AN EXPERIENCE OF DESIGN EDUCATION: INTEGRATION BETWEEN DESIGN METHODS AND INDUSTRIAL COOPERATION

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ABSTRACT

Achieving a strict correlation between academic and industrial world is an important development direction in the engineering education field.

The authors' first step along this path was the activation of several courses on methodical design, and the second step was the activation of a tight cooperation with industries, so that students could develop their thesis facing up to real problems.

The fundamental advantages of this approach are:

a) accustom the students to follow a design method;
b) increase students' ability to find out and to consider "all" the possible solutions for a given problem, with the scope to choose the "best" one;
c) increase students' ability to evaluate solutions' behaviour;
d) possibility for the students to follow the production of the designed or modified machine.

From the educational point of view, the two important aspects of this particular work are:

a) The cooperation with the industrial world: the design was developed in cooperation with a company specialized in die-cutter machine production. The company realised and now produces a new machine based on this work.
b) The application and integration of several design methods.

Keywords: design education, design methods, die-cutting machine.

1 INTRODUCTION

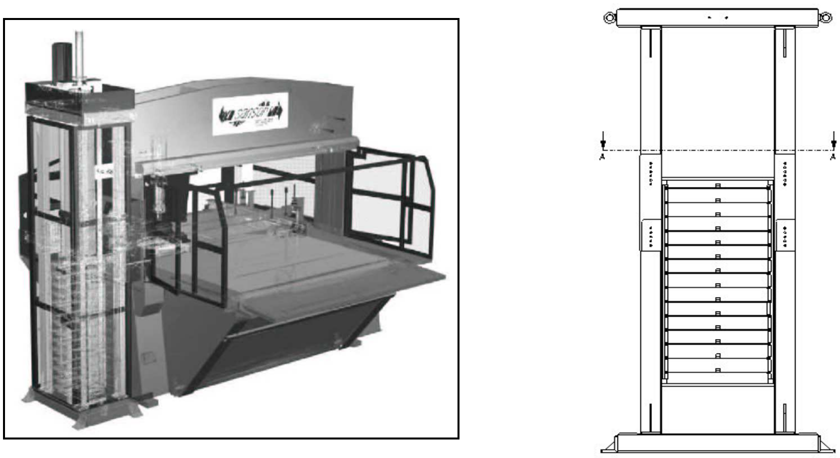
Beside the transmission of technical knowledge, synthetically, a complete design education requires an improvement of students' creativity and of their ability to link the design requirements to the product functioning. The basic tools used to accomplish these tasks are the design methods grouped in the following two big categories:

a) Theory of Technical Systems (*TTS*), that, by using heuristic methods like TRIZ [9], [10], [11], critical observation of historical heritage [12] and of natural phenomena [15], [16] develops new principles and new constructive solutions to perform the given function;
b) Design for X (*DfX*) that, by using methods like as LCA, evaluates the product development and behaviour in the phases of the life cycle and permits choices among many products and upgrading a given product [13], [14].

A typical exercises for the students consists in developing a set of products that perform the same given function and the subsequent evaluation of their behaviour during their life-cycle, in order to choose the “best” one.
In this kind of activity, the cooperation with the industry is very important and, therefore, welcome.
Particularly significant is the study of problems proposed by the industry. In Italy, little industries are very common and widespread, and, sometimes, involve the universities in the product development activity, that, adequately simplified, could also become case study for the students training.
In the present paper the development of some constructive solutions of a machine in cooperation with industry will be described.
The machine considered in this paper is a die-cutting machine (Figure 1 a) 3D model, b) orthographic projection of the machine grant), produced by a little firm near Pavia in Lombardy.
This machine cuts sheets of various materials by means of several tools (The considered machine has 14 tools). Each tool is rigidly connected to a square plate, and all the plates are enclosed in a container. In the past solution, the vertical movement is accomplished by mean of a screw ball. A re-design of this device has been required because of the following problems of the screw ball solution:

a) big vertical dimension;
b) cost;
c) difficulty to find other different suppliers.

The fundamental design requirement is then a new motion device for the tool container.



(a) (b)

Figure 1: the die-cutting machine

a) 3D model, b) orthographic projection of the machine grant

The objective of the present paper is then to present a didactic experience [8] that very briefly can be described as the application of the above mentioned design methods to an actual industrial problem.

