Paper 10

A Digital Pattern Methodology supporting Railway Industries in Portfolio Management

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Abstract

The object of this paper is the development of a decision support system involved in the bidding for invitations to tender in the railway field. The proposed methodology is based on the characterization of the whole train and its components, through several attributes according to a digital pattern approach. In particular some key components were chosen such as the traction motor, the bogie and the auxiliary equipment converter. The system measures the extent to which the products offered by the company fit the one required by the customer, comparing the homologous attributes. Such analysis is called 'adopt/adapt/innovate' (AAI). In this way it is possible to identify products already designed that fully or partly fit what required, obtaining huge benefits in terms of effectiveness and efficiency.

Keywords: decision support system, digital pattern, digital portfolio, bid, virtual prototyping.

1   Introduction

In the railway field the success of a project is strictly linked to the right decision about whether to bid to an invitation to tender (BID/NO BID). Companies operating in this sector mostly make to order. Consequently they need to evaluate appropriately the technical and economic feasibility of the required vehicle [1].

The process involved in bidding to an invitation to tender is very complex. It involves several business functions with different priorities and goals. Mistakes and unfounded choices would be unavoidable if decisions were taken on the basis of mere intuition or subjective analysis. Therefore the process of preparing the bid is expensive in time and money. To use the knowledge heritage of the Company is mandatory to evaluate in a short timeframe whether to bid or not [2], [3].

This paper proposes a tool to improve the company products portfolio management using a methodology based on Digital Pattern (DP). In particular times

and costs are reduced by using all the process or product patterns existing within the Company, according to Knowledge Based Engineering (KBE) approach [4], [5], [6]. A digital pattern represents a series of predefined and parametrical data structures, both geometrical and numerical; such data structures adapt to specific different contexts. Designers reduce the concept phase time and improve the reliability of choices using simulations, specific models and reference rules and standards as decision support tools [7], [8], [9].

In particular, the Decision Support System (DSS) object of this paper allows:

- To catalogue and visualise Company products. It is possible to interrogate the system in order to extrapolate information about standard products (e.g. vehicles, subsystems and components);
- to compare catalogued products to those required in the invitation to tender. The system provides the list of the products best fitting the required one with a percentage affinity index. This index is calculated on the basis of the comparison between homologues features of the products using a specific research algorithm.

The opportunity represented by the systematic visualization of the company portfolio and its confrontation with the required product supports the whole bidding decision making process. Activities were carried out in collaboration with AnsaldoBreda Spa, a Finmeccanica Company.

2   Methodology

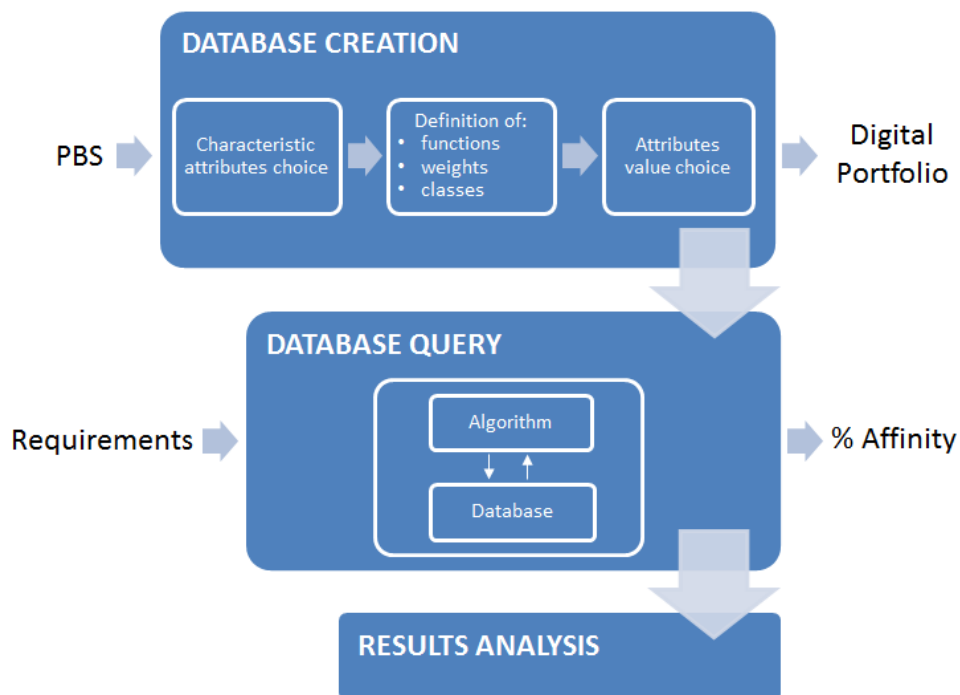DSS methodology is structured in the three phases in the figure below:

Figure 1: DSS Methodology

The Database is created from the elements of the Company Product Breakdown Structure (PBS) [10]. Each element is described by a series of characteristic attributes [8]. Every attribute is associated with a comparing function, a weight and a class. These objects are used by the search algorithm described in paragraph 3.

