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DEVELOPMENT OF INNOVATIVE PRINCIPLES TO PERFORM GIVEN FUNCTIONS

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1. Introduction

The mechanical design process requires, as fundamental aim, to realize the technical solution for the functions that the product must perform as specify by the market.
The process requires the ability to conceive the solution by means of the elaboration of information furnished. For this, the principal role of a designer is to make decisions on the basis of scientific criteria and technical experience. Decisions are governed by multiple measures of merit and involve the treatment of multileveled information. The information required to arrive at a decision comes from different sources, disciplines and, in many cases, they may not be available.
One of the most important questions about the design process regards the definition of the tools able to support the search and the management of the information. These tools must be able to come up to expectations of the designer in terms of knowledge, examples and methods.
In this environment, an important problem for the designer is, for example, how to identify and choose the technical principles among the ones that perform the functions. While the choice depends from the requirements of the specific product in design, the identification is a process that could be expanded in diverse directions, without limitations. The identification process, in fact, could be useful to inspire the creativity of the designer, providing a wide spectre of technical principles as examples. Many examples are directly obtained from both the experience and the know-how of the designer, but many others could be derived from different sources. The development of a procedure to face this stage together with its implementation in a computer tool is an interesting effort to support the designer work.
This paper reports the activities in progress to achieve the definition of a general method that the designer could follow to satisfy the previous explained goals. The research opened at the Mechanical Department at Politecnico di Milano is focused on the creation of tools, as well as, design procedures that can be used during the decisional process [1-2].

2. Method and objectives

The figure 1 shown the general procedure under study, from the function required to the product solution adopted to satisfy it. Two principal steps are highlighted on the flow diagram, created in compliance with the Concept Maps representation criteria [3]. As previously described, the two steps are referred to the identification of the technical principles able to perform the function required and to the choice of the final solution for the product.
Actually the first step of the procedure is under study, while the second will be object of future analysis.
So, the objective of the research in progress is to realize a general procedure to list all the technical principles that perform a given function.

Another strictly related goal is to realize an interactive catalogue of the most important mechanical functions and their principles.

3. Identification of technical principles

The first step of the proposed procedure regards the identification of the technical principles. This step could be performed by the subdivision of the principles in two categories: the first one based on known solutions and the second one based on innovative solutions (Fig. 1).

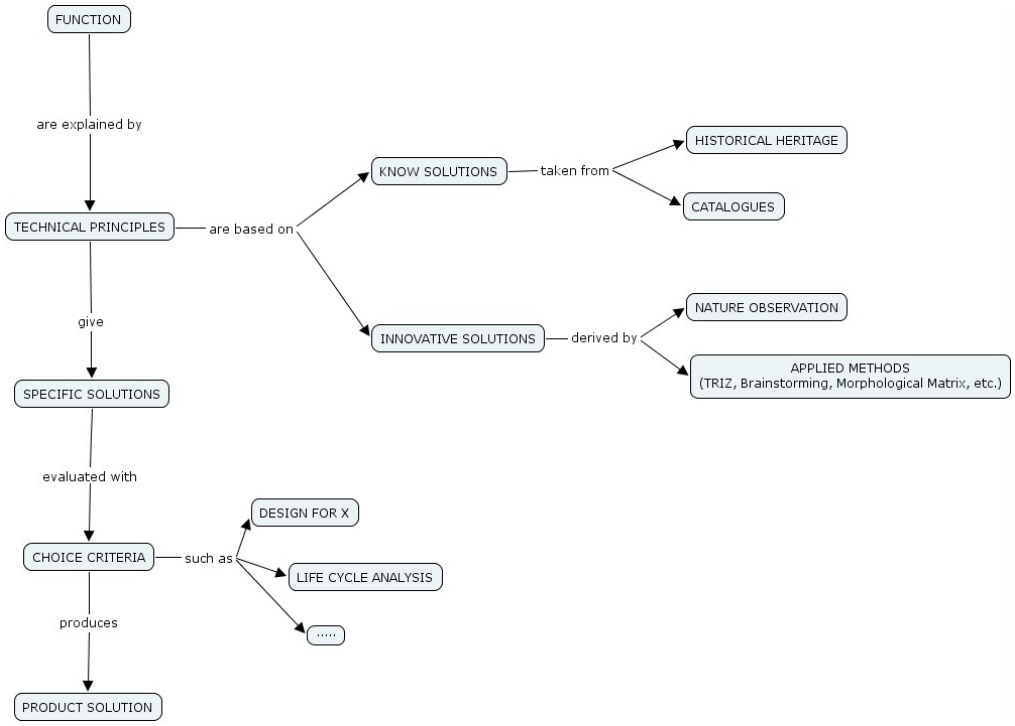

Figure 1. Concept maps scheme of the method to identify the technical principles that perform functions.

