NEW TEACHING METHODOLOGY: THE ENZO FERRARI MODEL

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Abstract

The Mechanical Engineering course of the Engineering Institute of Coimbra (ISEC) was reformulated within the “Bologna process”. Under these circumstances a new subject with a new teaching methodology was established. Within this subject, a group of students proposed to draw and manufacture a 3D model of Enzo Ferrari with 353 mm of length, 153 mm large and 78 mm height, using CAD/CAM technologies.

It was used a process that consists in using different 2D images of the car in different angles (blueprints). These images were introduced in a CAD software (Solidworks) and used as a base in order to draw the entities that defined the 3D model.

Whereas CNC milling machine available on our facilities has just 3 milling axis, it was decided to perform milling starting from 6 blocks, which were machined by stages. The programming of mill toolpaths used on this project, was made with Mastercam software using High Speed Toolpaths cycles.

This project was submitted to the educational competition (Wildest Part Competition) promoted by CNC Software Company (USA), and won in 2008 the first place in postsecondary division, such as it is noticed in Mastercam website.
(http://www.mastercam.com/WildestParts/Winners.html).

Keywords: CAD/CAM technologies, Enzo Ferrari, machining

Resumo

Na sequência da introdução do acordo de Bolonha na remodelação do curso de Engenharia Mecânica do Instituto Superior de Engenharia de Coimbra (ISEC) foi criada uma unidade curricular com uma nova metodologia de ensino. Neste contexto, um grupo de alunos propôs desenhar e fabricar um modelo 3D de um Ferrari Enzo, com 353 mm de comprimento, 153 mm de largura e 78 mm de altura, utilizando para o efeito as tecnologias CAD/CAM.

Diferentes imagens 2D do carro obtidas em diferentes ângulos (blueprints) foram introduzidas no software CAD (Solidworks) e utilizadas para desenhar as entidades que definiram o modelo 3D.

Uma vez que o centro de maquinagem CNC disponível possui somente 3 eixos de maquinagem, foi decidido efectuar a maquinagem a partir de 6 blocos de material, os quais foram maquinados por etapas. A programação dos ciclos de maquinagem foi efectuada com o Software Mastercam, utilizando ciclos de alta velocidade.

Este trabalho foi submetido ao concurso educacional (Wildest Part Competition) promovido pela empresa CNC Software (USA), tendo obtido em 2008 o primeiro lugar na divisão do ensino superior, tal como está descrito na página web da Mastercam. (http://www.mastercam.com/WildestParts/Winners.html).

Palavras-chave: Tecnologias CAD/CAM, Ferrari Enzo, maquinagem

1. Introduction

The Mechanical Engineering course of Engineering Institute of Coimbra was reformulated in agreement with Bolonha process and in this context it was introduced a new subject with a new teaching methodology, which the aim is to do an integrated project, applying the Computer Aided Design, Computer Aided Manufacturing and Computer Aided Engineering (CAD/CAM/CAE) technologies. Although the project developed include all these technologies, the work presented at this moment is only focused in CAM technologies.

Here is presented a study developed by a student's team and coordinated by professors, which drew and manufactured a model of Enzo Ferrari. This work was submitted in 2008 to the Educational Competition (Wildest Part Competition) promoted by CNC Software Company (USA), which develops Mastercam software.

The invention of Computer Numerical Control (CNC) machine is the major technological evolution in manufacturing. It has changed the manufacturing industry and is the foundation of modern manufacturing technologies, such as CAD\CAM [1]. CAD\CAM is the technology concerned with the use of digital computers to perform certain functions in design and production. This technology is moving in the direction of greater integration of design and manufacturing. Computer Aided Design can be defined as the use of computer systems to assist in the creation, modification, analysis, or optimization of a design, whereas Computer Aided Manufacturing can be defined as the use of computer systems to plan, manage, and control the operations of a manufacturing plant through either direct or indirect computer interface with the plant's production resources [2].

2. Objectives

The main objective of this work is to obtain a 3D model of the Enzo Ferrari using Computer Aided Manufacturing (CAM) software, starting from a model of Enzo Ferrari drew by Computer Aided Design (CAD) software.

