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Modeling methods in parametric design. Order matrix

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Abstract

Purpose:
This paper is the result of a project to improve methods of digitization through parametric CAD software.

Method:
Geometric relations are one of the most repeated problems in digitization models. Therefore, it was proposed a tool to help manage the work of establishing the necessary relationships in models digitization. It is based on doing, previously, a Functional Analysis and a Geometric Analysis of the model. (López Soto et al. "Analysis of modeling methods in parametric design. Analysis of Geometric Relations." XXI International Congress of Graphics Engineering. Lugo, Spain, 2009).
The purpose of this paper is a protocol which gathers all the results obtained after applying the previous analysis. Thus, the information condenses into a single document the Model Analysis.

Result:
This protocol of analysis would be a prelude to the implementation of the model with CAD software. It lets you define, and sequencing, the primitive geometric components and order to achieve maximum independence.
The tool consists on a matrix that relates the geometry of the part with the CAD software operations, resulting in a highly graphical and intuitive tool. It shows the process of digitization to get a quality model.

Discussion & Conclusion:
The Model Analysis involves a time of preparation of the steps to digitization a part. This extra time is compensated by a greater time savings in subsequent interpretations and model reuse.
Of course, the Model Analysis should be independent of the CAD software used in its implementation. Once the analysis is completed it shall proceed to elect the best CAD software to continue the design process.
The activity of designing objects requires many revisions and updates of its parts. To succeed, we must be systematic and give utmost importance to detail from the beginning to the end of the design activity.
Therefore, it is essential to perform a detailed Model Analysis for the modeling process, but software developers announced that all applications can be modified without unexpected changes arise.

1 Introduction

The approach of the work to be done with a CAD software is decisive in the result obtained. Without a approach, you just do what you can do, not what you want to do with a particular CAD software.

The design engineer establish the tasks to be delegated to the CAD and find a way to do that. Never should be the CAD options the one to decide what to delegate.

A good approach, also, must be generic, independent of any specific commercial software.

The CAD was born in response to the needs of the aerospace and automotive industry in the 50's. Therefore, the revolution in computer systems was conducted based on the interests of production, and CAD was also developed based on these premises.

The common use of these applications is that, it is unlikely that users who work for companies that manufacture various products, any of them design from zero. About 80% of a typical design are modifications of existing designs.

D. Garrido [2] acknowledges that: “We continually find customers thet benefit from the power of parametric system, but that advantage turns into frustration when they need to make an unexpected change in the original design”. “The existing geometry editing represents a bottleneck in the iterative process of design”. “The market demands a solution to such questions as: How to design better and faster?, How to make better use of existing designs?”.

A.J. Medland [1] conceived the design process as a process that defines a problem and its variables, eliminating all that which has no influence on the design. Set the parameters, you can start working.

So, what is needed is a process of computer-based design that takes into account the nature and uncertainty of the activity of designing. Design is not only produce images of an object, is to provide answers to specific problems in engineering. It is more important for a designer to have high quality data that high quality images.

The design engineer who use the system, must know the parametric modeling possibilities. Therefore, specific knowledge and preplanning is necessary before to application system.

Design Parametric / Variational has two fundamental characteristics: the definition of the key parameters of design and use of Intelligent Geometric Features and Functions.

We think this will manifest itself in:

- Different methods in use of CAD software.
- New pedagogical approaches when designing and / or modeling of objects.
- New methods in the industrial-technological design.

1.1 Objectives

The main objectives that we aim achieved are:

1) Develop a methodology for Parametric CAD application usage. This methodology will be independent of CAD commercial software. Should facilitate the design and redesign of machines, mechanisms, etc., within the context of Concurrent Engineering.
2) Find a balance between ease of learning the method and its practical use. Both from the standpoint of teaching, as the professional development of parametric geometric modeling.
3) To analyze the genesis of geometries, its order and its relations so that the parametric modeling process are robust and flexible. Robust in the sense of obtaining a logical, orderly and functional process to facilitate monitoring. Flexible in the sense of admitting any changes easily and fast.
4) Improve productivity in the design process, since the incorporation of new technologies facilitates the design and redesign of machines, mechanisms, etc. Furthermore, if this happens within the context of Concurrent Engineering design process is enhanced.

2 Method

The great potential of parametric CAD is the possibility to make changes by entering new data from the redesign, allowing updating the affected geometry. J. Shah [6]

2.1 Functional Analysis

Functional Analysis is a method proposed by L.D. Miles [7] as part of a cost reduction method.

