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Development of a Web Platform for Casting Process Selection

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Abstract. The choice of the right process for casting components is a complexactivity, and impacts directly on the design and manufacturing of the product. A single failure in the casting process selection can increase design and production time and, in critical cases, result in a collapse of the manufacturing and assembly of components. This process is usually based on guidelines scattered in the literature, or based on the designer's accumulated experience, but this action could be carried out by software containing a casting process database that can be employed during the product development stage, assisting the designer. In this context, our goal is to adapt a method for selection of casting processes previously developed into a web platform to support casting process definition. The adopted selection method uses Quality Function Deployment (QFD) and Design for Manufacturing (DFM) principles to provide a structure to support casting selection decision based on part features and process demand. The proposed software was developed for the Web using HTML and JavaScript, providing better usability than the previous format of the proposed selection method using spreadsheets. For validation, ferrous and nonferrous cast parts were analyzed using the proposed web platform. The results were compared with the selector provided by the American Foundry Society and with processes actually used in the industry. Thus, the results showed a good relationship with the other methods, also providing a quantitative classification (prioritization) of the results. In addition, this software supports the design of the manufacturing process by means of a checklist to adapt the part to the metal casting process presented to the designer.

Keywords. Casting process, Process selection, Web platform, Quality Function Deployment, Design for Manufacturing,

Introduction

Brazil is one of the ten largest producer of castings in the world, producing about two million and a half tons of molten materials per year. Furthermore, in 2014 the country produced an average of 10 tons a day. This industrial segment employs about 62000 people in almost 1300 companies. Most of these establishments are small and mediumsized, mainly created with investments from national capital sources [1].

The choice of the casting process directly influences the dimensional accuracy, finishing and mechanical properties of the component to be manufactured [2]. The right choice of the process usually ensures a reduced costs and production time, increasing reliability due to the lower probability of failure in production. Despite the existence of

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many methods for manufacturing molten parts, the designers tend to use materials and processes that they are familiar with, which is still a prevalent tradition. This action results in the deletion of processes and combinations of materials that could be more economical [3].

According to Swift and Booker [4], some designers are experienced and understand the limitations of each process they deal with; however, a lot of them do not understand the risks of a bad choice. An incorrect choice of manufacturing process results in substantial increase in design and production time, it also increases the chance of failure during the manufacture and assembly

Ashby [5] emphasizes the importance of specifying the functions related to the needs of the consumer or product operation. In addition, according to Lovatt and Shercliff [6,7] the selection of the manufacturing process is influenced by the material and the shape of the component. This relation between function, form and material is essential to understand the ways of selecting manufacturing processes [8,9,10,11].

It is possible to find in the literature several methods for process selection, including: expert systems, process information maps, rational methods, set of rules and multicriteria methods [7,12,13,14]. A particularity unanimous procedure among the selectors cited is a comparison of the part features with the parameters of each process. Darwish and El-Tamimi [13] and Setti [15] consider the characteristics with different weights, resulting on diverse importance for each of them. Only Swift and Booker [4], during the project development, consider the component requirements, at the end of selection process, in order to compare with the obtained requirements. Finally, Karthik et al. [14] and AFS [16] apply their respective selectors on a web platform. The Web format is independent of operation system and does not need a special configuration or download to work. In the web platform, users may have access from anywhere, at any time needing only a browser [17,18].

In this context, our goal is to adapt a method for selection of casting processes previously developed into a web platform to support casting process definition.

1. Metodology

The web platform was developed using HTML and JavaScript coding and was based on the Bringhenti et al [19] selector. The methodology embedded on this web selector combines QFD and DFM concepts and aims to choose the most appropriate casting process during the product design phases [20,21,22]. The interaction of these tools is described in the flowchart of Figure 1.

Geometrical characteristics of the component as well as requirements of the project are the start point to distinguish the material nature and to provide the component's functions and characteristics values [23,24,25]. Based on this input data, the selector is able to generate a ranking of casting process, pointing the most appropriate. To complete the selection, a Checklist is provided in order to correct the component's parameters, or to adapt the project to fit the feature's characteristics of the process in order to make the it more efficient.

Bringhenti et al. [19] proposes to differentiate between ferrous and non-ferrous metals, since some casting process can not be applied to both cases. The characteristic values which should be provided by the designer are: mass, minimum section thickness, draft angle, surface finish, dimensional tolerances, minimum lot and lead time. Due the fact that the dimension of the part is directly linked with the value of the dimensional tolerance, so it is necessary to inform the greater dimensional value for the desired tolerance.

