Considering constructive-functional optimization as a stage of product design in industrial practice

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Abstract. This paper is part of a product optimization study, conducted at the request and together with an important national and international economic agent in the automotive industry. The presented results are focused on highlighting how the design activity is influenced by technical and technological progress, by the specific knowledge of the design engineer and by the way they integrate into new generations of products on the one hand having constructive and functional features and on the other hand, minimized costs.

1. Introduction

The development of a product requires the determination of customer requirements, their "translation" against the perspective of the company, the development of the product concept as a result of the marketing study, the development of the technical specifications of the product, the design of the product and the manufacturing technologies, the distribution and the service for the products sold, and ultimately the disposal of the product. All of this is based on management, communication and decision-making processes for organizing and integrating product life cycle phases, including financial, legal, strategic planning, research-development, etc. [1, 2]

Regarding the product development (PD) process, in literature exists exist several approaches. The descriptive and prescriptive approaches to product development [3] result from investigation into actual design practice the descriptive one and the second approach recommend or prescribe guiding principles, steps/phases or techniques that, in theory, are thought to improve specific aspects of PD.

The prescriptive approaches have at basis methods, tools, approaches that refer to product design and development – [4, 5, 6]. They offer a general orientation to products development (design) offering a problem solving approach using tasks and decision making to a design team rather to indicate what tools to use. They say what is to be done but they must be adapted to specific of PD project. The product development process reaches its objective through knowledge accumulated passing from abstract to detail.

The detailed design provides all other data missing from the exhaustive description of the new product, such as materials, installation / adjustment rates, etc. It is necessary to complete iterative steps in order to solve these conception / optimization problems and to analyse several variants using knowledge about means such as statistical methods and tools, manufacturing process [6,7], software,

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hardware and systems implementation, product reliability and qualification, physical analysis methods, computer-aided design and simulation programs [6,7], specific technology etc.

This paper is part of a product optimizing study, product that is a part of a larger project, conducted at the request and with an important national and international company in automotive horizontal industry, highlighting differences from the theoretical approach. A major company in the Eurasian market (which we call Original Equipment Manufacturer with the acronym OEM) produces a car (called the new CAR), which incorporates a series of sensors (called SZs) with various functions and size (overall dimensions) features.

OEM requires to a company from the horizontal automotive industry (acronym MCP) that besides the actual SZ, to deliver also the support (hereafter referred to as SS) which allow the sensor to be embedded and also, allow mounting of the subassembly in the indicated location of the CAR. OEM expresses the requirements for this SS in the form of functions it desires to be fulfilled. Functions are translated in univocal technical features, in the form of tables, with engineering language, so that their reading should not allow interpretation. To design the SS, the engineer must meet all OEM requirements and embed them in a single product, even if the number of technical specifications can reach up to several thousand.

2. Fulfillments of functional conditions

The SS that embed the SZ must match the OEM 's CAR "environment". For this, investigations of the machine's "environment" for about 240 hours have been made, during which an intense exchange of information between OEM engineers and those of MCP that will produce SS has been carried out to determine which changes are possible and if there is a solution, among those found to be agreed on both sides, so that the design can continue based on it.

After the investigation period, the design team of the MCP sent the OEM first result, in the form of the V1 support concept. This concept is a "box" type with a wall thickness of 2.5 mm. The support incorporates 2 interfaces:

A. Interface with SZ (figure 1) - consisting of the 5 geometric structures numbered in the figure as follows:

1. Two M4 internal threads that are inserted into the mould prior to injection and fasten SZ through 4 screws. Fixing is done with screws; 2. Locating (set up) surface 2 consisting of 4 surfaces, which together represent the horizontal plane of SZ location (set up); 3. Four surfaces denoted with 3, which are distributed 2 by 2 on each side of SS, are designed so as to provide a small SZ guide in SS and left-right positioning;
4. Two geometric elements in the form of "fins" which come in contact with the side of the SZ and block the movement on the Z axis. The element 4, together with the elements 2 and 1, constrains the SZ on the Z axis and pre-stresses it so that it is fixed; 5. Two SZ contact surfaces at the top. This element together with the element 1 positions the SZ in the front and rear direction.

B. Interface with CAR (figure 2) - This interface is customer-conditioned and constraints in the machine environment, so in this case, we have the following elements:

