# SISCOI - Software to aid establishment od design specification of injection molded components

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**Abstract:** In the development of injection molded components, using a group of procedures (processes) and design tools (means) the design team can obtained the product conception. This conception must be accorded to the customers' needs and it contemplates the aspects, the recommendations, the impositions, the limitations, the related restrictions related to the design engineering, materials, injection molded process and costs. These information constitute the design specifications of injection molded component. To define the design specifications of injection molded components the design team must considered the dependence and the interdependence among the requirements, the rules, the strategies and the design recommendations involved in the development of this product. However, in the beginning of the design process, the level of abstraction of available information is high and, the methodologies just present superficial recommendations to define design specifications. The objective of this paper is to present a methodology to aid the process to definite the design specifications of injection molded components, to describe a software that it support this activity and its example of application in the development of a group of guides for bills. This paper was elaborated in the Department of Mechanical Engineering of Federal University of Santa Catarina.

**Keywords:** Design Specification, Injection Molded Components, QFD, TRIZ and Software.

## 1. Introduction

The injection molded components constitute a special category of industrial products that, according to the design process, presents special characteristics. The development of these products can be defined as being a group of procedures (processes) where the design team using appropriate tools (means) can develop a solution to satisfy the customers' needs and to fulfil the aspects, the recommendations, the impositions, the limitations and the restrictions related to the different fields of knowledge involved in this activity (information). The engineering of component design, materials, injection process, mold and costs constitute these fields (FERREIRA, 1999).

The development of injection molded components involves the phases of conceptual, preliminary and detailed design. Among them, the conceptual phase stands out; the characteristics of the product that determine its acting along its life cycle are defined in this phase. To put it briefly, this phase involves, initially, the definition of design specifications and, in the sequence, the generation of the product alternatives of conception.

In the process of definition of the design specifications of injection molded components, the dependence and interdependence among the requirements, rules, strategies and design recommendations should be considered. However, in the beginning of the design process, the level of abstraction of the available information is high, and the methodologies present only superficial recommendations on relative aspects about the process of defining the design specifications. The consequences of these aspects are reflected on the generation of conceptions with high costs, on the lack of approaches for decision taking and on the loss of resources during the project process. Thus, this paper aims at filling the existent gap in this area.

The objective of this work is to present a methodology of definition the design specifications of injection molded components, the software SISCOI to support this activity and an example of application in the design of a group of guides for bills.

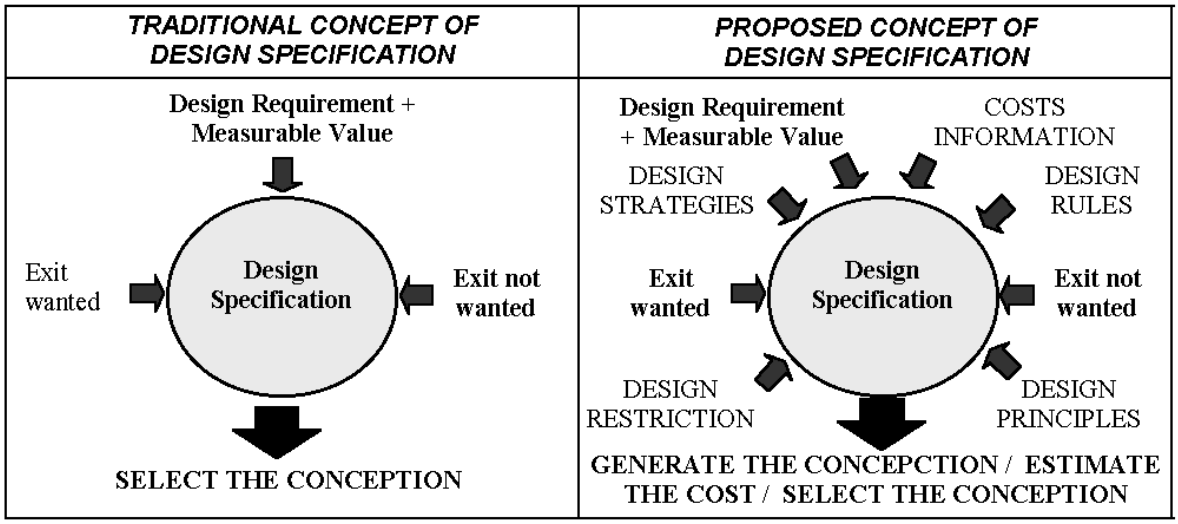



Figure 1. Design specifications according to the traditional and the proposal concepts.

## 2. Design Specification of Injection Molded Component

In this proposition, the concept of design specifications is enlarged. It can be understood as strategies, rules, restrictions and project beginnings for the development of the injection molded component. Thus, the design specifications can be used to generate product conception, estimate the component costs and select the conception of the product (FERREIRA, 1999) (MAZUR, 199-). In the traditional concept, the design specifications are expressed by the design requirement associated with a measurable value, usually applied in order to select the product's conception (Blanchard and Fabrick, 1990) (Malloy, 1994). The new concept aims at allowing the development of the injection molded component according to its characteristics. Figure 1 compares the traditional and the proposed concept for design specification of injection molded component.

The introduction of the design strategies and rules of injection molded components in the concept of design specifications has the objective of minimising and, if possible, eliminating the conflicts and the contradictions among the design requirements. As the development of plastic products is based on the specialists' experience, the strategies and the rules try to incorporate this knowledge and reflect the best practices in this activity.

With regard to the introduction of the concept of design principle, efforts are made to create "visual" incentives to the design team in order to facilitate the generation of alternatives of conception of the injection molded component.

