DEVELOPMENT OF A CAR BODY DESIGNING PROCESS

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Abstract: *Car industry is one of the first industries that started using computers in the designing process. A replacement of a conventional designing process has been a long-lasting procedure, especially regarding collaboration. In addition to the necessity for designers' training and changes in the way of thinking, considerable investments were needed as well. The ambitious goals were not accomplished after all, since the entire process had been conditioned by a large number of participants at various development levels. In this paper, the differences between the conventional designing, designing by computers and virtual designing are presented. A new model was produced, without manufacture of classic prototypes which were replaced by vehicles from the test production. There are the upcoming analyses of the effects, which will certainly influence further development of the designing process.*

KEYWORDS: CAR BODY, DESIGNING, NOVELTIES.

1. Introduction

Car industry was one of the first industries that started using computers in the designing process. It has been a very long procedure, with transition phases and necessity for maintaining the conventional designing in transition period. The situation and possibilities for collaboration, especially regarding smaller suppliers, have been the additional complication. In the beginning of the car designing process, the computer was mainly used for designing of a car body, interior and exterior parts, which was the consequence of a very complicated classic designing process, so the application of the computer contributed to a considerable shortening of time of designing; using the example of a car body, this is accomplished:

- By analysis of several versions of the carrying construction in the initial designing phase. Based on calculation results, several versions are selected and the most favourable among them undergoes further optimization.
- By designing a car body on the computer, manufacture of a prototypes batch can be reduced, which considerably reduces the costs of sending a new vehicle model into the production.
- By rapid analysis of effects of new materials application.
- By a public display of activities related to this area, which will contribute to improvement of the image of the company, which is increasingly more used for marketing etc..

2. Conventional designing method

A project task is defined according to the market demands. This part of preparatory activities all the way to project task defining is the same for all designing methods. When designing a new model, i.e. car body, it is necessary to carry out a lot of preparatory activities before a project task is defined. One of the most important activities is market research, as well as analysis of production initiation. Fig.1 shows a stylistic study of the exterior and study of the interior of a vehicle, based on which analysis of market was performed.

Fig. 1 *Study of exterior and interior of the vehicle*

Fig. 2 *Stylistic models*

After that, in conventional designing several plaster models are made in proportions 1:5, see fig. 2. After several proposals are observed, two models are adopted, which are then made out of gypsum in proportion 1:1, see fig. 2. Model of vehicle interior, with completely defined interior regarding style, is also realized in proportion 1:1. After presentations, considerations and acknowledgment of comments, model 1:1 is adjusted, i.e. a final version is made, with controlled dimensions and finishing paint. Model has the form of the vehicle. After that, the model undergoes final investigations in aero tunnel, see fig. 3.

Fig. 3 *Investigations*

After the decision is made to accept one model, designing of carrying construction of a car body starts. It is necessary to define the positions of all the supports and to propose the shape of their cross sections and inter connections applying the concepts used on previous models and used by competitors. Lately, major attention is given to the protection of space for passengers, where car body plays one of the major roles. Most decisions made at this time are based on experience acquired by participation in previous concepts and constructions, subjective grades and similarities with already existing constructions. Only after execution of such an analysis can the presented stylistic model be accepted, construction of car body initiated and, later, a certain number of prototypes made. In the following cycle, car body prototypes are subjected to laboratory investigations, first, and then to travel investigations, both individually and as parts of vehicle. One of the first investigations of a car body, performed in laboratory conditions, is bending and torsion static investigation of car body, see fig. 3. Laboratory investigations which are implemented can be related to investigation of a car body behaviour, connections of movable car body parts, connections of elements which are attached to a car body, adjustment to regulations etc. In addition to car body investigations, these parts are also investigated individually. Based on previous experience and legal regulations valid at the period of designing, i.e. production initiation, critical points are modified. After that, a new batch of prototypes is made. The investigation cycle is repeated on the new batch of modified prototypes. Construction documentation is modified, if necessary, based on results of repeated investigations. In the last part, homologation, i.e. verification of the accepted model is needed, for which a master (clay) model is made. Car body is assembled on assembly line and painted on painting line, fig. 4. The operations are mainly performed manually. At the same time, painting of plastic parts is organized, on car body painting line or parallel to this line. Assembling of vehicle is organized on assembly line. It is done

manually, where equipment for assembling is defined on special points. Conventional concept reflects the accomplished technological level at the preparatory period and is adjusted to the size of batch and need to employ a large number of workers in the overall process.

