Gabriel Marcel BOGHIAN, Nicusor BAROIU

GRAPHICAL REPRESENTATION OF A HYBRID-AIR VEHICLE USING CATIA V5 SOFTWARE

Abstract: *Development and implementation of alternative solutions in vehicles propelled by internal combustion engines are made by creators of technology and environmental planners only through technical information and rigorous technical calculations applied from the design stage. In this context, Hybrid-Air vehicles are gaining ground being supported by environmental policies for reducing emissions and the fuel consumption, addressing at the same time issues of global warming and global dependence on oil. This paper describes the procedure to graphically represent a vehicle using Hybrid-Air technology with the help of Catia V5 software.*
The way in which this system can be graphically represented is presented step by step; its solid foundation is represented by engine and transmission calculations performed in Mathcad and Mathconnex.

Key words*: HYBRID AIR, transmission, pneumatic-hydraulic converter, CAD, Catia V5, Mathcad, Mathconnex*

1. INTRODUCTION

2016 is considered for the automotive market the third consecutive year of consistent growth (+17.8%), with a sales volume of over 142,000 units, according to APIA - The Automotive Manufacturers and Importers Association [1]. Across the market, total deliveries of motor vehicles (cars + commercial vehicles) recorded in the first two months of 2017 an overall increase of 15.1% compared to the same period in 2016.

In terms of electric and hybrid cars [2] - (BEV - Battery Electric Vehicle, EREV - Extended Range Electric Vehicle, PHEV - Plug-in Hybrid Electric Vehicles), their share continues to grow, registering in the first two months of 2017, a 1.7% share of the total market. Even though the volumes are still small, increases are significant (electric vehicles +125%, and hybrid vehicles +212%) and show there is an important potential for growth of this category of cars that should be encouraged.

In this context of future strategies to reduce emissions, new working methods are tried, from the optimization of existing engines, up to the development of revolutionary technologies, such as HEV - Hybrid Electric Vehicles.

A hybrid vehicle is a vehicle that uses multiple propulsion systems, compared with the conventional ones, which contain only propulsion of internal combustion engine. A proposal for a hybrid technology, which, instead of batteries, uses the compressed air solution, is that of the PSA Concern (Citroen-Peugeot) that conceived in 2010 an engine based on two technologies already used – hydraulic system and gasoline engine [3].

2. HYBRID-AIR SYSTEM

Hybrid-air system is revolutionary because it significantly reduces the level of pollution and increases energy resources saving.

This paper presents the procedure for making the graphics of a car using Hybrid-Air technology with the help of Catia V5 software [4].

It shows, step by step, the way to represent graphically such a system, with the solid foundation of engine and transmission calculations made in Mathcad and Mathconnex.

Hybrid Air system means the combination of a gasoline engine and a propulsion system based on compressed air, and consists of a gasoline engine, an air compressor, a hydraulic pump (having the role of a propulsion engine powered by compressed air) and transmission, Figure 1 [5].

Fig. 1 The Hybrid-Air Car [5].

Heat engine, hydraulic pump and the gearbox are placed at the front, as in the case of an ordinary car while the central tunnel hosts the main compressed air tank (together with the air compressor); at the rear, next to the fuel tank, a secondary air receiver is placed, Figure 2.

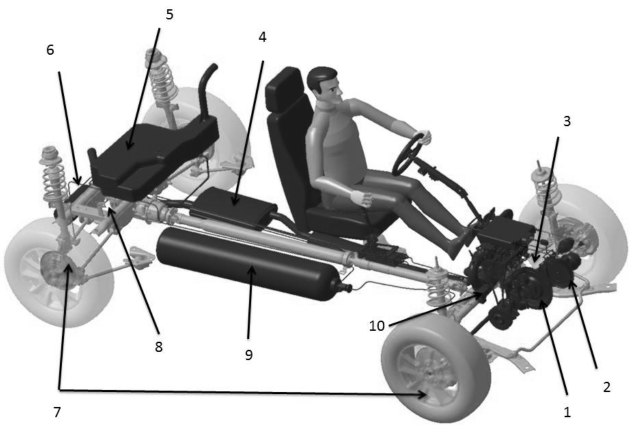

Fig. 2 The hybrid-air system: 1-clutch, 2- rotary hydraulic motor, 3-gearbox, 4-exhaust system, 5-gasoline tank, 6-extra air tank, 7-car decks, 8- pneumatic-hydraulic converter, 9- main air tank, 10-air compressor.

3. HYBRID-AIR VEHICLE MODELLING

3.1 Modeling the drive mechanism and transmission

To simulate the drive mechanism, calculations were made for its sizing; for the calculation of the clutch and of the gearbox, Mathcad and Mathconnex software programs have been used.

The internal combustion engine presented has 3 in-line cylinders and a cylinder capacity of 1000 cm^3 and 52CP.

Crankshaft modelling also involves the drawing of the oil ducts, followed by the drawing of bushes, connecting rod and piston.

For the positioning of components, the *Cumulative Snap* control was used in *Assembly Design* module, Figure 3.