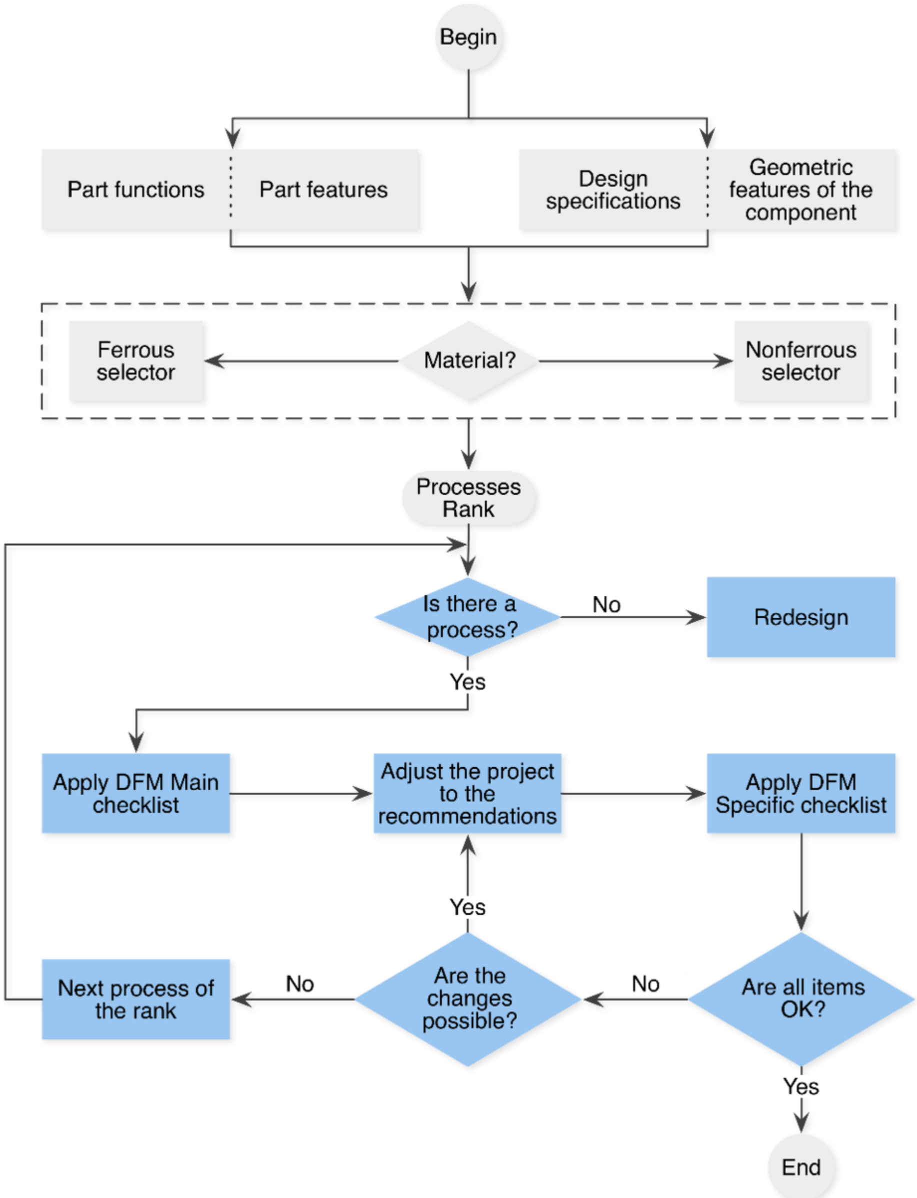


Figure 1. Selector operation flowchart integrating the DFM [19].

The starting point for the use of this selector is during the embodiment design of the product, which has already set much of the product architecture and some parts were selected as candidates for the casting process. In addition, it is also known its function and some desired design parameters (geometry, finishing, materials, etc.), which provides better suited information for the selector. The conceptual model used, shown in Figure 2, consists of two parts: (a) a Correlation matrix and (b) a Selection matrix.

