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THE CONCEPT AND 3D MODELING OF THE CAR BODY IN CATIA V5

Abstract: *Catia V5 is a reference program in the field of computer-aided design which offers an integrated solution, in addition to common solid-state modelling features characteristic to all representative applications. Furthermore, it puts at disposal stylistic modules available to specialists, allowing the development of computer usage even in pre-construction stages. This paper presents the main design steps and the 3D representation of a car body using the design leading software, Catia V5. Two subassemblies are considered, front part and passenger compartment. General considerations of surface generation in automotive car body design are highlighted. Sketching modules were used in order to create the conceptual sketch, in which the required geometries for the solids were drawn, the Part Design module, in which the solid parts of the car body were made, the Assembly Design module, the module in which the car body components were imported and assembled, the Sketch Tracer module, a module in which real-world scale shots are imported to create a custom concept, and the Freestyle module, in which the 3D lines of the car body were drawn, after which the areas for surface generation were filled.*

Key words: *car body, concept, surfaces, superstructure, substructure, Catia V5.*

INTRODUCTION. THE CAD CONCEPT

The concept is, generally, the root of the ideas, thoughts made by mental images that, in turn, are individual and processed by the human brain, the concept often defines an idea in management, science or technology [1].

In computer-aided design concept, the geometry of a product is composed of several basic elements (lines, curves, different types of surfaces and volume elements). Depending on the features of the virtual product model, these elements are combined, applying specific methods and strategies, called design rules [2].

Generally, a complex CAD assembly model such as a car body contains many components and modules that are structured into subassemblies and assemblies. Thus, the geometric representation of a car body, for instance, implies the specification and creation of complex curves, surfaces and solid bodies in a virtual CAD environment, using different geometry defining technologies, the most important being the approximation and interpolation.

The car body is the part of the car that, by design, takes over the tasks involved in assembling the vehicle, as well as the forces involved during its displacement.

Fig. 1 Hyundai Tucson conceptual sketch [6].

The car body is composed of the superstructure, the part containing its outer covering elements (wings, the boot lid, side panels) and the substructure, which contains the body frame and other stiffening elements in its structure [3], [4], [5].

The conceptual sketch represents the unfinished start-up sketch, the basic idea from which the future project starts.

Figure 1 illustrates the concept sketch of the Hyundai Tucson [6].

2. GEOMETRY AND SURFACES OF A CAR BODY

According to technical standards of some car manufacturers, a reference system materialised by three perpendicular planes is used in the construction of a vehicle, as follows: the vertical plane X is the plane of symmetry of the vehicle; the vertical Y plane is the frontal plane on the basis of which the driver's visibility degree is determined; Horizontal plane Z - vehicle support plane [7], [8].

In a classic representation, a car body diagram can be likened to a parallelepiped consisting of finite components which, by parameterization, can be transformed into curves and surfaces obtained by moving the generators according to certain laws.

Classical representation, based on analytical calculations, would be much more difficult, because in order to study these curves and surfaces, one needs their equations, that is, their analytical representations [9].

Analytically, curves can be described by implicit, parametric or explicit equations, depending on their type [10].

The explicit Cartesian equation of an elementary plane curve is $y = y(x),$ then implicit one is $F(x, y) = 0,$ while the parametric equations of the plane curve are:

$$\begin{cases} x = x(t), \\ y = y(t) \end{cases} \tag{1}$$

Regarding elementary spatial curves, they are defined as the set of points whose coordinates are continuous functions of a real parameter (t), which takes values in a I range:

$$\begin{cases} x = x(t) \\ y = y(t), t \in I \subset \Re \\ z = z(t) \end{cases} \tag{2}$$

The 3D surface is defined as the set of points whose coordinates are continuous functions of two real parameters, each taking values in a range:

$$\begin{cases} x = x(u,v) \\ y = y(u,v), u \in I_1, v \in I_2; I_1, I_2 \subset \Re \\ z = z(u,v) \end{cases} \tag{3}$$

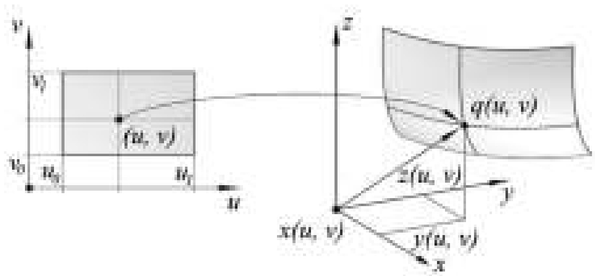

Fig. 2 Parameterization of a 3D surface [2].