Fig. 4 *Car body assembly line and painting line*

3. Car body designing by using a computer

The process of designing of passenger car body by using a computer is very different from a classic designing method [1].

Fig. 5 *Definition of exterior style and model of exterior surfaces*

The differences in the designing method can be observed at the very beginning of the process of defining large surfaces of exterior or interior parts. Already in this phase the stylist is able to simulate the behaviour of vehicle in the aero tunnel and to eliminate the weak points which influence the definition. In computer designing, the stylist has the opportunity to facilitate the job for the constructors significantly and to facilitate the manufacture of prototypes by defining style (of the exterior or interior).

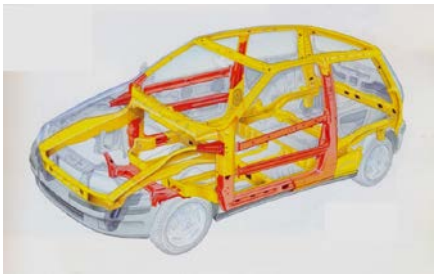

Fig. 6 *Defining of the carrying construction*

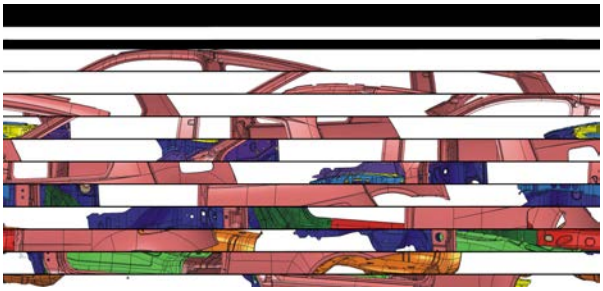

Fig. 7 *Defining of the overall car body construction*

The advantage of such designing is the possibility to analyze the main and alternative concepts in a short time, in the initial designing phase. Based on results of comparative analysis, we can eliminate unfavourable concepts already in the initial phase. The results and reliability of the analysis depend on accuracy and possibilities of the selected programme, mathematical model quality and the knowledge of the analyst. In the first few analyses we can already determine the concentrated strain points and, if needed, the necessary modifications of the observed model can be performed quickly, in order to obtain the most favourable distribution of strains and movements on carrying construction elements. After the analysis, an optimized carrying construction is obtained, fig. 6. After that, the constructors define the car body, see fig. 7. **In this designing phase, reduction of the total car body designing time can be influenced considerably, because manufacture of the first batch of prototypes can be avoided, which is necessary in classic designing**. This is achieved by simultaneous work of stylists, calculators and constructors, the results of which is an optimized construction. After that, a batch of prototypes is made and the further procedure is the same as for conventional designing. The greatest progress is achieved in the manufacture of prototypes, which contributes to a considerable reduction of total designing time. All the models are made on numerical machines, where the results of previous designing are used, especially in manufacture of large surfaces. Quite often, with the aim of rapid comprehension of designing effects, polyurethanes of small hardness, easily formed, are applied. In that way style or construction can be tested or perceived. In addition to that, new methods for prototypes manufacture have been developed (rapid prototyping etc.), due to which testing of dimensions is easily performed, and functional testing can also be realized if better materials are applied. Due to the introduction of new technologies, there is no longer a problem of negative angles, complicated geometry and similar, due to the previous testing of their assembling. Defined shapes of parts on the computer can be used for manufacture of models, prototype parts or tools for prototype parts manufacture, and also later on, for manufacture of small batches.