In the Functional Analysis is considered that the products or components produce effects (functions). The functional analysis seeks to identify the effects, breaking them down into subordinate effects, and thus define the essential of these components in producing effects. Then the Functional Analysis examines those effects analyzed as a response to needs.

The functions identified during the above process can be independent or connected to each other. The set of functions developed an overall effect that is designated as the overall function of the object. To make the Functional Analysis is necessary to determine what relationships exist between the various partial functions of the product.

This structure usually take the form of functional tree, in which the functions are connected in a family tree of functions. In the classification and management of functions, is passed from the most general level to more specific.

It is proposed, as an example for the discussion of Functional Analysis and Geometry Analysis, the adapter of fig.1. See map at Appendix 2.

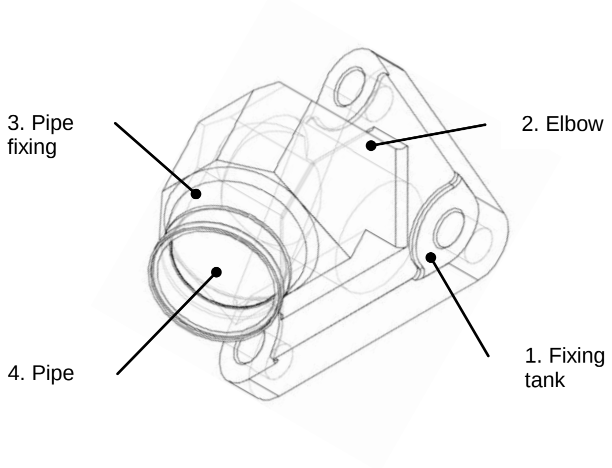


Fig.1 Adapter.

The part is a binding element between a deposit and a pipe, so that the pipe form 25º with the deposit surface. The elbow-shaped conduit has a cylindrical interior. The adapter is in contact with the deposit on a flat surface and is fixed by screw. While the pipe is fixed by a fusion welding of workpiece material. Fig.2. J. López Soto [5].

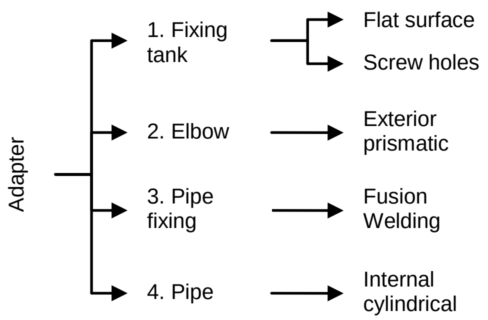


Fig.2 Function diagram

2.2 Geometric Analysis

It should be analyzed what you want of the model. Consider what and how to change the dimensions and design features. Make a flexible parameterization, anticipating the changes that will occur.

The analysis of relationships begins by dividing the part into simple elements so that each of these items link to a function of the part, either primary or function of another order.

The geometric elements will be a matrix entries, to be completed with the relationships between each pair of geometric elements that come into play. The diagonal matrix contain the internal relations, while the remaining positions contain external relations. Tab.1.

The reading of the cell “a, b” is “a is related to b” or “a depends b”. For example, the cell “1,2” shows the data to be executed the geometric element 1 that will be extracted from geometric element 2, without which it is impossible to execute the first geometric element.

The right column, “Parents”, shows the number of dependences that will cause a geometric element. While in the last row, “Sons”, shows the number of geometric elements needed to create this one.

The adaptor decompose, geometrically, in four parts: triangular base (1), prismatic elbow (2), cylindrical end of revolution (3) and conduit (4). The order in which the four parts are made is very important, because it will influence the flexibility of the model to dimensional modifications.

	E1	E2	E3	E4	P
E1	Composite solid: - 3 side tg to cylinders h=6 - Same 3 sides rounded R7 y R1; h=7 - 3 chamfer holes	- Same origin in the vertical plane, relative position - R1,2		- Same origin in the vertical plane, relative position - ¡not to cover 4!	0
E2	- Same origin in the vertical plane, relative position - R1,2	-Polyhedral solid, square section in the vertical plane and the same section at 25º - Chamfers	- Same axis at 25º, relative position - R2	- Same axis - Same origin in the vertical plane, relative position	0
E3		- Same axis at 25º, relative position - R2	- Solid cylindrical + conical	- Same axis at 25º - Same origin in axis at 25º, relative position	0
E4	- Same origin in the vertical plane, relative position, dependence of remove	- Same axis, relative position - Same origin in the vertical plane, dependence of remove	- Same axis at 25º, relative position - Same origin in axis at 25º, dependence of remove	- 2 cylinder + cone whose axes intersect, bases in the vertical plane and in axis at 25º	3
S	1	1	1	0	

Tab.1 Relationship Matrix.