It is also possible to express any rational and irrational parametric surface by an implicit or explicit equation, Figure 3, or to find interpolation formulas for various functions that define, as accurately as possible, the component surfaces of a car body, Figure 4.

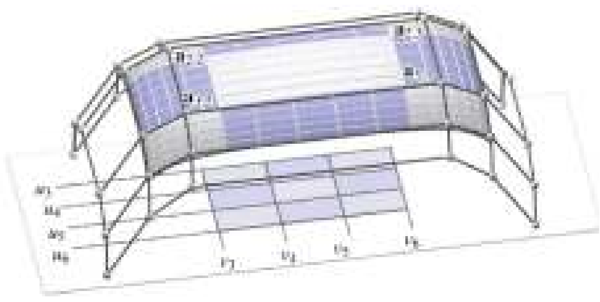

Fig. 3 Representation of an explicit NURBS surface (Non-Uniform Rational B-Spline surfaces) [2].

Figure 4 presents the Lagrange polynomial interpolation applied to multiple points, being defined as the sum of scaled basis polynomials.

The interpolation polynomial passes through all the points, and each scaled basis polynomial passes through its control point.

The Lagrange interpolation form of the polynomial is more preferred in theoretical arguments, especially that, every time a node changes, all Lagrange basis polynomials must be recalculated.

Since the mathematical solutions to represent a car body are relatively difficult to apply, the car body will be represented with the design leading software, Catia V5 [11], [12].

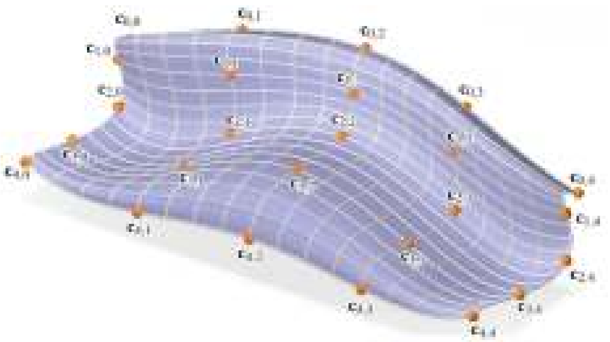

Fig. 4. Lagrange solution of bivariate interpolation [2].

3. MODELLING OF THE FRONT PART OF A CAR BODY

Modelling begins with the front part of the substructure, more precisely with the engine compartment of the car body.

The engine compartment is the front body assembly consisting of rigid components of the main substructure supporting the power train, with an important role in the moto-cooling fan, intake / exhaust system, mechatronic installations. The frame grinder, Figure 5, represent the roughest and heaviest part of the substructure. These are not righteous, their shape being chosen in order to provide optimal support.

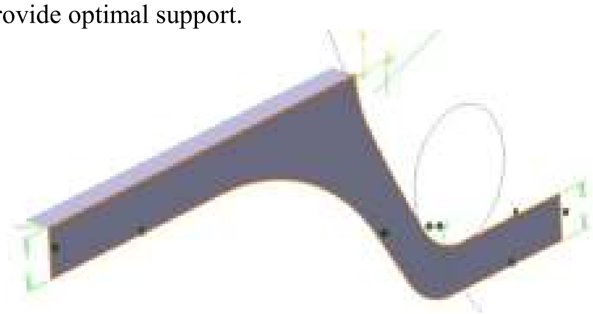

Fig. 5 The sketch of the semi-frame grinder.