In this way a pattern of a specific element of the PBS is created. To complete the database (DB) creation, assigning a value to pattern attributes is needed.

This procedure allows to populate the DB. Therefore this process is reiterated as many times as the number of products in the digital portfolio. For example the PBS element "Traction Motor" was reiterated 18 times, which is the number of different traction motors chosen for the digital portfolio.

The pattern containing the attributes with a value of a specific company product represents the Charactericts Matrix. All the Characteristics Matrices of the different PBS elements form the digital portfolio.

Similarly the pattern containing the attributes with a value of a product required by an invitation to tender is called Requirements Matrix.

The second phase concerns the database query, with the purpose of finding the product that best suits what required. The system compares the Requirements and Characteristics Matrices by a search algotithm. Such algorthm outputs the affinity indexes of the digital portfolio products. In particular the offset from 100% represents the effort needed to make the digital portfolio products fit to what required.

Starting from the affinity index the results analisys is performed with the paradigm Adopt/Adapt/Innovate (AAI). This paradigm consists in "adopting" a product if the affinity index is 100%; in this case no effort is required to satisfy client requests. The algoritm output is "adapting" if the offset requires an accetptable effort. Finally, if the offset is bigger than a certain amount, the output is "innovating" the product, since designing from scratch a new product involves less money and time than modifying what is already available [1].

3   Search Algorithm

A key element of the methodology above described is the search algorithm which, receiving requirements in input, provides in output the affinity index between the requested element and those available in the Digital Portfolio.

It consists in three steps represented in the diagram below (Figure 2). It is suitable to search for any type of product, be it a whole vehicle or a component.

Each stage is characterized by input, output and functions. For each output corresponds a different level of view.

The inputs that characterize the step 1 of the algorithm are represented by the requirements of the tender notice and by the characteristics of the products in the Digital Portfolio. They are contained in the Requirements and Characteristics Matrices. The two matrices are compared by specific "Comparison Functions" (C_t). The matrices attributes can be of different type (numeric, range and string); for each type of attribute a different type of function is used.
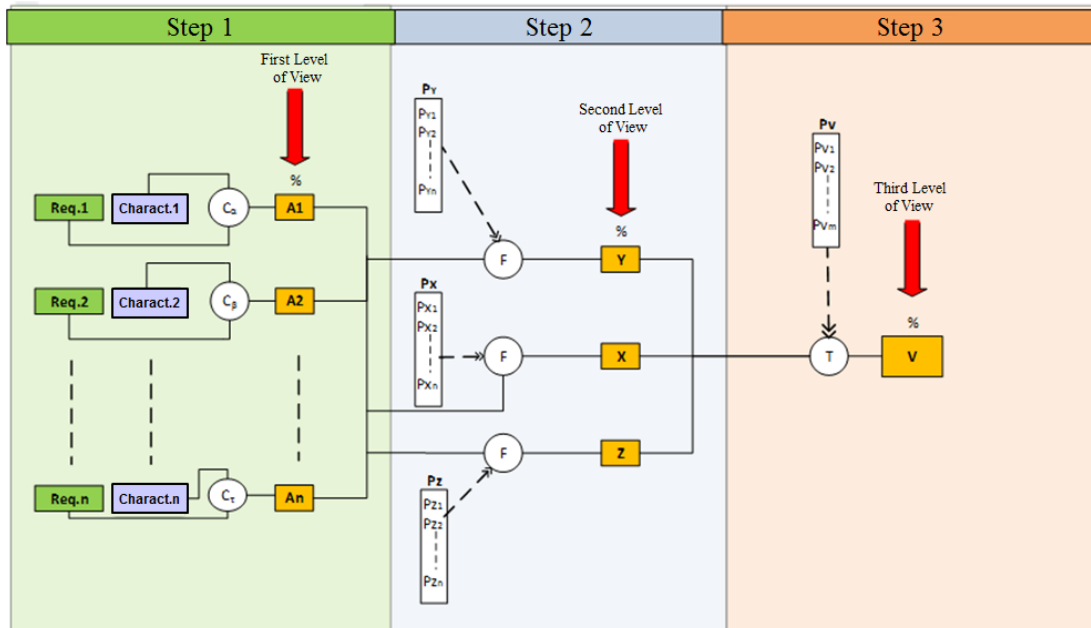
Figure 2: Search algorithm

The comparison functions provide the outputs of Step 1, the affinity index of each attribute (Ai). They indicate the percentage of affinity of each attribute with the requirements of the customer in the tender notice.

The Ai represent the input of Step 2. To generate the synthetic indicators of affinity is the objective of this stage. For this purpose, the attributes with similar characteristics are grouped in the same class. Furthermore, for each attribute a weight between 1 and 10 (Px, Py, Pz) is assigned.