The analysis of the Relationship Matrix provides the following results:

- You can start by any of the geometric elements 1, 2 or 3, since they are independent.
- It helps to make a 2D profile (sketch) containing the axes and the endpoints of the axes, since they are shared by several geometric elements.
- The base plane is a vertical plane and the symmetry plane is the second vertical plane.

So, the adaptor will be initiated by the prismatic elbow (2), as the functional element that arises from the need of the design and central part. An easy way to get it is through a symmetrical extrusion. It ends with the chamfer of edges.

The triangular base (1) is achieved with an extrusion, round corners and holes. Attention should be paid to the position of the centers of the holes referred to the prism side.

The cylindrical end (3) is obtained by revolution. The geometry of this profile presents certain difficulties:

- Tangency of an arc (R2) to a line that is not the profile contour.
- Passing an inclined straight (7 º) by an intermediate point thereof and tangent to arcs at both ends.

Finally, the conduit (4) will be done by two holes using as plane base the faces of element 1 and element 3. J. López Soto [5].

2.3 Order Matrix

One of the key steps to establish a methodology is the Analysis of Model. The Analysis of Model should be independent of the CAD software used, therefore, there has been created a protocol to guide this analysis.

This protocol allows you define the primitive geometric elements, and so, sequence and order to achieve maximum independence.

For each part is registered:

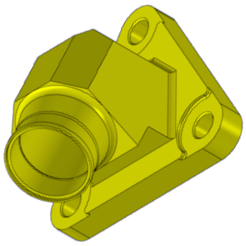
- Operations to be executed, with the data used for its realization and the sketch of the geometric element resulting.
- The different phases at each module and its chronology.

The protocol Analysis Model consists of a matrix of operations and sketches, tab.2.

The input of geometry part helps decompose the different basic elements that make up the part. J. López Soto [4].

The input of operations recalls the possibilities offered by CAD software. The operations contained are common to all CAD software analyzed.

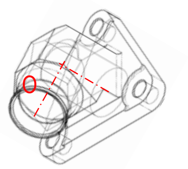
The operations are ordered according to the sequence recommended in the basic procedure. Thus, the completed cells will approximate to the main diagonal of the matrix.

		(3D sketch)	(3D sketch)
PLANE	Plane 2D sketch		
ADD	Extrusion Revolution Sweep Helical Sections		
REMOVE	Extrusion Revolution Sweep Helical Sections Hole-Thread		
MODIFY	Round-Chamfer Flange Demolding Thickness		
OTHER	Copy- Symmetry Multiple Copies		

Tab.2 Order Matrix.

3 Result

According to this analysis, as a preliminary step, it will create a profile (or sketch) 2D, to use as a reference. This reference profile is set up in one of the vertical planes, provided by default, where will draw the axes of the two holes (Geometric Element 4), marking on them the beginning of each of the holes. The vertical axis of the hole will have one end in the coordinate origin, to facilitate the operation of the triangular base (Geometric Element 1). Tab.3. Fig.3.

	
PLANE	Vertical plane of symmetry Origin: O
ADD	
REMOVE	
MODIFY	
OTHER	

Tab.3 Reference sketch.

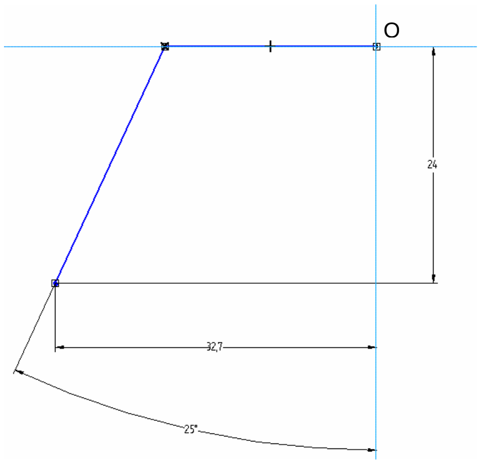
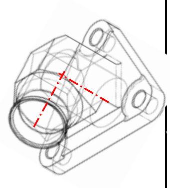
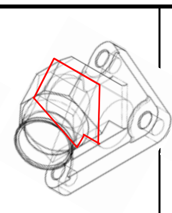
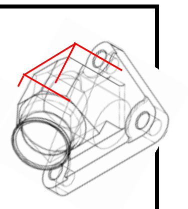


Fig.3 Reference sketch.

