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IMPLEMENTATION OF PLM METHODOLOGY IN UNIVERSITY TEACHING. CASE: AUTOMOTIVE

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The present project consists in the implementation of a project management system based in the Product Lifecycle Management (PLM) methodology, in the environment of the technical school IQS School of Engineering.

By means of finding the most adequate perspective of this methodology to be applied in an educational environment, plus a software solution suitable for the future professionals which are the students of this school, a state of the art study has been made. The purpose of this study is to determine the current state of PLM in the industry, along with figuring out what are the main software solutions available in the market referred to PLM.

Furthermore, by defining the importance of the processes based on an academic perspective, a selection criteria has been established regarding software tools, to ensure a friendly learning experience for students. Hence, it can be presumed that graduates may achieve a solid knowledge of PLM methodology. Assuming that PLM is a rather recent strategy for most of industrial enterprises, the demand of professionals with expertise in that effect, is growing every day.

Keywords: *PLM; Product Lifecycle Management; Project Management*

IMPLEMENTACIÓN DE LA METODOGÍA PLM EN DOCENCIA. CASO TIPO: AUTOMOCIÓN

El presente trabajo consiste en la implantación de un sistema de gestión de proyectos empleando la metodología Product Lifecycle Management (PLM) en el entorno universitario de la escuela técnica superior IQS School of Engineering.

Con el fin de hallar la vertiente de esta metodología más adecuada para un entorno pedagógico, así como una solución de software idónea para los futuros profesionales que son los alumnos de esta escuela, se ha hecho un estudio de la situación actual de la gestión del ciclo de vida de los productos en la industria, así como de las principales herramientas informáticas existentes en el mercado para tal fin.

Asimismo, se han establecido unos criterios de selección en cuanto a software se refiere, basados en la definición de los procedimientos más importantes desde el punto de vista pedagógico, para asegurar un aprendizaje ameno para los alumnos. Con ello se pretende garantizar que los graduados tengan un conocimiento sólido de la gestión del ciclo de vida de producto o PLM, pues al tratarse de una forma novedosa de trabajar, la demanda de profesionales con conocimientos de PLM es cada día mayor.

Palabras clave: *PLM; Gestión de ciclo de vida de producto; Gestión de proyectos*

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1. Introduction

The PLM methodology is a business strategy applicable to any industry, involved in the manufacturing of tangible consumer goods. The main feature of this philosophy is built on the real-time control of all processes, design stages, and raw materials necessary for the successful manufacturing of a product, from the initial conceptualization stage to its market withdrawal.

Since the major industrial companies worldwide have implemented and used it successfully, this project lays out the creation of a method for teaching this tool to industrial engineering students, and providing them with the necessary skills and knowledge necessary to access the labour market with skills better suited to today's complex business environment.

2. Objective

The main objective is primarily to implant in the engineering studies curriculum a practical and theoretical training on the current PLM tools. Secondly, the aim is to implement the appropriate software as well as the practical case studies necessary for that purpose.

3. PLM concepts

Product Lifecycle Management (PLM) is often described as a technology, although it is more accurate to say that it is a technical/economic strategy. This strategy enables industrial companies to become more innovative and productive thanks to the synergy created between data management and the integration of the different software tools used.

The main goals of this strategy are cost reduction, increasing the quality level in the company, facilitating the creation of innovative products and services, and managing the adaptation to the market's constant changes. It is one of the four pillars of the information technology infrastructure in a corporation. The other three pillars are:

- **Customer Relationship Management (CRM)** is used to collect the needs of the customers and analyze trends to allow for continuous innovation.

- **Supply Chain Management (SCM):** is used to manage the required procurement activities with the suppliers.

- **Enterprise Resource Planning (ERP**) is used to manage production and the company's activities in general.

These tools allow companies to monitor the life cycle of a product in real time by using the intellectual property created by the different company departments. It also makes possible to manage and interpret efficiently the data generated from a product's conception to the end of its life.