The step 2 outputs the affinity indexes divided into different classes (X, Y, Z) by appropriate functions (F).

In this way it's possible to monitor the percentage of affinity of a subset of attributes that have in common a same functionality.

In the last step as well, a weight from 1 to 10 (Pv) is attributed to the affinity indexes X, Y, Z. Merging these inputs by the function T, we obtain as output the percentage of total affinity (V).

In conclusion, it is important to highlight that the comparison functions and the weights are defined with the aim to obtain the affinity index whose deviation from the 100% represents the effort to achieve the target value. In particular, the function used for attributes of numeric type is based on the Digital Pattern approach. Indeed, thanks to the flexibility guaranteed by its 8 parameters, it is adaptable to a multitude of specific cases (Figure 3).
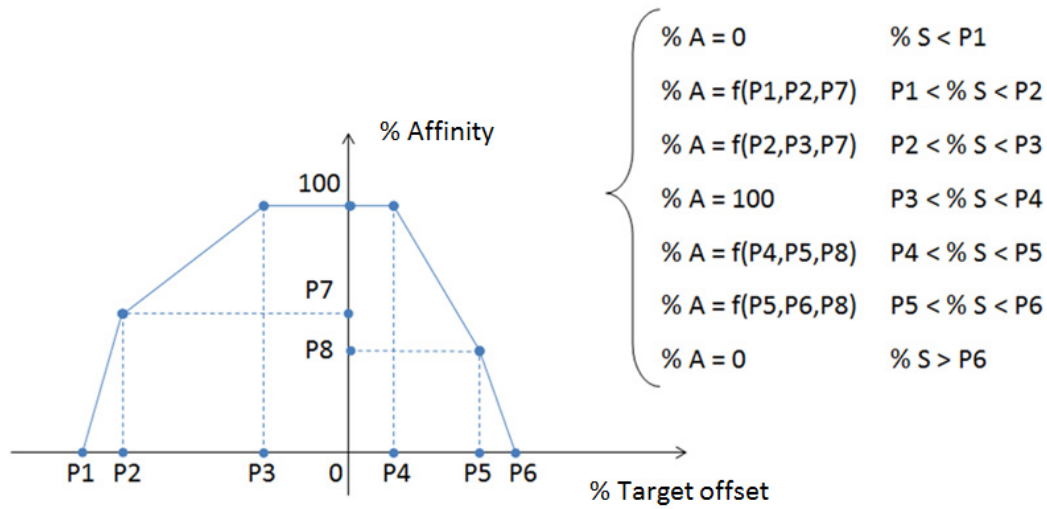
Figure 3: Numeric Function

4   Case Study: "Asynchronous Traction Motor"

During the work carried out at AnsaldoBreda, the methodology described above has been successfully applied both to the whole vehicle and to different components [Figure 4]. In this section the case study for the component "Asynchronous Traction Motor" is shown as example.
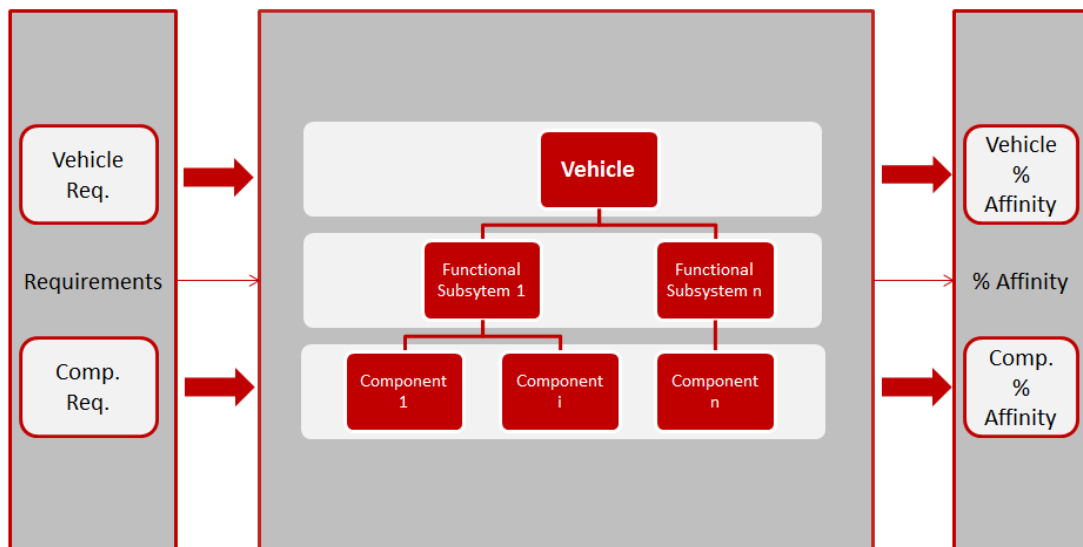

Figure 4: DSS architecture

First of all, the characterizing attributes and classes were selected and to each one of them a weight was assigned (Table 1).