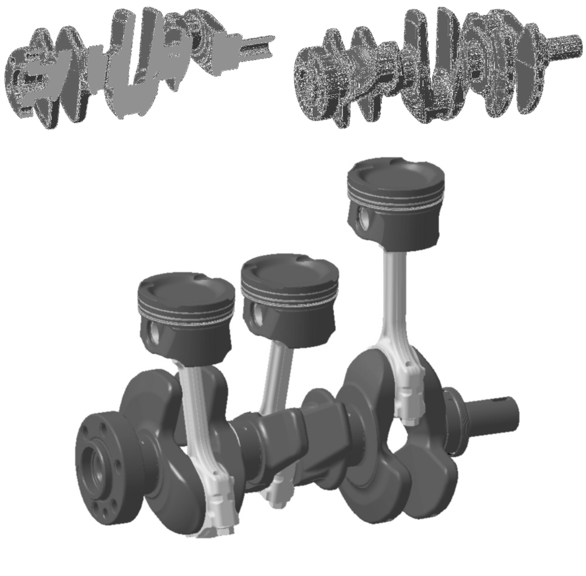

Fig 3. Drive mechanism.

3.2 Representation of gas distribution system

To obtain the distribution mechanism it was necessary to prepare a wireframe drawing, where local axes systems for the main components, such as camshafts, valves, latches and camshafts pinions were inserted, Figure 4.

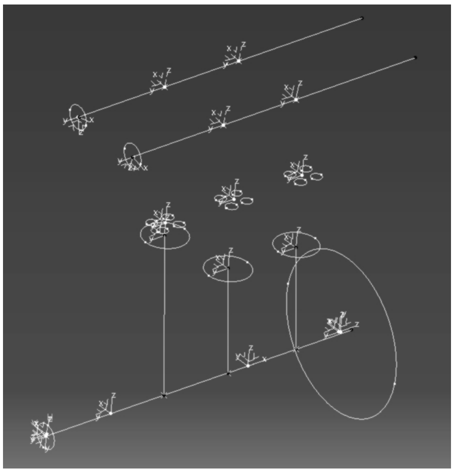

Fig 4. Wireframe drawing for the distribution mechanism.

This method of representation is safe and effective, because it contains all reference systems and allows easy assembly of all parts.

After creating the outline, camshafts are represented; they are obtained by extruding a 240 mm cylinder and subsequently inserting a new *Body,* in which cam profile will be represented. After accessing the command *Rectangular pattern*, the camshaft is obtained, Figure 5.

.

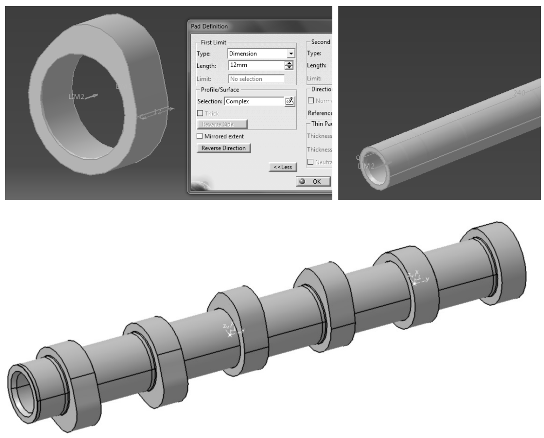

Fig 5. Camshaft.

The representation of valve is based on the realization of a drawing in which it is drawn half of the profile; then by applying *Shaft* control the valve in Figure 6 is obtained.

Fig 6. Valve.

The latch mechanism is similarly represented due symmetrical elements allowing the frequent use of *Shaft* control. Suction valves have blue coloured springs, exhaust valves have red springs, valve disk being larger in diameter for a quick exhaust of flue gas, Figure 7.

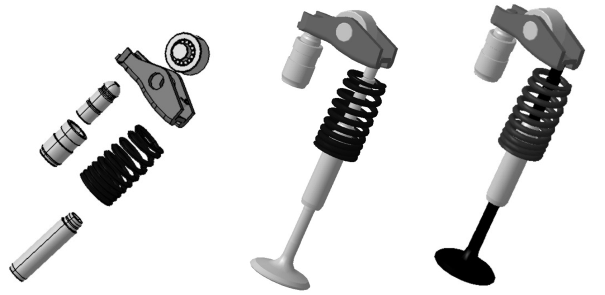

Fig 7. Mechanism of latch - suction and exhaust valve with rocker actuator.

After representation of all parts, it is performed their multiplication using *Rectangular Pattern* control and their placement in the operating position using *Cumulative Snap* control selecting, in advance, *Snap Automatically to Object,* Figure 8.

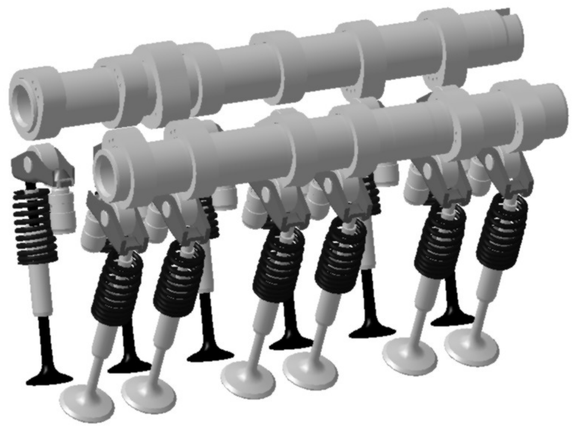

Fig 8. Flue system representation.

To represent the catalyzer, the same representation method was used based on a wireframe drawing, divided into areas, in the *Generative Shape Design* module.

Using polylines, catalyst route has been achieved, the lines having the role of *Coupling Elements* for *Multi Section Surface* control.

Then, local axes systems were created for Lambda sensors location, Figure 9.