The modeling starts at the elbow prismatic (Geometric Element 2), as the functional element that arises from the need of the design and central part. A simple way to obtain it is through an extrusion symmetric, taking the axes of the reference profile to dimension the extrusion profile. The prismatic elbow profile will be located in the same plane as the reference profile. Tab.4. Fig.4.

			
PLAN E	Symmetry plane		
ADD		Symmetry extrusion, length L1	
REMO V			
MODIF			Chamfer (5)
OTHE R			

Tab.4 First module.

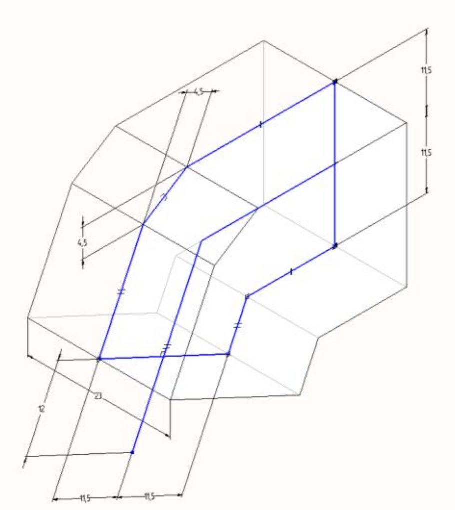
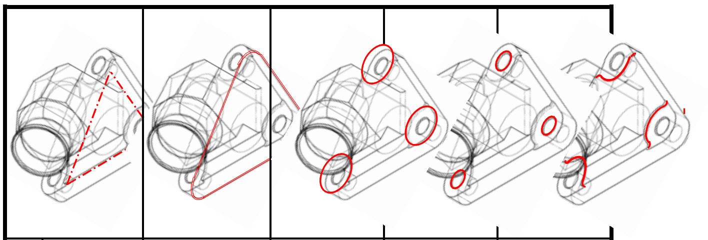


Fig.4 Symmetry extrusion.

The prismatic elbow ends (2) with the removal of edges with chamfers on two operations, to allow flexibility to change. Fig.5.

					
P	Horizontal plane				
A		Extrusion, length L2			
R			Extrusion, depth P1	Counter-sunk hole (3) diameter D1	
M					Round (6), radius R1 Round (3), radius R2
O					

Tab.5 Second module.

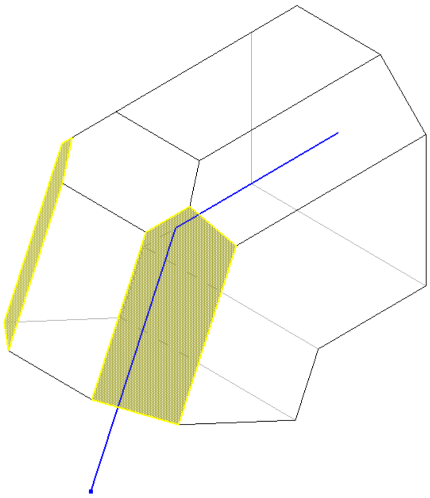


Fig.5 Chamfer.

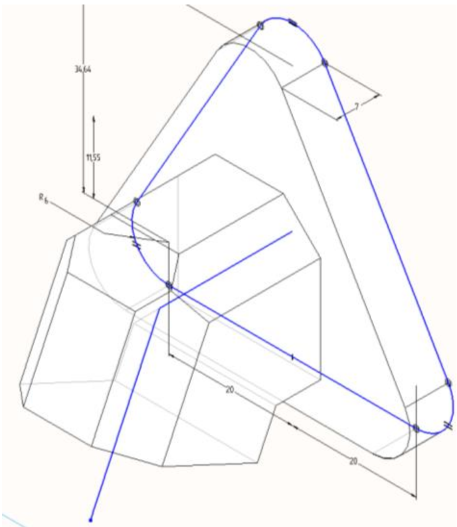


Fig.6 Add extrusion.