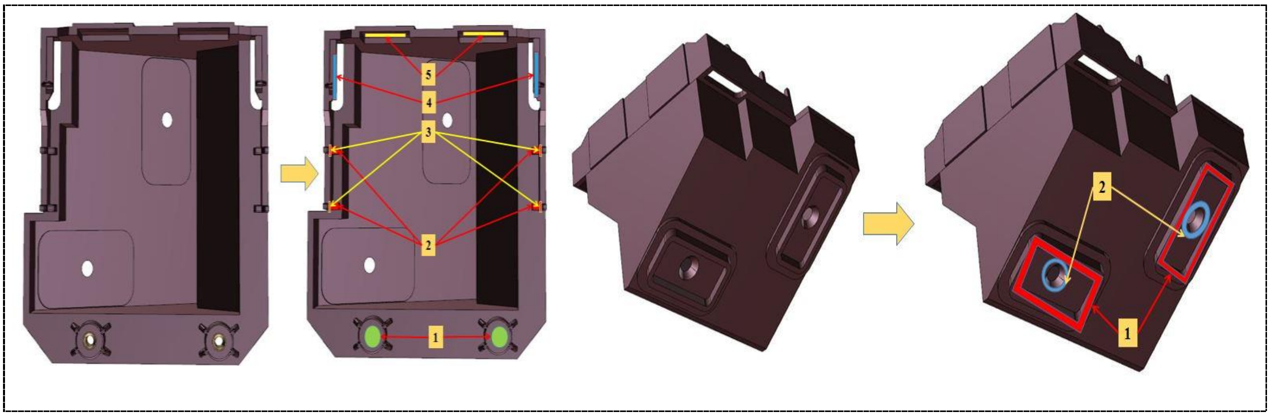


Figure 1. SZ –SS interface .**Figure 2.** CAR-SS Interface..

1. The joint surface created by 2 ribs that come in contact with the CAR plate on which the SZ is positioned;
2. Two passage holes for 2 screws, which will then assemble 2 elastic metal clips that pass through the metallic CAR metal sheet, and once past, pretension and make enough tension to position the SZ and fix it;

3. Product constructive optimization

3.1. Optimizing product weight

The imperative desire to achieve the best products determines customers to collaborate with other companies to get more expertise (opinions) for the same product. For the previously described product, because OEM
later introduced the 20% reduction in CAR weight, it sent variant 1 of the SS product to a third company to conduct a study and provide solutions to reduce its weight.

The finality of third-party studies ended with a report containing several weight reduction suggestions and recommendations that could be grouped into two broad categories:

- Making cuts in the SS walls
- Adding stiffening ribs after a certain logic

Taking into account the suggestions above, SS solutions development are thought so as to embed this suggestions. The initial SS variation has undergone numerous changes by which it was mainly intended to optimize the amount of material used in the SS in relation to its mechanical strength. After the multiple variants and finite element analysis, they came to a variant with removed walls but without the addition of ribs, as it was found that they only needlessly load the model, and there is no real need for additional resistance to the given force loads - variant 2 of figure 3.

It is noteworthy that, following the stress tests, it was found that the SS in the V2 variant is even more resistant than the previous variant, given that all characteristics of the injection material were preserved as V1 (PA6.6 GF30 with a density of 1360 kg / m3) and the weight decreased from 86 g in V1 to 55.8 g. Therefore, a reduction of 30.2 g was obtained, i.e. V2 is lighter by about 26%. Both the OEM and the third-party consultant were pleasantly surprised that without adding ribs but merely modifying the geometry, an easier product and better mechanical properties were obtained.

3.2. Optimizing the SS manufacturing process

For SS in V2, the model details were made taking into account the tool making process and were looking for the suppliers to deliver this part.

In parallel with this stage of preparation of the SS manufacturing in V2 - although the analysis of injected material flow into the mould cavities is an optional one and often avoided the design team has also decided to carry out an analysis of this type using the Mold Flow Analysis software [8]. The results of this type of analysis for the given case were as follows (table 1). As a result of material flow, there are three welding lines that could cause problems for the piece. In figure 4, the location where SS is maximally deformed, located for on one of the positioning legs (C2). By virtue of a responsible design activity, it has been decided to put the injecting tool preparation into stand-by and to continue the design process, also taking into account the capabilities of the injection process as outlined above.

After several models and trials, the V3 variant for SS has come to life, distinguished by a new geometry that allows a better material flow. Given the localization of the main issues at V2, it was concluded that by merging the two legs of SS, the problem can be considered as solved, as indicated by the new Mold Flow analysis for V3 (see table 2). It can be seen in figure 5 that the place of injection point has been modified (C3), and this has greatly contributed to avoiding the welding lines; the final result, SS in V3 variant is show in figure 6.