One of challenges faced in this project is to machine the 3D model with 353 mm of length, 153 mm large and 78 mm height, knowing that work area between the table of the milling machine and the tool placed in work position has not height enough to perform the milling of the rear or the front of the car.

3. Methodology

In order to obtain the 3D model of the Enzo Ferrari, It was used a process that consists in using different 2D images of the car in different angles (blueprints). These images were introduced in CAD software and used as a base in order to draw the entities that define the 3D model. After this long process that took many hours of work, the 3D model of Enzo Ferrari in IGES format [3] (figure 1) was obtained. The CAD software used to draw the 3D model was the Solidworks, version 2008 [4].

Since the CNC milling machine available has just 3 milling axis, to perform the project as a 3D model was necessary to mill 6 different blocks of material, which were machined by stages. The material selected for this project was polyurethane suitable for machining.

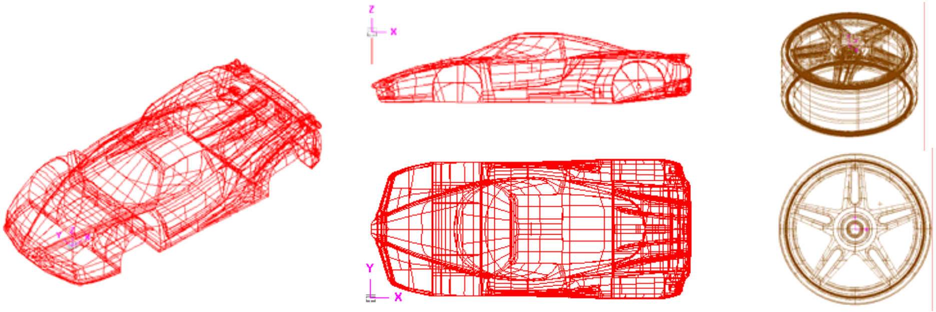
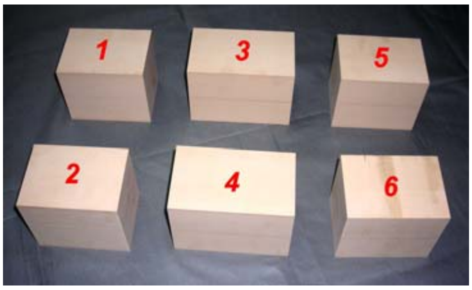


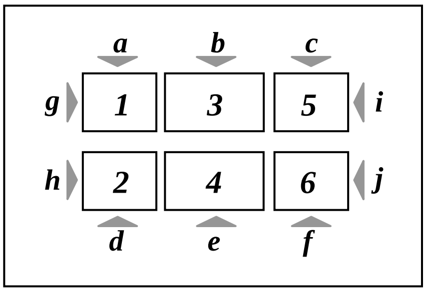
Figure 1. Different views of Enzo Ferrari model obtained in CAD software (IGES format).

3.1 Milling stages

The methodology applied to mill the 6 blocks of material in order to obtain the car, is illustrated in the figure 2 and involves 9 stages.



a)



b)

Figure 2. *a)* Initial polyurethane blocks where the milling is perform; *b)* Schematic figure of blocks with numeration and face´s designation.

Stage 1 - The front part of the car is obtained by the simultaneous milling of blocks number 1 and number 2, in which the geometry is defined along the faces *g* and *h*, that remain together during milling.

Stage 2 - On a similar procedure to step 1, in order to machine the rear part of the car, it is used the blocks number 5 and 6, and the geometry is defined along the faces *i* and *j*.

Stage 3 - The left part of the car is obtained by the simultaneous milling of blocks number 2, 4 and 6. The geometry is defined on faces *d*, *e*, and *f*.

Stage 4 - Following the same procedure described before, the right side of the car is obtained by the simultaneous milling of blocks number 1, 3 and 5. The geometry is defined on the faces *a*, *b* and *c*.

Stage 5 - The bottom part of the car is obtained by the simultaneous milling of the bottom surface of all blocks, which remain together during milling.