2 METHOD

Before introducing to the students the actual problem, they have to follow some courses focused on design methods. In these courses the transmission of the knowledge has been organised by applying the theories of technical communications. The scope of every technical communication is to reach in the users (i.e. the students) a desired “terminal behaviour”, intended as the amount of knowledge that permit to the users a sought behaviour. First of all, it is mandatory to define the desired terminal behaviour of each specific course. Briefly it can be summarized stating that [2] the designer

- starting from the assigned function and the correctly formalized requirements of the product;
- using means (as materials components, HW/SW, cooperation with colleagues and so on) and methods (as *TTS* (Theory of Technical System), *LCA* (Life Cycle Analysis), *DfX* (Design for X), calculation and evaluation methods, …);
- determines all the information (as forms, dimensions, materials, tolerances, …) needed to produce the product;
- achieving the requirement of a good behaviour of the product in all phases of the life cycle.

Table 1 shows that the path to the terminal behaviour could be subdivided in three parts; then also the technical communication has been regarded as composed by the three correspondent parts (listed in Table 2).

Table 1: Terminal behaviour components

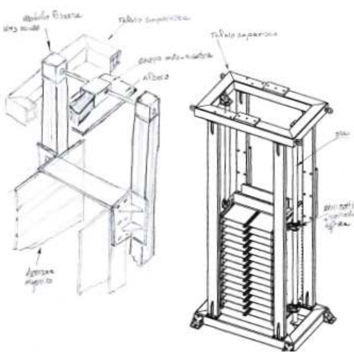
Components	**Contents**
Informative	Acquisition of information
Critical	Critical elaboration of the acquired information
Practical	Application of information to solution of problems

Table 2: technical communication schema

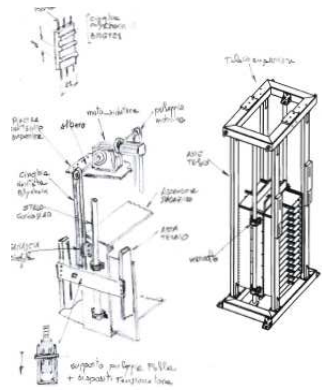
Parts	Name (Symbol)	Contents
Informative	Rule (RUL)	Room lessons about *TTS*, *DfX*, *LCA*, Axiomatic design, …
Critical	Complete example (EG)	Critical analysis of rule, exercises and applications critical evaluated and discussed
Practical	Incomplete example (EG’)	Definition of an industrial problem (i.e. the development of a new machine, like the die cutter).
		Formalization of the requirements of the machine.
		Proposal of new concepts (from Theory of Technical Systems)
		Evaluation of the behaviour of the concepts, from *DfX*, *LCA*)

This schema has been then applied also to the solution of the actual industrial problem. In this task, the incomplete example is the required modification of the die-cutter machine.
The considered concepts are:

a) integrated linear modules A-00 (Figure 2-(a))
b) timing belt B-00 or chain C-00 (Figure 2-(b))
c) rack and pinion D-00 (Figure 2-(c)).



(a)



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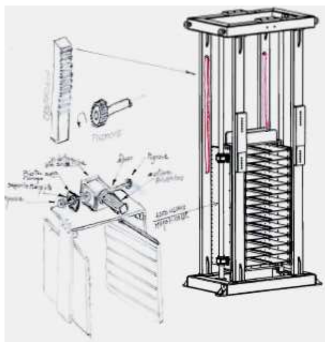

(c)

Figure 2: the considered concepts

At this stage the problem consists in choosing among these alternatives. Several criteria can be adopted to orient the choice toward the “best” concept in relation to specific requirements of the design [17].
The adopted method relies on the “concept screening matrix” $[V_{ij}]$, where:

- $i = 1$ corresponds to the actual concept, adopted as a reference;
- $i = 2,\dots n$ corresponds to the generic $(i\text{-}1)^{th}$ proposed concepts;
- $j = 1,\dots m$ corresponds to the $(j\text{-}1)^{th}$ “behaviour aspect”, that has been considered interesting for the comparison. They come from the life cycle analysis of the considered product.