The development of injection molded component depends on information and characteristics associated to the technical system, process, mold and also to the injection material. This information can be understood as design restrictions and it should be understood as being customers' needs that should be met independently of the adopted design solution.

In operational terms, the process of definition design specifications involves the following steps: definition the design problem; definition the product life cycle and design restrictions; establishment of the customers' needs and design requirements; development of the House of Quality; and definition of the design guidelines of injection molded component. In order to facilitate the execution of these stages, a group of design tools was developed (means), which were implemented as a software (OGLIARI, 1999).

In economic terms, the process of defining design specifications involves the preparation of information to estimate the cost of the component, which involves the definition of the cost-goal and the establishment of the component cost breakdown structure. The methodology to establish the design specification of injection molded component and the software SISCOI to support this activity will be presented in the following section.

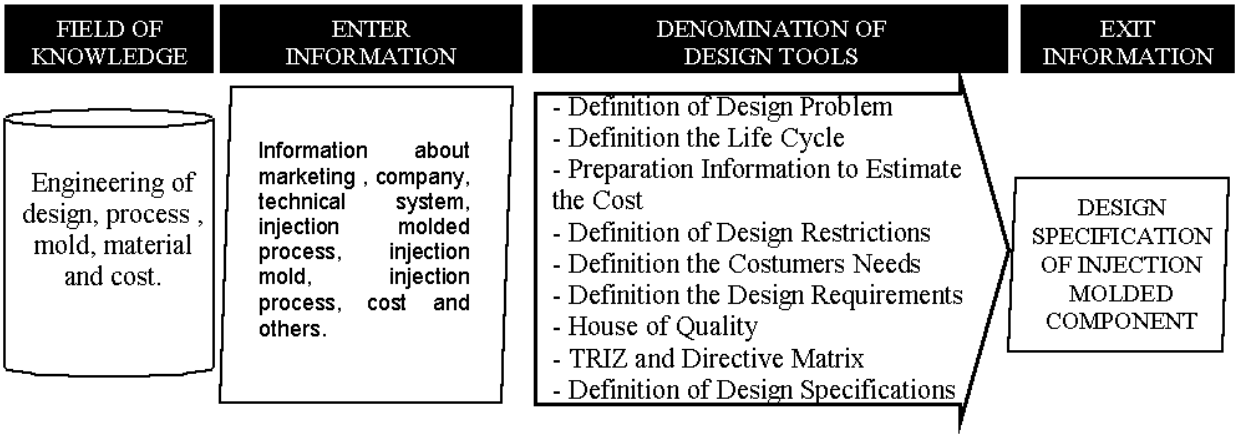



Figure 2. Philosophy of the methodology to define the design specifications of injection molded component.

## 3. Methodology to define the design specifications of injection molded component

The proposed methodology is a result of observations of the practices in component design type, investigation and research accomplished in this area, as well as the literature study (FERREIRA, 1999) (BLANCHARD AND FABRYCKY, 1990) (Mazur, 199-). This proposition tries to reflect the relationship among the knowledge fields involved in this activity, to satisfy the needs of this area and to treat the development of this product according to the philosophy of the Simultaneous Engineering.

In order to begin the presentation of the methodology, it is convenient to visualise, as illustrated in figure 2, the relationship among the fields of knowledge, the entrance information, the project tools and the specifications of project of the injected component.

The methodology illustrated in figure 3 is suggested as a means to define the specifications of project of the injected component, considering the aspects previously described. It shows the steps, the design tools and the knowledge fields involved in this process.

To define the design problem, the companies involved in the development of the component are identified, and the business opportunities are evaluated, aiming at the initial understanding of the project. In the sequence, information, activities, objectives and actors involved in the life cycle of injection molded component are defined (BLANCHARD AND FABRYCKY, 1990). The preparation of cost information involves the determination of information of similar products, the establishment of the component cost breakdown structure and the definition of the target cost of injection molded component (FERREIRA, 1999).

The development of the component, in most cases, is associated to the design of the system. In this case, it depends on technical and economic limitations associated to the productive process of the system. These restrictions should be understood as being those costumers' needs and design requirements that should be contemplated in the development of the injection molded component, independently of the adopted principle design used. Thus, a specific check-list (Ferreira, 1999) is used in order to define the spatial, geometric and functional restriction associated to the technical system and injection process, injection mold, injection material and costs.

In the next step, the customers' needs are defined and the design requirements are established by using the method of QFD (Quality Function Deployment); the needs and design requirements are analysed in this step. The objective of this analysis is to obtain a better understanding about the design problem (AKAO, 1990).

According to the methodology proposal, in the QFD Matrix of Correlation, contradictions among the design requirements are identified, i.e., the negative relationship. Considering the contradictions and the order of importance of the design requirements obtained, the design requirements to be optimizated and the respective that is in conflict are defined. Comparing the design requirements in contradiction, the most important is the design requirement to be optimizated and the other one will be in conflict. In the sequence, two procedures are described to minimize the design contradictions and, if possible, to eliminate them (FERREIRA, 1999).