3.1 Product management difficulties

Managing a product during its life cycle is not trivial, as multiple factors beyond the manufacturers' control come into play. During the development stages there is nothing physical - only virtual sketches and models- and it is not uncommon to lose control of the processes. In the same way, when the product is delivered/sold it goes to the customer's facilities, and again it is difficult to have control over it. (Stark, 2011)

The objectives of PLM are mainly:

- Manage the Product Portfolio structure.
- Maximize the economic return of the Product Portfolio.
- Provide control and visibility of the product throughout its life cycle.
- Manage the product's development, support, and delivery effectively.
- Manage the feedback on the product form customers, field engineers and the market in general.
- Encourage collaborative work between designers, suppliers and customers.
- Manage the processes to assure they are consistent and efficient.
- Manage and maintain the integrity of the product definition securely, making it visible when needed.
- Retain the exact knowledge of the product's characteristics (both technical and financial) along its life cycle.

Broadly speaking, the objective of PLM is to manage, store and distribute all the information of the product's life cycle so that it reaches the right people, at the right time, and with the adequate quality.

As examples of some of the challenges to overcome in the different stages of the life cycle, we could mention:

- During the creative phase: assuring that the requirement guidelines are followed at all times.
- In the definition phase: guarantying that the objectives defined in the conceptualization stage are achieved during product development.
- In the manufacturing stage: verifying that the product version established in the definition stage is the one being produced.
- In the use phase: checking that the product has an adequate maintenance program that takes into account and reflects the possible updates or changes in the market's technical evolution.
- In the end of life phase: assuring that all toxic components have a proper recycling strategy.

While for an ordinary user it may seem unlikely that so many factors should be controlled in all the stages, an engineering student should assimilate that the industry handles large amounts of information. Moreover, along a product's life cycle changes and revisions are constantly performed according to the product's behaviour in the market. These changes are carried out by different departments and at different levels in the company hierarchy - and consequently- by a large number of professionals. This makes losing control in any of the phases all the easier. In fact, this is how it happens in the industry, the more complex a project is, the more necessary it becomes to use PLM methodology and tools.

3-2 PLM paradigm

We talk about PLM when there is a global approximation to the project control problems, or when the different processes are united in a coherent way. More specifically, when one of the following connections occurs (Stark, 2011):

Product Development	and	Product Support
Product Infancy	and	Product End-of-Life
CAD, PDM	and	Project Portfolio Management
Product Development	and	Product Disposal
Product Assembly	and	Product Disassembly
Product Development	and	Product Liability
Product Developers	and	Customers
Product Definition	and	Environmental Issues
Product Development	and	Sustainable Development
Product Innovation	and	Mature Products
Project Portfolio Management	and	Product Portfolio Management

The existence of these connections justifies the application of the PLM methodology. To tackle the problem in an effective and comprehensive way, all the factors involved in the product manufacturing are integrated in a superstructure where the products, processes, data, applications, equipment, methods, governance structure, human resources, and the metrics used to evaluate everything; are at the service of the company throughout the life of the product.

It should be noted that the implementation of the PLM philosophy is carried out gradually, since it is highly recommended - as well as the most sensible option – to introduce different components and consolidate them before introducing additional ones. The total implantation of the PLM philosophy is a process that can last years, because it is not enough to purchase new software, but that all the personnel must adapt to this new approach, with a daily learning process. It also demands a change of mentality and of mind-set, and a different way of working throughout all the hierarchical levels of the company.

