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Use of CAD tools: potential for technology education

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Abstract

Purpose:
The aim of this paper is to present a thought about the educational use of CAD tools for technology education. The first part deals with the evolution of the practices due to the arrival of new design tools in industry as well as in the training community during the preceding two decades. Consequently, the necessary change of educational practices is highlighted with several aspects: the first one concerns the modification of the sequencing of learning activities because the knowledge of drawing codes is no longer necessary. The second concerns the evolution of the contents of teaching accompanying evolution of professional practices. The third aspect deals with the various teaching approaches implemented with the CAD tools. Examples illustrate how the CAD tools can be educationally efficient for technology teaching. Finally, the present thought leads to investigate the evolution of the teacher's work using the CAD tools.

1 Introduction – The Digital Mock-Up stemming from a solid modeller

It can be easily admitted that the computer-aided design (CAD) includes all the software and the geometrical modelling techniques allowing design, virtual test - by means of a computer and digital simulation techniques - and the manufacturing of industrial products and tools to machine them.

This could let think that the only interest of the current designer's tools would be to make it possible the numerical treatment, with realistic representations, of each design step of a product that was previously carried out on a paper base.

This vision is very partial. Indeed, the model doesn't only represent the geometry of the product but is constituted by the entire technical information throughout the design phase and even throughout the entire product life cycle. It constitutes then a real evolutionary prototype.

For example, the solid model of a gearbox allows not only to define the geometry of the various parts as well as their connections by leaning on standard elements issued from a digital library (bearings, gears...). But it also makes it possible to define the masses of parts, their characteristics of inertia, to verify that the wished kinematic is well obtained, that the strongly strained parts resist to the efforts, can be manufactured by FAO … All this even before the first physical prototypes are realized.

2 The digital model today

2.1 Technical representation history

The technical communication in the industrial domains and in particular the mechanical engineering ones was organized for a long time around the "technical drawing" or "industrial drawing".

At the end of the XVth century, Leonardo da Vinci invents the technical drawing. His inventions are represented by perspective drawings, with annotations and a coding system of the sizes for a reliable manufacturing. For a long time, the technician or the engineer contents himself with a representation of objects in the form of freehand sketches (Fig. 1)

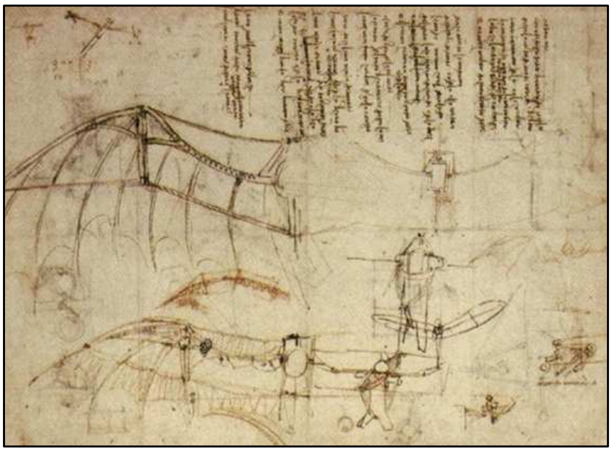

Fig. 1 Representation of a flying machine by Leonardo da Vinci.

At the beginning of the XIXth century, with the multiplication of patents accompanying the industrial development, the necessity of a universal language leads to the definition of a technical common language of representation. This was defined by Gaspard Monge and based on the principles of the descriptive geometry. The strong idea of the technical drawing is the arbitrary abolition of one dimension, which makes possible to see the two others in the real size. As a result, at least two different views are necessary to obtain all the geometrical characteristics of the represented object. This representation is based on conventional rules which are the object of official standards.

Mechanical engineering is historically one of the first domains to have been equipped, in the 1960s, with software of computer-aided draft resuming partially the forms of representation of the technical drawing. These tools quickly evolved to become Computer-Aided Design software (CAD tools) : they progressively integrated, around the purely 3D-geometrical models, more and more non geometrical knowledge.

This kind of models is now called “associative, parametric and variationnal digital models. The VARIATION of the value of a parameter (material, value of a dimension…), decided by the technician or resulting from internal or external relations (e.g. spreadsheet) is reflected on all ASSOCIATED models or documents (part, assembly, 2D drawings, simulation module,...)

Today, the use of CAD tools in a necessarily association with PLM[1] in the companies of the mechanical sector is very widely spread for the technical data management (creation and/or use). At the same time, communications tools with the arrival of the digitalized information very widely accompanied this evolution. These tools allow then a communication between people working in vaster fields of application and with different trainings and backgrounds. It is very obvious that the representations on paper (technical drawing) were a serious brake to lead all the actors of the company to communicate on a same product because this representation was based on specific codes, known by the only specialists. It is now possible thanks to the 3D image.