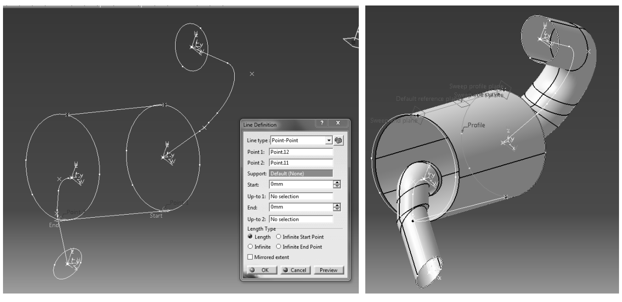

Fig 9. Primary elements for the representation of the catalyzer.

After applying the finishing operations by *Bump* and *Close Surface* operators, it is initiated a routine to convert the surface into solid, *Thick Surface* control, Figure 10.

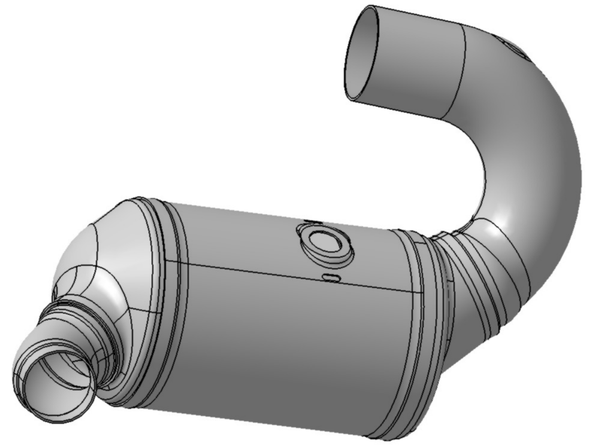

Fig 10. Catalyzer.

To achieve the flue gas collector, it has been proceeded in the same way as for the catalyzer, working in the *Shape Design* module, and obtaining the collector in the form shown in Figure 11 using *Multi-Section* control.

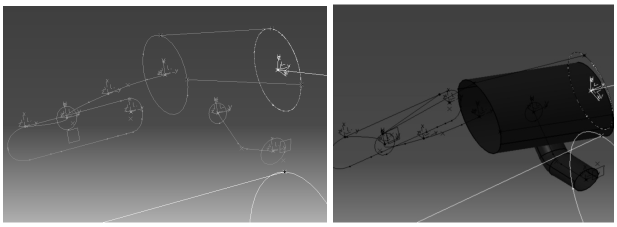

Fig 11. Primary elements for representation of the collector.

To finish the flue gas collector *Thick Surface* control has been used to achieve a solid; then, using *Part Design* module, all connections and coupling sides were completed, Figure 12.

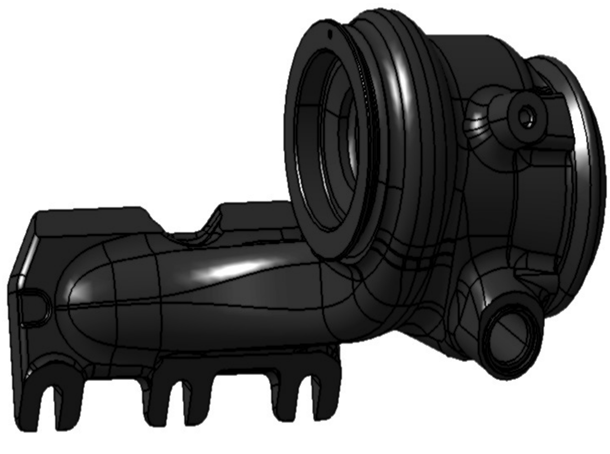

Fig 12. Collector.

Wireframe drawings were used to achieve all parts, to have the most complete picture possible of the engine.

Thus, in a similar manner, the combustion chambers and suction screen were achieved.

All subsystems were assembled using *Cumulative Snap* and *Snap to Object* controls in *Catia DMU Space Analysis module*, resulting in the engine in Figure 13.

.

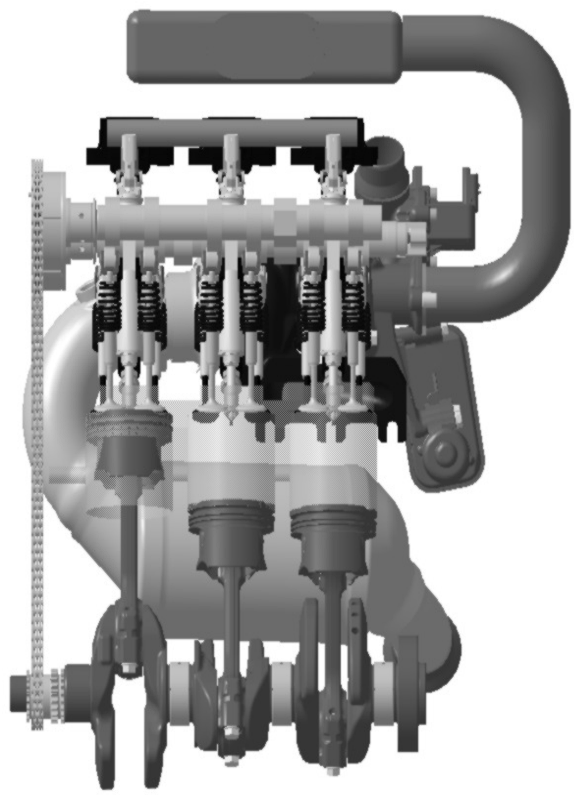

Fig. 13. Engine assembly.