After sketching the semi-frame grinder, in order to make it a solid, commands such as *Pad*, *Pocke*t, for cuts, *Hole*, to make boreholes, *Fillet* and *Chamfer*, used to obtain the junctions and chamferings, Figure 6.

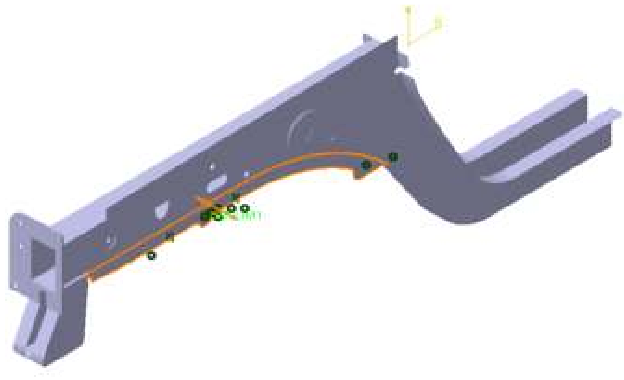

Fig. 6 Solid model of the semi-frame grinder.

The representation of the other 3D guide marks of the front axle was made in *Sketcher*, *Part Design* and *Assembly Design*.

After the frame grinder was build, the sketch of the bumper support and the drive train was attached, Figure 7.

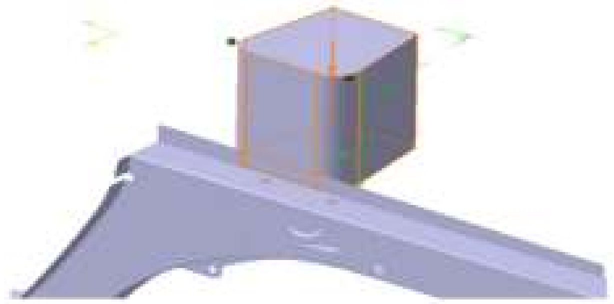

Fig. 7 Bumper support – sketch.

The special dome of the support is joined by the structure of the semi-frame grinder and the inner wing.

Thus, its sketch was drawn, after which the solid model was obtained, Figure 8.

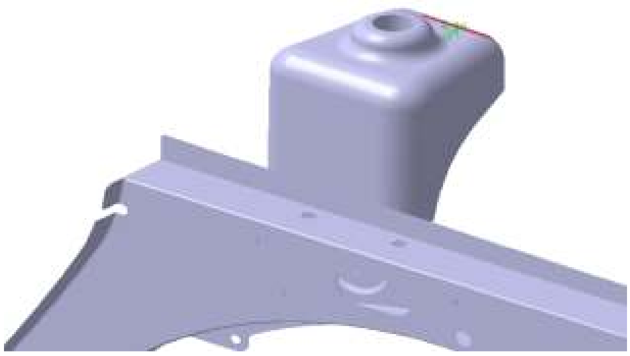

Fig. 8 The solid model of the bumper's support.

The inner wing is the component of the engine compartment substructure which supports the outer wing superstructure and it is attached to the support the bumper.

The rated distances for the inner wing are necessary, even to determine the size of the ground clearance of the vehicle and for the space required for wheel assembly and running, Figure 9.

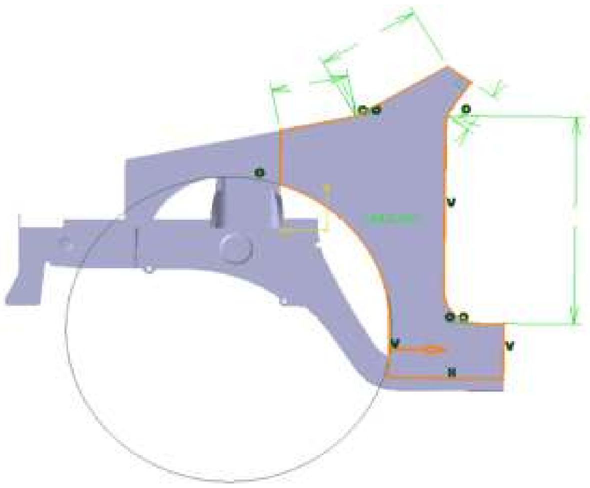

Fig. 9 The sketch of the inner wing and its drawing annotations.

