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THE IMPROVEMENT OF ENGINEERING DESIGN EDUCATION THROUGH THE STUDY OF THE TECHNICAL HISTORICAL HERITAGE

Mario Fargnoli, Edoardo Rovida, Riccardo Troisi

Abstract

The design education can be improved by the study of the “historical heritage” of engineering design. The goal of the paper is to describe and discuss the approach followed in such a context both at Politecnico of Milan and at University of Rome “La Sapienza”.

Keywords: Engineering Education, Design Science, Technical historical heritage

1 Introduction

The technical solution from past experiences represents a useful support for the present research work in the engineering design field. Such an approach, of course, is not a novelty: for example, the French philosopher Cartesius (1596-1650) attributed great importance to the role of the history of technique in scientific problem solving, and promoted the setting up of the first modern museum dedicated to technical knowledge (“Conservatoire des Arts e Metiers”, built in Paris in 1794).

Nevertheless, in recent decades, the importance of the already existing technical solutions and experiences has been more and more underestimated in the engineering education field. Clearly, the increasing number of technical disciplines and specializations, as well as the great variety of technical systems nowadays available have significantly modified the requested background of the modern engineering designer.

On the other hand, the study of technical experiences from the past can contribute to enrich the designer’s basic knowledge not only because some “old” solutions might be useful even now, but also because some ideas, which could not be applied in the past, might be feasible today, thanks to technical and technological progress. Furthermore, we have to consider the importance of these aspects in creative problem solving: for instance, the TRIZ method was developed by Altshuller by analyzing thousands of already existing technical solutions and projects.

For these reasons, both at Politecnico di Milano and at the University of Rome “La Sapienza”, specific studies focused on revaluating the technical-historical heritage have been carried out in recent years, outlining the role of these topics in the teaching of the methodical design theory. The goal of this paper is to present and discuss the approach followed.

2 Background analysis

As already mentioned, the study regarding the background knowledge which a novel designer should have in order to face engineering problems in a more effective and efficient way is not a novelty.

In fact, in the scientific world much research work has been carried out with the aim of investigating the various aspects which can directly or indirectly influence the skills of designers during the course of their studies. Our idea, of integrating the study of the historical scientific-technical heritage into the teaching of the methodical design science, was based on the consideration of the following aspects:

1. problems related to the knowledge process and the knowledge management: the importance of the so called "tacit knowledge" emphasizes the role of the dynamic knowledge process and the manners by which the knowledge can be "captured" and reused by designers [1, 2, 3].

2. the possibility of finding optimal options for the solution of technical problems taking into account already existing solutions, patents, etc., which has emerged as one of the key-factors in the creative problem solving field [4];

3. the use of the engineers' experience and the different approach to problem solving between novel and experienced engineers [5, 6].

4. the importance of following a methodical and systematic approach in the development of design activities [7, 8, 9].

At the same time, also the study of technical solutions from the past has been considered as a way to contribute in enriching the designer's basic knowledge not only because some "old" solutions could be useful even now, but also because some ideas, which could not be applied in the past, could be feasible today, thanks to technical and technological progress [10].

Finally, a specific analysis of the problems related to the didactic aspects has been performed in order to find out the optimal way to integrate the topics of the classical machine elements theory together with the modern design science approaches. In fact, as far as this point is concerned, it has to underlined that modern engineers have to acquire more and more extensive information and knowledge which concern not only the traditional topics (i.e. Mechanics, Physics, etc.) but also regard different fields, such as marketing, economics, psychology, law and so on. Moreover, the development of software and computer facilities brings people more and more to informatic studies; but, even though the knowledge of such tools allows us to reduce time and consumption of "resources" in many activities (i.e. calculation), on the other hand it also carries the risk of belittling designers' "natural" skills, for instance: the tendency to follow "short cuts" in finding solutions and problem solving, or the lack of knowledge about engineers' language and rules, which makes the designers "weak" in facing problems in different contexts [11, 12].