3.3 Calculation, dimensioning and 3D representation of the clutch and of the gearbox

For the calculation of the clutch, Mathcad program has been used [6]. Mathcad is a professional software tool, manufactured by Mathsoft company, dedicated to carrying out mathematical calculations with particular application in technique, Figure 14.

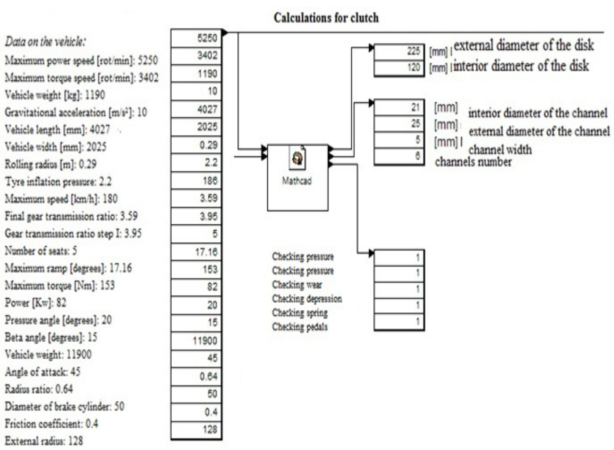

Fig 14. Mathcad calculation block defining the clutch.

Based on clutch dimensioning, its graphic representation is performed in Catia, in several stages, starting from the representation of the flywheel, pressure plate and thrust washer. Their assembly is performed with the *Assembly Design* module, Figure 15.

Calculation and dimensioning of the gearbox were made with the help of Mathconnex [7] software package, using Mathcad files.

In the work area the two Mathcad calculation blocks are inserted where calculation was carried out, and arrows are assigned to them - input and, respectively, output arrows - "*in/out*", to make connections with the other elements of the calculation block, Figure 16.

Figure 17 shows calculation elements of the gearbox, with insertion in Mathconnex file of operators for input parameters, numbered with *in0...inX*, in Mathcad.

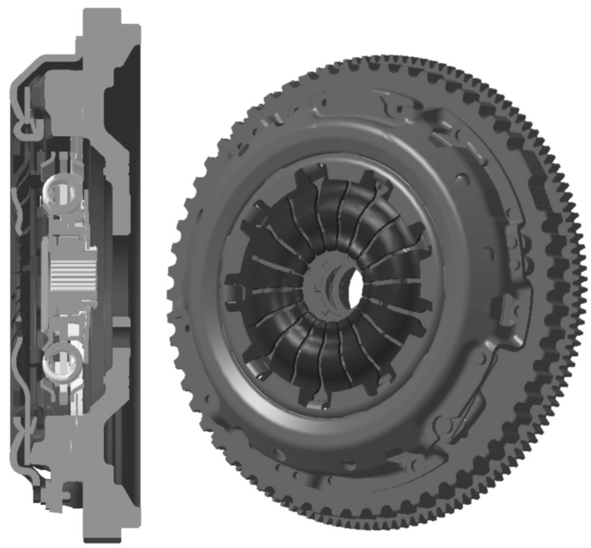

Fig. 15. Clutch image.

The results of the mathematical calculation were transposed into the 3D environment.

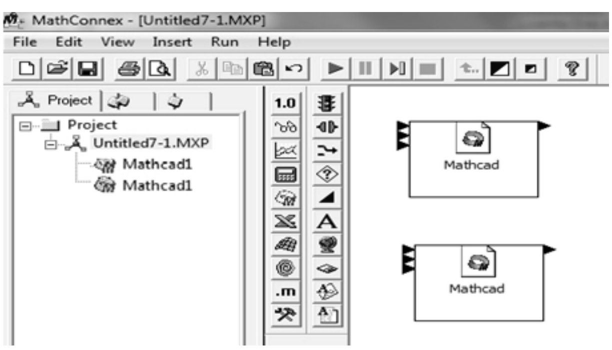

Fig. 16 Mathconnex work space.

To achieve the gear wheels *Solidworks 2014* [8] software package was used because it has a module for the sizing of gear wheels, thus resulting in a technically correct design.

The first step was to draw shafts in *Catia* and to associate them with the drawings corresponding to the diameters of the gears, Figure 18.

$M_m := A_{13,0}$ [Nm maximum torque of engine]

$i_{cv1} := inl_{0,0}$ [Gear transmission ratio for step I]

$\eta_{cv} := 0.94$ Gearbox yield

$P := A_{14,0}$ [kW] · Nominal output power

$n_{max} := A_{0,0}$ [rot/min] · Maximum power speed [rot/min]

$n_1 := \frac{n_{max}}{i_{cv1}}$ $n_1 = 1.517 \times 10^3$ [rot/min] Pinion speed at step I speed

$\alpha'_n := A_{15,0}$ (degrees) Dividing inclination angle STAS 821-82

$\alpha_n := \alpha'_n \cdot \frac{\pi}{180}$ $\alpha_n = 0.349$ [rad]

1.1 Determining the module

$M_s := M_m \cdot i_{cv1} \cdot \eta_{cv}$ $M_s = 497.6172$ [Nm]

$$m_{np} := \mathrm{floor}\left(1.27409306824538 + 3.52367088847428 \cdot 10^{-7} \cdot M_s^2 \cdot \log(M_s) + 6.80226790397718 \cdot 10^{-3} \cdot \frac{M_s}{\log(M_s)}\right)$$

$m_{stas} := (1.75\ \ 2\ \ 2.25\ \ 2.5\ \ 2.75\ \ 3\ \ 3.5\ \ 4\ \ 4.5\ \ 5)$

$$m_n := \left| \begin{array}{l} i \leftarrow 0 \\ \text{while } m_{np} > m_{stas_{0,i}} \\ \quad i \leftarrow i + 1 \\ m_{stas_{0,i}} \end{array} \right.$$

$m_n = 2$

Fig 17. Mathconnex calculation block for the gearbox.