In this classification, the known solutions derive both from the “state of the art” of the current industrial artefacts and from the historical industrial heritage.

The general path to realize a historical evolution of a given constructive solution is as follows:

- identification of the constructive application able to be investigated;
- analysis of the sources (museums, archives, libraries) of the solutions;
- choice of the most relevant solutions, for singularity and originality;
- digital reproduction and restoration of the selected solutions (e.g., in many cases, objects from museums can only be photographed);
- creation of the data-base records that may be linked to each picture.

Such a data-base can be considered as constituted in two parts:

- relative to the representation of the constructive solution: type of picture, such as photo, drawing or digital modelling;
- relative to the context of the constructive solution: general and component functions performed; technical principles of each function).

Critical recognition of industrial catalogues may also lead to recognised the general constructive solutions used in the state of the art.

The fundamental path of the determination of constructive solutions from a catalogue could be recognized as follows:

- identification of the function;
- individuation of technical principles and constructive solutions that perform such function, by analysing the scientific-technical and the technical-commercial sources;
- criteria of the choice of the “best” principle/constructive solution, in relation to the requirements of the specific design; such choice can be made by the personal experience of the designer or by qualitative or quantitative evaluation of the behaviour of the principle/constructive solution in the phases of the life cycle; the evaluation can be realized by tables or by expert systems;
- proportioning criteria, by critical analysis of the “state of the art”.

The result of the above proposed procedure is an archive of known technical solutions that fulfil the given function. This archive could be useful to extract ideas that could be critically analysed for the determination of innovative solutions.
These innovative solutions can be derived from the observation of the nature and especially from the use of design creative methods, such as TRIZ [4], brainstorming, Morphological Matrix [5], etc.

4. Results, conclusions and future develops

From the schema proposed in figure 1 some activities are developed and some goals are already achieved. These activities are the follows:

a) Realization of the plan of the historical evolution of the industrial products: such application aims to improve the creativity of the designer, forced to consider the historical heritage in a critical way. An archive of car suspension was realized and utilized in Engineering and Industrial Design courses [6]. The students, starting from the historical, realize new constructive solutions. One of the authors is involved in a new course, called “History of the mechanics”, at the Industrial Engineering school. In such course, the students will realise the plan of the historical evolution of the industrial products, analysing and evaluating the given constructive solutions.
The figure 2 showed an approach to the historical evolution of pumps. This is, of course, only an index: each constructive solution must be completed by constructive, technological and cultural considerations.

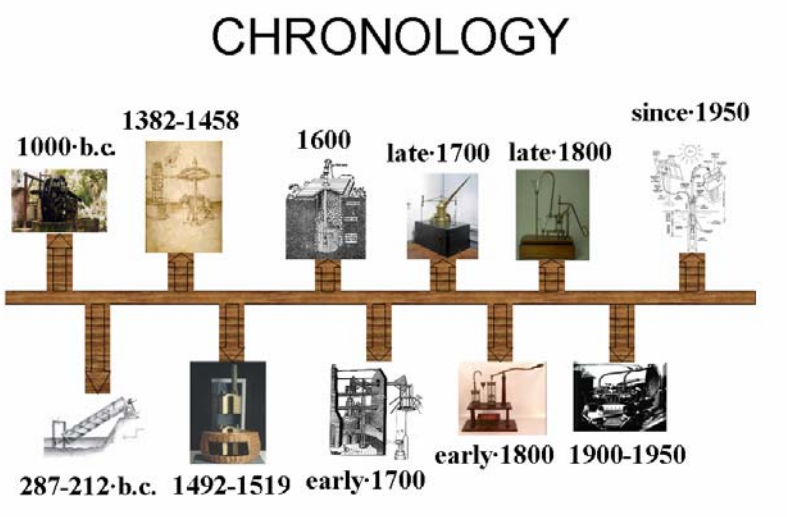

Figure 2. Timeline of the historical evolution of pumps.

b) Catalogue functions and relative technical principles: such activity, that is the core of the new research at Politecnico di Milano, aims to guide the designer in the choice of technical principles. The first considered functions are: axial constraint, radial constraint, radial and tangential constraint, force transmission, force transformation, moment transmission, moment transformation, transformation of motion.
The figure 3 represents, as an example, some principles realizing the transformation of the continue rotating motion into alternative translation motion.