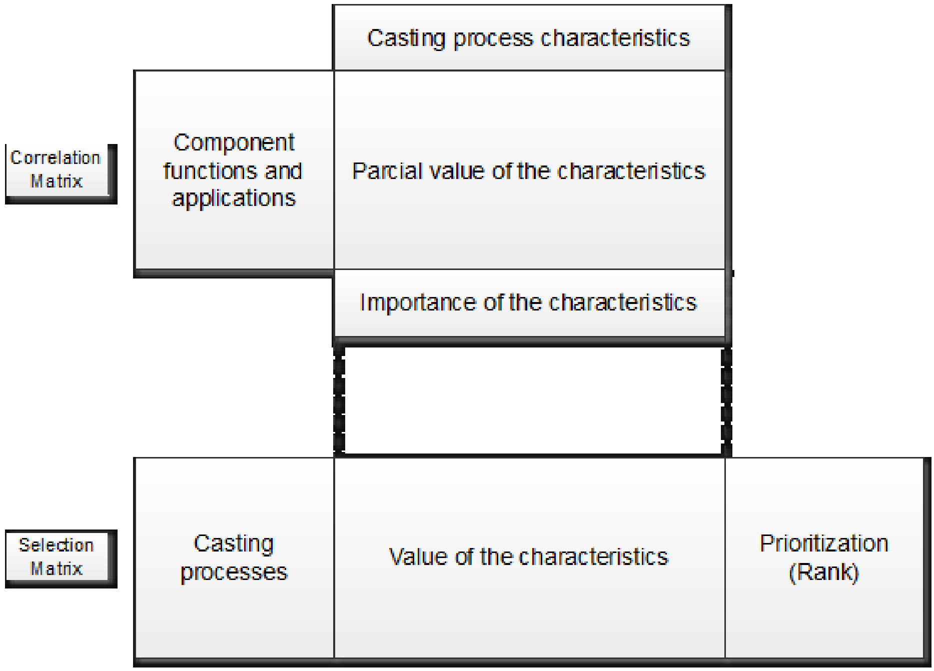


Figure 2. Selector operation flowchart integrating the DFM [19].

The correlation matrix gather the associations between component functions and applications, called "Description", with the casting process characteristics, in order to obtain the importance of the characteristics processes (mass, minimum section thickness, draft angle, surface finish, dimensional tolerances, minimum lot and lead time). In this matrix the correlation must complies with the scale ranging from 0 to 5, where 0 means nonexistent correlation and 5 means a very strong correlation. In the web platform, this matrix was concieved as an interactive table, shown in Figure 3, where the user can add and remove lines according to the number of functions and applications of the product, meanwhile the value of characteristic importance adds or decreases automatically in the last row of the table.

Figure 3. Correlation matrix of the web platform, based on QFD, in order to obtain the importance of the characteristic values.

In the selection matrix, to obtain the prioritization, the values of characteristics are compared with the casting processes capabilities. For each process characteristic, by Bringhenti et al [19] established four levels for the “value of the characteristics” namely: 1) Extreme minimum, 2) Minimum of 3) Maximum and 4) Extreme maximum. This values are matched with a database which is already built into the proposed web platform. To obtain the prioritization rank, the design goals are compared with the values of the characteristics of each casting process. From this comparison are determined indicators of capability ranging from 0, 1, and 2, where: 2 means design goal is between minimum and maximum value (within the usual limits), 1 means design goal is between the minimum and extreme minimum, or between maximum and extreme maximum (within the extreme limits), finally, 0 means design goal is above maximum extreme or below minimum extreme (out of process limits).

The ratio of each characteristic is then obtained by multiplying the value corresponding process capability (0, 1 or 2) with the importance of the characteristics obtained by the correlation matrix. Therefore, the grade for each case process is the result obtained by the sum of resulting ratios of the characteristics for each casting process (lines). The results are standardized in the range 0 to 10 (obtained by dividing it by the maximum value multiplied by 10) facilitating in this way the interpretation of the final result. If any process obtain index 0 in any feature, its final score will be zero, in other words, the process is unable to produce the desired component characteristics.

In order to consider the characteristics of the process since the beginning of design, and based on the DFM principles, it is also provided a checklist as a guide to help designers review their project goals. The checklist is a list of functions to verify and document the selection routine, to make this process organized and simple [19]. This tool should be used for the best process ranked and all the fields in the list must be checked. If the features are not in compliance, changes related to costs, physical and dimensional limits shall be adjusted until all items are checked. Using the checklist, the designer will be able to adapt the component that will be merge with the requirements of the ranked process, ensuring a better efficiency in the fabrication process. The Checklists are provided to download int he web platform in PDF format.

To validate the web platform, the obtained results using two components from the industry were evaluated and the results were compared with the ones employed by the industry and the AFS [16] web platform.