The triangular base (Geometric Element 1) is generated with an extrusion, a removed extrusion and holes. Profile extrusion is layed in the horizontal plane, as expected when making the reference profile. This extrusion is carried out with the maximum height (h = 7 mm.) and equal radii at the corners. Attention should be paid to the position of the holes centers relative to the axes of reference, rather than position with respect to the prismatic side, to promote the independence of these two elements to geometric changes. Tab.5. Fig.6.

The depth dimension of the emptying of the vertices of the triangular base (1) is not included directly in the data plane, so is established by a formula in which data appear flat. This will facilitate location of future changes. Fig.7.

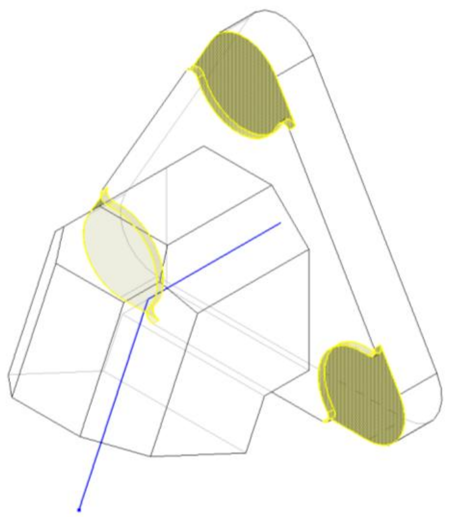


Fig.7 Remove sketch.

The countersunk holes will serve to terminate the Geometric Element 1. Fig.8.

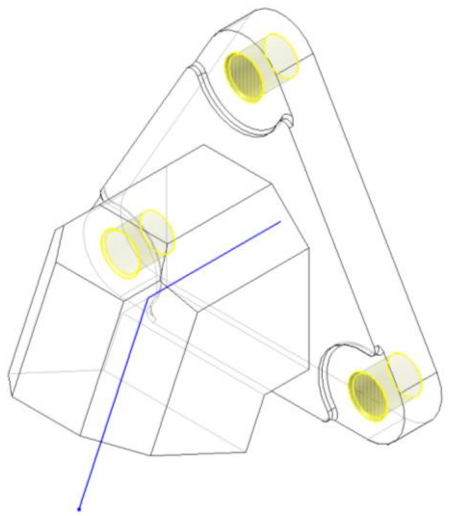


Fig.8 Countersunk hole.

The new edges generated in the operation of emptying are rounded to the same radius for all. Fig.9.

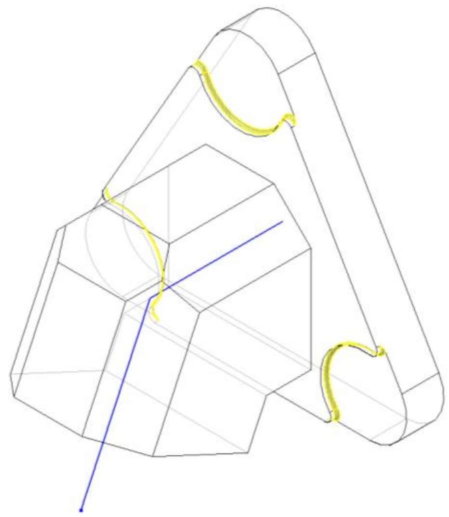
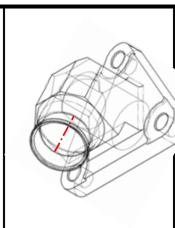
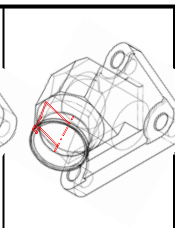
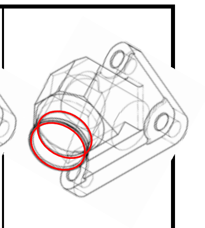


Fig.9 Round.

The cylindrical end (Geometric Element 3) is obtained by revolution around the axis at 25° of the reference profile. The sketch of the cylindrical end will be located in the same plane as the reference profile. The binding of this geometric element with prismatic elbow (2) is ensures including, by copying, the required geometry of prismatic elbow. Thus, if it were lost the reference of prismatic elbow, only is removed the link of "include", running without problems, the cylindrical end (3). Tab.6.

			
PLANE	Symmetry plane		
ADD		Revolution	
REMOV			
MODIFY			Round, radius R3 Round, radius R4
OTHER			

Tab.6 Third module.

The geometry of this profile presents certain difficulties, Fig.10. Fig.11:

- Tangency of an arc (R2) to a line that is not in the profile contour.
- Passing a inclined straight (7º) by an intermediate point thereof and tangent to arcs at both ends.