Stage 6 – On a similar procedure to step 5, the top part of the car is obtained by the milling of the top surface of all blocks.

Stage 7 - The 4 wheels and respective rims are machined separately of the car. At the end of all operation they are assembled to the car, using aluminium spindles.

Stage 8 – The base is machined to support the car. On the base, the word “Mastercam” is machined “according to the rules of Wildest Part Competition [5].

Stage 9 - The parts of the car that are not being permanently fixed are assembly with aluminium pins and the model is varnished at the end.

3.2 Programming the toolpaths with CAM software

The CAM software applied in this work was the Mastercam, version X2 [6]. The toolpaths are divided in roughing and finishing strategies. Inside each one, there are different cycle types available that define the milling sequence. The figure 3 shows a general view of Mastercam layout.

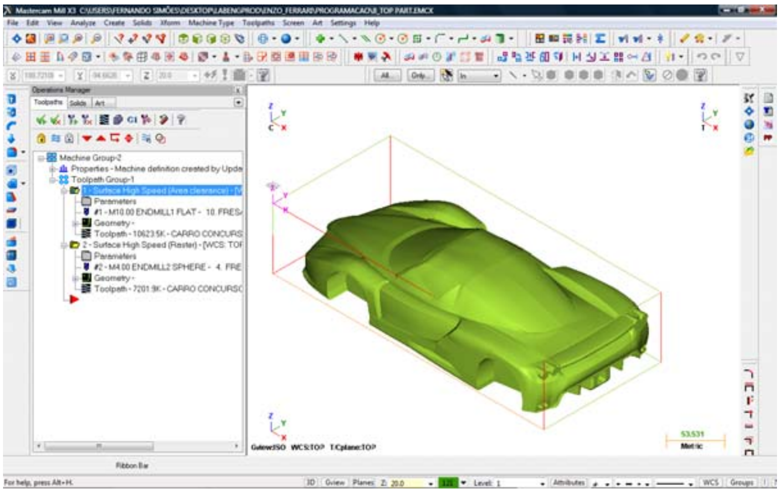


Figure 3. Layout of Mastercam software

For each stage described before, it was selected one roughing strategy followed by one or several finishing strategies, depending of geometry's complexity. The selected roughing toolpaths are generated from a set of surface profiles that describe the shape of surfaces at different heights, plus a set of offset profiles that let rough out stock as it approach the part. Finishing toolpaths create narrow cutting passes where the tool follows all geometry details and thus enables a good end result.

For each toolpath, to create the milling sequence, it is necessary to define several parameters in different tabs. As example, figure 4 shows the tool and cut parameters tabs.