After completing the inner wing sketch, the wing is no longer defined in the *Workbench* section, automatically being transposed into 3D, in order to be able to build the solid, Figure 10.

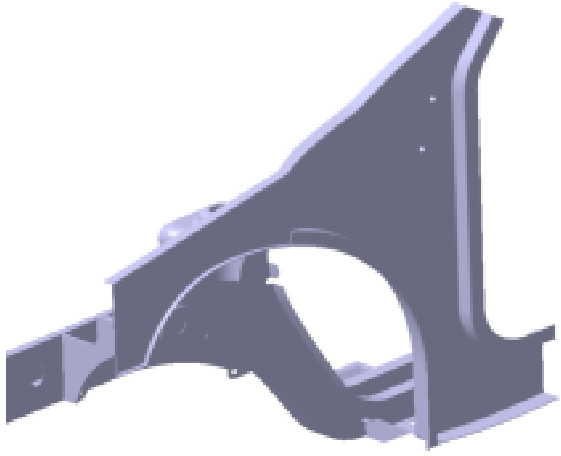

Fig. 10 Solid inner wing model.

After drawing and obtaining the two solid components, these will be mirrored with the *Mirror* option, with half of the rated distance, Figure 11.

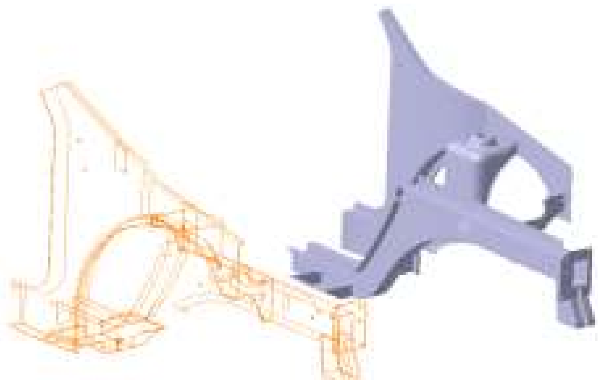

Fig. 11 Mirroring the solids.

For the engine-nacelle bracing compartment there is a crossbeam joining the two semi-frame grinders supporting the front wall (firewall), Figure 12.

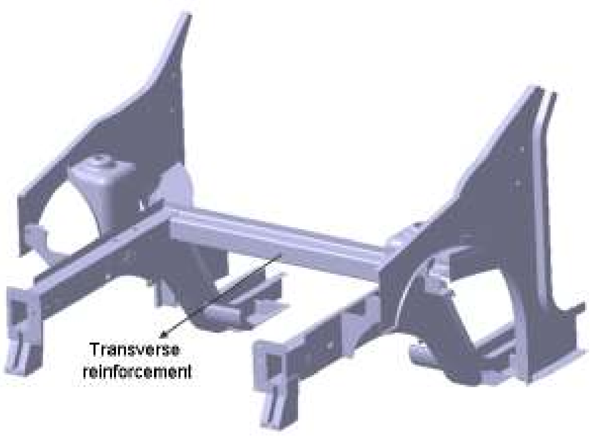

Fig. 12 The joining crossbeam of the semi-frame grinders.

After connecting the rigid crossbeam, the abutment of the engine will be established. Taking into account the transversal design of the power train, the support was placed on the right side. The engine support reinforcement is an element consisting of glued metal and rubber which supports the engine. It is fixed to a pan support, on which an element resembling to an arm is supported, fixed on the frame grinder, Figure13.