4. Definition of the teaching PLM methodology

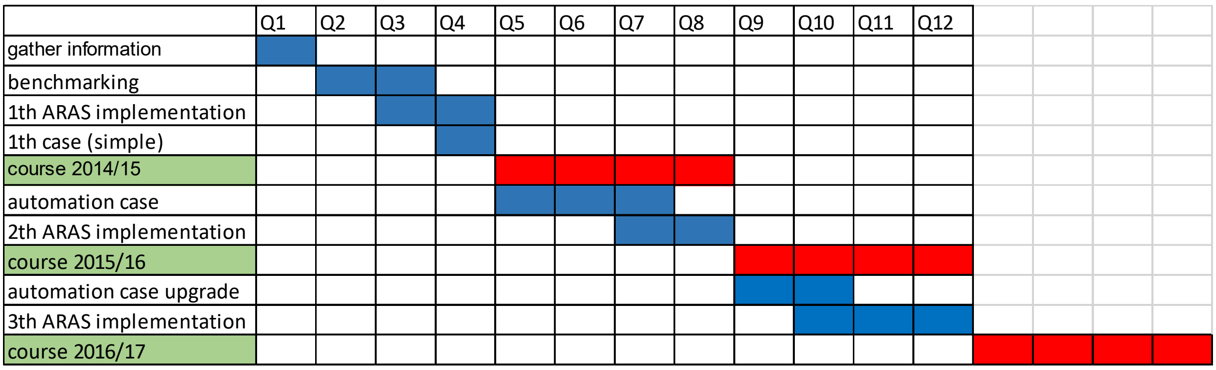
4.1 Planning

With regard to the materialization process for the project object - due to the characteristics of a small-scale implementation - it has been defined a “turnkey” delivery period of three (3) years for a fully functional PLM platform.

To meet this deadline, the total delivery time has been divided in twelve (12) quarters in order to complete all the necessary stages to delivery, according to the schedule shown below.

Each of the implantations (courses 2014/15 to 2016/17) is self-sufficient so that students can use and understand the PLM philosophy and technology.

Fig.1.- Planning (own source)



4.2 Benchmarking and PLM selection

In order to carry out a comparative analysis as objective as possible between the different PLM solutions existing in the market, we have defined some parameters whose study can determine which tool is the most appropriate for a successful PLM implementation.

The parameters analysed are the following:

- Network sizing: determine the number of users supported by the studied software.
- Industrial Sector: investigate what software is the most widely used according to the client's sector. It is always interesting to see how the competition addresses the same problems, because their solution can also be the most appropriate.
- Features Offered: study the characteristics of each software and see what may be the most suitable for the present project.
- Customization Opportunities: determine to which extent the solution is flexible, and whether the level of flexibility meets the established requirements.
- CAD/CAx supported formats: it is of the utmost importance that the PLM software is compatible with the CAD/CAx solution used by the organization to be deployed. This is important since to shorten the implementation time it is recommended that the adopted PLM solution is compatible with the CAD/CAx tools typically used by the company.
- Platform used: evaluate the software and hardware requirements needed for the execution of the PLM solution.
- Price of the licenses: As is to be expected for any investment made by a company, you should evaluate the cost of this investment.

The main PLM software packages in the market have been benchmarked:

TEAM CENTER, WINDCHILL, ENOVIA, SMART TEAM, ARAS INNOVATOR

The benchmarking has provided a very clear picture of the performance of the four (4) software packages analysed. Each and every one of them would be valid for the project that aims to develop because of their respective qualities.

On the other hand, taking into account the fact that they all share a very similar structure, and that they are going to be used in an academic context, the final decision has been based on the following criteria:

- License price
- Flexibility
- Compatibility with the CAD programs used in IQS School of Engineering.

Since the most widely used CAD products in the technical School are SolidWorks and CATIA - from the Dassault Systèmes group - it might seem logical to think of the Enovia® PLM software, also of Dassault Systèmes. However, this is a very complex option for teaching, because it requires a thorough training in order to get a performance that justifies paying the price of the license. Therefore, this would turn out to be an underused option.

On the other hand, it is known that the compatibility of the PTC Windchill 11 ®, of PTC ® and Teamcenter® software packages - from SIEMENS® - with SolidWorks and CATIA - from the Dassault Systèmes group - is neither the most suitable or user friendly for an academic environment.

On the other hand, the flexibility of the PLM ARAS Innovator® software - from ARAS® - would allow a very personalized and exclusive implantation for an academic environment such us object of the present project. In the same way, its free license has favoured the possibility to test (successfully) this software several times, as it will be shown later. Another point in favour of the ARAS® software is its compatibility with the SolidWorks and CATIA software packages - from the Dassault Systèmes group.

In light of the foregoing, it has been decided to propose the ARAS Innovator® PLM solution – form ARAS®, for the implementation of the PLM methodology in the Projects subject in the Industrial Engineering studies at IQS School of Engineering.

4.3 Modules to implement

In a first phase, it is advisable to implement the CPD and PDM modules, in order to evaluate both the software and the student's response. Because it is a new technology - which they will never have encountered- it is advisable that their first contact is enjoyable. The modules to be implemented in the first place are the following:

CPD (Collaborative Product Development/Design)
CAD (Computer Aided Design of the product components) - Revision Management / Change Management -Visualization - Concurrent Design
PDM (Product Data Management)
Materials (and raw materials) Management - BOM (Bill of Materials) - Production process Management - Quality Specifications Management - Import/Export Product Data -ECM (Engineering Change Management)

As the students' knowledge is consolidated, additional modules may be implemented to offer a broader training; as long as it is guaranteed that the proposals are aligned with the established objectives.