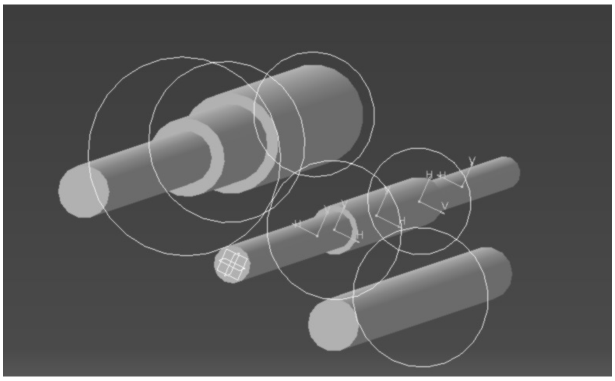

Fig. 18 Drawings for the gearbox shafts.

Sized gear wheels and shafts will be assembled respecting their ratio of transmission, Figure 19.

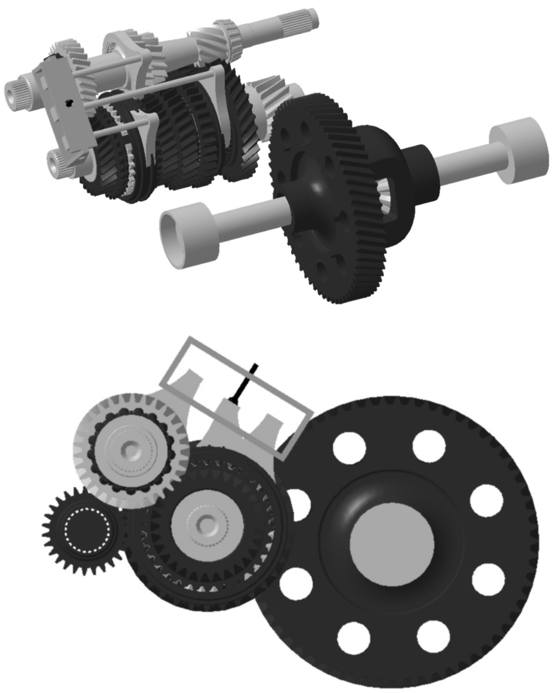

Fig 19. 3D representation of the gearbox.

Rotary hydraulic motor is put into operation by fluid energy transmitted through the pneumatic-hydraulic converter that, acting on the gearbox shaft, will convey in its turn energy to the wheels, through the planetary gears, Figure 20.

The representation of the drive mechanism, clutch and gearbox is finished with the assembly of all parts using the *Assembly Design* module, *Cumulative Snap control.*

To make the assembly, the gearbox shaft axis & crankshaft axis - Figure 21, will be selected, followed by the association of coaxiality of the other components, resulting in the drive mechanism–transmission ensemble, Figure 22.

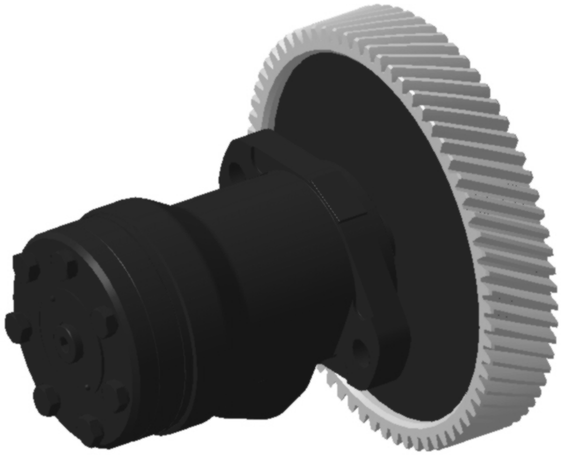

Fig 20. Representation of rotary hydraulic motor.

According to technical standards of various car manufacturers, when a vehicle is built the reference system used is that of PMF cars (live front axle) 4x2 or 4x4; it is materialized in thee perpendicular planes.

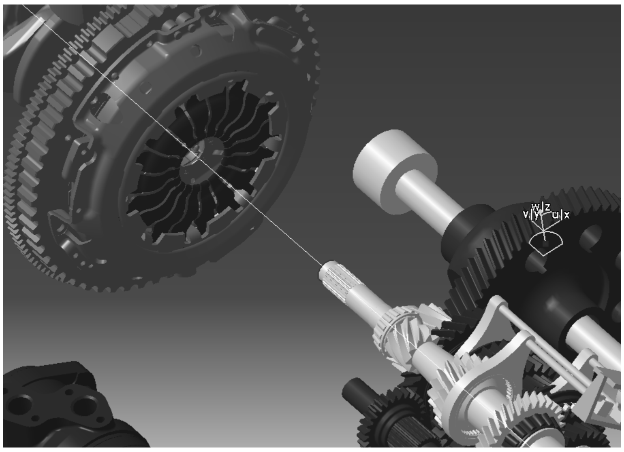

Fig 21. Assembly through Cumulative Snap control.