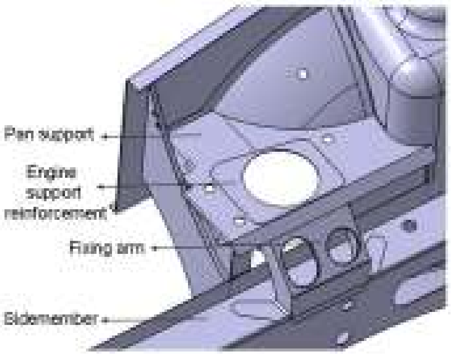

Fig. 13 Mounting engine support reinforcement.

The front passenger compartment wall is a dash panel, separating the engine compartment and the passenger compartment, with the primary role of passenger thermal protection. The wall contains numerous cuts in order to allow the passage for the auxiliary power panel wires, the clutch and acceleration wires, the steering column, or the central brake pump, Figure14.

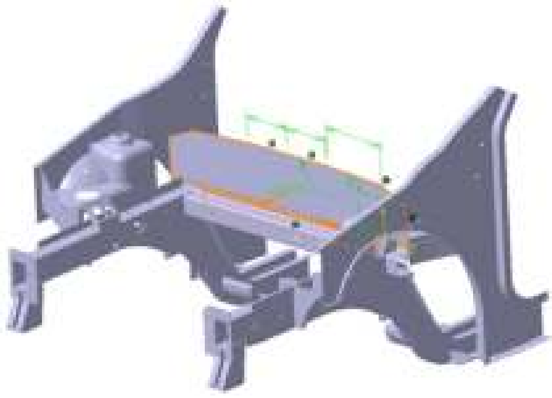

Fig. 14 Front passenger wall sketch.

After the sketching of the front wall, it was turned into solid. Cuts and joints were made on it, Figure 15.

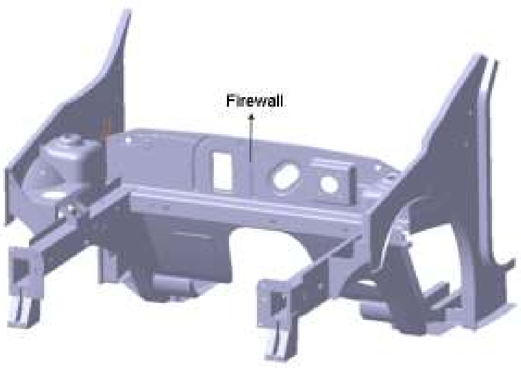

Fig. 15 Solid wall of the passenger compartment.

For better stiffening of the front wall, structural elements have been introduced, obtaining positive torsional stiffness and bending in the front part of the passenger compartment. This element is named *Deck,* which can be of different thicknesses, different material qualities and different profiles, Figure16.

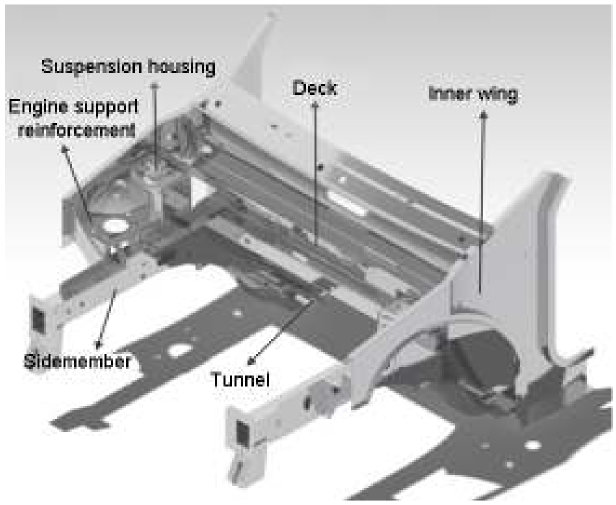

Fig. 16 Engine compartment.

4. MODELLING OF THE FRONT PART OF A CAR BODY

The intermediate component also includes the passenger compartment. The passenger compartment is the space allocated to the driver and passengers. In addition to the essential comfort that it must comprise, the passenger compartment also has a high safety level. The components of the passenger compartment are: the floor; side frames (side walls); the dome (the roof); the front wall; the back wall. Frame-chassis base frame is an assembly of beams interlaced with each other, with the main role of supporting the car body and absorbing the stresses encountered in motion. As a constructive solution, it can be considered as consisting of three beams arranged under the main parts of the superstructure (front / rear consoles and passenger compartment).