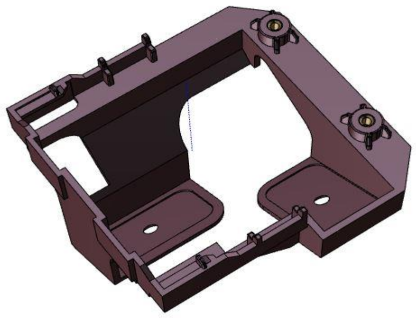


Figure 3. SS-variant 2

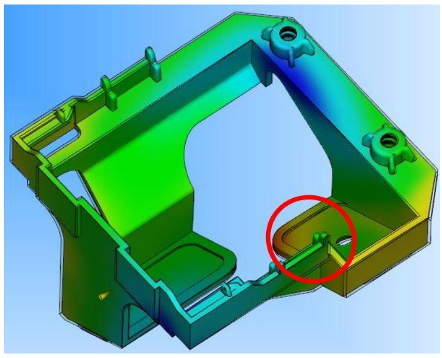


Figure 4. Maximum deform. place-C2

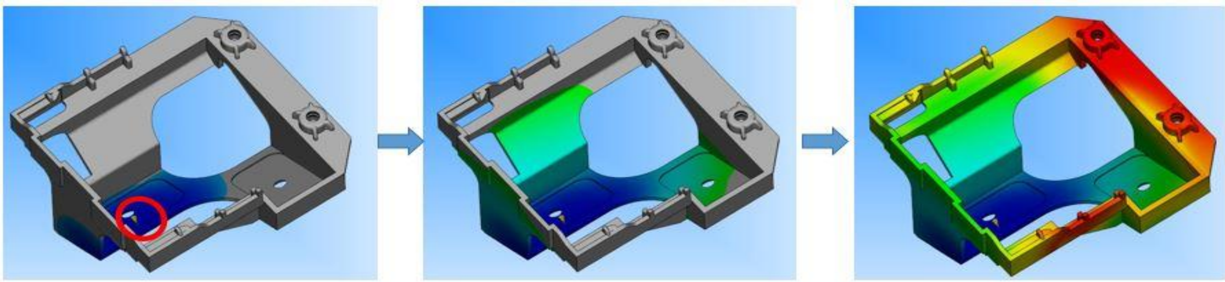
Table 1. Mold Flow Analysis Results for SS in V2 variant

Variant	Injection time [s]	Wieight[g]	Inj. Point. Temp. [ºC]	Pressure [MPa]	Vol. Contract [%]	Estimated contraction [mm]	Deflections [mm]			
							X	Y	Z	T
SS/V2	1.48	55.8	291.4	40.84	14.61	1.08	1.02	0.96	0.8	1.35

Table 2. Mold Flow Analysis Results for SS in V3 variant

Variant	Injection Time[s]	Wieight[g]	Inj. Point. Temp. [ºC]	Pressure [MPa]	Volume contract[%]	Estimated contraction [mm]	Deflections [mm]			
							X	Y	Z	T
V3	1.24	59	290.3	27.5	15.15	0.67	0.41	0.72	0.5	0.87

In figure 7 we can see the places C4 where the largest deformations are located: the two corners of the piece, areas that do not have functional importance.



(a) **(b)** **(c)**.

Figure 5. Cavity filling and injection point

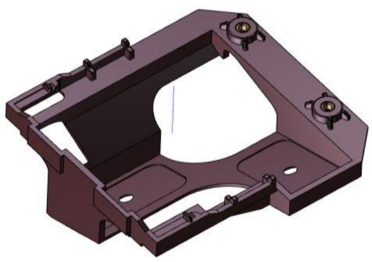


Figure 6. SS in V3 variant.

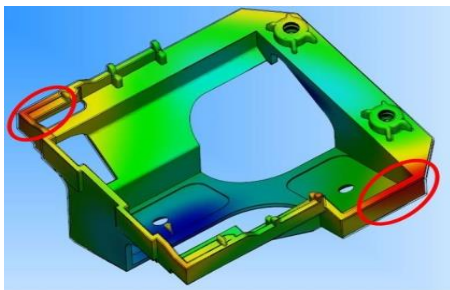


Figure 7.Places with maximum deformations -C4

4. Conclusions

The design phase of this project, by reaching the V3 variant of the SS, can be considered as completed, but the project is far from complete in terms of production, which offers the opportunity to meet new challenges from which can result in better solutions or can be examples of good practices that are included in new industrial product design procedures. In this sense, we highlight at least 3 issues that should complement the development of new projects:

1. Consideration of the type and conditions of the manufacturing process must be a mandatory phase of analysis among the design stages for example, if the product is one of the injected types, then Mold Flow Analysis should be mandatory from the early stage of a design, even in a simplified version.

2. Reiterating the design process with the inclusion of each additional specification should be considered as an essential step in generating improved product variants.

In the analysed case, the V2 variant of the SS brought a weight reduction of 26%, and in V3, even if it required the addition of material (the introduction of the bridge between the two legs added 3.2 g of material), it is easier than V1 by 23%.

3. The maturing of the implementation of new product design of the first two aspects above represents an important step towards the realization of a technological ideal generally pursued by companies: obtaining products that best meet the basic requirements, ie light and resistances.

The design case presented showed that in the working mode that embraced the "tips" above, the easiest piece was obtained according to the customer's requirements, provided that its gauge is not the smallest, but corresponding to the conjugated piece in which will be assembled.

Moreover, the mechanical properties of the piece have improved, which makes us affirm that optimization has been achieved at least in two directions. The data in table 3 is an argument in favour of this statement: only the weight is a negative aspect for SS variant 3 while the other parameters favour its choice, sufficient reasons to decide that the project will be continued in this variant.

Table 3. Comparative Mold Flow Analysis for V2 and V3

SS Variant	Timp de umplere[s]	Weight [g]	Pressure [MPa]	Estimated Contractions [mm]	Deflections [mm]
V2	1.48	55.8	40.84	1.08	1.35
V3	1.24	59	27.5	0.67	0.87

More than the realization of the design experience by completing the procedures, it is to notice that in the case of a responsible design activity, the research of the optimization study carried out by the competing third party is inevitable.

5. References

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