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AUTOMATIC DESIGN OF A PRESS BRAKE FOR SHEET METAL BENDING

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1 Introduction

The paper presents a software application, realised for a SME that automates the design process of a presses brake family, characterized by bending force up to 250 tons and bending length up to 5 meters.

The automation of design process is very useful because customers can require different parts, sizes, tools and accessories for the same bending force and this fact implies continuous design activities to satisfy customer requests.

We analysed traditional design procedures implemented by the producer and then we represented it by using a KBE (Knowledge Based Engineering) development tool.

The application is based on product architecture and design process representations. A little set of specs actives an automatic process that produces 3D press brake virtual prototype, 2D drawings of all parts that must be machined, BoM in conformity with standards of enterprise PDM.

2 Design automation and KBE

The evolution of computer aided techniques has progressively led, in particular cases, to the direct automation of full product design process. An IT application to automate design activities is a tool that permits to reduce dramatically time and costs to develop a design solution; moreover, knowledge and best practices of the enterprise are always used. In this paper we describe an application, developed by using a KBE (Knowledge Based Engineering) tool, dedicated to the design of a machine tool family.

KBE is a technical domain that comprehends methodologies and tools to acquire, formalize and represent in IT system the knowledge of a specific application field; fundamental aims of KBE approach is the reduction of the "time to market" (TTM) and the representation, finalised to reusing, of the best practices of an industrial company.

Knowledge Based Engineering (KBE) was developed from the 80s of last century; first remarkable commercial systems of this type were *ICAD*® and *The Concept Modeller*®. They were based on object-oriented (O-O) language to define product architecture, parts parameters and methods to choice, dimension, and assembly them; a geometric modeling kernel, tools to define customized graphical user interface, interfaces to external data-base and programs complete the characteristics of these systems.

In [1] an example of O-O description of the product architecture is documented; the O-O representation of product architecture is a very important contribution to represent knowledge to automate or aid design activities. In many industrial fields, like automotive or aerospace, this approach has been adopted to automate some design activities or procedures; for example, Jaguar, from 1988, uses *ICAD*® system by KTI to design the headlight of its cars [2]. In fact, every time car style designers change the form of the car body, it's necessary to modify the structure and the light projection angle in order to keep the right visibility of the road. Headlight data are made available for suppliers, in order to build and assembly the right components. In aeronautic, Airbus uses *ICAD*® to generate a simple wing model for its airplanes, to be sequentially optimized in a FEM code [3]. The wing shape depends from data such as weight, dimensions, speed and similar information deriving from customer requirements.

KBE can be used also to plan and manage analysis activities; for example, Craig et al. developed a KBE system named DART for automotive industry [4]. In this application, geometrical, materials and sizing information deriving from car components, as motor or gear box, are available to improve the shape of the chassis to be analyzed in a FEM code.

The greater restrictions to dissemination of such approach, principally in SME, are due to burdensomeness of the development of an application; for example, in [5] a manager of KBE development team writes: "A typical KBE development team usually consists of about four individuals. One member is the design expert, (…). The others are the KBE programmer, who has experience in object-oriented programming, a program/project manager, (…) and an information systems engineer …". In last years, to overcome this limit, a new generation of KBE tools has been developed; its main characteristics are more user-friendliness and the possibility to represent in independent way the product architecture and the design process. An example of this new type of KBE application is described in [6]; it has been developed in a small enterprise, by only one mechanical engineer with a good know-how in CAD and programming.

The last approach was applied to automate design process of a hydraulic press brake family, characterised by a bending force up to 250 tons and bending length up to 5 meters. This paper is the result of the cooperation between Mechanical Department at "Politecnico di Milano" and COLGAR Spa, Italian SME, in presses brake suppliers.

3 Knowledge acquisition and formalisation

The type of press brake treated by the application described on this paper is illustrated in figure 1. The set of main parameters that permits to configure an instance of the family is the following:

- bending force.
- bending length;
- distance between housing;
- throat depth;

- throat height;
- stroke.

Figure 1. The hydraulic press brake.

A logic scheme of the KBE application is described in figure 2; in particular, outputs required are as follows:

- parts dimensioning;
- machine architecture configuration;
- components modifying/substituting;
- technical documentation, such as virtual prototype, constructive drawings, and BoM.