Component	Class	Weight	Attribute	Weight
Traction Motor	Normative	7	EN603492	8
			EN613771	8
	Mechanical characteristics	8	Max speed	8
			Transverse dimension	9
			Longitudinal dimension	9
	Electrical characteristics	10	Voltage (braking)	9
			Voltage (traction)	9
	Performance	10	Synchronous speed	7
			Voltage	9
			Power	7

Table 1: Traction Motor weights and classes

Data needed to describe the traction motor and its associated attributes were collected through the format shown in figure 5.
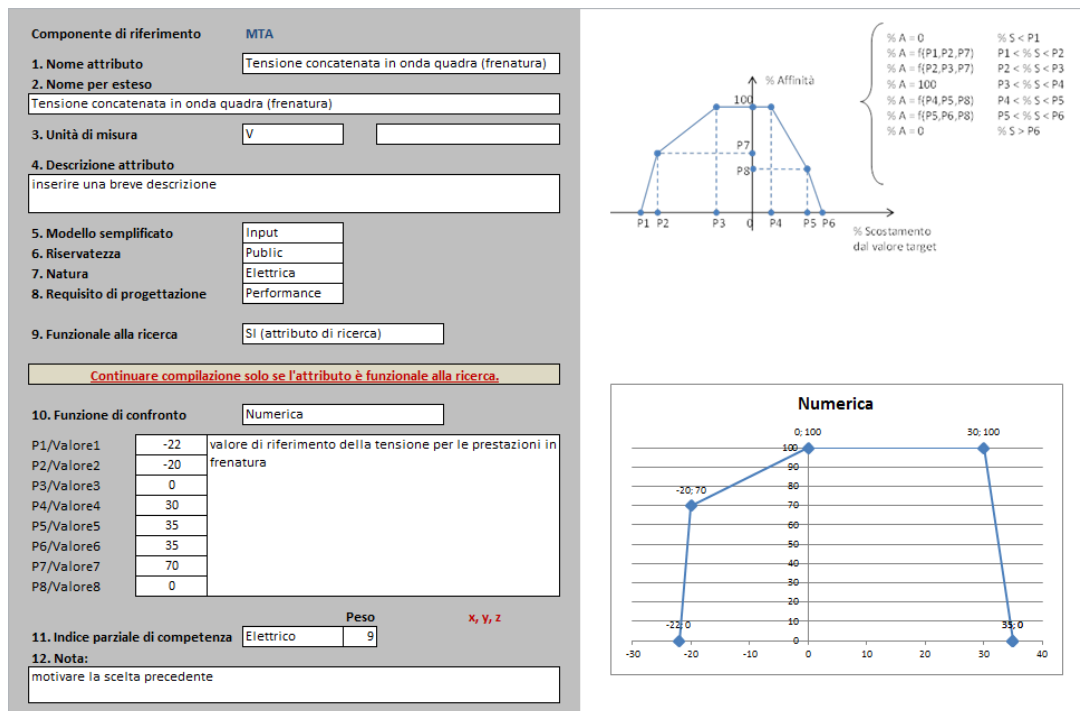
Figure 5: Attribute format

As can be seen in Figure 5, the format for the collection of attributes also shows the comparison function with its parameters and classes.

At the end of the data collection, the information was saved into the PLM Collaboration Desktop software.

Within this platform, the attributes were given a value filling the blanks in the screen below (Figure 6).

Figure 6: New product input data window

Moreover, in a similar screen the values of the requirements of the tender notice were inserted, in order to begin the search for the most similar component in the Digital Portfolio. The achieved result is shown in the Figure 7.
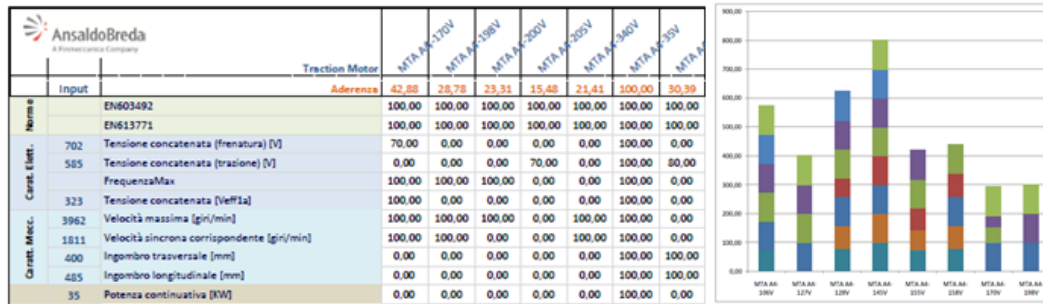
Figure 7: Output report

5   Digital Pattern applications

Within Digital Pattern research project other activities were carried out at AnsaldoBreda, all confirming the possibility to implement the proposed methodology. The purpose of these activities is to achieve a quality improvement and to collect data for Portfolio Management in order reduce times and costs of product development.

