DESIGN PROCESS FOR A SINGLE-SEAT CAR BODY

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SHRNUTÍ

Článek představuje proces vzniku návrhu nového designu karoserie, který je postavený na podvozku sériového jednomístného vozidla Mitsuoka MC-1 při zachování veškerých funkčních prvků. Základním cílem bylo zlepšení ergonomických vlastností a zatraktivnění designu, který se zaměřuje na cílovou skupinu mladistvých. Pro získání přesných vstupních dat bylo využito metody optického skenování systémem ATOS II. Další fáze procesu vývoje nového designu zahrnují od skicování, následný převod a zpracování digitálního 3D modelu v prostředí Rhinoceros po 3D tisk modelu v měřítku 1:5.

KLÍČOVÁ SLOVA: CAD, DESIGN, KAROSERIE, SKICOVÁNÍ, SKENOVÁNÍ, RHINOCEROS, RAPID PROTOTYPING, 3D MODEL

ABSTRACT

The paper presents the design process of a new car body proposal which is built on the chassis and other functional groups from the Mitsuoka MC-1 single-seat production vehicle. The basic aim was to improve ergonomics and develop an attractive design focused on the target group of high school and university students. To acquire exact 3D data input, a method of optical scanning with the ATOS II system was used. The following phases of the project, starting with sketching, then digital 3D model development, and finally the 3D printing of a scale model are also described.

KEYWORDS: CAD, DESIGN, CAR BODY, SKETCHING, SCANNING, RHINOCEROS, RAPID PROTOTYPING, 3D MODEL

1. INTRODUCTION

A project concerning the designing (redesigning) of a new car body for a small single-seat vehicle has emerged at the Institute of Machine Design BUT making use of two of the mass production Mitsuoka Kit Cars mostly for tutorial reasons (testing of an engine, computing of basic parameters and exploring of uncomplicated techniques by students) with subsequent test drives. A major problem of poor internal space for the driver together with unsuitable ergonomics was obvious. Even with the smallest students driving with the seat right back, the space in area of the knees was highly insufficient. Additionally, students are not attracted by the outdated design that is also accented by unsatisfactory manufacturing details. This project was therefore an appropriate task for the Department of Industrial Design, which is part of the Institute.

The aim of new design was to create a car attractive to a target group of young people covering high school as well as university students, and to introduce adequate ergonomics. The new car body had to stay compatible with all functional parts such as the chassis, the steering and braking systems, and the engine with

FIGURE 1: Production design of Mitsuoka MC-1 with combustion engine (L × W × H 1755 × 1080 × 1455 mm).

OBRAZEK 1: Sériová podoba vozidla Mitsuoka MC-1 se spalovacím motorem (d × š × v 1755 × 1080 × 1455 mm).

all related controllers and systems. It also has to be economically acceptable for the production of two pieces.

The production version of Mitsuoka MC-1 (Figure 1) comes originally from Japan and as other similar cars that fall into a category termed "microcars", it is intended for transportation around urban areas. The 50 ccm combustion engine located in the back with a performance of 4 kW and total weight of 160kg falls within the Light Quadricycles category [1]. It has the advantage of allowing driving with the license type AM (minimum age of the driver 15 years) and further supports definition of the target group.

2. DESIGN PROCESS

Before starting the design process itself, an analysis of the target group had to be performed. In the next step activities towards gaining relevant input data were realized.

1.1 PROJECT TARGET GROUP

In order to achieve a suitable design that matches the wants and needs of our target group, a lifestyle research was essential. Our target group consisting of young people between 15–25 years old generally comes from the lower-middle social class background. In line with their current studies (education improvement) we can identify a gradual shift in their aesthetic taste towards that which is typical for a higher social class than the one from which they originate [3]. Such people are mostly characterized by an active lifestyle with a preference for a more lively and colorful design style, often playing around with surface or color patterns. The final design should also represent the Department, a Faculty and BUT. Therefore the identities of these institutions have to be considered.

On the basis of our own target group questionnaire and market analysis, a final concept was selected. For the purpose of using the microcar for fun in addition to practical use a mostly half-open concept was selected.

1.2 INPUT DATA

For the purpose of new design development it was necessary to obtain exact input data such as shaping and dimensioning of the chassis, the exact positions of connecting points for the car body and volumes with dimensions of other functional features connected to the chassis (fuel and oil tank, electronics, steering, dampers, etc.).

As already mentioned, the ATOS II scanning system was employed. To get a clear 3D polygonal model including complex shaping of the steel welded tube frame and the other above mentioned parts and connecting points, it was necessary to establish multiple projection of the scanned area from different positions. Consequently, all particular views were composed together by points of reference in order to acquire the entire model.