Finally, the display of products via free software associated to every CAD software (e-drawings), or in PDF format is not only useful within the company but also in the relations with the customer or the partner. Fig. 2 illustrates how a Pdf3D document, appeared at the beginning of 2000s, with the version Adobe8®, accessible by all, allows here to understand the disassembling of a braking disk system. For the trainer of maintenance of motor vehicles, for example, this document type opens numerous and rich educational fields of investigation.

2.2 The technical representation in the industrial environment

A press release, dated March 2011, about the acquisition of a new software of computer-aided design (CAD), tell these comments of a PLM specialist at Aston Martin Racing: "To reach an optimal efficiency, we needed a PLM system exhaustive and unique, able to taking care of the entire process of design, from very first phases of development to the manufacturing of the products".

This sentence illustrates the desire to reduce the development delays in order to limit the costs. Indeed, the solid modellers allow, through the evolutional virtual mock-up of the product, to include all the components of the design process on the same digitalized support, in a collaborative way. This digital model, carrying out all the information bound to the product constitutes the central pole of the digital chain. Organized around this model, the digital chain allows the coincidence in time between the various phases of products elaboration: taking into account, from the first steps of the design process, the constraints of manufacturing, industrialization, maintenance and recycling, for example. The global approach of this technical information became a necessity. The digital chain allows first of all to leave behind the archaic vision of the linear and hierarchical based development of a product. For every link of the chain, according to the appropriated needs, particular modes of technical representation are possible. They all have as common to be edited from the Digital Mock-Up (DMU), and to bound to this one. In fact, “CAD is only a part of CAx. CAx engineering is an integrated part of modern product development and manufacturing” [10]

For example, for the activity of maintenance, the digital mock-up can be used as medium as it is shown by the article "specification sheets become animated thanks to the CAD" appeared in September, 2006, in "L'usine nouvelle", [1], and which explains that " even if tools CAD make the realization of a scenario (of maintenance activities) more intuitive, their adoption will be a matter of training and cultural evolution " (Fig. 3).

Fig.2 Dismantling of the disk brake BD 13 from a PDF3D [1]

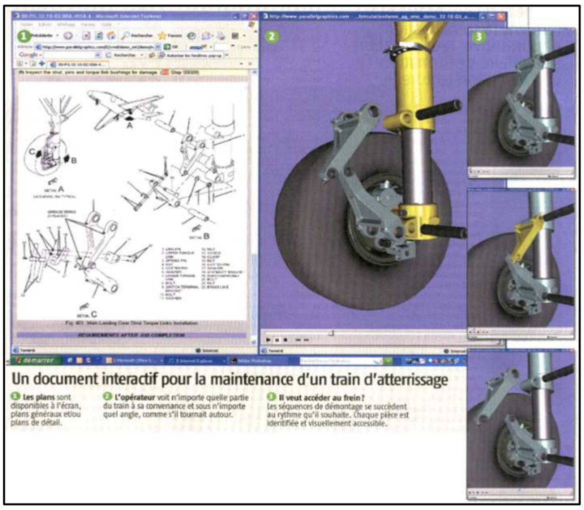

Fig. 3 Use of CAD tools in a service of maintenance [2]

These industrials applications and needs does not match the usual approach in education which generally

[1] *PLM : Product Lifecycle Management*

consists to dread CAD tools with beginners by the construction of one part, disconnected from its technology environnement. More over the great majority of self training devices like educational softwares are focused on the use of particular software features in the aim of modellizing non technological products. The trainees are learning how to realize shapes (even sometimes complex shapes) but nearly never how to analyze or design technological assemblies with CAD tools. As an illustration : a classification of on-line educationnal supports in all the french official académics web sites reveals that betwen 90 and 100% of them intend to shape parts, without any technological or functional analysis before. It usually consists to reproduce a known geometry. This leads to differents "models" for the same part genarally not exploitable if a redesign or a modification need to be implemented in the future...

An interesting study, [4], on correlation between training and efficiency of CAD users, leads on a sample of senior engineers, beginneers on CAD modellization, measure the performance by the time and the number of software features used for modelling single parts. It probably leads to many different solutions with the same final geometry. Certainly, according to the concerned product, some ways of modelling were preferable than others... This know-how for 3D models construction is by evidence an important parameter in order to measure efficiency of a technician and the utility of his work in the long-term.