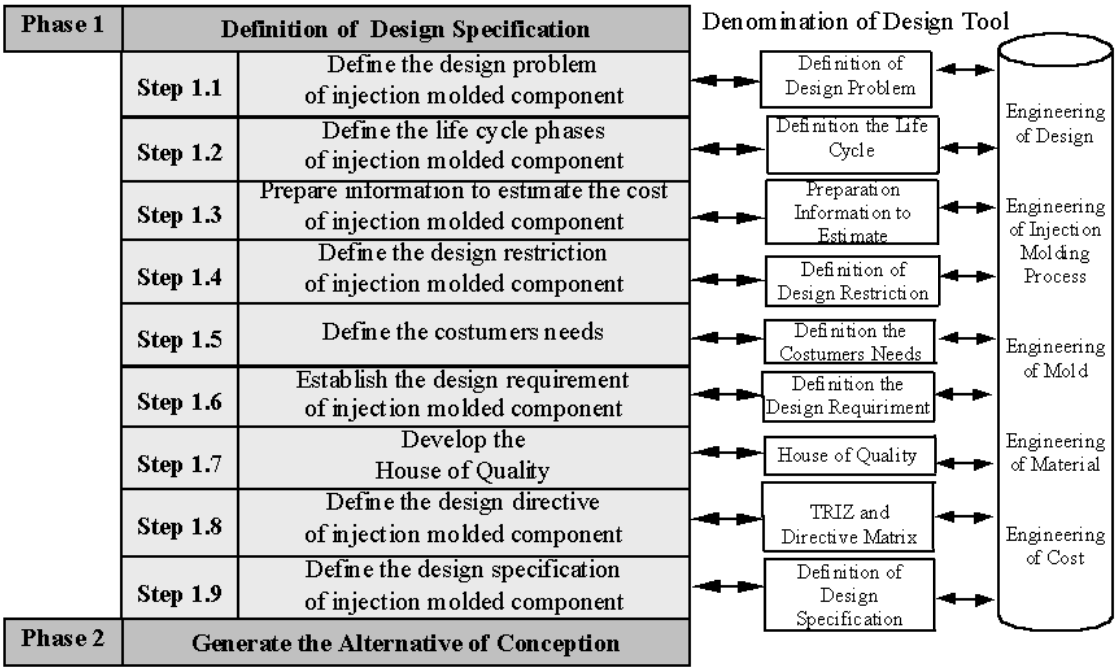


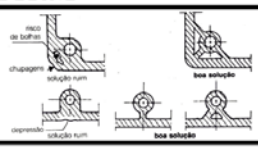

Figure 3. Methodology to define the design specification of injection molded components.

The concept of design guidelines of the injection molded component is introduced in order to solve the contradictions among the design requirements considering the dependence and the interdependence among them and the development of the component according to the practices of these activities and the philosophy of the Simultaneous Engineering. These guidelines have information about the component design and the injection process, which have the following organisation: i) design rules: they indicate the appropriate way of executing an action to reach a specific objective. These rules are established considering the knowledge checked by designers in this area; ii) design strategies: they indicate the best conditions to reach a specific objective. These strategies are obtained considering the observation of the practices in this field; iii) design principles: basic forms (features) used to design injection molded components (FERREIRA, 1999) (OGLIARI, 1999).

The use of two design tools is proposed to define the design guidelines: the Matrix of Definition of the Design Guidelines of Injection Molded Component and the Matrix of Contradiction of TRIZ, Theory of Inventive Problem Solution (FERREIRA, 1999).

The Matrix of Definition of the Design Guidelines of Injection Molded Component was developed considering the domain of design of injection molded components. It presents a similar structure to the Matrix of Contradiction of TRIZ and it differs from the type of available information. In table 1 the typical information in the Matrix of Definition of Design Guidelines of Injection Molded Components is described considering, as an example, the engineering parameter to be optimized "larger structural strength of the component".

Table 1. Example of information in the Matrix to Define Injection Molded Component Guidelines.

| | |
|---|---|
| Parameter to be optimized | Larger structural strength of the component |
| Conflict Parameter | Larger thickness of the wall of the injected component |
| DESIGN GUIDELINE | |
| • Increase the number of ribs of the component. Increase the thickness of the component, reducing the accumulation of material in local points. |  |

Finally, according to the methodology proposed in figure 3, considering the information obtained, the design specifications of the injection molded component are defined. These specifications, as illustrated in figure 1, are orientations and recommendations to develop the injection molded component. These specifications are established in the form of design strategies, design rules, and design principle, cost information and design restrictions.

## 4. Software SISCOI - System to define design specifications of injection molded component

The software SISCOI (System to Support the Definition of Design Specifications of Injection Molded Components) was developed to aid the execution of the methodology presented. This software was implemented in visual programming and objects orientated using Borland C++ Builder [3] and the database Paradox [3] for storage of the design information. The main screen of SISCOI is presented in figure 4 and shows the House of Quality of QFD and its corresponding fields.

The menu "Design" shows the design tools related to the design methodology. The menu "Cost" presents resources to prepare the information to estimate the cost of the injection molded component. In the menu "Database", information related to the materials, machines and injection molds is stored. This information aids the design team in the accomplishment of the stages proposed by the methodology and, mainly, in the definition of the design restrictions. The result of the employment of these tools is presented in SISCOI under the form of technical reports.

The House of Quality is a systematic matrix that it ables the work in the qualities manifested by the customers (needs of customers) considering the product life cycle. This approach seeks the obtaining of a group of information (design specifications) that its aid the conduction of the product development. The software SISCOI supplies resources to work with these customers' needs. These resources involve:

♦ Determine the degree of importance of the customers' needs;

♦ Evaluate the products' competitive about the customers' needs - considering the characteristics of the competitive and similar products, by means of a competitive analysis done by the customer and in the market information it allows to verify a need it is a strong point of sale;

♦ Planning the quality of the new product - considering the customers' needs and the result of the evaluation of the competitive products, the project team should accomplish the planning of the quality of the new product. The planning the quality of the new indicates the quality levels that the new product should have.