These perpendicular planes are, Figure 23:
- *Vertical plane X*, which is the plane of symmetry of the vehicle;
- *Vertical plane Y* - it is the foreground plane, based on which it is determined the driver's degree of visibility;
- *Horizontal plane Z* - it is the support plane of the vehicle.

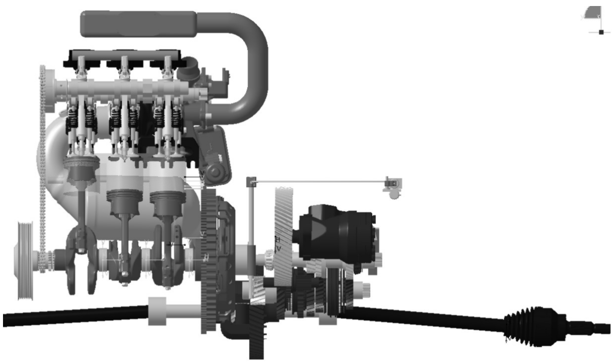

Fig 22. Drive mechanism and transmission assembly.

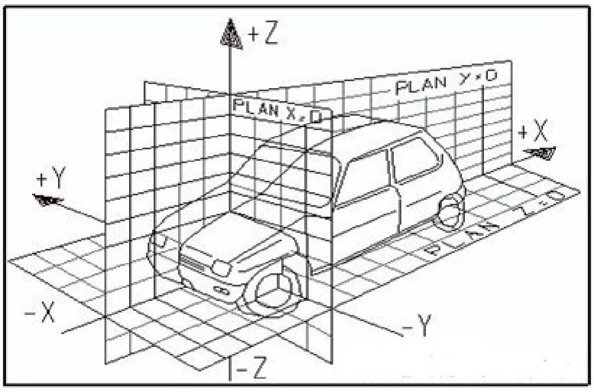

Fig 23. Reference systems - PMF cars [9].

To represent the hybrid vehicle the rules for positioning (setting) of the powertrain (GMP) must be established, considering that the vehicle shown has 4x2 traction PMF (live front axle). In these conditions, the positioning of the drive mechanism will be made in a vehicle reference frame.

Vehicle reference frame is a coordinate axes system around which the entire vehicle is modeled, starting with the tilting of motor 8 degrees to the driver, Figure 24.

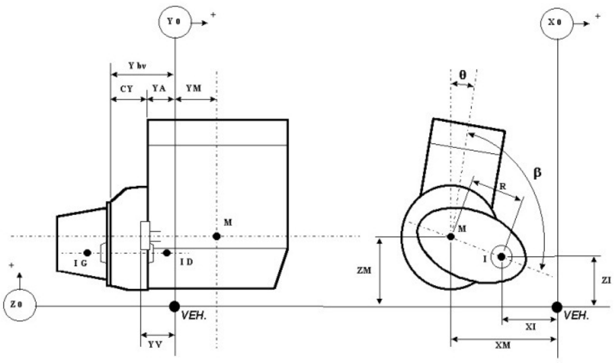

Fig 24. Positioning scheme (setting) of GMP.

Flue gas exhaust system is composed of a car exhaust pipe and 2 mufflers, the intermediate muffler and final muffler. The representation of the two mufflers was made in *Sketcher* module, by outlining an ellipse, to which *Pad* control is subsequently applied, to extrude the profile previously drawn. By applying finishing operations in *Part Design* the housing of the center muffler will be obtained, Figure 25.

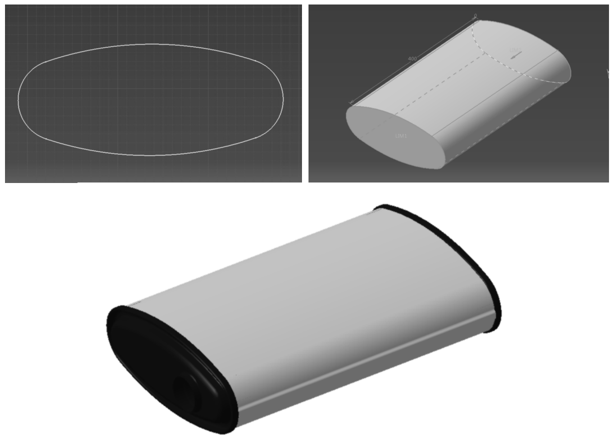

Fig 25. Center muffler.

The same will be done for the representation of the final muffler; to achieve the connecting conduits between mufflers a local axis system will be inserted; then extra points will be placed, using *Point* control, defined through coordinates from the origin of the local reference system.

The points will be joined by a polyline, to which *Sweep* control will be applied, Figure 26.

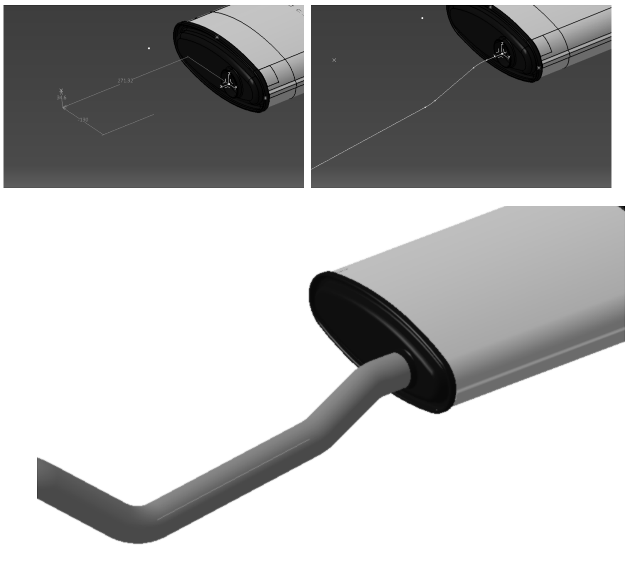

Fig 26. Connecting elements - center muffler –final muffler.