2.3 From industrial vision to teacher's practice

The technical education had to take into account these evolutions of the tools of technical communication.

For the teachers responsible for training of technicians and engineers, the first digital tool which is going to be educationally introduced, is a tool of 2D representation, from the beginning of the 1980s. This kind of tool is for the designer like a digital drawing board. Appropriation of the computing tool represents then the only challenge for teacher. This difficulty, although not insignificant, does not cause any questioning about the educational practice bound to the technical representation.

The second technico-educational consequence is more discreet and concerns the evolution of the computing tools peripheral to the representation tool: tools of manufacturing, tools of calculation, tools of simulation and dimensioning. These technological evolutions highlighted very gradually the real evolution which is today present in the concept of digital chain. At the end of 1980s, training programs plan the use by students of dedicated software : some for the dimensioning, others for mechanical simulation or others else for the manufacturing.

The real change arrives at the end of XX century with the arrival of the 3D modeler [8]. And it can be noticed with interest that 3D CAD "might (also) encouraged creativity in designing" as it is shown in [11]. This technical evolution is going to have an essential educational impact, at the same time in terms of knowledges and skills to be acquired, but also in terms of educational organization and educational coherence or still educational wealth as illustrated in chapters 3 and 4.

3 The educational use of the modeller

This chapter shows how and why the arrival of the solid modeller questions an organization of the teaching progression as well as the nature of some knowledge concerning the education of the mechanical engineering.

3.1 Towards a simultaneous vision of the education

Since the early 1990s, the education of the mechanical engineering leaned on the downward analysis by leaving of the mechanical system as a whole to focus gradually on the elementary mechanisms, on the mechanical linkages then on the parts. This new approach in the technological teaching leads teachers to approach the fundamental notions of the mechanical technology in all their complexity and with more coherence, with more meaning.

Nevertheless, another twenty years ago, the learning of the codes of 2D representation was made the other way around. The teacher began the learning of 2D representation codes by firstly studying a simple part, then parts with more complex forms, to finish on assemblies. First weeks of the learning cycle were thus often dedicated to get acquainted with the plane representations through very little fascinating exercises of correspondence of views and a very limited technical interest. So, the education could only be sequential as far as the understanding of the functioning of a system imposed preliminary phases of codes of representation and visualization learning. Mechanical engineering teacher was then forced to organize his educational progress according to the discovery and to the control of the codes of representation by students.

The tool modeller offers now an answer to this paradox: it potentially allows to reconcile the downward analysis of the mechanical systems and the learning of the technical representation tools. The teaching can be now simultaneous (Fig. 4) because the understanding of the functioning arrives much earlier and allows then to approach the learning of the technical representation tools even on a complex system.

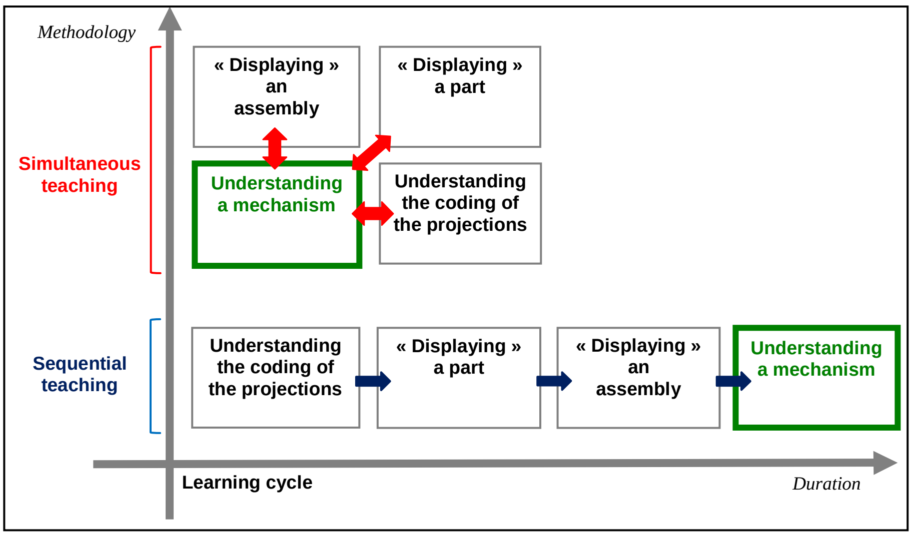

Fig. 4 Evolution of a sequential teaching towards a simultaneous teaching - According to [3]

At the moment, solid modelers allow to respect the general to specific approach from the technical system in all its global nature and its complexity to the study area which can be introduced in context. Indeed, it is not more difficult to address the use of a modeler by the representation of an assembly with much more interest in the technical viewpoint instead of a single part, extracted from its mechanism.