3 Research approach

On the basis of the above mentioned considerations, a common research project has been developed in recent years at the Politecnico of Milan and at the University of Rome "La Sapienza" concerning the teaching activities of Design Science. Such an approach consisted in the study of the historical technical heritage and in its introduction in the topics of a specific course.

3.1 The historical technical heritage

The historical scientific-technical heritage could be defined as the total amount of scientific-technical knowledge and experiences acquired hitherto, which have taken shape through the modern scientific-technical accomplishments: in other words, such an amount of knowledge represents the "state of the art" in each scientific field. In the historical mechanical heritage it is of particular interest to further analyze the historical evolution of a given constructive solution. Such a historical evolution, with critical explications, can be an important basis for the modern designer and represents the realization, with modern means, of the idea of Cartesius.

The analysis of the constructive solutions, after the definition of the objective, can be performed by the individuation of the principle and the embodiment design of each solution. In this way, it is possible to better distinguish the characteristics of the design solutions and divide them in: known solutions (the historical heritage) and new solutions (the innovation). As an example of the important role of history as a source of "new" ideas, in Figure 1 a patent Fiat (1926) regarding a front suspension is represented: it is easy to recognize that such a patent, which has never been implemented in a technical accomplishment, is an anticipation of a McPherson suspension, that would be applied only after 1950.

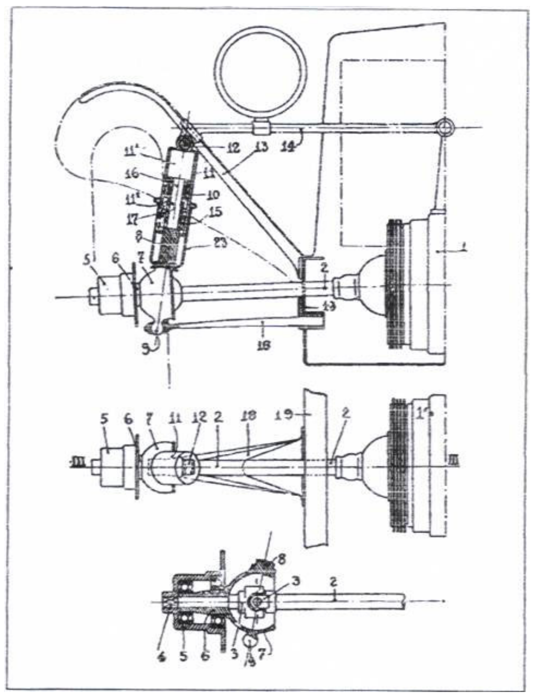


Figure 1. Patent Fiat (1926) with an idea anticipating the McPherson suspension.

The general steps to realize a historical evolution of a given constructive solution are as follows:

- determination of the constructive solution to be investigated;
- sources (museums, archives, libraries) of the solutions;
- individuation of the most relevant solutions;

- informatic reproduction of the selected solutions (e.g., in most cases, objects from museums can only be photographed) and restoration;

- individuation of the data-base to link with each image.

Such a database can be considered as constituted in two parts:

1. relative to the image (type of image, such as photo, drawing, 3D model), type of applied projection (orthographic, axonometric, prospective), white/black or colours, hand or computer drawings);

2. relative to the contents of the drawing(general and component functions performed by the represented object, principles and constructive solution of each function).

Following this scheme, it was possible to classify numerous technical systems and mainly define the innovative ideas and technical solutions developed. These data were analyzed using the theory of technical systems [13] and implemented in a technical database.

3.2 The didactic implementation

From the didactic point of view, these data were proposed in the ambit of the Methodical Design Science courses: students were required to carry out projects that consist of designing a certain mechanical system following the rules of Methodical Design and using the historical technical heritage as background information for developing innovative solutions.

4 Results

The first results of this experiment have shown an increase of new ideas in the students' projects as well as an improvement in understanding both design principles and technical issues (in particular in the constructive elements fields). In the following paragraphs some examples concerning the students' case studies, respectively at the Politecnico of Milan and at the University of Rome "La Sapienza", are shown.