2. Evaluation of the web platform proposal using industrial components

For process selector validation it was used real parts applied in the local metalworking industry, described in Table 1, being one ferrous and another one non-ferrous. They are:

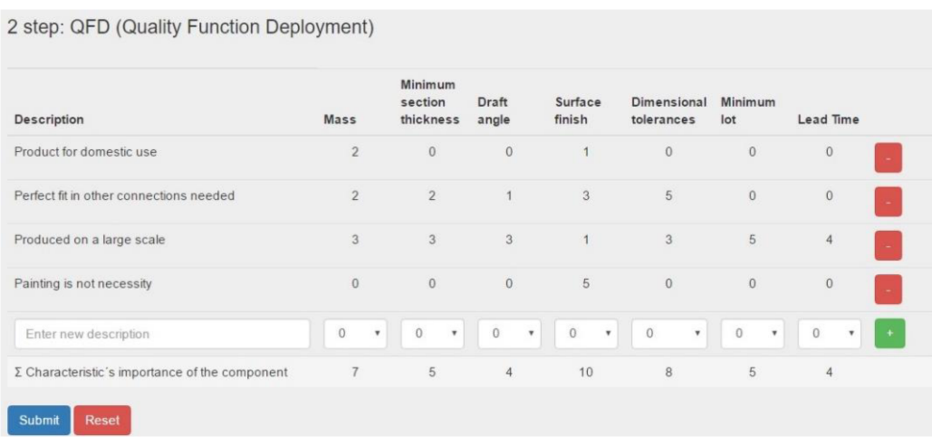
a) Planetary gear housing: component used in the automotive industry, where the planetary gears are engaged Planetary gears;
b) Gate valve: component used in civil construction to interrupt the water flow in an installation.

The item (b) of the Table 1 will be used as a model to illustrate, step by step, how the web platform works. First, the data input from the Table 1b is given by the user in order to fill the initial web page data.

Table 1. Components analyzed from the metal mechanic industry.

	a. Planetary gear housing	b. Gate valve
Part		
Material	Nodular cast iron	Brass alloy
Mass [kg]	17.38	0.191
Minimum section thickness [mm]	14	2.5
Draft angle [o]	0.5	5
Surface finish [Ra]	40	40
Dimension [mm]	225	28.4
Dimensional tolerances [mm]	±1.4	±0.3
Minimum lot [components per year]	300	20 000
Lead Time [days]	Not specified	Not specified

The gate valve is used in civil construction to stop water flow in case of leaking or eventual maintenance. The water pressure combined with open and close movement can wear internal components of the gate. Based on this information, functions and features of the gate valve were chosen to fill the correlation matrix (Figure 4): (i) Domestic use, (ii) perfect fit other connections, (iii) has a large scale production and (iv) do not have to be painted.


2 step: QFD (Quality Function Deployment)

Description	Mass	Minimum section thickness	Draft angle	Surface finish	Dimensional tolerances	Minimum lot	Lead Time
Product for domestic use	2	0	0	1	0	0	0
Perfect fit in other connections needed	2	2	1	3	5	0	0
Produced on a large scale	3	3	3	1	3	5	4
Painting is not necessity	0	0	0	5	0	0	0
Enter new description	0	0	0	0	0	0	0
Σ Characteristic´s importance of the component	7	5	4	10	8	5	4

Figure 4. Matrix Correlation filled with values of the importance of each feature component of the gate valve.

When all inputs and importance are filled in the platform, the web selector is able to calculate each process grade, considering characteristics and comparing with minimums and maximums values.

Table 2 illustrates how the proposed algorithm calculate scores for each process, using the gate valve as an component and Investment Casting as a process example. The values in Table 2, columns C, D, E and F, are embedded on the platform and represent maximum and minimum values.

Table 2. Summary of the characteristics values and their importance for Investment Casting the gate valve part.