This goal was fulfilled by using, integrating and, whenever possible, unifying all the process or product patterns within the Company, including numerical simulation and virtual reality tools.

In the following sections the most meaningful activities are presented.

With regards to the Decision Support System proposed, the results of these activities are used to improve the "adapt" phase.

5.1   Digital Pattern Methodology in structural mechanics

As for electric motors, Digital Pattern methodology has been applied to structural simulations. These simulations are performed using Finite Element Method (FEM). To Generate a finite element model (preprocessing phase) can be very time consuming, especially for complex systems, therefore the methodology has been applied to this phase.

The goal is to generate a parameterized FEM model for each structural analysis performed on motors. Each model handles the variability of the analysis (e.g., geometric dimensions, loads, material). In this way it is possible to get the required FEM model simply typing the input data; so the preprocessing phase is reduced to the choice of the input parameters. In this way the Company know-how is used to optimize the process.
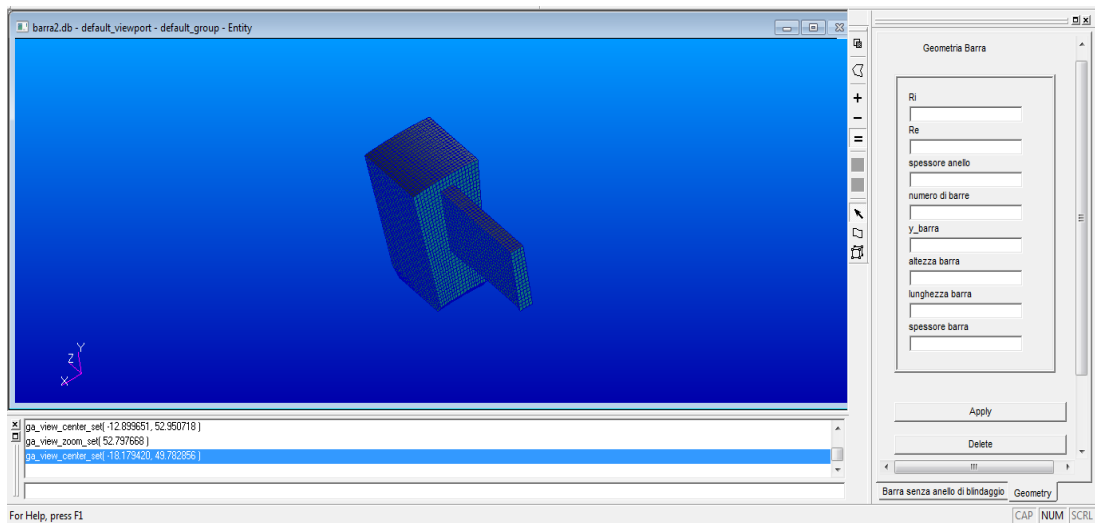
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Figure 8: GUI that allows the user to enter dimensions.

The first case study is the rotor cage. This is a yield analysis; the load is the centrifugal force caused by the rotation of the rotor. Patran by MSC is the preprocessor software used to generate the model; Nastran is the Finite Element Analysis program chosen. In detail, a tool of the Patran suite has been used, the Patran Command Language (PCL). This is a programming language that can be used to write application, perform variational modeling, and build GUI (Graphical User Interface). A tool has been developed in Patran using PCL; it allows the user to automatically generate the finite element cage model, to enter dimensions (Figure 8), load values, and material through an interface.

After performing the analysis in Nastran, the tool developed allows the user to post-process the results, for example plotting element stresses and strains.

The described methodology drastically reduces the duration of the design phase of electric motors, as a result of reduced time spent performing structural analysis.

5.2 Digital Pattern Methodology in converter thermo fluid dynamic modelling

Digital Pattern methodology can be applied to the design of aeraulic ducts for cooling electronic components.