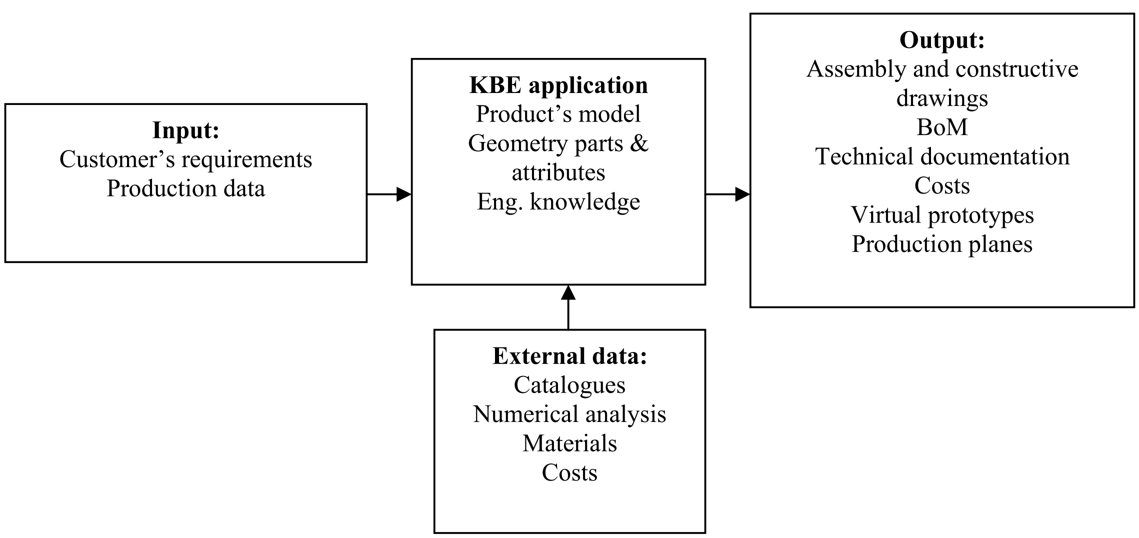

Figure 2. General scheme of KBE approach.

Other important requirements are expandability, easy of use and management, easy integration both in processes and informative system of the enterprise.

The development of the KBE application has required various activities: knowledge acquisition and formalisation, implementation and finally testing. The first activity concerned As-Is design process analysis; it is based, principally, on a modification of the 2D drawings of a press brake master and it starts when the customer has specified the working capacity (i.e. maximum bending force) and the above mentioned five geometric parameters. The engineering staff chooses the machine with the nearest values of parameters and then modifies it with the aim to reach the required values. Such operation is, of course, very complex and time expensive. To assist engineers in this phase a parametric 3D model of the press brake was realized but such a model does not permit to change parts or modify machine architecture. In As-Is design process analysis knowledge from design team, manuals and technical documentation has been acquired.

To develop the application we utilised a KBE tools named RuleStream^{TM}, developed by homonymous company; it comprises many separate software modules, which operate in concert with the Windows operating environment, the CAD/PDM/CAE systems, a web browser, and Microsoft SQL Server technology to provide knowledge capture, storage, usage, enforcement, and analysis capabilities. Table 1 refers in detail the utilized software.

Information acquired during the previous phase has been formalised in order to respect the characteristics of RuleStream that adopts a hierarchical representation of the product; figure 3 shows the tree representing the master of a press brake family. Each part, subassembly and assembly is characterised by a set of parameters, geometrical, functional, and technological and so on. Design process is represented by relations and procedures that correlate and determine the mentioned parameters; figure 4 shows the sequence of modifications determined by a changed parameter.

Table 1. Software tools utilised to develop application.

Software	**Use**
RuleStream^{TM}	KBM-System, to define architecture and design process of the press brake
MS SQL^{TM}	Data base, to store all information and knowledge
Solid Works^{TM}	CAD system, to realize the virtual prototype and the constructive drawings
Visual Basic^{TM}	Programming language, to develop program for the management of part lists
MS Excel^{TM}	Electronic sheet, to realize lists of all parts of the machine in the BoM

4 Implementation and example

All the parts, the subassemblies and the final assembly constituting the press brake were defined in RuleStream and their parameters also; 3D parametric models of each part were modelled in SolidWorks^{TM}. The procedures that manage the complete dimensioning of the machine were represented by using the programming language (Basic-like) of the development tool. A specific graphic user interface was programmed; figure 5 shows a partial view of the first panel where the user can choice a specific model (in this case PS75, with a maximum bending force of 750 kN) to configure.