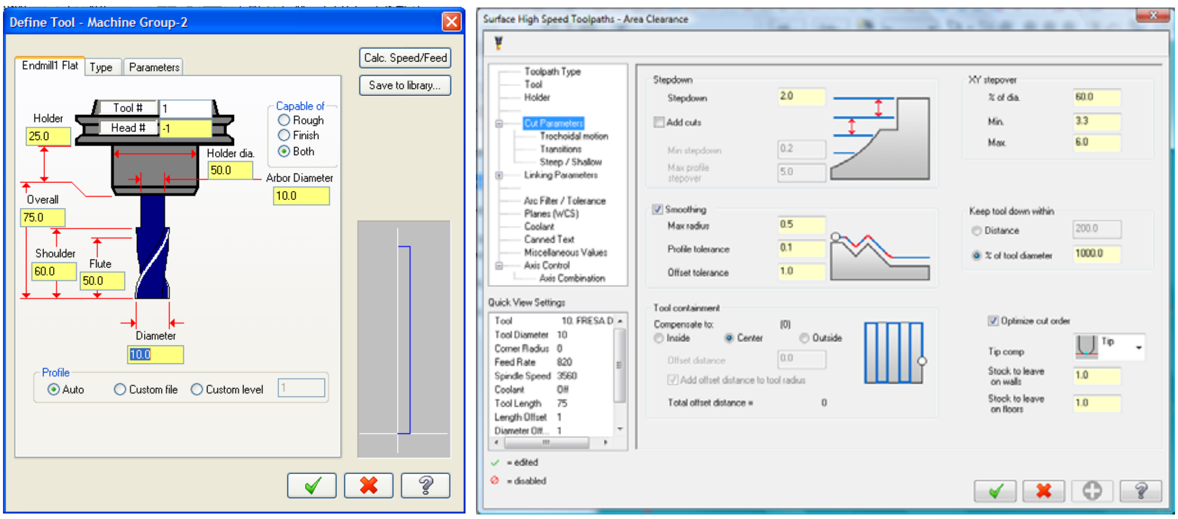


Figure 4. Tool and cut parameters selected for a specific roughing toolpath.

On roughing, the main tool was an endmill flat with 10 mm of diameter and it is kept a stock to leave of 1mm. On finishing, the main tool was an endmill sphere of 4 mm diameter. The spindle speed and linear feed rate tools parameters were calculated take into consideration the polyurethane stock material and the formulas described in Machinist´s Handbook [7].

The CNC milling machine has the tool aligned with Z axis. Therefore, the milling plane where is described the geometry is X-Y plane. That is why the model car must be rotated before each milling stage, in order to machining the right faces.

After toolpaths optimization, it is necessary to do the post processing. Post processing, refers to the process by which the toolpaths part files are converted to a format that can be understood by the machine tool's control. The program called post processor, reads the file and writes the appropriate numerical control code (NC code) [8, 9] (figure 5). Mastercam workstation is connected to the machine tool's NC control, and the program is sent by serial communication through an RS-232 port.

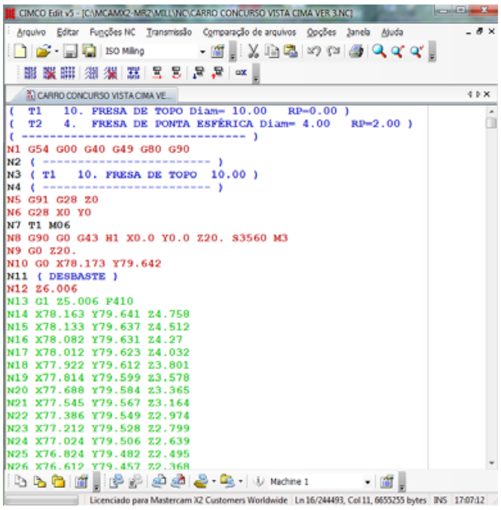


Figure 5. Fragment of NC code generated for a machine with a Fanuc-OM controller.

4. Results

The result of toolpaths developed according with milling stages described before, are now introduced. For each stage, it will be shown the simulations of roughing and finishing strategies and some pictures obtained during and after milling.

4.1 Front part of the car (stage 1)

In first stage, the front part of the car was placed as the figure 6a shows (front part perpendicular to the z axis). The maximum milling depth was set to 30 mm.

The figure 6b illustrates a simulation of the finishing toolpath over roughing toolpath. On the milling process, it was used the the milling faces *g* and *h* of blocks number 1 and number 2 (figure 2). These two blocks have been temporally linked on a press that was mounted on the milling machine table. The figure 6c and 6d show the described milling process.