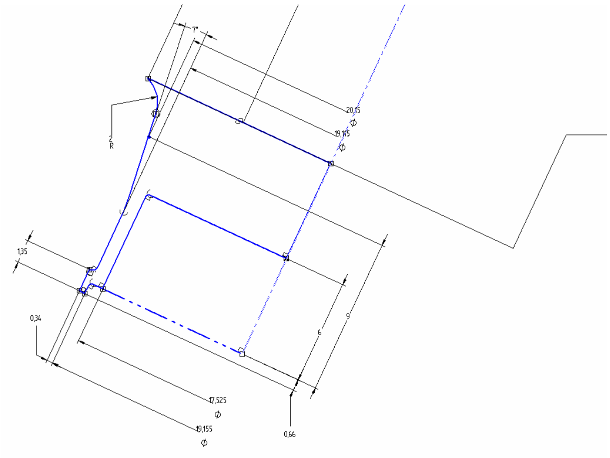


Fig.10 Symmetry plane.

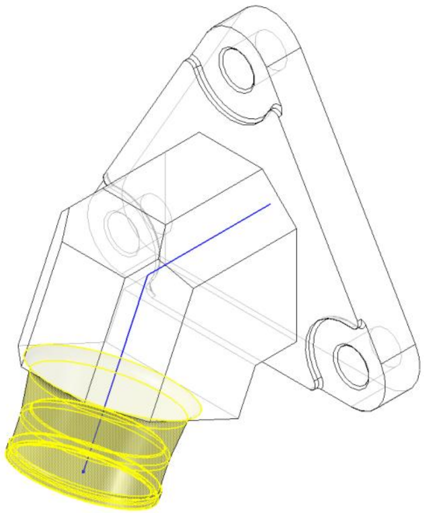
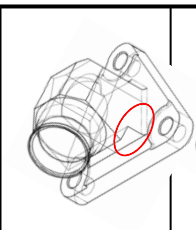
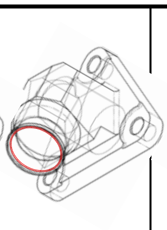
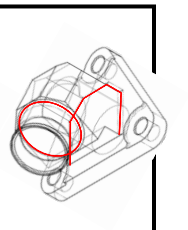


Fig.11 Revolution.

The conduit (Geometric Element 4) will be held by two emptying using, as base plane, faces of Geometric Element 1 and Element Geometric 3. Tab.7. Fig.12. Fig.13.

			
PLANE			
ADD			
REMOVE	Hole, diameter D2, depth P2	Hole, diameter D2, depth P3	
MODIFY			Round, radius R5 Round, radius R6
OTHER			

Tab.7 Global operations.

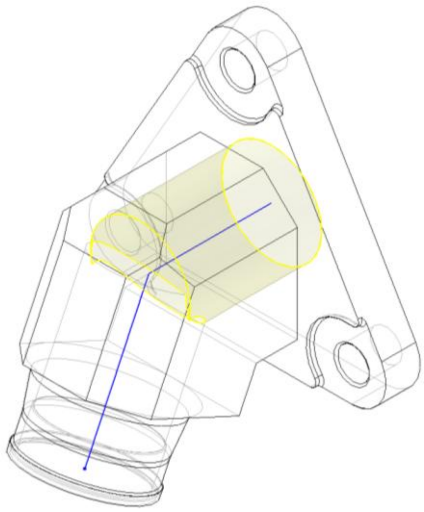


Fig.12 Hole.

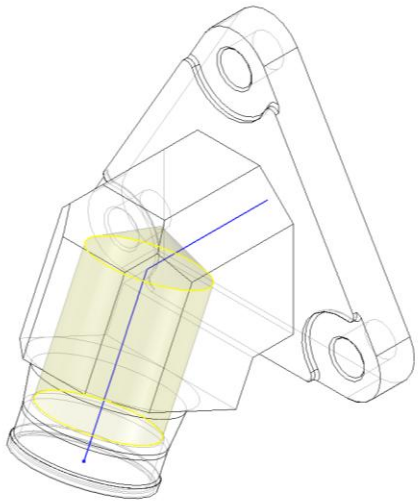


Fig. 13 Hole.

Finally, it take place the requirements rounding between Element Geometric 1 and Element Geometric 2. Fig.14.