4.1 The design exercises in Milan

At the Politecnico of Milan, on the basis of an informatic archive concerning car suspensions, students were required to develop new solutions: more in details, students had to perform a design project assuming as a starting point the historical evolutions of given machines, underlining for, at the same time, each one of the constructive solutions considered the following information:

1. constructive aspects: which is the constructive configuration of the machine and why the fundamental choices are made;

2. technological aspects: how the machine is realized, in relation to the technological processes and materials;

3. historical-cultural aspects: which relation it is possible to recognize between machine configuration and historical-cultural events of the time.

On the basis of this approach, students were stimulated in finding new solutions from the analysis of the historical ones: for instance, in Figure 2 an example of one of the historical solutions analysed by students is shown; in Figure 3 a solution obtained by students, after a critical elaboration of such an example is represented.

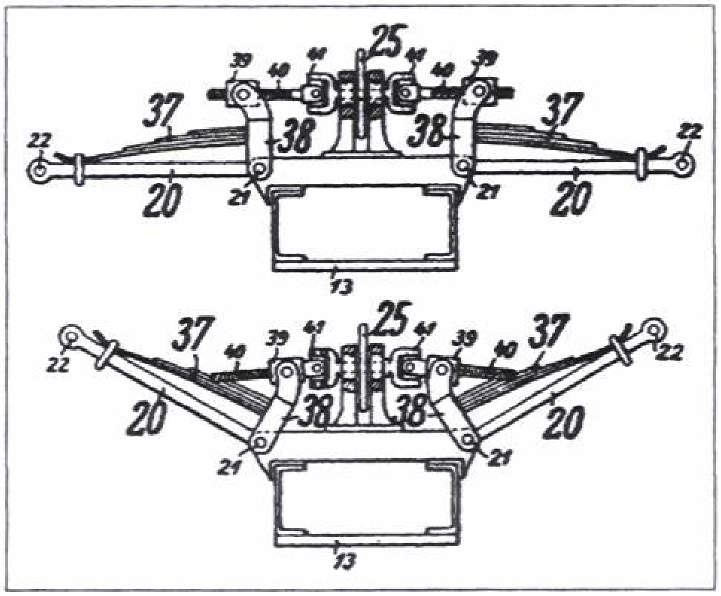


Figure 2. German patent (1940) regarding a mechanical system to level adjustment.

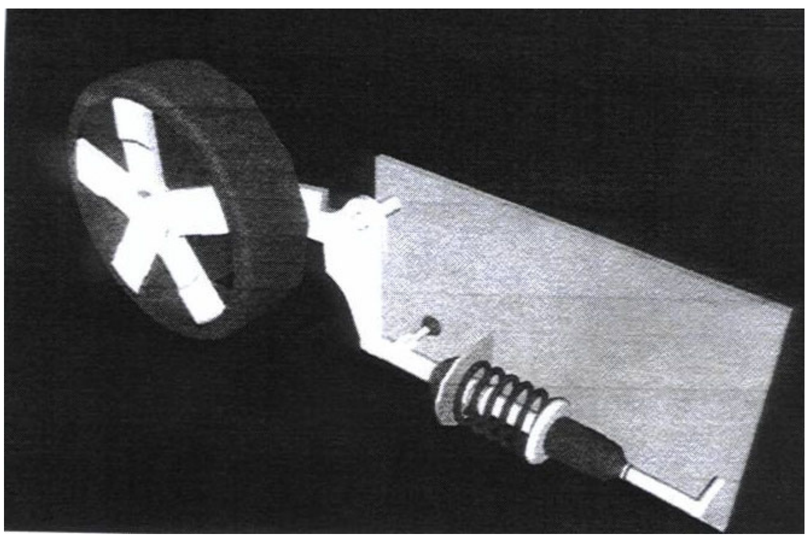


Figure 3. Student's solution obtained by critical elaboration of the above historical example.

4.2 The design exercises in Rome

At the University "La Sapienza" the students' project work was more focused on the methodical approach: in fact, students were stimulated in performing a design task following the methodical design process [8, 14] and concentrating their attention in searching for new ideas through the analysis of already existing solutions, patents, etc.