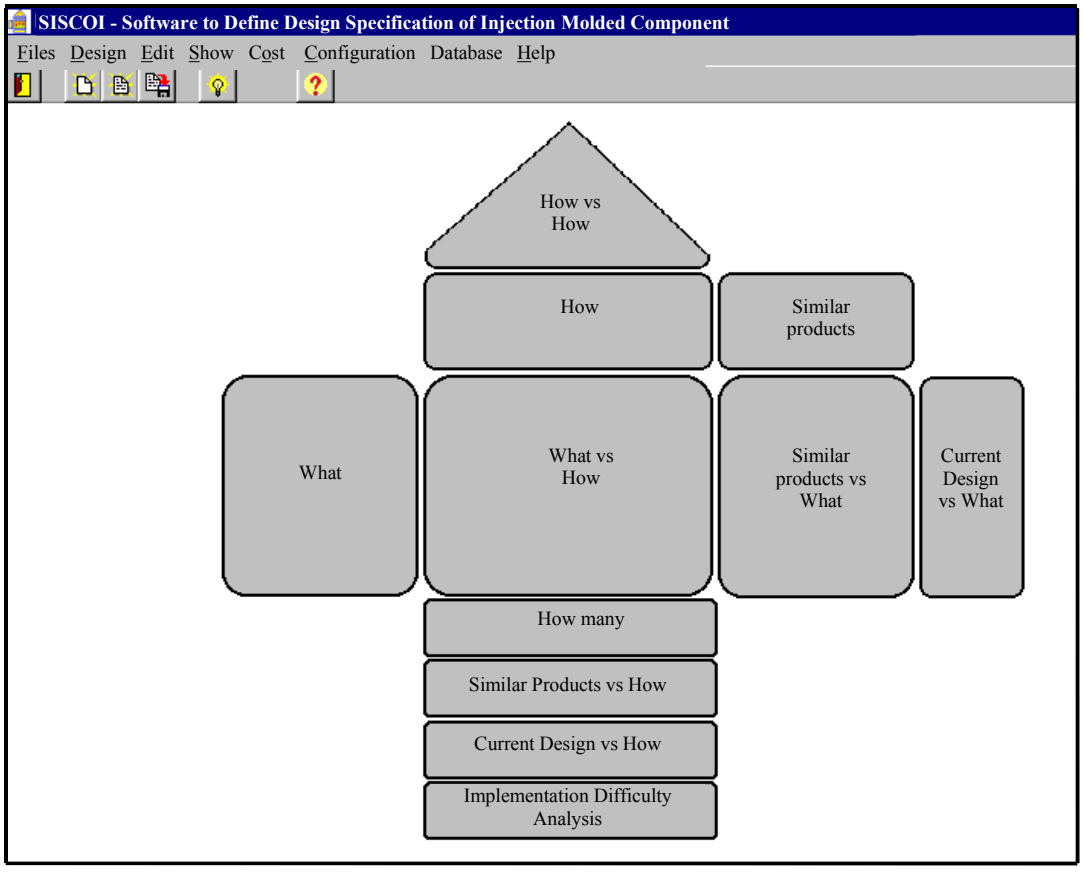



Figure 4. The SISCOI main screen to define design specifications.

♦ Relationship of the customers' needs with the design requirements - it is a systematic form of identifying, respectively, a relationship level or dependence between the customers' needs and the design requirements.

♦ Identify the contradictions among the design requirements - it is analysed the relationship or dependence among the design requirements. The correlations of the type negative and strongly negative, as exposed in the methodology proposal, they are of matter it interests, once they represent the contradictions of design of the product.

♦ Indicate the most important design requirements - the obtaining of the most important requirement can be calculated in two ways. In the first the result of the relationship is considered between the needs and the requirements. In the second case, the result obtained in the roof of the House of Quality is used to calculate the most important design requirement.

♦ Identify the design requirements that must be optimizated and, the respective ones, it is the conflict requirement - it should be accomplished considering the correlations of the type negative and strongly negative, obtained in the roof of the House of Quality, besides the result of the classification of the design requirements. As proposed, these relationships indicate contradictions among the requirements. Thus, taking the pairs of the requirements in contradiction, the most important it will be considering the requirement to be optimizated. And, consequently, its pair will be considered the requirement that it is in conflict.

♦ Analysis the product' performance in relationship to the design requirements - is evaluate the performance of the product considering the design requirements. The result is a list of products that best assists to the design requirements and, consequently, it can be extracted its characteristics and the design team can use it in the development of a new injection molded component.

♦ Plan the quality of the new product considering the design requirements - considering the result of the executed analysis can be establish the new quality patterns for the product to be developed.

♦ Determine the factors of difficulty of implementation of the design requirements - it indicates the difficulty of implementation the quality drifted for the new product. This difficult is expressed in technical terms and economic. Technical analysis involves limitations in the injection molded the component that reflect in mold manufacturing and in the injection material properties. The economic difficulty is associated to financial subjects that hinder to reach the quality drifted in the product. The knowledge of the critical points of design is had and of the type of "necessary effort" to reach the quality drifted for the new injection molded component.

Considering this approach, the design team has available a group of information that guide the development of injection molded components. Besides, through the accomplished analyses the design team has a better understanding about the customers' needs, design limitations, product performance, as well as, the design problem.