In the next step a NURBS model was created from the obtained polygonal model with regards to CAD modeling software Rhinoceros 4.0. With the help of supporting software Atos v6.0.2–4, intersections were created for all single elements of the polygonal meshes model with reference planes (Figure 2). The resulting NURBS spline curves were used together with NURBS approximated primitives for the blending of non-complete surfaces such as radiuses originally deformed by bending during production (is not possible to win approximated primitives).

The final input model was completed with other parts such as fuel tank, engine and controllers. Parts that were not, for various reasons, suitable for the ATOS scanning system were manually

FIGURE 2: Reference curves for the model completion were created by intersections of the polygonal model and reference planes (left). Completed digital 3D input model (right).

OBRAZEK 2: Referenční křivky byly vytvořeny pomocí průsečíků polygonálního modelu a referenčních ploch (vlevo). Vstupní digitální 3D model v konečné podobě (vpravo).

measured and modeled. The completed input model excluding some controllers is shown in Figure 2 right.

1.3 PROJECT DESIGN PROCESS

The importance of design in the automotive industry has significantly increasing in recent decades [2]. The responses of end users have led to market segmentation depending on social-economic background [3]. Therefore car manufacturers pay growing attention to the design process.

The common design process applied to a mass production car covers [4]:

- Sketching,
- Tape rendering (basic views of the vehicle are depicted with highly flexible tape) over engineering package (showing basic dimensions of functional parts such as the engine, steering, fuel tank, etc.),
- Clay-model at a scale of 1:4–1:5 (special clay that is plastic at temperatures around 50°C),
- Reverse engineering,
- Clay model based on PU armature made by milling machine, scale 1:1,
- Reverse engineering,
- Model 1:1 (laminated).

Due to a very limited budget and the characteristics of this design, the standard design process was modified in our case. The following procedure was applied:

A) CONCEPT SKETCHING

At the beginning of the project various styles and basic concepts were proposed without any limitations regarding the results of questionnaires and market research. Different ideas about folding mechanisms, kit car systems or creating a car body

based on using a textile (Velorex Oskar like) came up. One of the concepts is depicted in Figure 3. It utilizes the same body panel for both the front part and the back of the vehicle to limit production costs. Differentiation of both sides is achieved by different lights and by the steering column. The driving position is similar to a motorcycle. The style represents a crossover between an off-road quadricycle and a microcar.

B) CLAY MODELING

Financial limitations of the project along with a design style represented by thin surfaces instead of volumes typical for the automotive industry contributed to a low use of clay for design proposing. A few concepts were modeled at a scale of 1:10. In later phases the mentioned limitations led us to abandon the use of clay modeling.

C) SKETCHING

Despite the growth of digital technology, hand sketching is still one of the most common design tools. Sketching has been one of the most time consuming parts of the described design project. During this period all concepts arose on the basis of target group responses and the market analysis. At that stage one of the most challenging points was to create a design which optically constructs a mass decreasing gradually from bottom to top and does not look flat. This related to the proportions of the car – small in plan view with a height similar to standard cars.

Figure 4 above displays several thoughts concerning the main shaping idea in the front and rear part of the vehicle without deeper production technology or price level considerations. In the upper sketch on the left it is possible to recognize the first design features common with the final design (roofing and cockpit outer shaping). The bottom part of the figure depicts one of the moves closer to the final design. It mostly

FIGURE 3: Open concept based on duplication of car body panels at the front and back.

OBRÁZEK 3: Skica otevřeného konceptu založená na využití stejných panelů karoserie v čelní a zadní části vozu.

FIGURE 4: Concept and more detailed sketching.

OBRÁZEK 4: Volné skicování a detailní rozpracování konceptu.

resolves details in the back part and front lighting in order to achieve a homogenous aesthetic expression. This process resulted in two basic design concepts that from a proportional point of view promised a high-quality product; it was then time to move onto the next step.

D) DIGITAL 3D CONCEPTUALIZATION

Digital 3D conceptualization became a very important phase of the entire project. Due to the limited use of clay modeling, this step had to partly provide a perception of the real proportions of the model. This phase took place subsequently to after the creation of promising sketches. It gradually took over the leading role in the design process with increasing importance.

The transferring of previously sketched concepts brought us to the decision of choosing just one of them due to inadequate proportions. The selected concept was then further elaborated into a more accurate form.