Finally, this opportunity must involve an in-depth reflection related to teaching progression. So, the teaching teams redefined the organization of their education on a learning cycle by taking into account on one hand inductive approaches and on the other hand use of the solid modelers. From the early first sessions, CAD tools allow to deal with technical problems leading to the acquisition of knowledge about technical systems analysis or kinematic modeling of the mechanical links.

The learning of the technical data coding/decoding, including mainly the 2D drawings, the relevant knowledge is addressed in a continuous way and in small steps according to the needs.

Another important change in the articulation of the teachings of design concerns the links between the mechanics teaching and the technology teaching. As presented in the first chapter, the digital mock-up occupies a central position in the digital chain and integrates all the information concerning the technical object: mechanical and geometrical characteristics, links, materials, dimensional and geometrical specifications… Then, calculation modules associated to CAD make possible to reach the mechanical and dimensioning parameters. Then, the links between the various taught concepts are largely facilitated (relation between construction and maintenance, relation between design, statics and materials resistance). The mechanical engineering teacher of design can approach technical systems of motion transmission and the input-output kinematics laws on the same educational sequence. It is the same for analysis of the connections and the mechanical loads or the functional dimensioning of parts and the strength of materials.

3.2 The representation of the real

A lot of technical trainings still include in their programs the necessity for the student to know how to decode the technical information carried by a technical 2D drawing. However, an analysis of training programs shows important evolutions with the use of modellers more widely recommended.

For example, in the vocational training of the semi-skilled workers in France, the knowledge related to the 2D representation codes are now restricted to the reading. And its concern only the meaning of the various "lines", the association of surfaces and volumes on various views and the statement of information carried out by a 2D drawing. And it is essential to outline that this 2D drawing is presented from a solid model.

From the analysis of the current training programs, it can be established the following report: abondant knowledge relevant to the codes of 2D representation disappeared leaving a larger place to knowledge about the use of 3D tools. For example, in order to understand the functioning of a system or to analyse the constructive solutions, the solid modeller allows to display an infinity of sectional drawings. This makes old-fashioned the use of cross-sections from parallel or secant plans. So, in most training, knowledge about the existence of these representation codes is not any more necessary. It is important to highlight other features of solid modellers for the needs of visualization: "hide/show" tool, "measurement" tool, design tree… These features constitute as many tools available to the teacher (and to the students) to approach "the identification of surfaces and volumes" or also "the decoding of subsets".

Finally, always in the same training programs, the only knowledges related to the representation concern either the 3D digital model or the free hand sketch. It illustrates well the necessity of revising the learning plans.

3.3 Thinking the solid modeller as an educational tool

Concerning the knowledge related to other interests than "the representation of the real", the basics of the mechanical engineering remained unchanged. But, if the teacher leaned on the 2D representation to approach them, the “modeller” as a tool stands out as the technical communication tool. As the synthesis lesson, at the end of practical activities, aims the same disciplinary knowledge and the same steps of problem resolution, the way to reach it has to be reinvented. Now, the digital tools allow much more teaching approaches, richer and more varied and eliminating the interference related to the 2D representation codes.

The next example (chap. 4) shows that it is possible and even strongly recommended to propose to beginners complex mechanisms from a familiar environment: it is easier to identify and put in situation a car than a particular part of the car, disconnected from its technological environment, and thus from its technological functions.

In conclusion, the new educational approaches related to the use of solid modellers lead to profound evolutions. First, it requires new knowledge, either related to a reasoned and technical use of the principles of the modeller’s organization, or about know-how consecutive to this use (notion of free hand sketch). It also requires the disappearance of former knowledge in particular related to the writing of the 2D representation. Whatever is the interest of the mental gymnastics for the decoding of an assembly 2D drawing, it is useful to wonder about its relevance, in the same way as it could be done if it were suggested to students to decode hieroglyphs!

The following chapter proposes to illustrate, through examples of activities, the relevance of the use of modellers and its rich educational opportunities.

Finally, these evolutions also concern the organisation of new form of works for the students because the learning is now partially made through the action of the students on the digital model. It is thus necessary for the teacher to define correctly this action and to wonder about what he gives to students, about the organization of his digital model, and about the question suggested to promote the learning. And if the solid modeller is a professional tool that can not be ignored, it can constitute also a very successful educational tool even in the very first sessions of education.