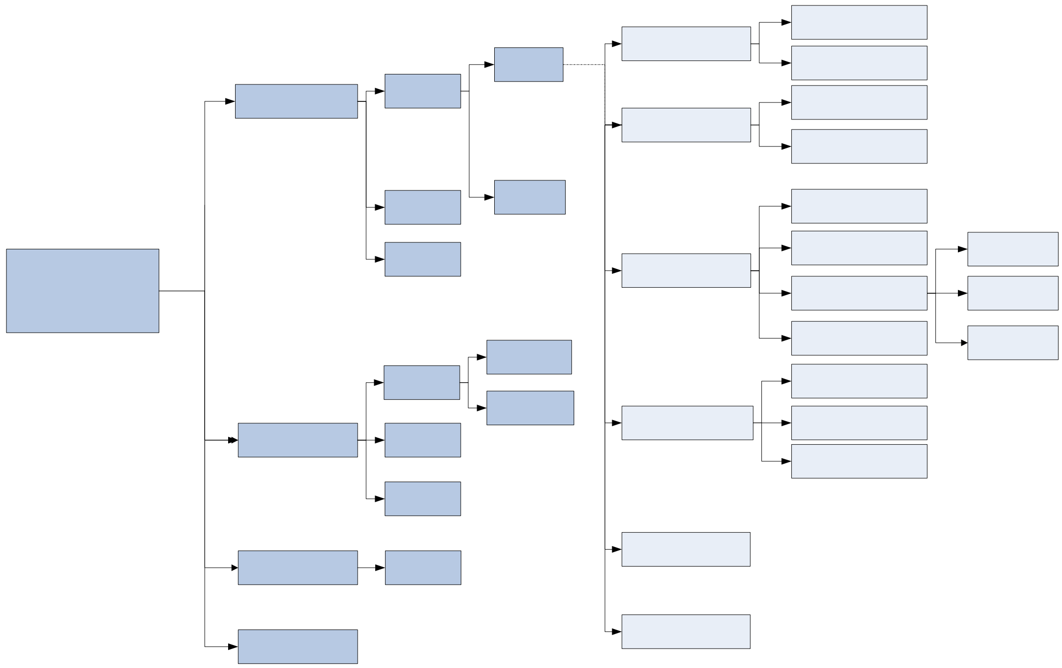

Figure 3. Partial architecture of the press brake.