In the development of injection molded components, the limitations associated to the technical system, injection process, injection mold, injection material and cost should be considered. These limitations can be defined as being design restrictions of injection molded components, which can be understood as being a limitation of technical or economic order associated to the development of this product. In other words, the design restrictions can be understood as being a group of design requirements that its should be contemplated in the development of the injection molded component, independent of the adopted conception solution for this product.

Considering these aspects the tool illustrated in the figure 5 was implemented. This design tool is supported by a checklist and it ables the product development team to identify the characteristics and properties associated to the technical system, manufacture process, injection mold, injection material and cost. These information introduce limitations in the injection molded component design and, in the sequence, it describes these information as a injection molded component design restrictions.

The definition of injection molded design restrictions begins with the determination of information that its influence the development of the component. These information are:

♦ Geometric, functional characteristics and the space disposition of the component in relation the technical system;

♦ The technical characteristics and properties related to the injection process, material and mold;

♦ The cost related to the technical system, process, material and mold.

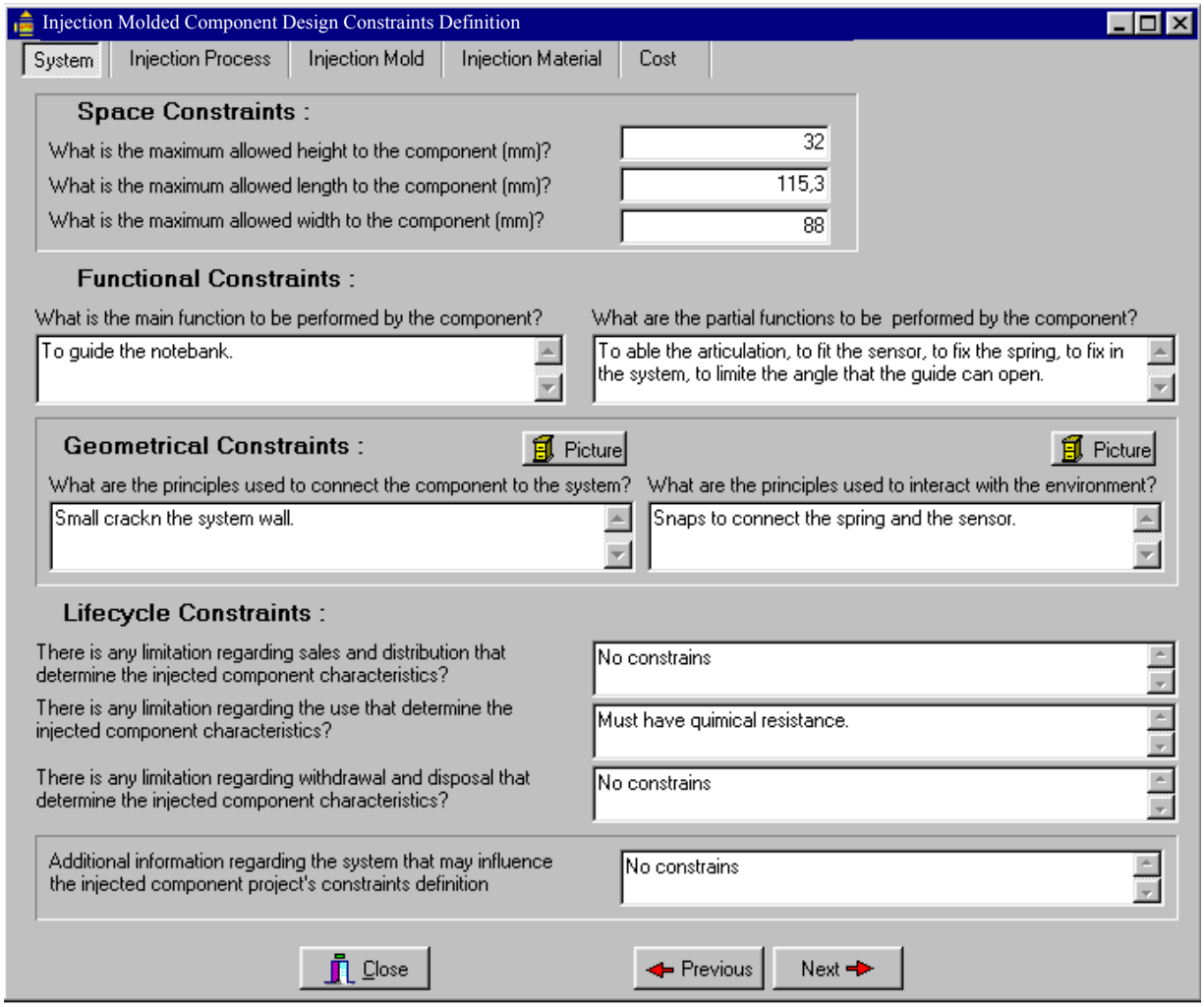



Figure 5. The SISCOI screen developed to support the process to define the restriction of injection molded components.

One of the most developed tools is the Matrix of Definition of Design Guidelines of Injection Molded Components. The process to define design guidelines begins by considering the result of the identification of the design requirements to be optimized and the respective that are in conflict. This result comes from the Matrix of Contradiction of QFD.

This Matrix was developed based on TRIZ (Theory of Inventive Problem Solving). This theory was developed in the former Soviet Union by Altshuller and co-workers. They analysed a larger number of patents (more than 2 million) in order to find general patterns. The analysis showed that most patents suggested means for eliminating system conflicts in a system. Such conflicts arise when a certain parameter cannot be improved without causing another to deteriorate. For example, increasing the speed of an automobile (improvement) leads to an increase in fuel consumption (deterioration). Furthermore, it was found that many invention are based on the same underlying principles and physical, chemical and geometrical effects, and that only about 40 principles and a few hundred effects were used. Too, they determined that 39 engineering parameters that characterise the technical system (product).