4 Educational potential of the solid modeller: applications

The teaching applications presented in this paper are primarily designed for students of engineering schools or high-level technical training. Some of them can constitute the first trainings session, without other uses of CAD tools before by the students.

The global context of educational exploitation is a project whose purpose is the partial re-design of the rear wheel-axle unit of a radio-controlled car for competition on a scale of 1/5 (Fig.5).

Fig. 5 Radio-controlled initial car and essential parts of the the rear wheel-axle unit to be re-designed

This context of re-design is based on the availability for the students of the initial product digital model (Fig.6), in compliance with the existing real product.

The following paragraphs present several ideas and track of scenarios for training sequences for students, future technicians or engineers of designing department. For each sequence, the educational potential of the modellers is illustrated. It is not possible (and not the aim here) to describe completely these examples and to give the operational lessons plans in this paper.

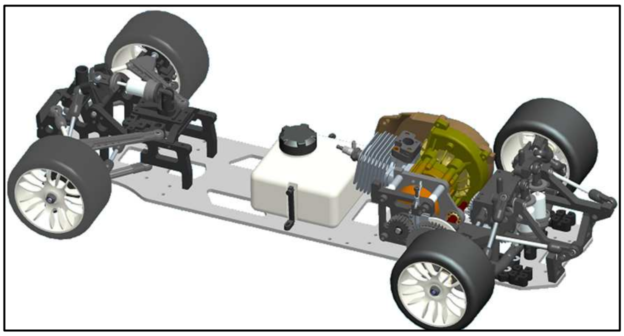

Fig. 6 View of the initial Digital Mock-Up geometry

4.1 Functional and structural analysis : assets of the modeller

Without any preliminary competences, the student thanks to features of his software is led to identify and to visualize the subassemblies associated with the study. The structured organization of the given digital model, quickly recognizable by the reading of the design tree, facilitates this first approach and allows especially to make sensitive the student on the importance of the structure of a mechanical system (Fig. 7).

From the very first session, the solid modeller allows the students to carry out the structural analysis of a mechanical system and leads them to become familiar with the technical vocabulary.

During this first phase, the relationship between the real system and the model is carried out (Fig. 7).

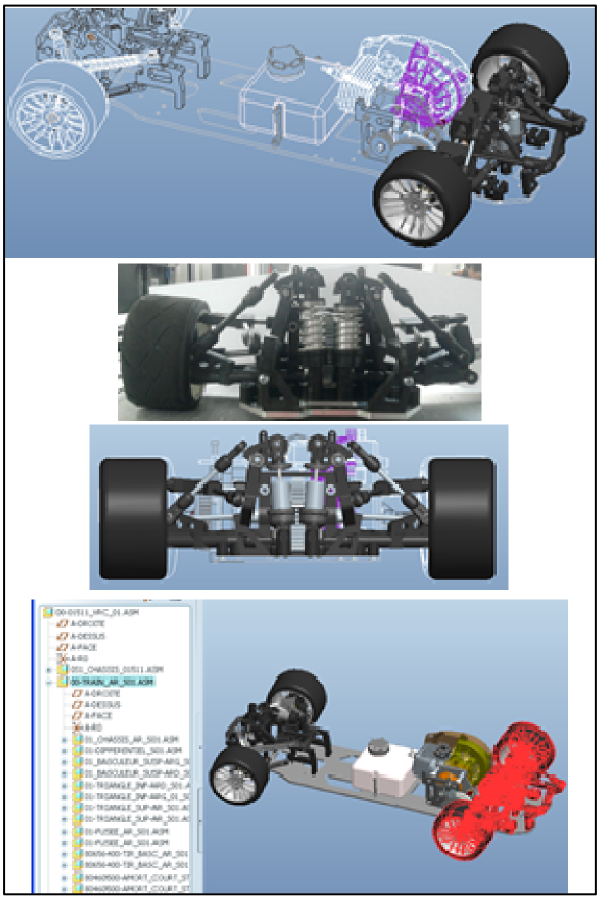

Fig. 7 Exploitation of a structured solid model: the use of display and identification software functions for exploitation of technical datas in relation with the real (photo above)

4.2 Analysing a behaviour

In connection with the kinematics lessons, the student is led to analyse the kinematic behaviour of one half rear wheel-axle unit with sereral phases :

- Identification of the kinematically equivalent subassemblies (made of parts without relative motion) (Fig. 8),
- Identification and characterization of the motions, from the animation of the model, which can lead to draw a kinematic diagram (Fig. 8),
- Identification of the geometrical parameters characteristic of this automotive suspension (Fig. 9),
- Evolution of the parameters during the motion,
- Production of a synthesis paper.