The propulsion of the hybrid air vehicle can be performed in two ways: the first is to use an internal combustion engine [10], and the second is to use a rotary hydraulic motor supplied by two air receivers, after conversion of pneumatic energy into hydraulic energy by means of the converter [3]; both are represented graphically in Figure 27 and, respectively, Figure 28.

The hybrid air propulsion system works as follows: the internal combustion engine is stopped and it pushes the air from the combustion chamber to the air compressor that feeds the main air tank.

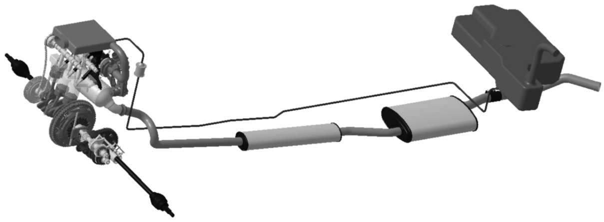

Fig 27. Propulsion system using MAI.

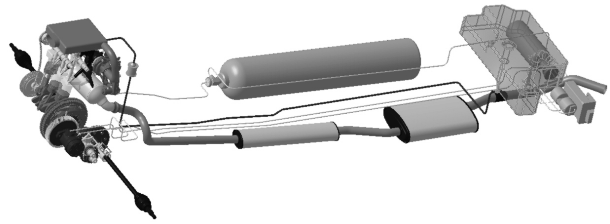

Fig 28. Hybrid air propulsion system.

In its turn, it conveys air to the pneumatic-hydraulic converter, where it transforms pneumatic energy into hydraulic energy that reaches the rotary hydraulic motor and ensures vehicle propulsion.

In order to represent the steering column, pedals and all controls that form human-machine interface (HMI) *Human Builder* branch from the *Ergonomics design & Analysis* module has been used.

This module allows you to create a mannequin with which you can simulate the natural position of the driver by using the *Posture Editor* controls in order to manipulate the mannequin's limbs, Figure 29.

Using wireframe drawings, connecting elements were built to define the speed-change gear and the connecting cables, Figure 30.

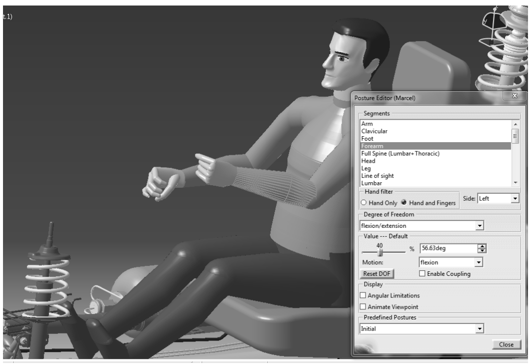

Fig 29. Mannequin.

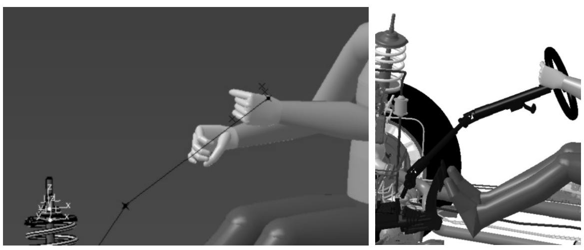

Fig 30. Wireframe drawing defining the speed-change gear and the connecting cables.

Representation of the speed-change gear and of the connecting cables

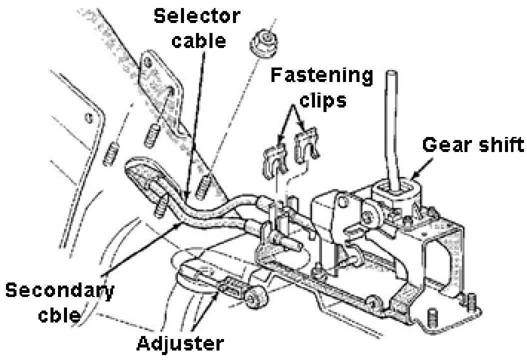

Fig 31. The structure of the gearshift [10].

In order to represent as closely as possible the principle of operation of the gear mechanism, the mechanism in Figure 31 was used as a reference.

In *Part Design* module each part of the shifting mechanism was achieved, and then, the assembly was finalized in the *Assembly Design* module*,* Figure 32.

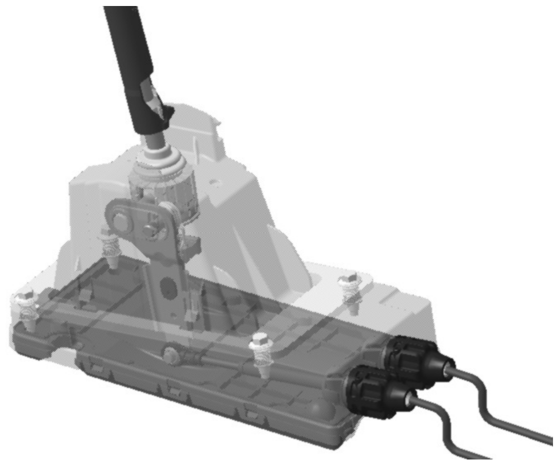

Fig 32. The gearshift– 3D model.