As a first approximation, the matrix element can assume one of the three following values with respect to the reference design:

- - worse;
- + better;
- *0* equal.

Of course, it is possible to realize a quantitative matrix, where the behaviour is expressed by a numerical evaluation.
Table 3 shows an example of the concept screening matrix for the die-cutting machine.
In the last rows a summary of the analysis has been realized.
Since the timing belt solution (B-00) exhibits the more promising improvement possibilities, it has been developed and is actually adopted on the new die-cutting machines.

Table 3: simple concept screening matrix for the die-cutting machine concepts.

	Reference design (actual)	A-00	B-00	C-00	D-00
Complexity (-)	0	-	+	+	+
Production easiness	0	-	+	+	0
Special components (-)	0	-	0	0	0
Reliability	0	+	0	-	-
Modularity	0	-	+	+	0
Assembling easiness	0	-	+	+	0
Noise emission	0	+	+	-	-
(+) total	0	2	5	4	1
(0) total	7	0	2	1	4
(-) total	0	5	0	2	2
Score	0	-3	5	2	-1
Ranking	3rd	5th	1st	2nd	4th
Develop ?		No	YES	No	No

3 CONCLUSIONS

The above described design education experience can be regarded as a successful cooperation between industrial and academic worlds.
It is worth noting that the cooperation with the industry is related to a specific but actual problem. The design method has been applied in order to the individuation a set of feasible solutions, alternative to the existing one, and to choose the solution that best fit the design requirement.
The method validity has been confirmed by the successful production of the developed solution.
Furthermore this experiment confirms that also the industry can obtain some benefits cooperating with university also in the educational field.

REFERENCES

[1] Suh, N., P. *Axiomatic Design: Advances and Applications*. (Oxford University Press, 2001)
[2] Biggioggero, G., F. and Rovida, E. *Metodi di comunicazione tecnica*. (Cittastudi, 1997)
[3] Biggioggero, G., F. and Rovida, E. *Metodi per la progettazione industriale*. (McGraw-Hill, 2005)
[4] Iannaccone, W. *La reingegnerizzazione del processo di progettazione*. (Ed. FRANCOANGELI, 2000)

[5] Schilling, M., A. *Gestione dell'innovazione*. (McGraw-Hill, 2005)
[6] Shigley, J., E., Mischke, C., R. and Brown, T., H. *Standard handbook of machine design*. (McGraw-Hill, 2004)
[7] Urlich, K., T. and Eppinger, S., D. *Progettazione e sviluppo di prodotto*. (McGraw-Hill, 2001)
[8] Vaona, G. *Progettazione e analisi funzionale di un nuovo prodotto.* (Tesi di Laurea, Università degli Studi di Pavia, A.A. 2005/2006)
[9] Altshuller, G. *And Suddenly an Inventor Appeared*, (Technical Innovation Center, Inc., Worcester, Massachussetts, 2002)
[10] Michaelewicz, Z. and Fogel, D., B., *How to Solve it: Modern Heuristics*, (Springer, 2004)
[11] Orloff, M., A. *Grundlagen der klassischen TRIZ*, (Springer, 2002)
[12] Rosa, F. and Rovida, E. The Historical Heritage: A Tool In The Abstraction Process In The Modern Design. (International Design Conference - Design 2006 Dubrovnik - Croatia, may 15 - 18, 2006)
[13] Pighini, U., Fargnoli, M. and Accinni, S. An integrated procedure for the design of sustainable products. (International Design Conference - Design 2002 Dubrovnik - Croatia, may 14 - 17, 2002)
[14] Pighini, U. A design procedure for the safety of Mechanical Systems. (International Design Conference - Design 2000 Dubrovnik - Croatia, may 23 - 26, 2000)
[15] Stakiotakis, M., Lane, D. M., Bruce, J. and Davis, C. Review of Fish Swimming. Mode for Aquatic Locomotion. *IEEE Journal of Oceanic Engineering. Vol. 24 no. 2, April 1999*
[16] Matthek, D., *Design in Nature. Learning from Trees*. (Springer, 1997)
[17] Pugh, S. *Total Design – Integrated Methods for Successful Product Engineering*. (Addison-Wesley, New York, NY., 1991)

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