4.4 Work Team Definition

Work teams shall be designated in at least two groups with a size of at least 8 students per group. The current case supports 4 groups, but it could be expanded if necessary by implementing more parts of the environment such as Pillar B, where four more groups could be formed.

The members of each group will be assigned roles and responsibilities, these roles can be repeated and some students can have different roles throughout the project. The main roles and the number of students recommended by the group are
- Project Leader / Manager (1)
- Designer (3-5)
- Change Manager (1-2)

- Revision Manager (1-2)

Each team will be in charge of one part: Pillar B, Pillar B cover, Pillar B cladding, and Pillar B internal reinforcement (if forming the 4 planned groups is possible).

Each role will be assigned a task according to the phase of the project according to the following table.

Fig.2.- Table of tasks (own source)

Stage	Substage	Project Leader	Designers	Revision Manager	Change Manger
Obejtive Setting	Create Planning	A			
	Verify Group Setup	A			
	Verify File Setup	A			
	Create checklist to verify the parameters of the parts in each design stage	A			
	Check Workflows	A			
Desing of each phase	Create Parts	I	A		
	Create CAD docs	I	A		
	Launch "Part release" workflow	I	A		
	Verify parts acccording to corresponding checklist	I		A	
	Release the Parts	I		A	
Assembly	Carry out simulations and verifications	I		A	
	Economic analysis	A	C		
Change Management	Create Change Management forms	I + A	I	A	A
	Create new Parts	I	A	C	C
	Verify new Parts	I		A	
	Release Parts	I		A	

A= Actor of the task

I = Must be informed

C = Must be consulted before performing the task

5. Definition of the Case Study.

It is necessary to create a specific case so that students can work with PLM and can understand the specific problem. They must be able to assimilate the methodologies and understand how PLM helps them have control over the project.

- Starting from these premises, a fictitious case of the automotive industry is created with the following characteristics:
- The students should be able to work on different teams and use concurrent engineering.
- The case should be complex enough so that the solution is not trivial.
- The project should preferably be about a not very well-known real part. Thus, specifications and contour conditions can be controlled by the teaching staff.
- The students will be given semi-developed material so that they do not have to waste too much time on less interesting aspects.
- Version change should be managed.
- It should be possible to manage the roles and permissions of each user.
- It should be possible for the student with the “Project Leader” role to define the workflows.
- At no time should the initial objectives of the project be abandoned.

- The project will have absolute traceability.

The project chosen for students is the development of the set of pieces called Pillar B inspired by the SEAT IBIZA 5- Door model

Fig 3: Body images and supplied environment (own source)

The student will receive a set of CAD parts of the environment, the typical sections, and a dossier with the technical specifications to be solved in 5 different phases:

The student also has a design file with the results of the design phase and its objectives.

Next, the pupil receives a considerable amount information about targets of the design phase objectives. This way they will have no option but to be methodical, use the tools provided, and be vigilant to avoid the project getting out of hand.

It should be noted that the student receives part of the know-how for this type of project by means of an ARAS from a hypothetical previous project.

Below are the requirements included in this template:

5.1 Specification list

The design of the Pillar B has to be carried out focusing it on the tests and requirements that the piece and its set have to pass. All this taking into account that it must also overcome the homologation restrictions and that one of the objectives is to obtain the maximum score in the EuroNCAP tests. (https://www.euroncap.com, June 2015)

The detailed specifications for the components object of study are defined in the following sections.

Front seat belts tearing

This test checks the resistance of the seat belt brackets and of the bodywork environment.

Structural rigidity

The test consists of checking the torsional stiffness (rigidity?) of the body in its full length. It is also checked that there are no deformations that affect functionality in the different areas (hollows for doors, boot/trunk and windshield, and rear wheel arches).

Door Slam

The test consists of checking the fatigue on the latch, hinges, gaskets, gaps and flushes.

Euro NCAP Side pole test

In Euro NCAP's test, a car is propelled sideways at 32km/h against a rigid, narrow pole.