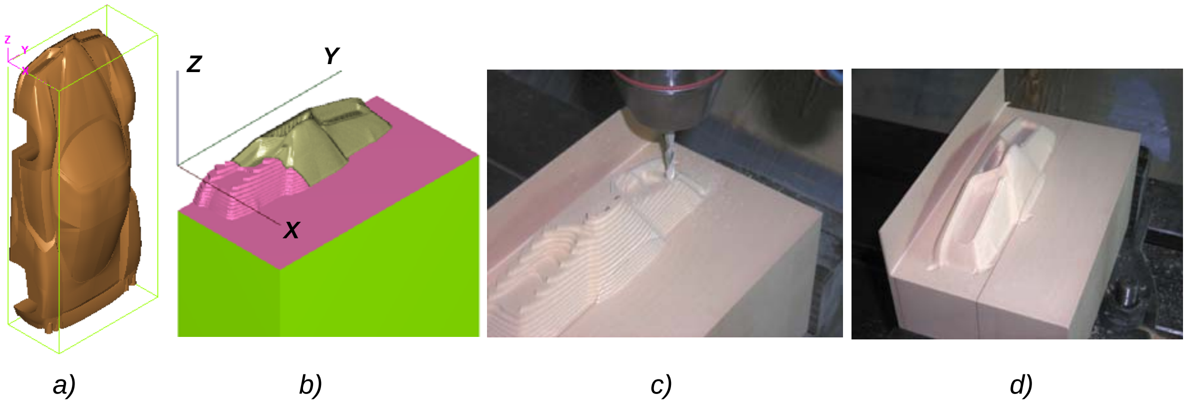


Figure 6. *a)* Model orientation to programme the stage 1; *b)* Roughing and finishing simulation; *c)* Front part during roughing cycle; *d)* Front part after finishing cycle.

4.2 Rear part of the car (stage 2)

This stage is similar to stage number 1. The model car was placed such as it is illustrated on figure 7a (rear part perpendicular to the z axis) to program the toolpaths needed to machine the rear part of the car. The maximum milling depth was set to 30 mm. The figure 7b shows the simulation of the programmed toolpaths. The figures 7c and 7d show the milling process on faces *i* and *j* of the blocks 5 and 6 (figure 2). During milling, these block materials were temporally linked on a press hold to the working table.

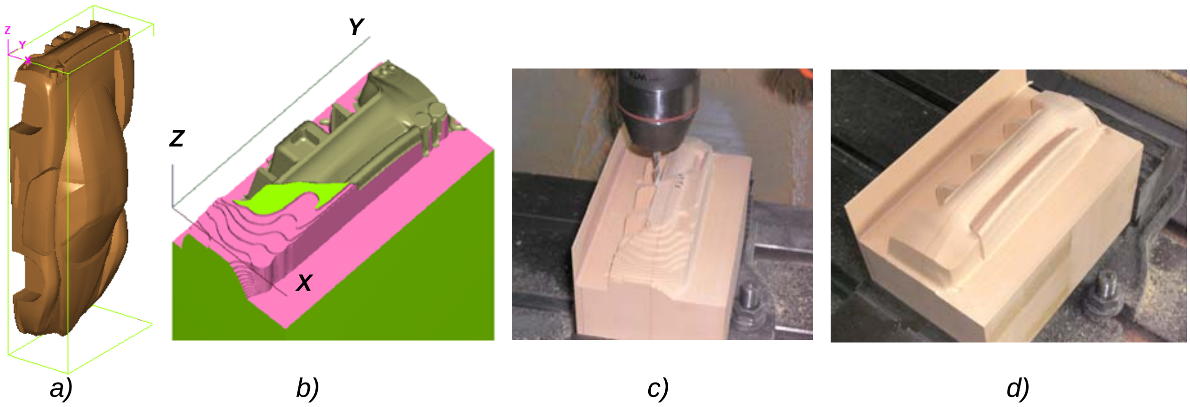
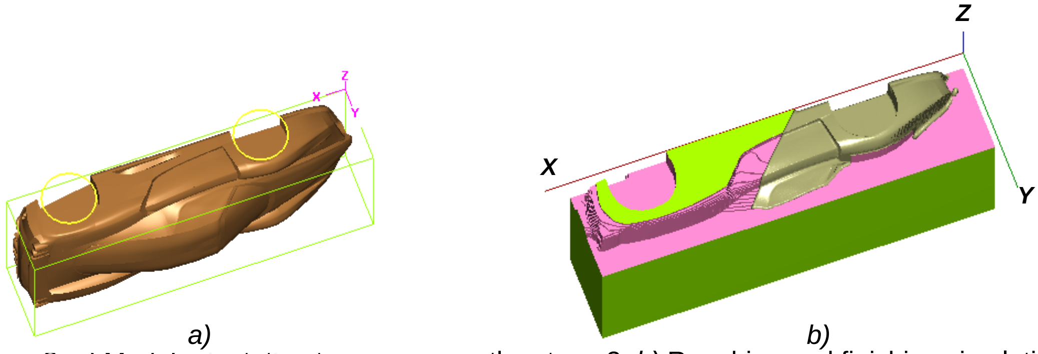


Figure 7. *a)* Model orientation to programme the stage 2; *b)* Roughing and finishing simulation; *c)* Rear part during roughing cycle; *d)* Rear part after finishing cycle.