In the following figures an example of the case study concerning the design of new suspensions for a bogie is summarized: in particular, students were requested to develop the following main points:

1. the study of existing solutions in the field and definition of the main parameters which characterize the mechanical system;

2. the definition of the functional structure of the system and the development of the Morphological Matrix;

3. the individuation of a series of design concepts and the definition of the solution.

It has to be underlined that such points represent the main steps of the Design Process, according to the theory of the Methodical Design Science [14]. More in detail, in Figure 4 the data collection performed in the first phase of the design process is summarized.

Name	**MR-S**	**STANGA-TIBB**	**METRO A (MA) Series 100**	**ET 01-100-420**
Type	**Tram**	**Tram**	**Underground**	**Urban railway**
Fabrication year	1930/34	1942 (the early) 1948/49 (the other)	1976	01-420:1926 100: 1941
Train length [mm]	13000	20375	88390	420→32800 01→36530 100→39820
Box maximum width [mm]	2300	2400	2850	2400
Train composition	B_o-2	B_o-2-B_o	B_oB_o-B_oB_o-22-B_oB_o-B_oB_o	22-B_oB_o-22
Running direction	Unidirectional	Unidirectional	Bidirectional	Bidirectional
Feed [V]	600 c.c.	600 c.c.	1500 c.c. (+20% - 33%)	1500 c.c.
N. of motor bogies per train (position)	1 (front)	2 (rear, 1° e 3°)	8 (rear)	2 (central)
Primary suspension	Helical springs	Helical springs	Axle box "metalastik" (rubber)	2 helical springs in parallel, not coaxial
Secondary suspension	2 carriage springs	2 couples of helical springs + rubber springs working in parallel	2 pneumatic springs	2 carriage springs
N. of trail bogies per train (position)	1 (rear)	1 (central, 2°)	2 (central)	4 (rear)
Primary suspension	Helical springs	Helical springs	Axle box	Helical or carriage springs
Secondary suspension	2 carriage springs	2 couples of helical springs + rubber springs working in parallel	pneumatic springs	Carriage springs
Floor height [mm]	835	835	1100	930

Figure 4. The comparison of the most common existing systems.

After the analysis of the design task, the study of the functional structure of the system was considered: in Figure 5 the function tree is represented.