The frame is located below the passenger compartment, located slightly below the console frames, with the goal of lowering the barycentre of the car.

The next component that is assembled above the frame is the pedal panel, Figure 17.

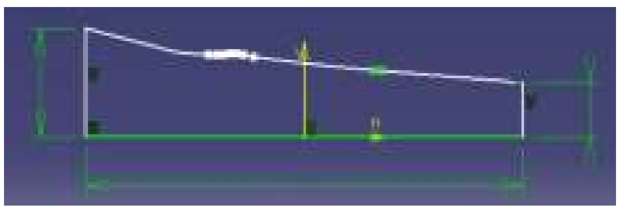

Fig. 17 Sketch of the pedal panel.

In this concept were reproduced 2 types of panels, one being the primary or the pedal panel, the other being the intermediate panel, which connects the primary floor with the last beam of the frame.

After drawing out the sketch, extrusion commands were used - *Pad*, for cutting - *Pocket*, joining and chamfering commands - *Fillet* and *Chamfer*, clipping commands on a desired trajectory - *Slot*.
Thus, the model of the pedal panel, Figure 18, was built.

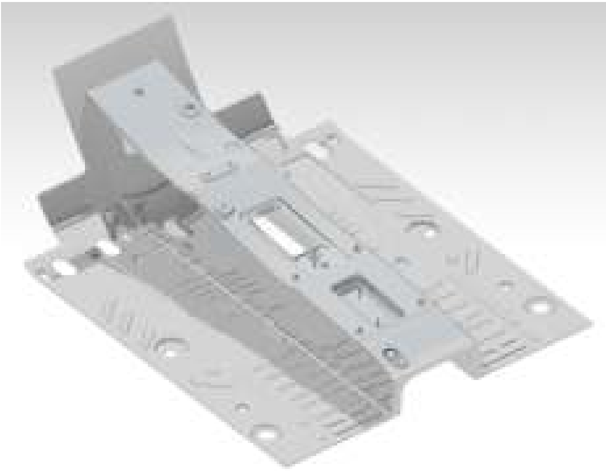

Fig. 18 Pedal panel.

After the assembly of the main floor, it can be assembled with the chassis, together forming the floor of the car, Figure 19. The floor represents the component of the load bearing base, obvious in the case of self-supporting car bodies. The components were assembled using the *Assembly Design* mode via *Snap* and *Smart Move* constraint commands.

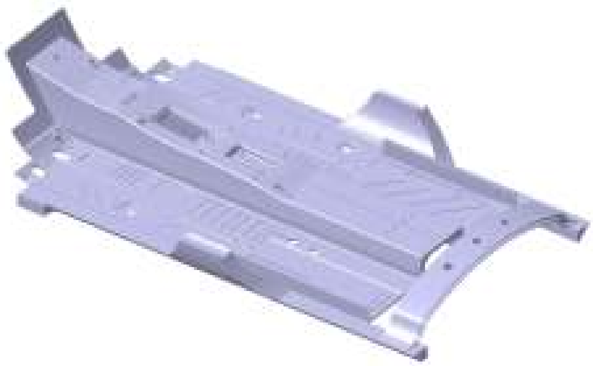

Fig. 19 Body bottom.

The side frames of the vehicle are made up of lateral pillars of the car body. The pillar profile consists of two combined panels which in turn form the lateral frame of the car body, Figure 20.

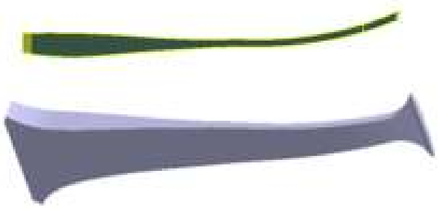

Fig. 20 The sketch and the solid resistance pillar.

The roof of the car body, along with the structure of the side frames, have a great influence on the body in the event of overturning, Figure 21.