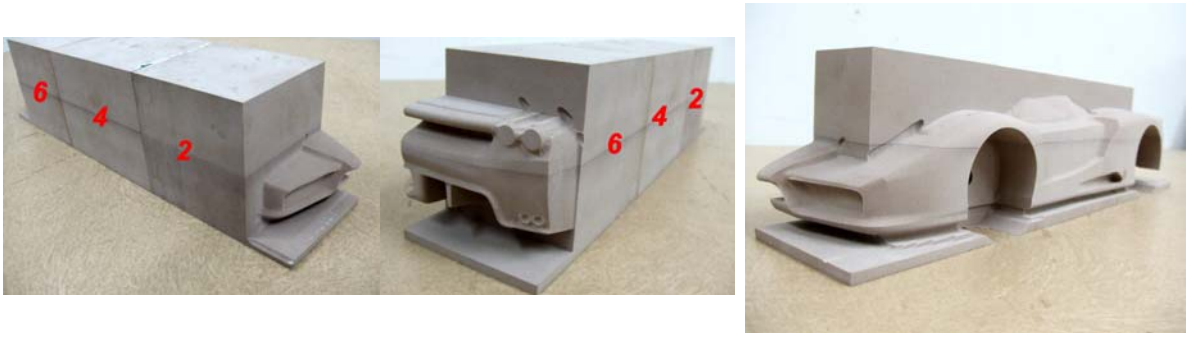
4.3 Left part of the car (stage 3)

On this stage, the left part of the car was placed perpendicular to the z axis (figure 8a). Figure 8b shows the simulation of the toolpaths programmed. To machine this part of the car, blocks number 2, 4 and 6 were joined and fixed permanently with glue. Once the front and rear blocks were previously machined on stages 1 and 2, this group of blocks look like (before stage 3) as is shown on figure 9a. The maximum milling depth used within this process was 30 mm. On figure 9b it is possible to see the result at the end of this stage.



a) b)

Figure 8. *a)* Model orientation to programme the stage 3; *b)* Roughing and finishing simulation.



a) b)

Figure 9. *a)*Two different views of blocks 2, 4 and 6 before being submitted to the milling process; *b)* Left part after to be submitted to the stage 3.

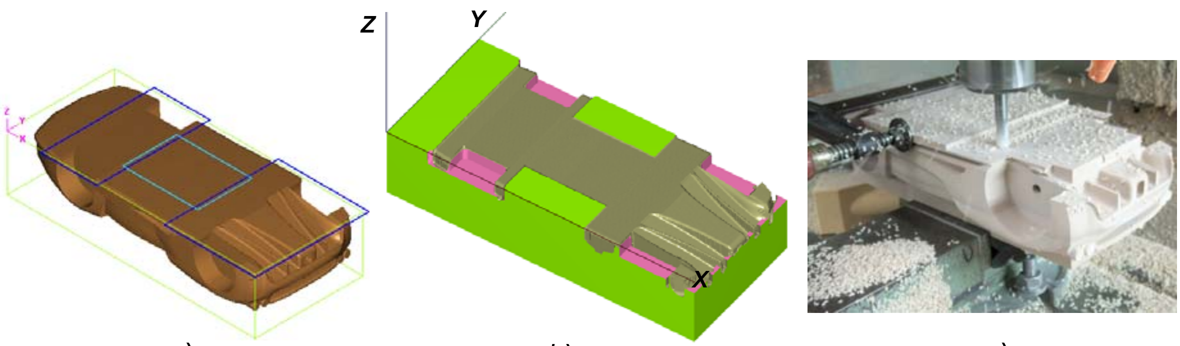
4.4 Right part of the car (stage 4)

This stage is similar to the stage 3. In this case, blocks 1, 3 and 5 were joined and fixed permanently, and subsequently machined.