EuroNCAP Side impact

In Euro NCAP's test, a deformable barrier is mounted on a trolley and is driven at 50km/h into the side of the stationary test vehicle at right angles. A side impact dummy representing an average male is put in the driver's seat and child dummies are placed in child restraint systems in the rear.

5.2 Technical and functional requirements

For the design of the Pillar B and its cover it is necessary to create the parts according to all those technical and functional requirements that guarantee their viability. Therefore, the following sections are dedicated to describing all the process and environment requirements to be met.

Minimum stamping angles
The deep drawing angles of the parts must not be less than 8 °. These angles are referred to the vertical walls of the pieces.
These minimum angles will allow for a more controlled stamping in order to minimize springback and result in unproblematic part extractions.

Minimum hot-stamping radius: 8mm
The deep drawing radii of the parts must not be less than 8mm. This must be taken into account for all the angles in the reinforcement for Pillar B, since it is hot-stamped. Radii smaller than 8 mm in hot-stamping would result counterproductive, since there is a risk that part gets stuck because of large stretching and breaks.

Smooth transitions between surfaces
Smooth transitions must be applied between all the surfaces of the Pillar B reinforcement and Pillar B cover. These transitions will prevent too aggressive edges and joints on the surfaces, which could cause problems in the simulations and crash tests, as well as an excessive thinning of the sheet during the stamping process.

RPS tables and holes with tolerances
Due to the fact that the students are not experts in these type of parts, they have been provided with the coordinates of welding points, RPS points, and holes of the previous model, so that they can have approximate idea of where they should be placed.

Therefore, the student must carry out the following tasks.

5.3 As PLM Manager

Define and decode documents, define workflows, and define checklists.

Fig 4: Template CAD Document (own source)

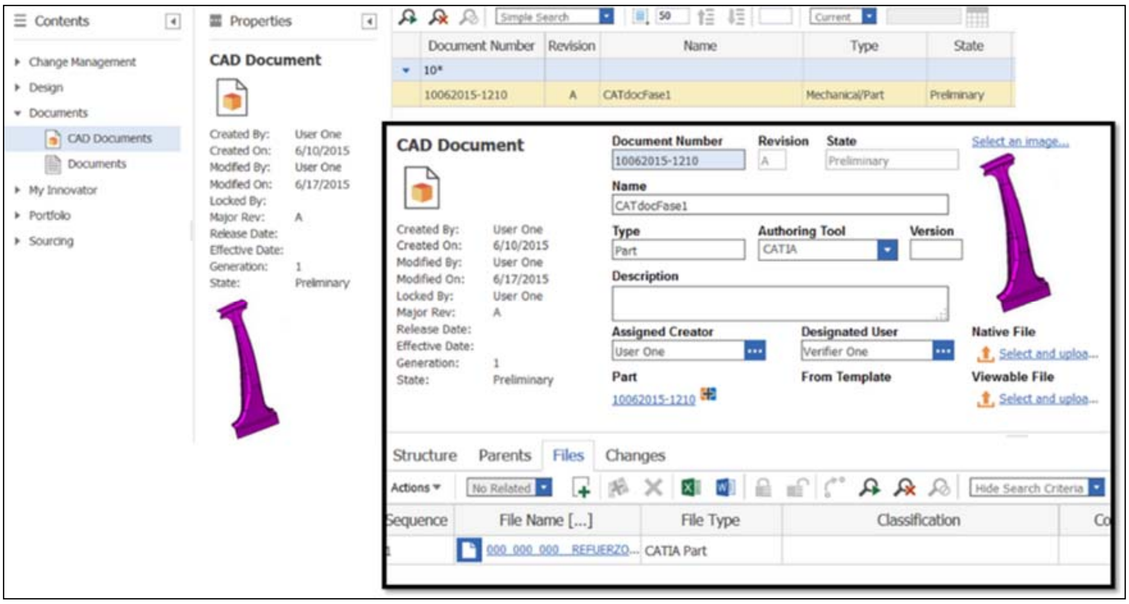
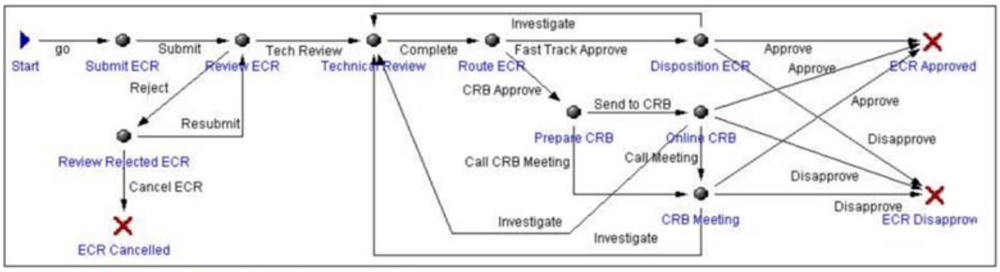