Although each vehicle has its own specifications, every auxiliary converter can be thermo-fluid dynamic modelled as a system composed of heat generating components, heat transferring components (heat exchangers), and cooling fluid moving components (cooling fans), figure 9. Particular attention must be paid in heat exchanger sizing and in the choice of the cooling fan.
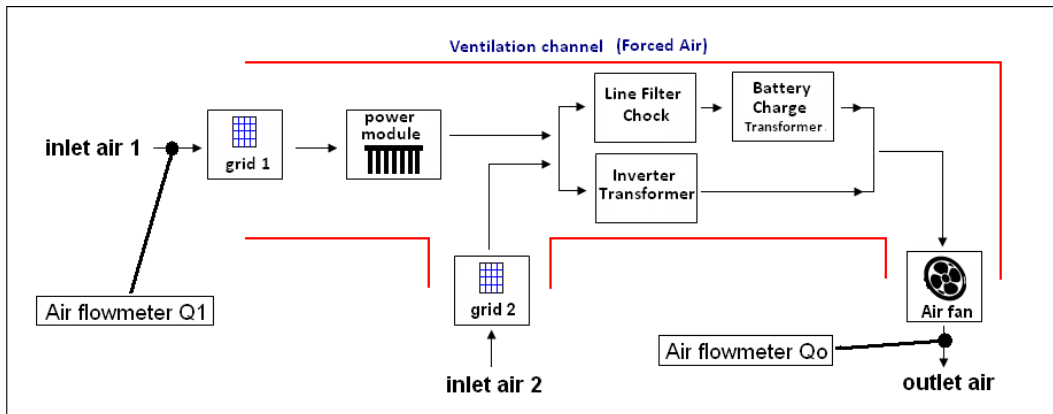
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Figure 9: Air flow pattern of an auxiliary converter

The traditional approach is to build the aeraulic duct, to experimentally measure the pressure loss, and to choose the fan. The use of CAD and CFD systems allows to evaluate the duct fluid dynamic characteristics and to perform changes in the design phase reducing costs and time.

The goal is to create a parametric geometric model; such model has to be simplified given the complexity of components' real geometry.
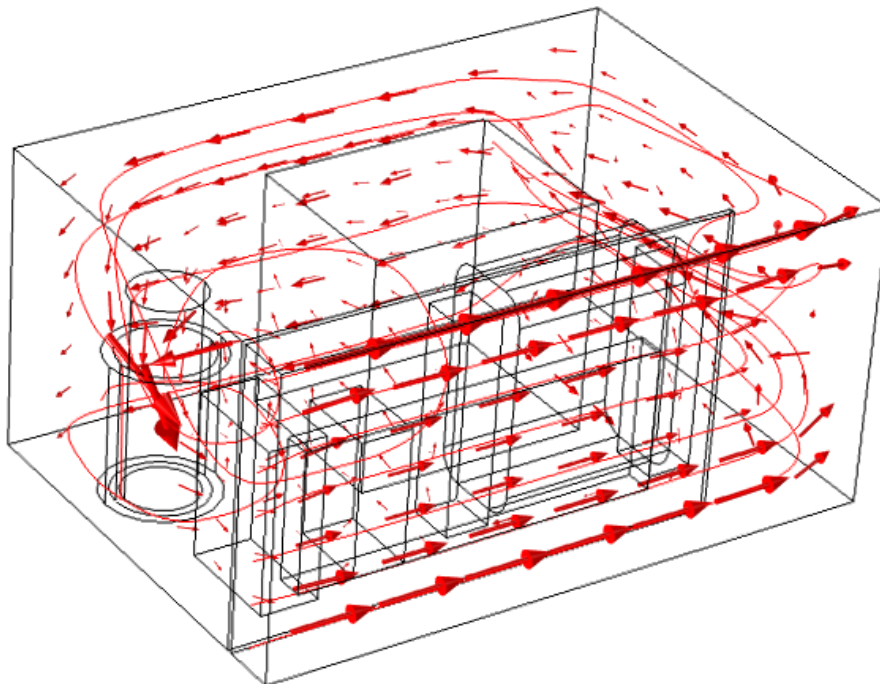

Figure 10: Mean value of the velocity field

The simplified geometric model is imported in Comsol Multyphysics through the LiveLink feature; the analysis can start after applying thermal and fluid dynamic boundary conditions. As example figure 10 shows the mean value of the velocity field obtained after the run.

Sometimes geometric variability, components' number and position, heat exchanger's possible presence do not allow to generate such model. Therefore a Matlab script has been developed; such script calculates the duct characteristic curve, requiring as input physical and geometric parameters. The user interacts with the script through a GUI. The script allows the user to calculate a stable operating point, intersecting the duct characteristic curve with the available fans' ones.

Though this method is less accurate than a CFD analysis, it quickly provides approximate results and it is more flexible.

5.3 Equipment design and process simulation

One of the main activities related to bogie manufacturing planning is to produce the equipment necessary for the manufacture and to set up the bogie manufacturing plant. Generally the aim is to design equipment that can be adapted to different types of products in order to reuse them in more areas; however, this is not always possible so it is necessary to design special equipment depending on the need.