A	B	C	D	E	F	G	H	I
Features of the part	Value of [A]	Extreme minimum	Ordinary minimum	Ordinary maximum	Extreme maximum	Associated indicator	Importance [A]	Priority value of the charac-teristics G x H
Mass [kg]	0.191	0.0045	0.05	6.8	113	2	7	14
Minimum section thickness [mm]	2.5	0.23	1.04	NE	NE	2	5	10
Draft angle [o]	5	0	1	NE	NE	2	4	8
Surface finish [Ra]	40	0.73	1.14	2.86	NE	1	10	10
Dimensional tolerances [mm]	±0.3	0.16	0.28	NE	NE	2	8	16
Min.lot [components per year]	20 000	1	10	1760	NE	1	5	5
Lead Time [days]	NS	60	120	NE	NE	NI	4	NI
			Priority value for the process (not normalized)					63

The selector can generate automatically a table with the results, ranking process according to the grades calculated and standardised as illustrates Figure 5. The results of the web platform for gate valve are:

1. Investment casting (10,00)
2. Die casting (10,00)
3. Permanent mold – Low pressure (8,89)
4. Plaster molding (8,73)
5. Lost foam (7,62)
6. Ceramic Mold (7,62)
7. Permanent mold – Gravity (6,98)

To Planetary gear housing the results are:

Investment casting (10,00)
Cold box (9,90)
Ceramic Mold (9,49)

All the others processes were considered unable to fabricate the part with the desired characteristics (0.00).

Ranking of process

Order	Process	Grade	DMF Checklist
1°	Investiment Casting	10.00	PDF
2°	Die Casting	10.00	PDF
3°	Permanent mold - Low pressure	8.89	PDF
4°	Plaster Molding	8.73	PDF
5°	Lost Foam	7.62	PDF
6°	Ceramic mold	7.62	PDF
7°	Permanent mold - Gravity	6.98	PDF
8°	Centrifugal casting	0.00	PDF
9°	Shell Molding	0.00	PDF
10°	Green sand - manual	0.00	PDF
11°	Cold box	0.00	PDF
12°	Green sand- automated	0.00	PDF
13°	Squeeze Casting	0.00	PDF

Figure 5. Final ranking of the casting process for gate valve.

It is worth to notice the small difference between the obtained scores that fulfill the requirements for different casting processes. It demonstrates that the expertise of the designer is still necessary to evaluate process costs and availability for the company. Furthermore, every process has a final check list, based on DFM, attached in the web selector which must have all the fields checked by the designer to complete the selection process. If any field is incorrect, the project should be reviewed until all the fields have been checked. As a result, it allows the designer adapt the project, considering the process selected during development.

Finally, the Table 3 compares the results obtained in the proposed platform with the web selector provided by the American Foundry Society and with processes actually used in the industry. For the ferrous parts it is observed a high matching among the results, however it is not possible to reach the same conclusion for the nonferrous parts, where the platform results suggest the process used by the industry, but not with good marks. Difference in results is caused by the selection of the maximum and minimum values for each procedure, which has been made by comparing the values suggested in different bibliographies cited in Bringhenti et al [19] thus producing large gaps between maximum and minimum extremes. This particularity gives a good acceptance of the processes in the web selector when the characteristics of the components are compared with the platform database. A characteristic of the American Foundry Society platform (2015)[4] is, instead of creating notes, just indicate which process agree whit the parameters set by them, in this way the appropriate procedures for each component tested on this platform are represented in Table 3 by the letter ’X’. Furthermore, their platform alert users on processes operating in danger conditions, in other words, process which work in the reference limits. These processes are represented in Table 3 in red. When both selectors are compared, it is possible to relate the processes that received the lowest scores of the web platform proposed, with the processes that have received the letter ’O’ in the AFS Platform (2015)[4].

Table 3. Comparison between the proposed selector, AFS Platform (2015), and the processes used in industry.

		Planetary gear housing			Gate valve		
		1	2	3	1	2	3
1.	Green sand – manual						
2.	Green sand						.
3.	Cold Box	9.90	X				X
4.	Shell Molding					O	
5.	Ceramic mold	9.49	X		7.62	X	
6.	Investment casting	10	X		10	X	
7.	Lost Foam				7.62	O	
8.	Centrifugal casting						
9.	Permanent mold - Gravity				6.98	O	X
10.	Plaster Molding				8.73	X	
11.	Permanent mold - Low pressure				8.89	O	
12.	Die Casting				10	X	
13.	Squeeze Casting						

3. Conclusion

In this paper it is presented a web platform to support the choice of casting process. The web platform uses a previously developed method for selection of casting processes. It employes Quality Function Deployment (QFD) and Design for Manufacturing (DFM) principles to provide a structure to support casting selection decision based on part features and process demand. The proposed software was developed using HTML and JavaScript, providing better usability than the previous format of the proposed selection method using spreadsheets. The results showed a good relationship with the other methods, also providing a quantitative classification (prioritization) of the results. In addition, this software supports the design of the manufacturing process by means of a checklist to adapt the part to the metal casting process presented to the designer.

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