Fig. 8 *Significantly improved technology of prototypes*

After the manufacture of prototypes, investigations are performed. The investigation procedure is the same as for conventional designing, except that it is realized with improved methods and on innovated equipment. Investigation methods must be constantly improved since the valid regulations are getting stricter all the time, as well as market requirements. One part of investigations is transferred to collaboration, while the grading tests are realized at the finalist's.

Fig. 9 *Innovated investigation desks with significantly improved investigation methodologies*

Nowadays, it is unthinkable to manufacture a large batch of car bodies without using a robot. Initially, the robots were used for spot

welding of sensitive points and points that were hard to reach. After that, the application was expanded to assembling of major connections and final assembling of a car body. At the present time, mainly the whole lines for car body assembling are robotized. For points with laser welding, robots were applied even earlier. There is a constant request for the reduction of these welding points. Even for car bodies assembled in this way, additional finishing is necessary, which is still manual. Production without errors is still only a goal.

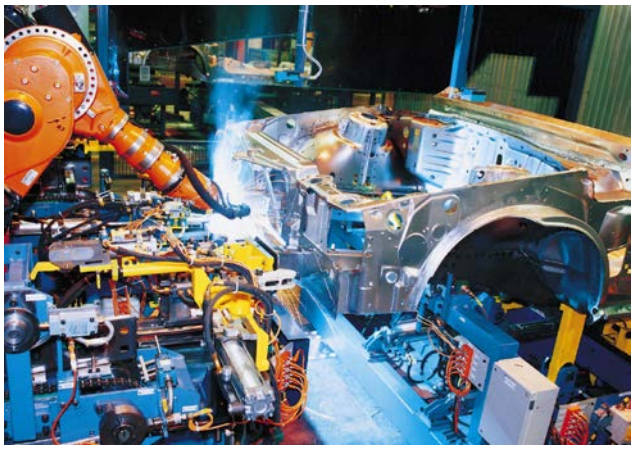

Fig.10 *Application of robots in car body assembling*

Fig.11 *Laser control of car body on line*

Fig.12 *Robotized painting of a car body*

In recent times, structural adhesives are increasingly more used for connecting of car body parts. For initiation of such a method for connecting of car body parts, it is necessary to change the existing connecting technology completely, with obligatory preservation of very strict production conditions. Regarding the improvement of production quality, the conditions for control of finished car body and for introduction of laser control on the car body assembly line itself were enhanced, see fig. 11. This control is more important from the aspect of parts installation in the assembling process in which robots are used. Painting of a car body is being given more and more attention with the purpose of getting as good appearance as possible and reducing errors to zero. Painting of a car body is mainly robotized, see fig. 12.

The process of vehicles assembling can be organized in various ways, depending on the producer. Fig. 13 shows the typical assembly line, where the process has been improved in the sense of better logistics and application of modern manual assembling tools. Introduction of new technologies, such as glass bonding, requires the change of assembling process which is realized on that work place. The application of a manipulator is frequent and the same ones are used for assembling of large and heavy sets (instrument panels, doors...). Robots are also used in the assembling process, for more complex operations and in large batches.

Fig.13 *Assembly line*

4. Virtual designing

Car industry had a plan to eliminate the manufacture of prototypes batch by using virtual designing and to go to production directly after the computer. What were the reasons for such optimistic expectations? The application of powerful computers, softwares for various purposes in the designing process as well as behaviour simulations were the causes for such expectations. The advantages of virtual designing are that the weak points on the construction are easily detected, e.g. contact points, see fig. 14. The detected point is either eliminated by modifying the construction or the conditions for undisturbed functioning are created.

Fig.14 *Modelling of the surrounding (car body)*

Big producers are leaving aggregates designing to collaborators nowadays. Conditions for installing are defined by the finalist. A collaborator is responsible for the success of his/her construction, such as fulfilment of valid regulations, elimination of all the errors in the batch and a guarantee period. The goal of each collaborator is to have his/her construction used in the first installing by which he/she acquires a reference, secure income and profit from the spare part. Along with the construction, calculations, i.e. simulations of certain processes, important for good operating of the vehicle, are realized, fig. 15. All technology departments are directly included in

the development process (manufacture of parts, safety, assembling, installing, quality, lifetime). Fig. 16 shows the simulation of the installation process, i.e. ergonomic studies at this work place.