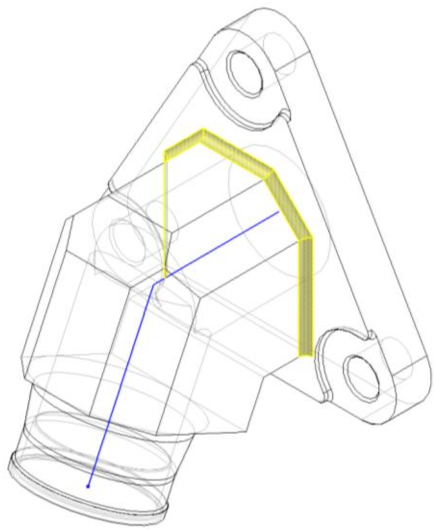


Fig.14 Round.

The parametric history of the part, generated with the Solid Edge software, is showed in fig.15:

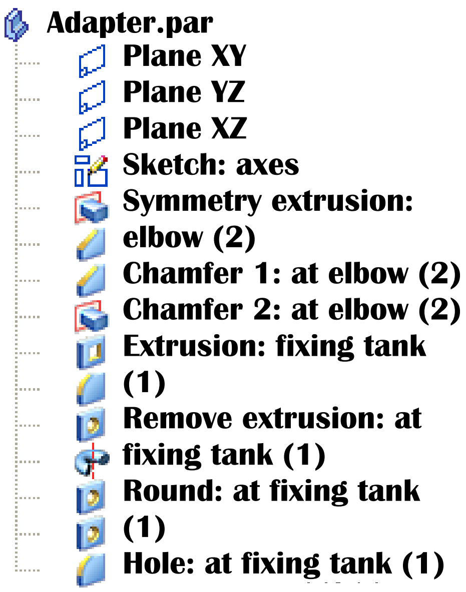


Fig.15 Parametric history with Solid Edge.

4 Conclusion

It is essential to do a detailed analysis of the model to establish the modeling process, although software developers advertise that all process can be modified without unexpected changes.

The protocols can collect data from different CAD software, and set comparable conclusions. This allows the discussion about the process instead of discussing the possibilities of a specific CAD program.

The Analysis Matrix of model allows to collect data to an adequate interpretation and elaboration of results about the modeling process followed, and so determine improvements, without the distraction of the steps and data required by a specific commercial software. These conclusions correspond to the first objective.

As important concept is that is possible learn and evaluate CAD, without using a computer and also be independent of a specific CAD software. Thus was achieved the second objective, which applies in the classroom.

Dedicate more time to preparing the process to digitize a part carries a greater time savings in subsequent interpretations and modifications. This was the third objective.

It is more important the geometric knowledge of the designer, that the potency of the computer. The design engineer will continue being the creator person of new products. The availability of a CAD tool is a great help, but, by itself, is unable to do anything.

The correct application of CAD allows to obtein significant increases in productivity, improved quality of design and in less time. Practical objective cited in fourth place.

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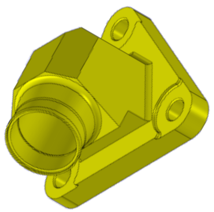
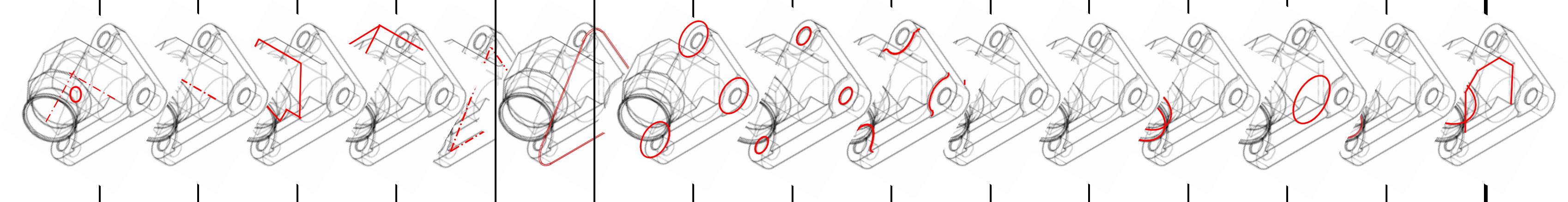
Appendix 1

Full matrix operations. Tab.8.

Appendix 2

Plane of Adapter. Fig.16.