Due to the tilting of the side walls, the windscreen and the rear window, to provide an aerodynamic shape, the shape of the roof is much lower, which owes its stiffness. The outer form of the roof should have a slightly convex shape to reduce noise and vibration.

Fig. 21 Frame of the roof.

To build the superstructure, use the Sketch Tracer module from Catia and the *Freestyle* module. The *Sketch Tracer* is a Catia tool that can import a new concept of a car body in 3D. You can position different sketch views in 3D with other modules, or you can draw 3D sketches of the desired pattern, Figure 22.

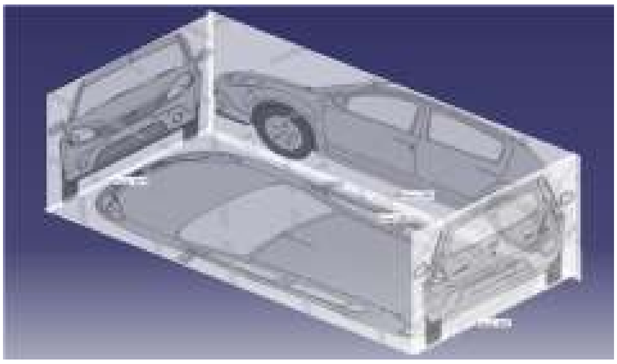

Fig. 22 Location of car body sketches.

Thus, after placing the sketches in the respective module, the rear console superstructure will be contoured with the *Freestyle* module. After importing sketches into *Sketch Tracer*, the *Freestyle* module will start. For contouring, use the *3D Curve*, keeping track of the shapes from the sketches, Figure 23.

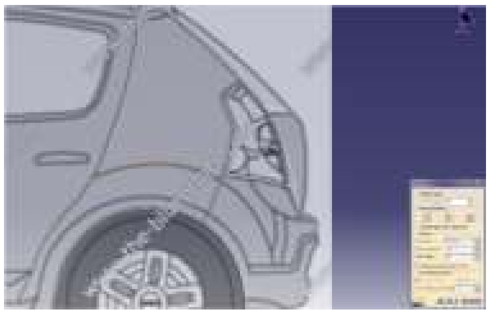

Fig. 23 Shaping the rear console.

The pattern resulting from contouring can be seen in Figure 24.

Fig. 24 Resulted contour.

Once the contouring process has finished, the resulting pattern will be filled with surface filling tools. Thus, the model generated by contour drawing and surface filling was obtained, Figure 25.

Fig. 25 Rear car body console.

Thus, after generating the body parts, the *Assembly Design* module was used to assemble and the model of the car body was finally generated, Figure 26.

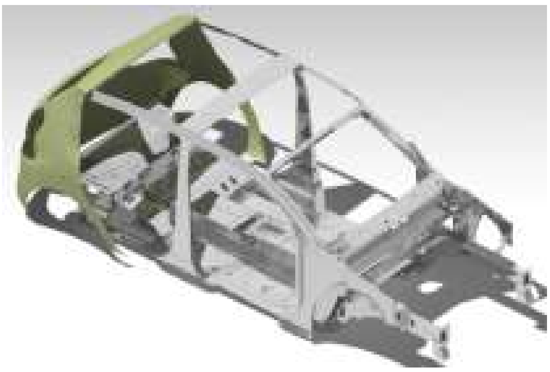

Fig. 26 Substructure and superstructure of the car body.

5. CONCLUSIONS

The following conclusions can be drawn from the paper:
- From the concept phase, the car body needs all its constructive parameters defined, based on precise mathematical calculations that sometimes are difficult to apply or require increased data processing time;
- An alternative, rapid, solution for building a bodywork through the aided modeling software Catia V5 is presented, manifesting a great contribution on the efficiency of the modeling process through the optimization and adjustment of the calculation parameters;
- For reasons of trade secrets, as a set of techniques, procedures and know-how elements based on which the car body components were designed, data containing numerical and dimensional values of the previously submitted landmarks could not be presented.

ACKNOWLEDGEMENT

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