The structured organization of the model, by kinematically equivalent subassemblies, allows beginner students to use the display options of the modeller to identify very quickly the structure of the mechanism.

According to the level specified, the motions of subassemblies are visualized on the display in order to characterise the mechanical linkages or student can be led to group the different parts in order to build the kinematically equivalent subassemblies. It may be noted that the starting model given to students is not the same depending on the teaching purpose.

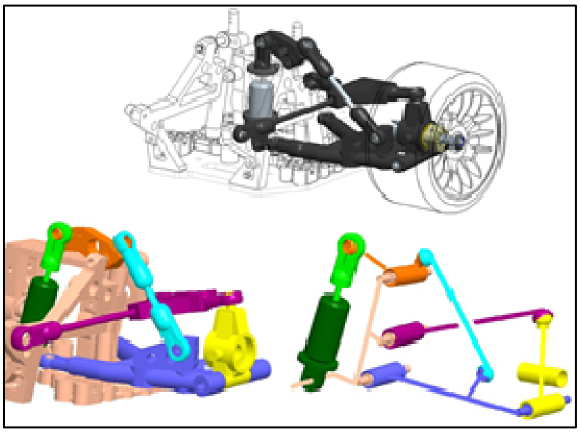

Fig. 8 kinematics analysis

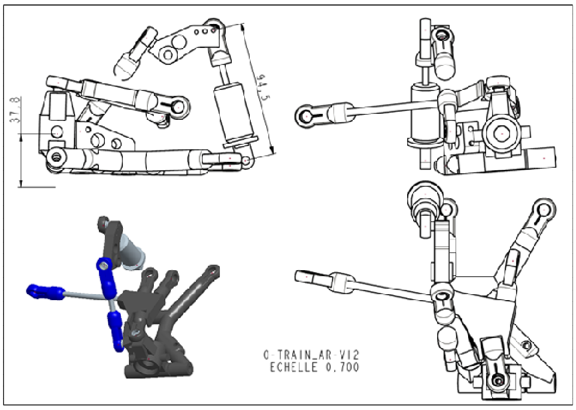

Fig. 9 Evolution of characteristic parameters

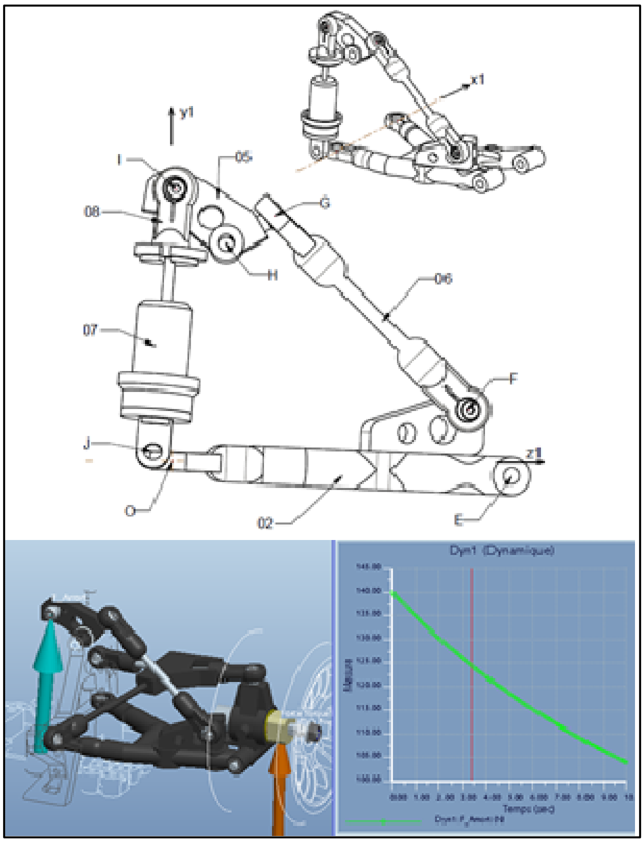

Fig. 10 Visualization of the evolution of the mechanical action of the shock absorber assuring the balance for the same effort on the stub axle during operation.

4.3 Simulating, modelizing

Always in connection with the mechanics lesson, the student is led to characterize the law input-output of this suspension in terms of efforts (Fig. 10). A parallel can be drawn between the calculated results and the results obtained with the digital simulation of the model. In order to realize this study, the modeller appears as a particularly successful tool.

When using this kind of approach, thanks to the software, the main part of the study can be focused on the "model / real" relationship and on the importance of the hypothesis by reducing the calculation aspect. For example, the results obtained via the simulation module can be compared with the results obtained by a graphics resolution associated with the hypothesis of a plane motion.