Fig 5: Workflow in ARAS software (own source)



Workflow History Report

Item: ECR-100008 — Enterprise Change Request
Started By: Verifier One — Started On: 6/3/2015 12:36:51 PM

Activity	State	Assigned To	Completed By	How Voted
Submit ECR	Closed	Verifier One	Verifier One	Submit
Review ECR	Closed	Change Specialist I	Changer One	Tech Review
Technical Review	Closed	User One	User One	Complete
Route ECR	Closed	Change Specialist I	Changer One	Fast Track Approve
Disposition ECR	Closed	User One	User One	Approve

5.4 As PLM User

As Project Leader, Designer, Revision Manager and Change Manager

- Enter data in the system according to the templates defined in ARAS
- Use the correct data in the correct time
- Use the defined processes correctly
- Check feasibility
- Verify the traceability of the parts

- Monitor the protect status at all times

We will elaborate a little more on the task "Check feasibility" task.

The students with the "Revision Manager" role must verify that the parts released comply with the following:

Technical feasibility of the manufacturing process

In this section are described all those aspects to be taken into account in order to assure the technical feasibility of the parts during their manufacturing process.

- Minimum radii
- Deep drawing directions
- Minimum distances between parts
- Shape, position and cuts tolerances
- Stamping defects

Technical feasibility of Sheetmetal process

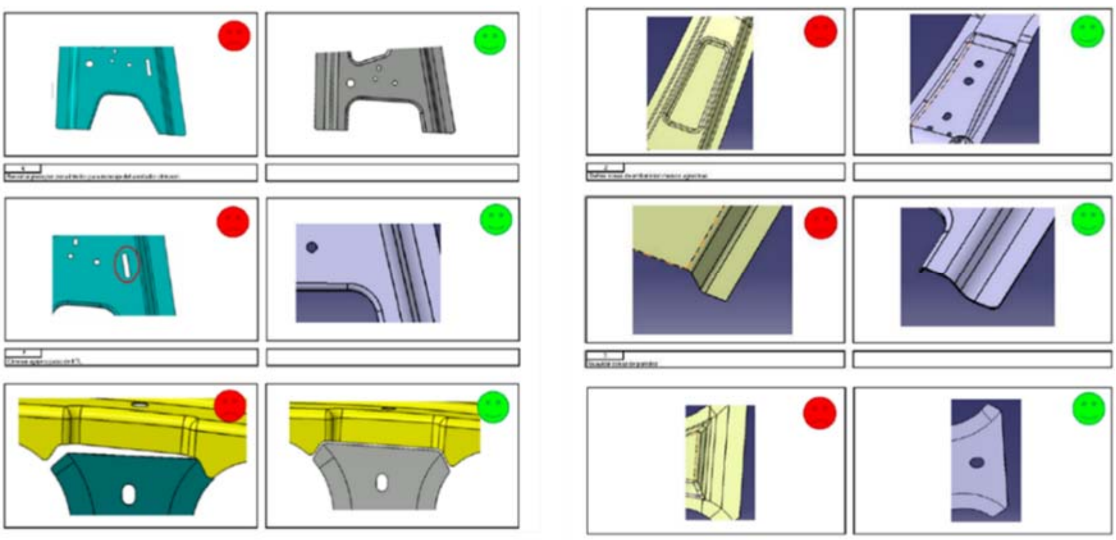
In this section are described all those aspects to be taken into account in order to assure the technical feasibility of the parts during the sheetmetal production process.