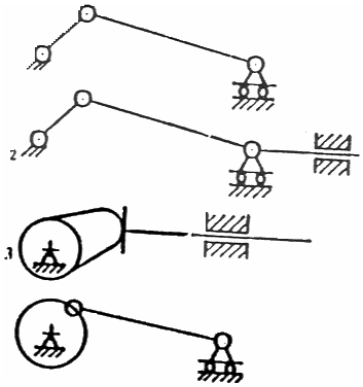

Figure 3. Some principles realizing the transformation of the continue rotating motion into alternative translation motion.

The problem is now the choice of the "best" principle in relation to the requirements. Such choice could be made by considering how each principle behaves in the life cycle, i.e. how it is possible the realization, the distribution, the utilization, the liquidation of such principles. Each of the above mentioned phases can be analyzed in some "aspects" that can orient the choice.
For example, if the third principle of the figure 3 is chosen, the component functions that can be highlighted among others are the following:

- contact between moving and moved member;
- return of the moved member.

So, the second one can be realized by means of weight (fig. 4), by means of spring (fig. 5) or by means of gas pressure (fig. 6).

c) Develop criteria to observe the natural phenomena, with the aim to gather new technical principles.
d) Integration of the points a), b) and c) with design creative methods

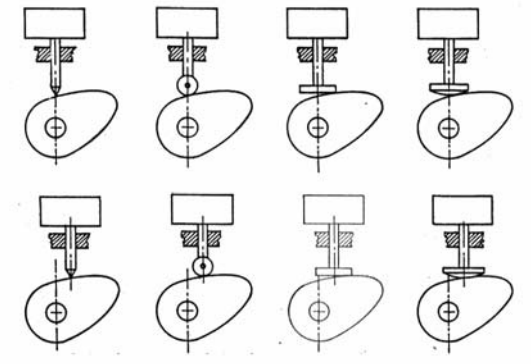

Figure 4. Principles with return of the moved member by weight

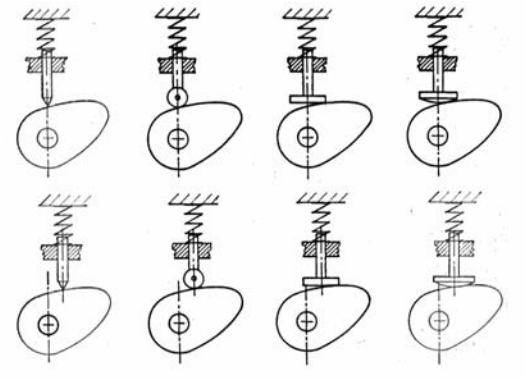

Figure 5. Principles with return of the moved member by spring.

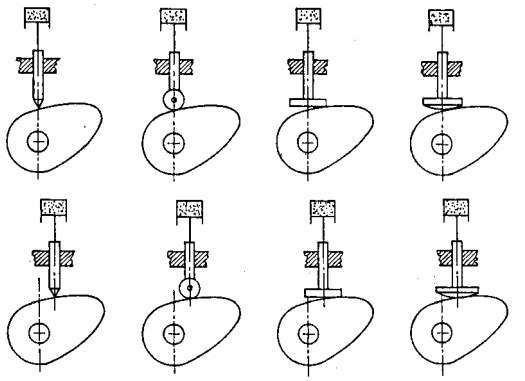

Figure 6. Principles with return of the moved member by gas pressure.

Some considerations can be explained with regards the procedure proposed. The research of tools able to support the designer during the design process is an important challenge. In the procedure proposed tools are made to derive joining historical knowledge with actual constructive solutions. This connection is not trivial, in fact, the historical solutions, studied in new materials and technologies context, can be sources of ideas for modern products.

At Mechanical Department, at Politecnico di Milano, the Authors are actively involved in the step b), with the aim to realize digital catalogues of the most important mechanical functions and, for each function, of the technical principles and constructive solutions, linked to a data base with information for the proportioning and the choice.

In future the research will be extended to the second step of the proposed procedure. This step regards the evaluation and the choice of the optimal principle that realises the given function, according to the design requirements (Fig. 1).
At the moment, the logic followed for the evaluation and choice of the final solution is based on the analysis of all constructive solutions using methods derived from the LCA (Life Cycle Analysis) and DfX (Design for X) theories.

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