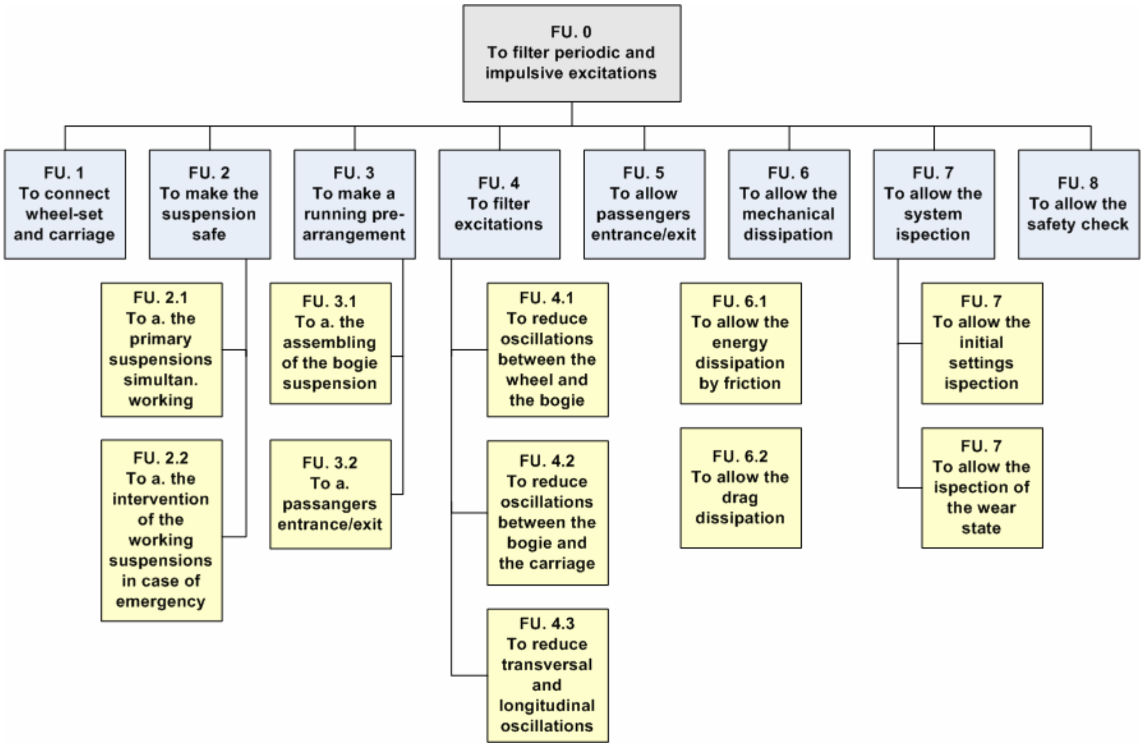


Figure 5. Function structure (hierarchical tree).

The study of the function structure led to the develop the Morphological Matrix (an excerpt of this application is shown in Figure 6).

The use of the Morphological matrix allowed students to select several alternative solutions (concepts), that have been evaluated both from the technical and economical point of view: in Figure 7 the layout of the optimal concept is shown.

5 Conclusions

In accordance with both the traditional theory of the mechanical systems and the needs of the industrial reality in developing constructive solutions, the requisites of the design education can be summarized in:

- the necessity of developing clear criteria to analyze historical evolutions of constructive solutions;
- the importance of stimulating students in creative problem solving through the study of criteria for the innovation.

It has also to be underlined that the study of the historical technical heritage is dynamic concept: in fact, it can stimulate both intuitive and deductive knowledge, leading to a more effective learning and understanding of engineering design.

Moreover, on the basis of the didactic experiences in recent years, a new course, called “History of Mechanics” and dedicated to the study of the historical technical heritage, has been included in the Politecnico of Milan courses portfolio and it has been held for the first time in the academic year 2004-2005.

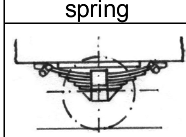
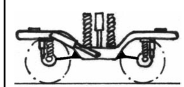
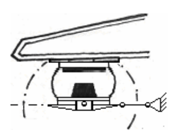
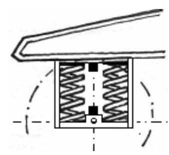
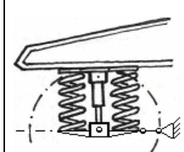
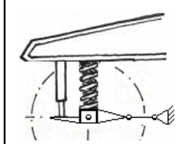
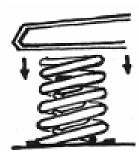
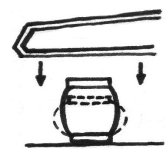
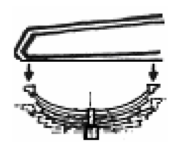
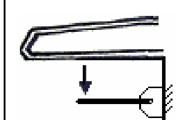
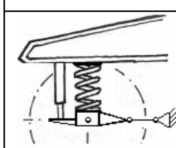
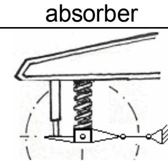
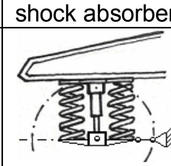
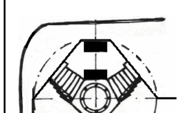
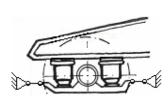
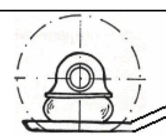
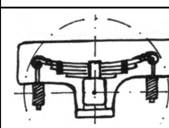
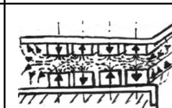
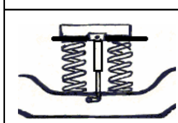
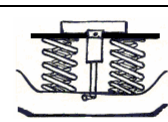
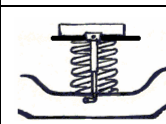
N°	FUNCTION	ACTUATORS			
1	**To connect the wheel-set and the carriage**	A Carriage spring	B Bogie		
					