Ergonomics was one of points tested during this phase. With the help of a dummy 3D model in accordance with SAE J 833a and VDI 2780, the position of the driver was easy to test. The dummy was also used in the interior to test comfortable reach of all switches and instruments, outside to check luggage hold availability and interior accessibility when boarding. Two heights of dummy were tested – 180 cm and 187 cm to reveal more about dimensioning limits and options.

E) DETAIL SKETCHING

This phase took place before and in parallel with 3D digital modeling, and the aim was to develop the comprehensive shaping of all details such as a bottom draining system lining, linking of front lights with the frame and plexiglass, cutlines execution, etc. One of the main goals was to bring together the shaping of internal and external surfaces. Because of developing the half-open

FIGURE 6: Testing of design ergonomics using a dummy.
OBRÁZEK 6: Testování ergonomie návrhu pomocí figuríny.

concept, the relationship between exterior and interior design has to be considered. This was achieved partly by the interlocking of the seat characteristic curves and surfaces that create fenders and continue further around the seat behind the driver.

F) DIGITAL 3D MODELING

In this phase the results of digital 3D conceptualization were further developed. Not only external shaping, but also the division into separate components and technological aspects (forming directions) came into consideration. The digital model takes into account external purchased parts such as lighting (Hella modules Premium) and rear view mirrors in this point. DZUS fasteners were chosen as connecting features for plastic parts.

After completion, consideration was given to technology, production, composition and supporting frames construction; the external shapes were completed by constructing shells in the case of plastic parts.

G) 3D PRINTING

We took the opportunity to use the previous digital 3D for production of the scale model as well. The model was made

FIGURE 5: A closer look at the shaping process for the back of the vehicle.
OBRÁZEK 5: Proces tvarování zadní části vozidla v prostředí Rhinoceros 4.0

FIGURE 7: Final design visualization.
OBRÁZEK 7: Vizualizace výsledného designu.

by FDM Rapid Prototyping technology on a printer Dimension SST 1200es located at the Institute of Machine Design BUT. The resulting parts at a scale of 1:5 are made out of ABS+ plastic (higher stiffness in the Z axis), wall thickness 1.5 mm.

3. RESULTS

The resulting design provides a solution for the internal arrangement of the driver area within the restrictions presented by the existing platform. Slightly shifting the position of the steering wheel (from an asymmetric position into the central longitudinal plane and equally sloped) and repositioning the gear lever from the left part of the dashboard to the left side of the seat have brought improved conditions, especially with respect to knee room (from a lack of space for all figures higher than 170 cm, to 15 cm of free space between knees and the knee blocker for the 180 cm high dummy). The dashboard was reduced and all switches and instruments were transferred into one zone that supports the intuitive behavior of the driver and are located in the direct visual field and below the cluster visibility line.

Also the seating quality now matches much closer norms ČSN 30 0720, ČSN 30 0725 [5] that regulate optimal seating position. This results from a reduction of the seat. The seat is newly integrated into the main part of the car body and has been downsized due to a reduction in upholstery not necessary for driving short journeys. A seating reference point located (or reflected point R) in the hip area has shifted downwards in comparison with the production version of the Mitsuoka MC-1 (X +44 mm, Z -114 mm, chair height 266 mm). This changes the angles that are defined by single body elements (the angle clamped by thigh and calf has improved from 87° to 100° even when comparing figures 175 cm – originally and 180 cm – newly). This also helps vehicle stability by repositioning the centre of gravity downwards.

Comparing with the production version of the Mitsuoka MC-1, the new design brings further advantages in the form of a mostly enclosed luggage hold that is placed behind the driver. Additionally there is also now another place for belongings in a new part of the dashboard.

In general the car body mass has been translated forward, the rear overhang is shorter whilst the front one is longer. Together with the shifted seating position it helps to improve ride qualities.

4. CONCLUSION

The final design depicted in Figure 7 corresponds with the input analysis and responses received indicate it is simultaneously attractive for the defined target group. However, the shaping could seem to be complicated, many surfaces are 2D designed only. It corresponds with the straightforward technology and the chassis construction, as well as with planned production technology.

Currently the above-mentioned scale model is in the last phase of production – the lacquering. On the basis of that the final decision regarding production will be taken. In the case of acceptance, we count on producing most of the parts by the method of direct lamination into one-piece negative forms, which is from a cost point of view the most suitable for the production of a small number. Included in the calculation is the hand finishing of parts with partly both-sides with visible surfaces.

LIST OF NOTATIONS AND ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
BUT	Brno University of Technology
CAD	Computer-Aided Design
NURBS	Non-Uniform Rational B-Splines
PU	Polyurethane

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