PLANE	Plane 2D sketch	Vertical plane of symmetry Origin: O	Symmetry plane			Horizontal plane					Symmetry plane					
ADD	Extrusion Revolution Sweep Helical Sections			Symmetry extrusion, length L1			Extrusion, length L2					Revolution				
REMOVE	Extrusion Revolution Sweep Helical Sections Hole-Thread							Extrusion, depth P1	Counter-sunk hole (3) diameter D1					Hole, diameter D2, depth P2	Hole, diameter D2, depth P3	
MODIFY	Round-Chamfer Flange Demolding Thickness				Chamfer (5)					Round (6), radius R1 Round (3), radius R2			Round, radius R3 Round, radius R4			Round, radius R5 Round, radius R6
OTHER	Copy-Symmetry Multiple Copies															

Tab.8 Full matrix operations

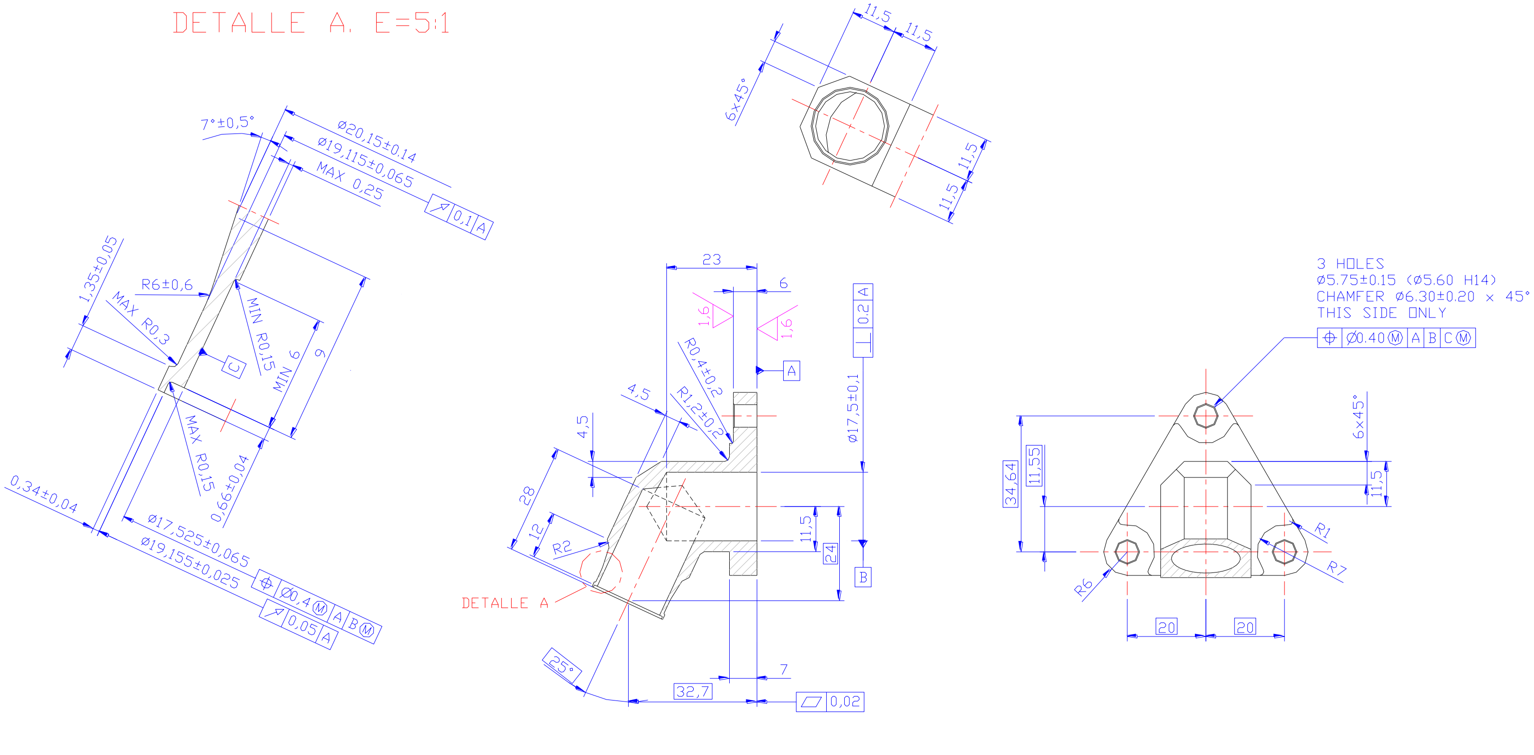


Fig.16 Plane of Adapter.