In the sequence, using the developed tool, whose main interface is illustrated in figure 6, the design guidelines of injection molded components is obtained. In the upper part of this interface the design requirements from QFD are presented. In the central part, these design requirements are associated to the engineering parameters stored in the data base. In the lower part are presented the design guidelines of injection molded components, considering the obtained information. In this representation, the disposition of the information described in table 1 is shown.

The application of this methodology and the software SISCOI has been accomplished in experimental plastic guides

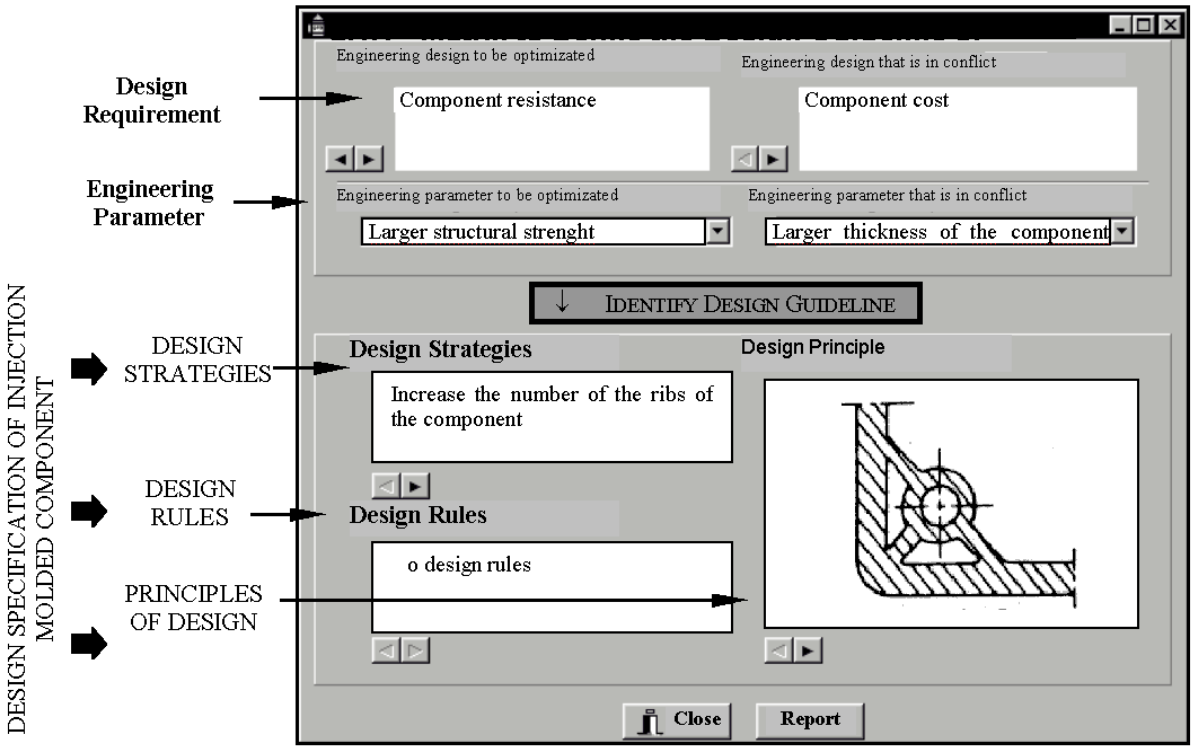



Figure 6. Screen of the tool to define the design guideline of injection molded component.

design of payment machines. This injection molded component is being developed in the PAT Centre (Centre of Development of Processes to Design Products with High Technology) in the Mechanical Engineering Department of Federal University of Santa Catarina. The figure 6 shows one of the collection of injection molded guides that it was developed in the PAT Centre. The example of application of SISCOI is described in the next section.

## 6. Example of Application of SISCOI in the Redesign of a Group of Injection Molded Plastic Component for a Banknote Collector Equipment

The example of the application of the Software of SISCOI was elaborated, considering the results of the case study developed in the ambit of the program PRONEX (Program of Support to Nucleus of Excellency) elaborated in the Department of Mechanical Engineering of the Federal University of Santa Catarina (UFSC).

The example described in this section is related to the redesign of a group of injection molded plastic components for a banknote collector equipment for bank automation. This design must consider the spatial restrictions and interface between the technical system and the component, i.e., the existent fixation, motion and traction mechanisms.

This collector equipment consists of a subsystem destined to the greeting, validation, storage and refund of banknote. This system is constituted by a mechanism to transport the banknotes from the validation system to the storage system. To transport the banknote through the collector, besides the traction mechanisms, a group of injection molded guides is included for support, conduction and alignment of the

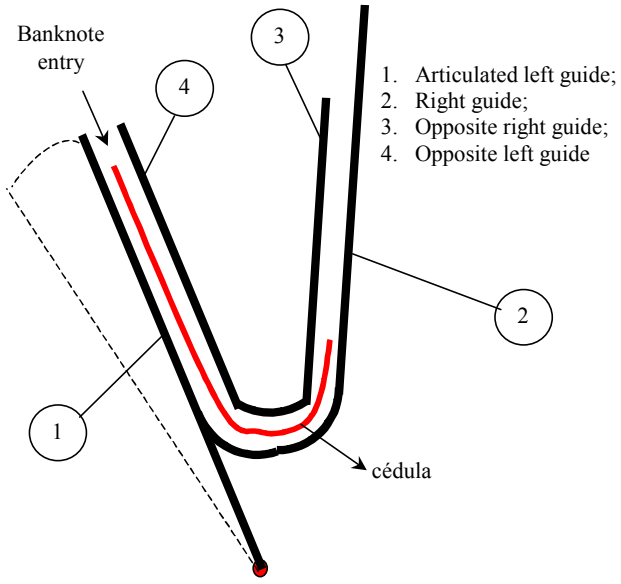



Figure 7.Conjoint of notebank injection molded guides.

banknotes. The red line stippled in the figure 7 indicates the approached course of the banknotes.