After stage 4, it is obtained a part similar to the one showed in figure 9b. At this point, the car is divided in 2 parts, in which it is missing to mill the bottom and top part of the car.

4.5 Bottom part of the car (stage 5)

To program the toolpaths for stage 5, the model was placed as it is shown in figure 10a.



a) b) c)

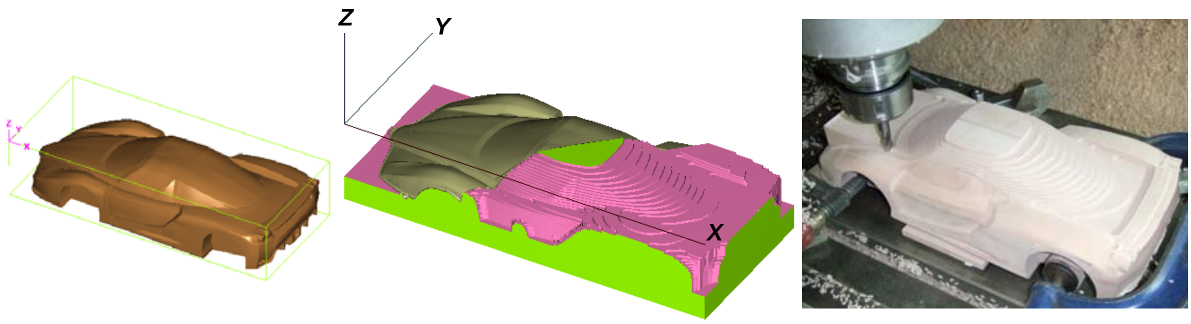
Figure 10. *a)* Model orientation on stage 5; *b)* Simulation of stage 5; *c)* Bottom part machining.

The bottom part of the car is just partially machined (figure 10b) because it is necessary to leave a flat zone that will be used on the next stage to fix with screws the bottom part to the base. Figure 10c shows the milling process during this stage. It is possible to see that besides the fixation of the blocks with a press, additionally, it is used also a clamp to perform a temporary tight that does not allow the blocks separation during the milling process.

4.5 Top part of the car (stage 6)

In order to program the toolpaths of top part, the maximum milling depth was set to 55 mm and the model was placed as shown on figure 11a. The figure 11b shows the simulation of finishing toolpath over roughing toolpath and in figure 11c is possible to see the roughing toolpath during milling.

It is important to notice that the machining of the bottom and top part of the car could be performed more easily if left part and right part were joined and fixed permanently with glue. Nevertheless, it was decided not to fix permanently the blocks, since it was our purpose to be possible to dismount the car in two parts at the end.



a) b) c)

Figure 11. *a)* Model orientation to programme the stage 6; *b)* Roughing and finishing simulation; *c)* Top part during roughing cycle.

4.6 Wheels and rims (stage 7)

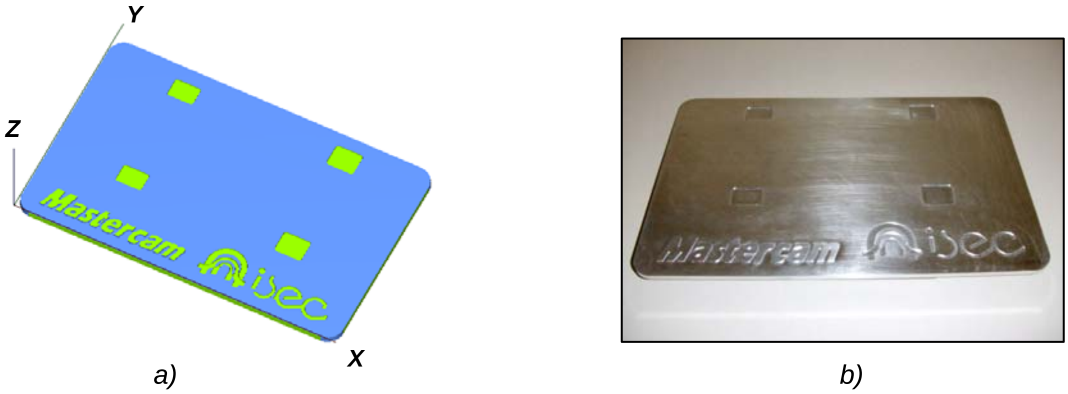
The machining of each wheel was executed separately. Therefore, it was necessary to make the same procedure 4 times. The material used on the wheels and rims was different from the rest of the car, in order to highlight this part. On figure 12a it is possible to see the simulation of the toolpaths. The figures 12b and 12c show two different stages of the milling process.