- Set parts assembly
- Distribution of joint techniques
- Well defined contact surfaces a cording to joint techniques
- Access to welding tools
- Main and secondary RPS for centering and support
- Clearance holes for RPS. Noise barriers

Technical feasibility of assembly processes

Another important point to consider is the assembly of the set parts and their environment. The correct placement of all the elements in the assembly line must be guaranteed, facilitating the availability and assembly of all the elements that make up the system.

Fig 6: Check list (own source)



6. Conclusions

The implementation of the PLM philosophy is very complex, and the implementation of PLM tools even more so. Students are used to work individually or in small teams on more or less difficult projects. However, understanding the complex management inherent to real projects is difficult for them, and therefore they do not understand the need for such complicated project management tools.

This implementation brings to the engineering students of IQS School of Engineering to challenges and issues of the real industry, and gives them a vision of the tools that in the near future will be common in all companies. Currently only large companies use PLM tools successfully.

The option to implant a complex industrial case has resulted successful, as it has allowed moving the focus from technology to PLM management. It has also allowed the students to delve into real-life problems and into the solutions currently offered to real companies.

PLM philosophy has proven to be a winning philosophy. In the coming years we will see a great demand for professionals who are knowledgeable about this technology.

A great difficulty has been experienced to successfully implanting this type of technologies, even in a priori simple educational implantation. The barriers and difficulties encountered have been remarkable.

7. References

Bruno, G., Antonelli, D., & Villa, A. (2015). A reference ontology to support product lifecycle management. Procedia CIRP, 33, 41–46. http://doi.org/10.1016/j.procir.2015.06.009

Chiang, T. A., & Trappey, A. J. C. (2007). Development of value chain collaborative model for product lifecycle management and its LCD industry adoption. International Journal of Production Economics, 109(1-2), 90–104. http://doi.org/10.1016/j.ijpe.2006.11.005

Danesi, F., Gardan, N., Gardan, Y., & Reimeringer, M. (2008). P4LM: A methodology for product lifecycle management. Computers in Industry, 59(2-3), 304–317. http://doi.org/10.1016/j.compind.2007.06.013

Kiefer J., Allegretti S., BreckleT.,(2018) Quality- and Lifecycle-oriented Production Engineering in Automotive Industry, Procedia CIRP, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2016.06.086

Kubler, S., Derigent, W., Främling, K., Thomas, A., & Rondeau, É. (2015). Enhanced Product Lifecycle Information Management using “communicating materials.” CAD Computer Aided Design, 59, 192–200. http://doi.org/10.1016/j.cad.2013.08.009

Manello A., Calabrese G. (2018) The influence of reputation on supplier selection: An empirical study of the European automotive industry, Journal of Purchasing and Supply Management ISSN 1478-4092 https://doi.org/10.1016/j.pursup.2018.03.001

Mathivathanan D., Kannan D., Noorul Haq A.(2018) Sustainable supply chain management practices in Indian automotive industry: A multi-stakeholder view. Resources, Conservation and Recycling, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2017.01.003.

Messaadia, M., Belkadi, F., Eynard, B., & Sahraoui, A. E. K. (2012). System engineering and PLM as an integrated approach for industry collaboration management. IFAC Proceedings Volumes (IFAC-PapersOnline) (Vol. 14). IFAC. http://doi.org/10.3182/20120523-3-RO-2023.00205

Rachuri, S., Subrahmanian, E., Bouras, A., Fenves, S. J., Foufou, S., & Sriram, R. D. (2008).

Information sharing and exchange in the context of product lifecycle management: Role of standards. CAD Computer Aided Design, 40(7), 789–800. http://doi.org/10.1016/j.cad.2007.06.012

Stark, J. (2011) Product Lifecycle Management,21st Century Paradigm for Product Realisation Second Edition. ISBN: 978-0-85729-545-3 978-0-85729-546-0

Tang, D., & Qian, X. (2008). Product lifecycle management for automotive development focusing on supplier integration. Computers in Industry, 59(2-3), 288–295. http://doi.org/10.1016/j.compind.2007.07.002

Umpfenbach E. L., Dalkiran E. , Chinnam R .B., Murat A. E. (2018). Promoting sustainability of automotive products through strategic assortment planning, European Journal of Operational Research,ISSN 0377-2217, https://doi.org/10.1016/j.ejor.2017.08.031