2.1	**To allow the primary suspensions simultaneously working**	A Pressure spring with rubber small block	B Helical springs working in parallel	C Helical springs working in parallel + shock absorber	D Coaxial helical springs + shock absorber
					
3.1	**To allow the assembling of the boogie suspension**	A Coaxial helical springs	B Pressure spring	C Carriage spring	D Torsion bar
					
4.1	**To reduce oscillations between the wheel and the boogie frame (primary)**	A Helical spring + shock absorber	B Coaxial helical springs + shock absorber	C Helical springs working in parallel + shock absorber	D Rubber springs
					
		E Rubber springs working in parallel	F Pressure spring	G Carriage spring	H Magnetic levitation
					
4.2	**To reduce oscillations between the boogie and the carriage frame (secondary)**	A Helical springs working in parallel + shock absorber	B Coaxial groups of helical springs working in parallel + shock absorber	C Coaxial helical springs + shock absorber	D Pressure springs (torpress)
					

Figure 6. An excerpt of the Morphological Matrix.

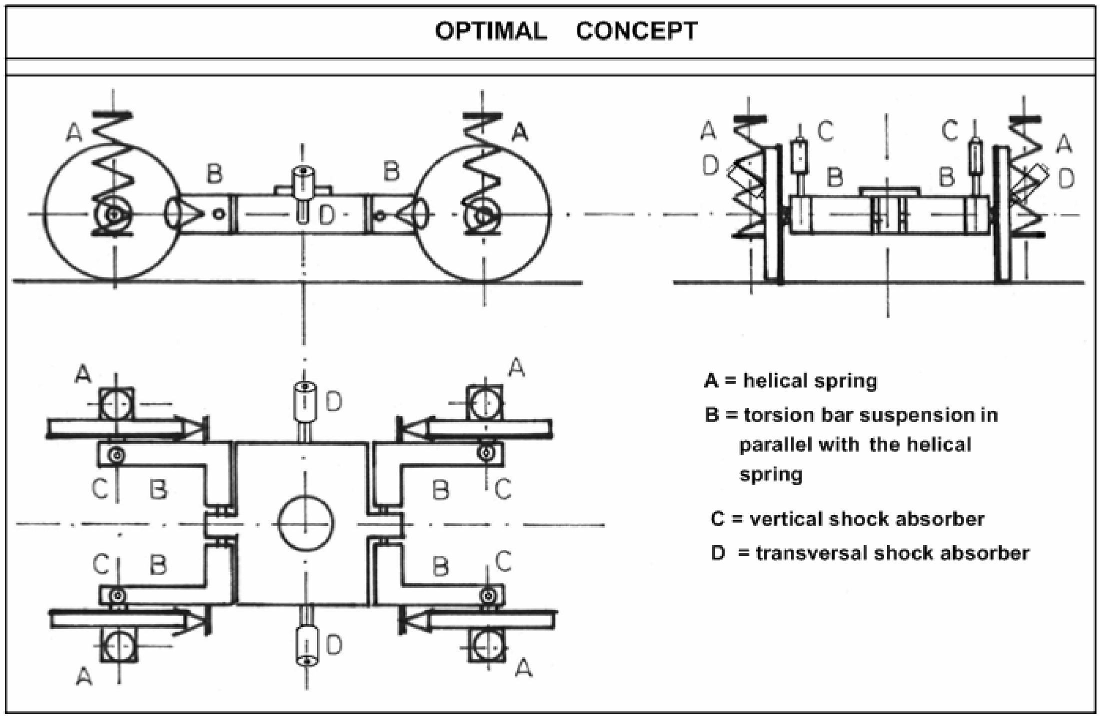


Figure 7. The optimal design concept chosen by students.

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Dr. Eng. Mario Fargnoli, PhD
University of Rome “La Sapienza”,
Department of Mechanical and Aeronautical Engineering
via Eudossiana, 18 , I – 00184, Rome
Italy
Phone: (+39) 06-44585236 - Fax: (+39) 06- 4881759
E-mail: mario.fargnoli@uniroma1.it