Fig 15. *Simulation of seat frame behaviour*

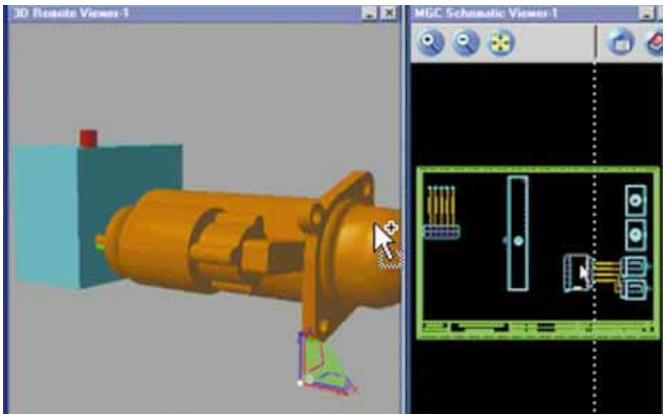

Fig.16 *3D model*

In this phase of the project, verification of technologic properties of the car part is necessary, as well as the construction of tools needed for manufacture of the car part. In addition to that, conditions of car part manufacture are simulated, especially for plastic parts, i.e. flowing process is simulated. Due to the stimulation of parts manufacture, it is possible to eliminate possible problems in this phase, i.e. to eliminate finishing works on the tool which could consume a lot of time.

Car industry strives to the production without the defective parts. For those reasons, the system of quality is getting increasingly greater attention. Advanced softwares are extremely useful in this process.

Company FIAT, as one of the leading companies worldwide, was the first to introduce a single model into a batch production (vehicle Fiat 500L), without manufacturing a batch of prototypes necessary for developmental investigations and project verification.

By the initiation of the production of model Fiat 500L, the new era in the batch car production began – introduction of the new model into the production without manufacturing a batch of prototypes.

In 2007, company FIAT started the production of model Fiat 500, and in 2012 the production of model Fiat 500L started. In 2013 a new model with seven seats was promoted, Fiat 500L trekking, a partially off-road vehicle.

The mark of both cars (500, 500L) indicates that these are two mutually connected models of vehicle, i.e. that model 500L was developed out of model 500.

For vehicle 500L, a concept of virtual designing was applied. According to information from company FAS site, the cancellation of batch of prototypes was accomplished due to:

- new architecture "Small Wide"
- thousands of hours of virtual simulations
- 200 tests of components and subsystems
- > 100 impact simulations
- > 100 impact tests.

It was not specified which subsystem tests were carried out and which were related to a car body, and in which phase of car body assembling. Over a hundred simulations of impact tests and a good basic vehicle were not sufficient to reduce the number of impact tests, which caused prolongation of the initiation of the production of the vehicle, modifications of the vehicle and increase of costs.

In the applied concept, the main project was handled by the finalist – starting with style, 3D forming, creation of a research, all the way to calculation and process simulation. The entire process was realized on the computer, by application of modern designing packages. The process was simplified by the fact that the data from project Fiat 500 were used (modified platform, developed and tested engine compartment etc.). In addition to all these advantages, over 1000 virtual simulations necessary in this phase of the project were realized. The processes of all simulations were probably shortened considerably, since no major problems were to be expected.

A modern designing process implies a complete responsibility of the finalist for the definition of the vehicle platform.

5. Conclusions

A new era began in the designing and development of vehicles – production initiation without a classic vehicle. Vehicle prototype was replaced by a test batch vehicle. Such a procedure probably shortens the time of new model initiation and reduces the development costs. Responsibility of the finalist is partly transferred to other participants in the production process (components producers, equipment producers etc.). In the following period, greater centralization of the development can be expected for some finalists.

6. Literature

[1] Milovanović M.: Designing of a car body, monograph, Faculty of Engineering, Kragujevac, 2013, ISBN 978-86-86663-993.