Considering this problem, the design team involved in this development study the problem, looking for the different problems involved in this design, i.e., costumers' needs, design requirement, functional problems, manufacturing problems and others. For this, it was proceeded, initially, the identification of the design restrictions, the customers' needs and the design requirements.

The establishment of the design needs was development through an initial meeting with the members of the development team and the contracting customer where a questionnaire of aid was applied to aid the establishment of these needs. After several meetings and discussion about the design problem, besides the understanding of the problem, it was obtained the priorization of the design requirements.

To identify the design restrictions was proceeded an analysis of the problem considering information related to the prod-

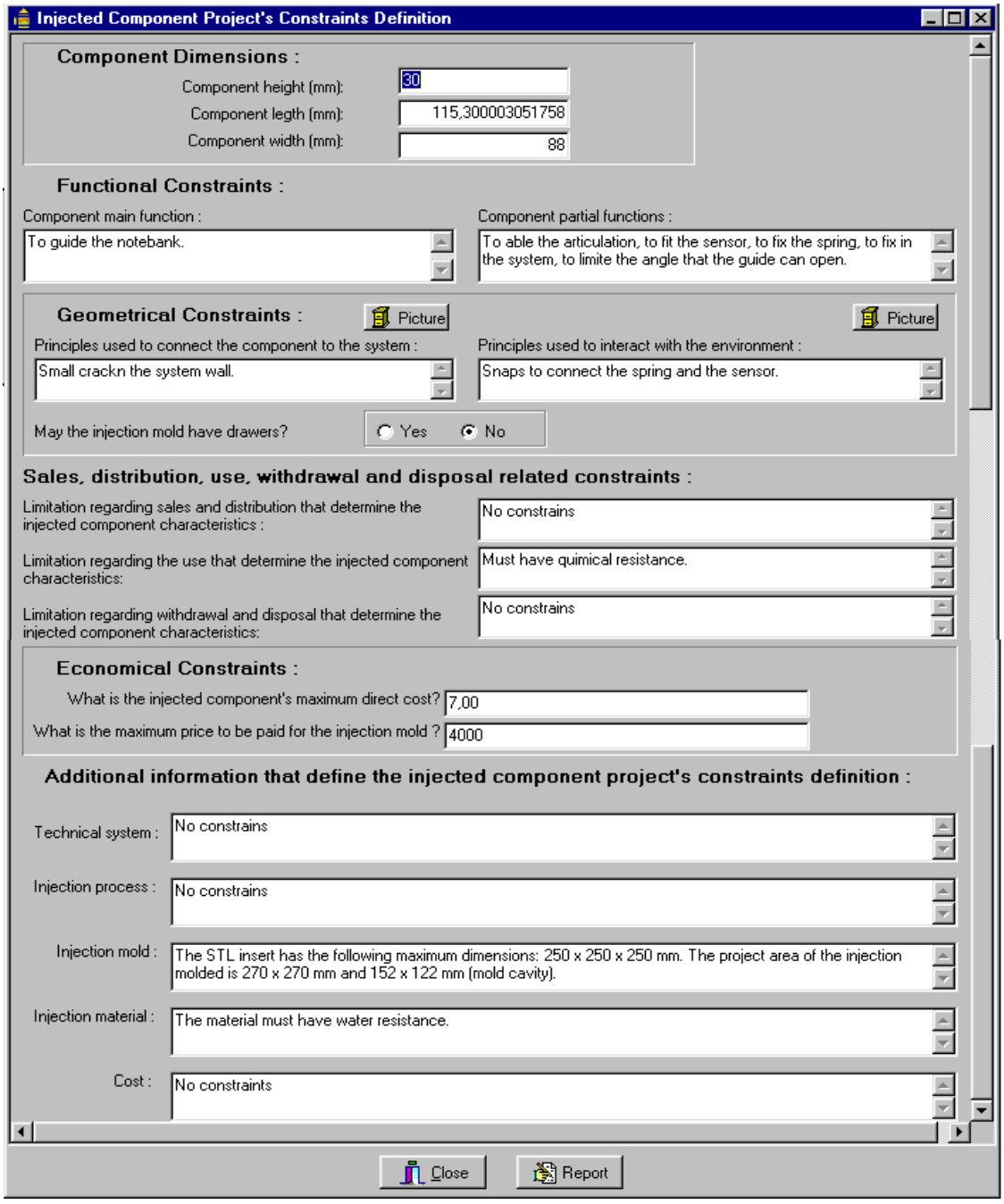



Figure 8. The SISCOI screen to define injection molded components design restrictions.

uct, process, mold, injection material and cost. The main identified restrictions were:

♦ Product - Max. projected area: 130x256mm;

♦ Product - Main function: to guide banknotes;

♦ Product - Auxiliary functions: to able articulation, to fit the sensor, to fix the spring;

♦ Process: Clamping force: 50 t;

♦ Mold: Width and length: 270 x 270mm;

♦ Mold: Minimum height: 225mm;

♦ Mold: Maximum height: 575mm;

♦ Mold: Length of cavity: 250mm

♦ Mold: Width of cavity: 250mm;

♦ Mold: Others restrictions: Use STL Mold

♦ Material: No restrictions

♦ Cost: Maximum mold price: R$ 16000,00

To support this activity in the SISCOI was developed a check-list. Comparing the results obtained using the SISCOI, illustrated in figure 8, and the other one obtained in the study case, the SISCOI software able to determine a major number of information.