a) b) c)

Figure 12. *a)* Simulation of stage 7; *b) and c)* Different stages of wheel and rim machining.

4.6 Base to support the car (stage 8)

The base to support the car was made in aluminium alloy with the dimensions of 420 x 250 mm and a thickness of 7 mm. According to the rules of Wildest Part Competition, the word “Mastercam” must be engraved on one part. It was decided to engrave this word on the base, at left, above top level of the base (height 1 mm). Additionally, the word “ISEC” and the correspondent logo were dug, at right, below the top level of the base with a depth of 2 mm (figure 13a). After machining, this part was polished and the final result is shown in figure 13b.

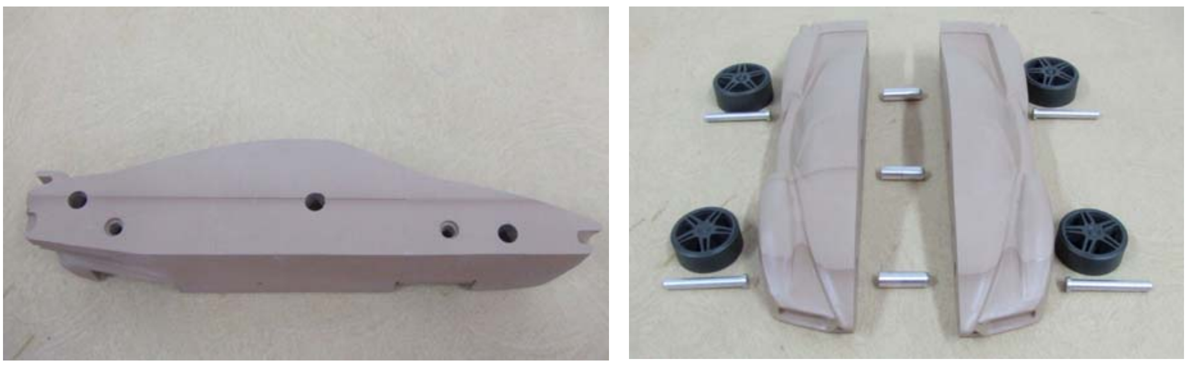


a) *b)*

Figure 13. *a)* Machining simulation of the base; *b)* Aluminium base after polishing.

4.6 Assembly (stage 9)

To allow the assembly of wheels and the connection of model parts, was performed the drill operation at left and right parts of the car (figure 14a). Additionally, were manufactured by turning, 4 aluminum spindles to connect the wheels and 3 aluminum pins to connect the left and right parts of the car (figure 14b).



a) *b)*

Figure 14. *a)* Holes opened in machined parts; *b)* Parts of Enzo Ferrari before assembly.

After assembly, the car looks like as is presented at figure 15a. At any time is possible to do the detachment of the car in two parts (figure 15b).

a) b)

Figure 15. *a)* Car after assembly; *b)* Detachment of the car in 2 parts.

5. Conclusions

The Enzo Ferrari model is an example of a project developed under a new methodology introduced in the Mechanical Engineering course when it was reformulated within the “Bologna process”. This teaching methodology combines the background knowledge acquired during this engineering course, the CAM technologies taught in this subject and the student’s creativity.

This was a project plenty of success once won, in 2008, the first place in Wildest Part Competition (postsecondary division) promoted by CNC Software Company (USA), such as it is noticed in Mastercam website (http://www.mastercam.com/WildestParts/Winners.html).

Figure 16 is a picture of the model car after all operations finished.

Figure 16. Car on base support.

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