate the availability of information for the design process knowledge basis, the manufacture knowledge should be organized and ranked in a systematized way during the knowledge formalization. From the information obtained with FMEA (recommended actions) the employment of a generic structure based on attributes is proposed to adequately organize and rank this set of information. Thus, every recommended action should be categorized in three attributes: product (maintainability, manufacturability), process (kind of injection mold machine, kind of resin) and morphologic (component of plastic, injection mold).

Maintenance of knowledge is established due to constant evolution required in the product form and function, allied to new technologies for the manufacture environment and back input propitiated from the new components and molds manufacture input. This stipulates the necessity of periodically up dated and reviewed knowledge basis.

4. Proposed model implementation

The presented model was implemented at a telecommunications equipment factory, on the plastic component production, molds and injection mold machine maintenance and R&D sectors. This work was accomplished by specialists in these areas: industrial and process technicians, toolmakers, maintenance workers and designers. Group was split in two during the work accomplishment. One group was in charge of making the Injection Process FMEA, while another was in charge of the Maintenance Service and Mold Design FMEA. Information produced throughout the acquisition and knowledge formalization stages were recorded and organized in a spreadsheet.

Some aspects were observed from the proposal implementation at the studied company. FAST application before the use of FMEA really helps in the functional analyses and the way the information is disposed allows a quick visualization and the necessary understanding for the unfolded functions.

For the appliance of FMEA and FAST tools it is crucial the effective interaction between a specialist leader and the work coordinator. This interaction should begin in the planning stage, when detailed plan is very import (and some preliminary tool usage simulations) to assure the work success.

Another basic point for the successful development of the different kinds of FMEA was the previous training on the tools used. Besides demystifying the tools usage, the clear understanding of the concepts involved by the employees was notorious. This positively reflected in the work and in the structured way of the specialists knowledge sharing.

The effective specialists participation guarantees the work success. Despite it was not done in this implementation, the participation of different suppliers representatives during the development process is recommended.

FMEA development provides knowledge generation and sharing of specialists in a structured way. From the FMEA implementation the work development gave a wild sight overview on several problems that occurs in the production of plastic components and molds maintenance, as well as on the different technical characteristics of the injection mold machine groups. Moreover, it strengthens the multi-discipline formation of the specialists, which is fundamental for quick and systematic resolution of the operation problems.

As the manipulated and recorded information quantity in the manufacture knowledge systematization is huge, it is recommended an specific developed IT system as support mean to facilitate the continuity of the knowledge basis maintenance work.

5. Conclusion

Manufacture knowledge systemization aimed to survey and organize knowledge from the line production specialists to allow its use in the design process in order to highlight the importance of the plant productivity; or to eliminate or mitigate problems frequently created throughout the entire development process due to lack of integration between design and manufacture. Not considering existent problems in the operation at design process creates a harmful effect to the manufacture performance: high level of plastic components waste, high level of injection mold failure, difficulty to make an efficient maintenance in the mold, low reliability in the mold components, amongst others. These facts directly affect product costs and quality and in a management context it can cause pauses in the assembly line, delay on customers orders delivery and loss of company's profits. From the design point of view, product cost in the life cycle is endangered for absorbing factory unproductiveness.

A simulation was realized based on recommended actions contents with existent products plastic component after knowledge formalization. From specialist experience and choice, two components from the "good" one mold, and another component produced by the "bad" one mold was evaluated. This "good" one mold component fulfilled 60% of recommended actions for the design component, while the "bad" one mold component 44%. An analysis from the statistic control process established that the "bad" one mold produced 0,8% more waste than the "good" one. Both molds under the same environmental condition, raw material state, process parameterization and injection mold machine operation state, then it infers this established difference is potencially associated to the components design. The 0,8% variation can not be representative, however, taking into consideration three years of production, this number should represent an estimated loss of 15.000 pieces, or under a financial point of view, this loss represents almost US$ 150.000,00.

In addition, the importance of including factory productivity characteristics into the design of the plastic component and injection mold is highlighted in order to achieve the desired productivity and consequently in the cost of the global life cycle, which positively reflects on the market, customers satisfaction and the organization profitability. In this sense and considering observed results in this research, this proposed method is a powerful technique to achieve these goals.

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7. Responsibility notice

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