So, the solid modeller allows to :

- introduce in context new mechanical quantities (speed, load, stress, …),
- introduce and highlight the concept of model and the importance of hypothesis for resolution of technical problems,
- interpret the results from a calculation or a simulation.

4.4 Constructive solutions study

The study of the constructive solutions related to the linkages allows the student to analyze technical realization like :

- ball-joint connexion, Fig. 11,
- pivot connexion , Fig. 12, 13 et 14.

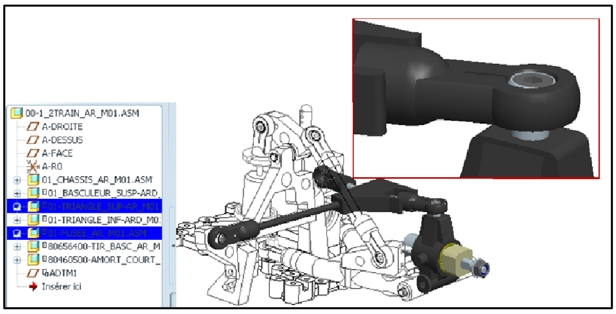

Fig. 11 constructive solution – ball-joint connection

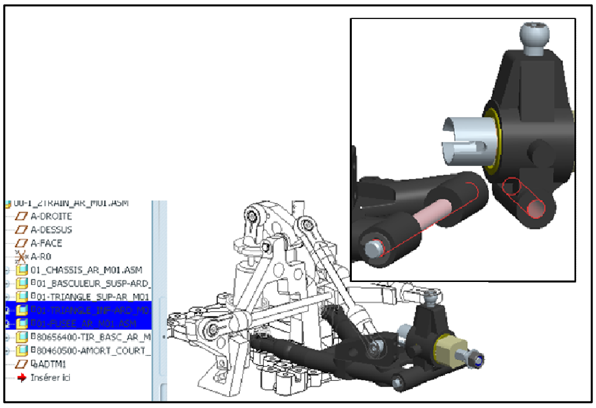

Fig. 12 constructive solution – pivot 1

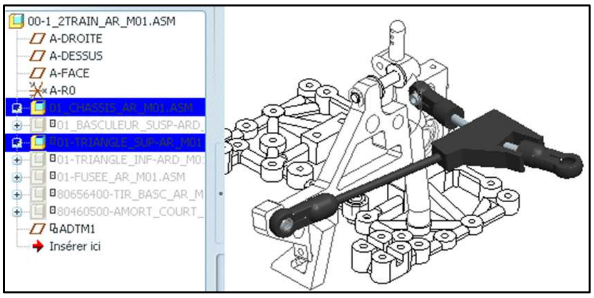

Fig. 13 constructive solution – pivot 2

The study of the pivot connections between the suspension triangles and the frame can make it possible to approach, in an inductive way, fundamental concepts like the structure of a connexion or the redondant constraints.

On the example, the “defect” which appears (fig. 14) can be significant only if the model is correctly defined. Then, it is possible to approach once again in a relevant way the model/real relationship which constitutes a fundamental knowledge in numbers of teaching curriculum.

As outlined above, this analysis of the constructive solutions is pedagogically facilitated by the general organization of the assembly where the couples of parts can be very easily isolated in the design tree and with the use of the software visualization functionalities.

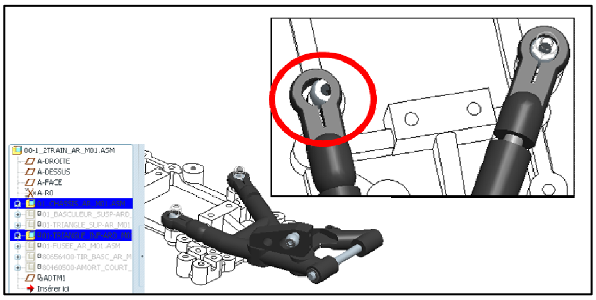

Fig. 14 constructive solution – pivot 3 kneecap connection interference – model/real relation

4.5 The re-design of the lower triangle

Within the framework of a collaborative work (in group) student are required to propose a modification of the lower triangle taking into account the data collected in the functional specifications and leading to realise a prototype which will be tested in competition. The constraints are :

- the use of the standard ball-joint connection of the company,
- the material Ertacetal,
- the means of production: manufacturing CN, via CAD-CAM (Fig. 15).