To draw the cables it has been used a punctiform network, similar to those in Figure 26, while cables have been outlined using polylines; then, they have been transformed in solid using *Thick Surface* control, Figure 33.

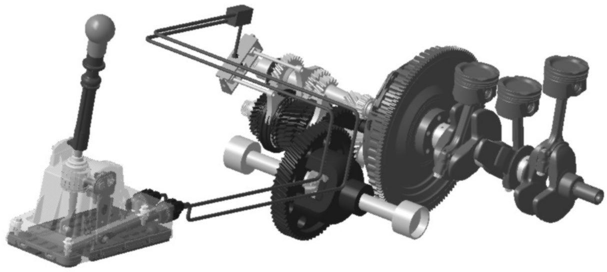

Fig 33. Gearshift-gearbox assembly.

The last steps to achieve the vehicle involve achieving the driver's seat and of the fuel tank, components drawn in *Part Design* module and obtained by extruding *Sketches*.

A profile of the vehicle body was also defined, Figure 34-35.

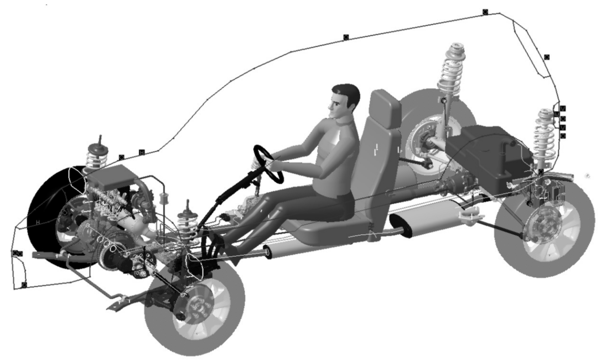

Fig 34. Vehicle with hybrid-air system.

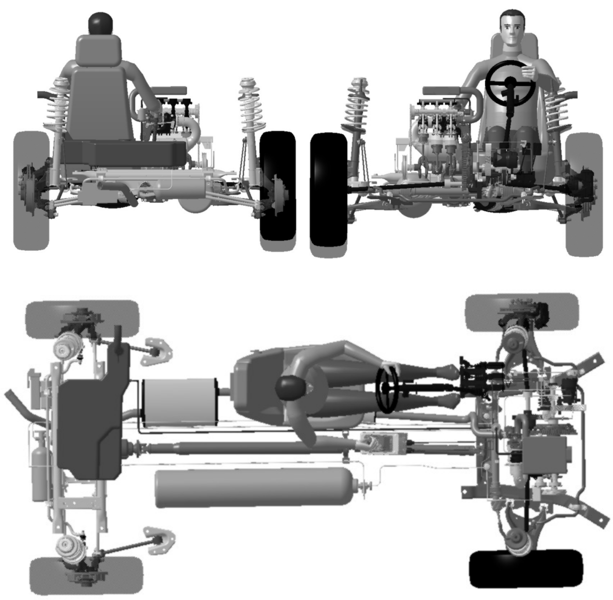

Fig 35. Vehicle with hybrid-air system – front-rear-top view.

4. CONCLUSIONS

Graphical representation of Hybrid-Air vehicle using CATIA V5 software, was based on the parameterized decks of a Dacia Duster car, while drive mechanism and transmission were drawn based on mathematical calculations and rigorous analysis in terms of organology and efficiency.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS – UEFISCDI, project number PN-II-RU-TE-2014-4-0031.

REFERENCES

[1] *http://www.apia.ro/informatii/comunicate-de-presa/, Accessed:* 2017-03-13.
[2] *https://shockingsolutions.wordpress.com/2009/05/28/hybrid-phev-hev-bev-what-does-it-all-mean/, Accessed:* 2017-03-13.
[3] *https://www.groupe-psa.com/en/newsroom/automotive-innovation/hybrid-air/, Accessed:* 2016-03-10.
[4] *www.3ds.com, Accessed:* 2016-03-10.
[5] *http://www.popsci.com/article/cars/car-runs-air, Accessed:* 2017-03-18.
[6] *http://www.mathcad-store.co.uk/, Accessed:* 2017-03-18.
[7] *http://mathconnex.com/, Accessed:* 2016-03-10.
[8] *www.solidworks.com, Accessed:* 2016-03-10.
[9] *http://vaie.vn/wp-content/uploads/2016/09/Reference_vehicle_3D.jpg, Accessed:* 2017-03-13.
[10] Fratila, Gh., Fratila, M., Samoila, Şt. (1998). *Automobile - cunoaştere, întreţinere şi reparare (Automobiles - knowledge, maintenance and repair),* Didactic and Pedagogical Publishing House, R.A., Bucharest.

Authors:

Student Gabriel Marcel-BOGHIAN, Department of Automotive Engineering, Faculty of Engineering, "Dunarea de Jos" University of Galați, E-mail: boghian.marcel92@yahoo.ro, tel.0040752545770.

Assist. Prof., PhD. Nicusor BAROIU, Department of Manufacturing Engineering, "Dunărea de Jos" University of Galaţi, Romania, E-mail: Nicusor.Baroiu@ugal.ro, tel.0040721771000.