Comparing the information illustrated in figures 5 and 8, it is observed that the component' height (design restriction) was altered because it was considered information associated to the injection mold and the injection process. As it can be observed, this design tool allows the design team consider integrated information associated to the development of the injection molded component. This approach avoids the need of alterations in embodiment and detailed design phases.

The icon "figure", illustrated in the figure 8, allows the design team identifies files, which can contain information related to the interface between the injection molded component and the technical system. In this case, as illustrated in the illustration 8, the group is shown spring-component must be considered in the notebank guides deign. In other words, this interface can not be altered, i.e., it should be obtained a design solution that its contemplate these elements (spring-component). In SISCOI the drawing of the spring-component can be identified and it can aid then development of embodiment and detailed design phase of the product.

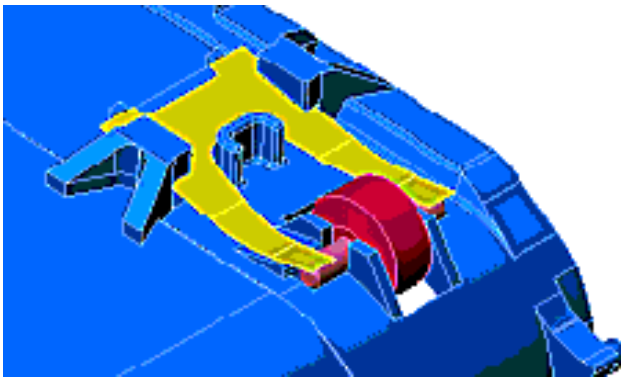


Figure 9. Conjoint spring - component.

The result of the information analysed to define the design restrictions, as well as, for the other implemented tools they can be visualised through design reports implemented in SISCOI software.

In this section were presented some resources implemented in the software SISCOI, which aid the development of the injection molded component informational design phase. In this section it was focus only the tool to define the injection molded components design restriction. This analysis is typical of the development of this product and, not to have knowledge of another design tool able to support the execution of this activity in the initial product design phase in an integrated way.

## 6. Conclusions

This work is part of a methodology to design and to estimate the costs of injection molded components in the conceptual design phase [4].

This methodology ables the design team manipulate a lot of information in this design phase. These information come from the different fields of knowledge in an integrated way, according to the philosophy of Simultaneous Engineering and according to the concept of design specifications of the injection molded component represented in figure 1.

As a result of this approach, the design team has knowledge of the critical points associated to the development of injection molded components. Thus, the necessary efforts to design the product can be established. The design of injection molded components is in most cases associated to the development of technical systems. In this sense, the introduction of the concepts of design restrictions and design guidelines in the methodology facilitates the manipulation and the consideration of information associated to the system, pro-

cess, mold, material and cost in the initial design phase. As a consequence, the design team has the opportunity to reduce the number of changes in the product during the embodiment and detailed design phases, to minimize the costs and the time to develop the injection molded component.

In this proposition it was looked for to incorporate graphic elements associated to the injection molded component design. These elements can be considered design principles of solutions. Thus, it is waited that the existent lacks between the process to define design specification and generation of component' conception can be minimised.

The design of injection molded components, in most of the cases is associated to the development of technical systems. In this sense, the introduction of the design restrictions in the process to define design specifications facilitates the manipulation and the consideration of information associated to the system, process, mold, material and cost in the initial design phase. As consequence, is it possible to reduce the number of design alterations in the embodiment and detailed design phase, minimize the cost and the time to develop the injection mold component.

The software SISCOI allows the manipulation of a larger amount of information in a systematic way. Using this software, the design team has available information that can be visualised in the screen and printed as a technical report. In this software, the tools to define design restriction and design guidelines of injection molded components and TRIZ are outstanding.

Information related to the materials, machines and injection mold must be considered in order to define the design restrictions. This information is stored in the software databases. Thus, by selecting the necessary information with information of the system determined by the design team, the software defines the design restrictions of the injection molded component. The software SISCOI allows the design team to identify graphic elements associated to the technical system, which accomplishes the interaction or the connection with the component. Thus, the design team has previous knowledge about the forms used for the conceptions among the technical system and the component. So, considering these graphic elements, it is possible to fill in the gaps between the process of defining design specifications and that of generating the product conceptions.

The tool to define the design guidelines of injection molded components is a database with orientations, recommendations and rules that come from design specialists. This database is structured and organised and it has the objective of solving the contradictions among the design requirements, to create visual motivation to facilitate the process to generate conceptions and, finally, to aid the process of defining the design specifications.

With regard to TRIZ, the software SISCOI presents examples of application of TRIZ inventive principles in the domain of injection molded components. These examples are visual incentives to generate conceptions and solutions for the contradictions among the design requirements.

This methodology was proposed considering a specific manufacturing process. Considering that design team can change the information in the SISCOI database this methodology can be applied in differents manufacturing process.

With this work it is waited that the process to define the injection molded component design specification can be developed considering the peculiarities of this activity.

## 7. Gratefulness

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