An analysis of the process was necessary to increase the productivity of the painting department because it is a production bottleneck which is currently a bogie frame at a time. So, after a well-defined design requirements the equipment was designed (Figure 11).
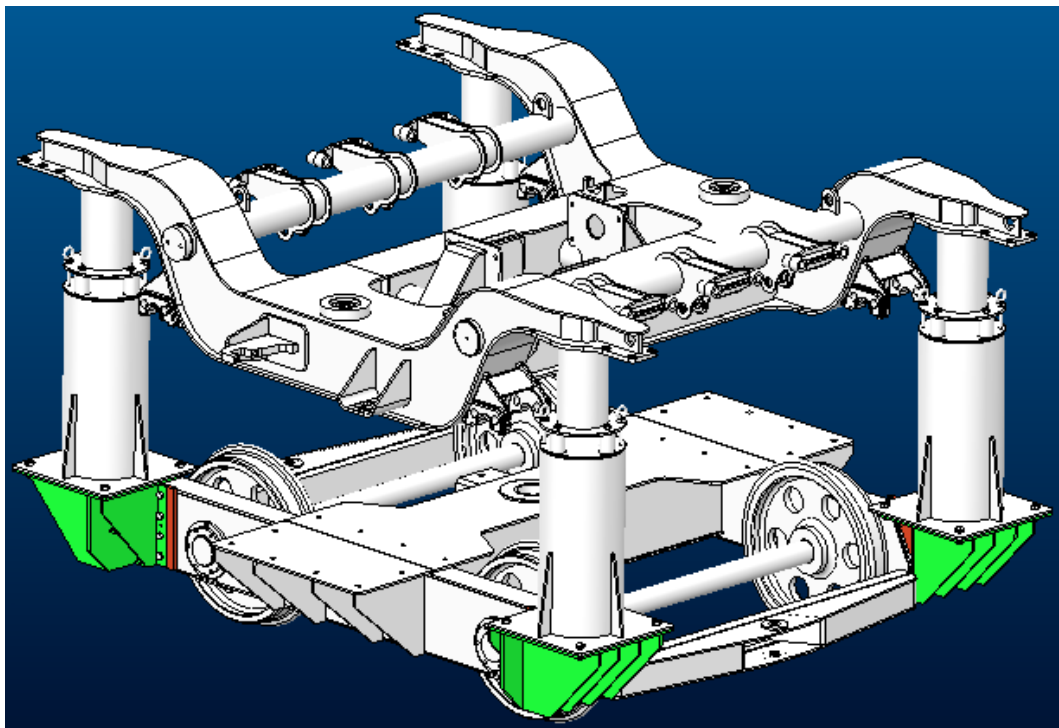

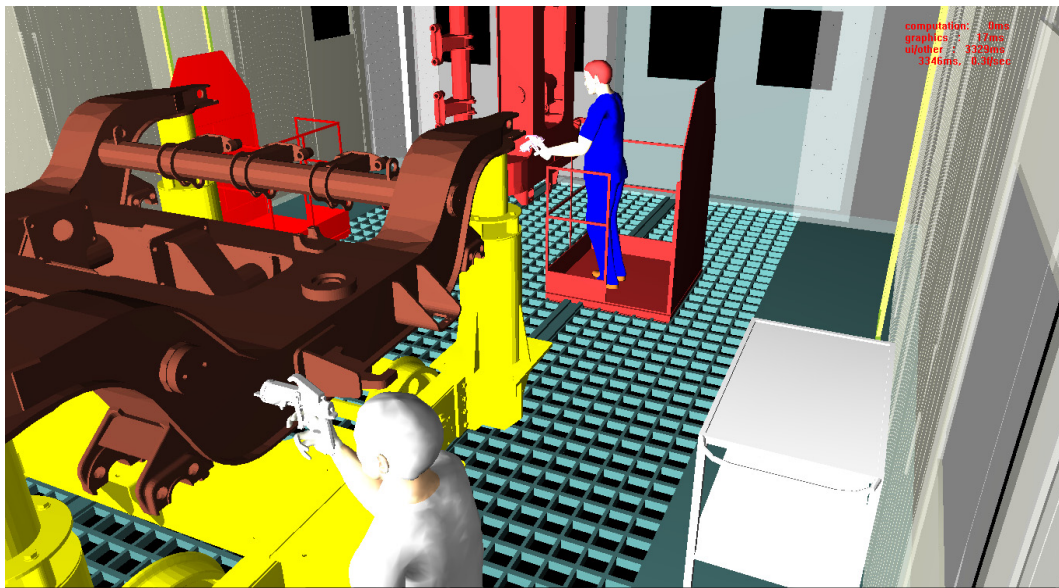Figure 11: Equipment built with 3D modeling software Creo Parametric.

Figure 12: Simulation of the painting process in the cabin by Jack Siemens software.

Such equipment allows to paint a bogie frame disposed in a horizontal position in addition to the pre-existing vertical one.

By using 3D and digital human modeling software, according to the Digital Pattern paradigm, the equipment was designed and the effectiveness in a virtual environment was verified (figure 12).

The ability to simulate the process and to verify the interaction between operators, equipment and surrounding environment has allowed to anticipate and ensure a more consistent assessment of the adequacy of the design process. The simulations have allowed to identify possible ergonomics, accessibility and workability issues at an early stage of the project and before the production of physical parts expensive to change.