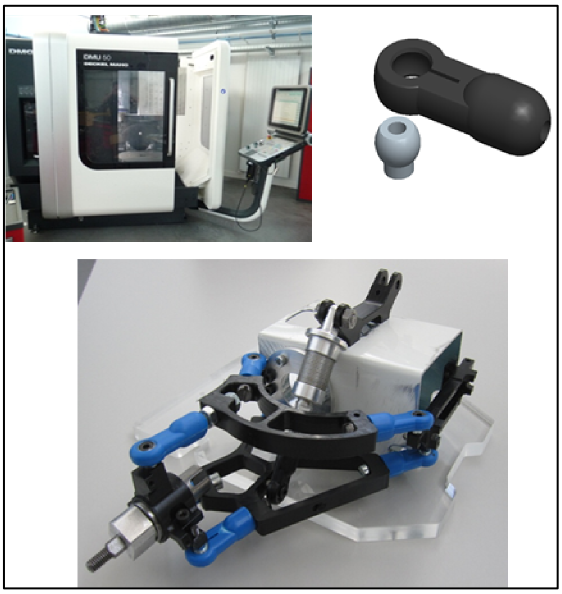

Fig. 15 standard connections and means of production

Each group of students propose a parameterized general architecture of the subassembly integrating the results of the previous study (Fig.16).

Each student of the group deals with the structured design of a part which can be prototyped for validation before manufacturing (Fig. 17).

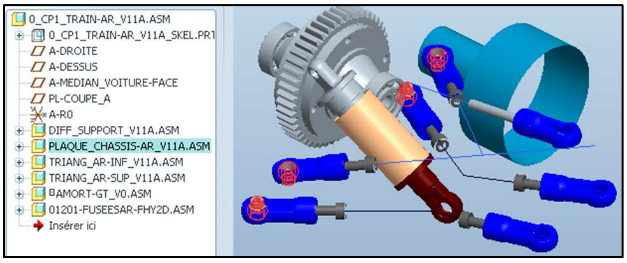

Fig. 16 General structure of the project – subsets are identified in the design tree.

In this last phase, each group proposes a redesign of the lower triangle starting from the functional surfaces and verifying criterion of resistance and of manufacturing (Fig. 18).

This last phase highlights the central and federative place of the solid model within the digital chain. “The skilful use of almost unlimited possibilities of creating virtual prototypes of real objects provides modern engineer with ability of overcoming many design barriers” [9].

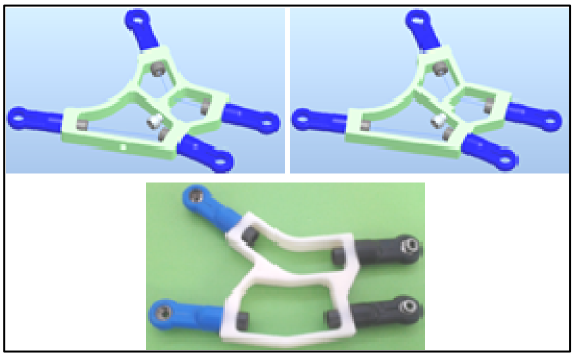

Fig. 17 Preliminary design of the lower triangle (rapid prototyping)

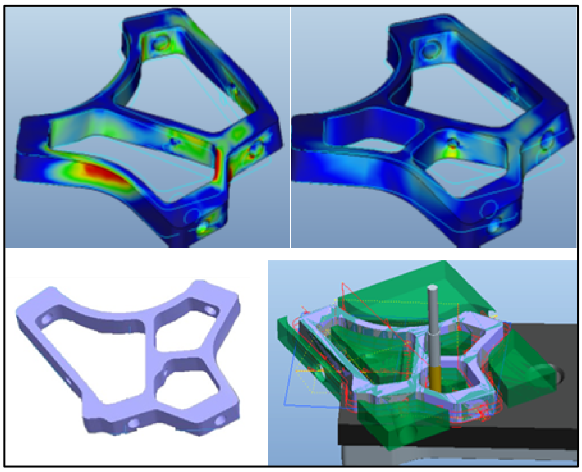

Fig 18 Validation of morphologies (strain and stress criteria) taking into account of the manufacturing and preindustrialisation constraints of the triangle.

5 Conclusion

The evolution of the technical representation tools which occurred during the last decades generates a fundamental reconsideration of our teaching approaches in the field of mechanical engineering. Solid modellers facilitate the access to the technical data and allow reconciling, even at the beginning of a training cycle, the learning of technology and the learning of mechanical knowledge. These two learning can operate on common supports and in a simultaneous way. This constitutes a true revolution which requires a careful thought of the educative teams. It also requires for teachers to prepare the solid model according to the focus of learning.

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