5.4 Industrial Engineering tools design

Digital pattern concepts can be successfully applied also in the Industrial Engineering field. Though every commission has its own peculiarities, there are nonetheless some operations which are conceptually the same no matter what kind of train is being assembled (i. e., positioning of door drivers, traction converter assembly, motion of specific big parts in space-constrained contexts…); for many of these operations, production cycles often require custom-made tools.

The traditional approach requires the Company to design these tools from scratch for every new commission, or to buy this project from third Companies. The above mentioned analogies however imply that the tools themselves are analogous each other: dimensions, shape of some features or other minor aspects can differ, hence the use of parametric functions allowed by the modern CAD systems, coupled with

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the knowledge heritage preservation and valorization allowed by PDM/PLM systems give the Company the possibility to reduce the costs and time required to design the above mentioned tools (figure 13). Moreover, the tools can be tested in a virtual reality environment, so a subset of mistakes can be corrected in the design phase, when the economic damage is minimized.

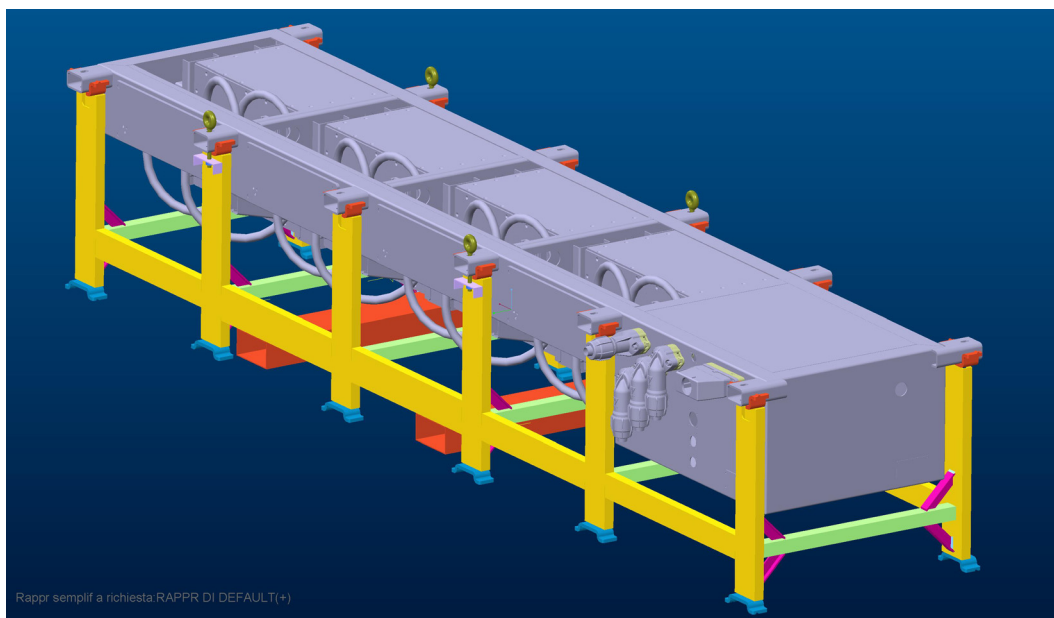Rappr semplif a richiesta:RAPPR DI DEFAULT(+)

Figure 13: A tool for moving and storing traction converters. The design can be easily adapted to every other traction converter.

Finally, virtual manikins can be used in all the circumstances where ergonomics is a concern, or where the health and safety of the workers is at stake.

For these reasons Digital Pattern philosophy can be a valuable asset even in the Industrial Engineering field, since it allows the Company not to waste precious time and resources, to avoid mistakes and to anticipate them in a production phase where the damage is minimized.

6 Conclusions and Future Developments

The aim of the research has been to study a methodology and to implement a system that supports a company acting in the railway market in the evaluation of its existing products that best suit the requirements of new bids.

Digital portfolio not only is an archive of standard products but a database of the whole Company knowledge. It is also integrated with PLM by the direct link between products and CIs.

DSS was validated with the critical analysis of the results obtained for the "Asynchronous Traction Motor", using as inputs a set of requirements whose results were known in advance.

A perfect match was found comparing the search outputs with the expected results. In conclusion though DSS does not provide a deterministic result about whether bidding or not to an invitation to tender, gives the bidding team in a brief time a series of parameters supporting their decisional process.

In this way decisions are less impulsive and do not depend only on subjective opinion of one individual.

This methodology offers good development possibilities if applied to a specific component. In fact an automatic modeling of the single component it is currently object of study. Such modeling is based on the correct definition of the key attributes and on the parametric modeling principles. In other words, the goal is to generate automatically the 3D model of the component starting from the client requirements.

Acknowledgements

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