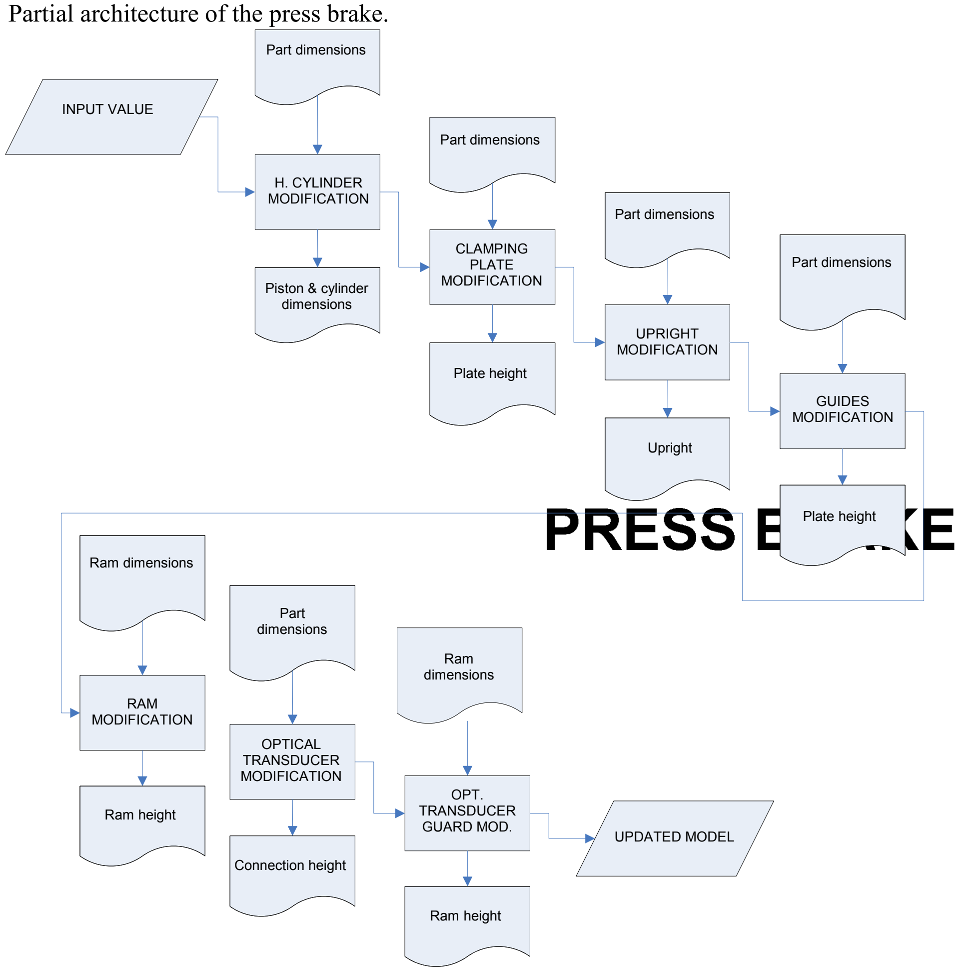

Figure 4. Relations among some parts of the machine

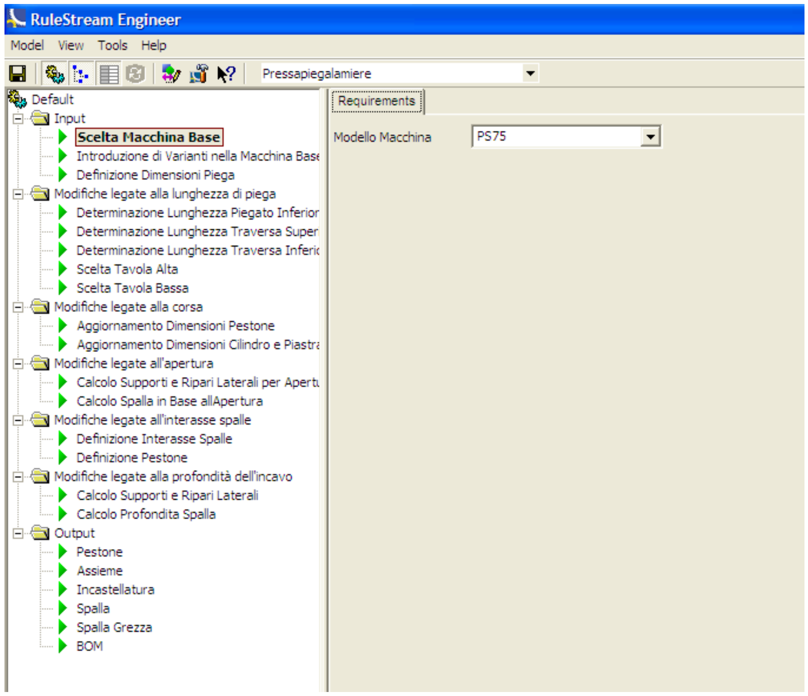

Figure 5. Partial view of a first panel of the application GUI.

Figure 5 documents also the first step that the user must do; then, she/he inputs remaining specifications and the application dimensions automatically all the parts, assemblies them, and produces electronic BoM and 2D drawings. Figure 6 portrays the virtual prototype of a press brake produced by the application, whereas figure 7 shows an example of a 2D drawing.

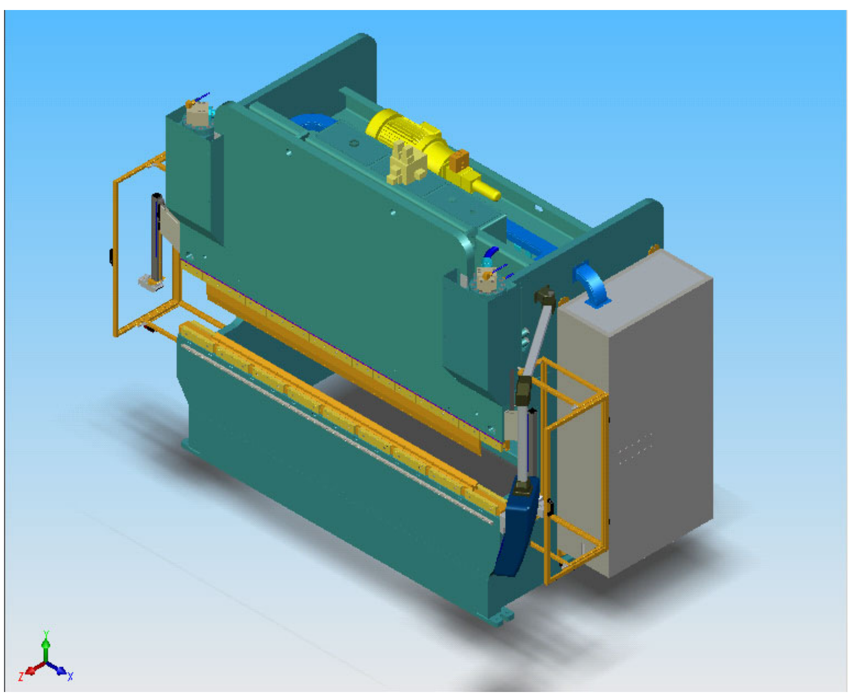

Figure 6. Virtual prototype of a press brake configured by using the application developed.

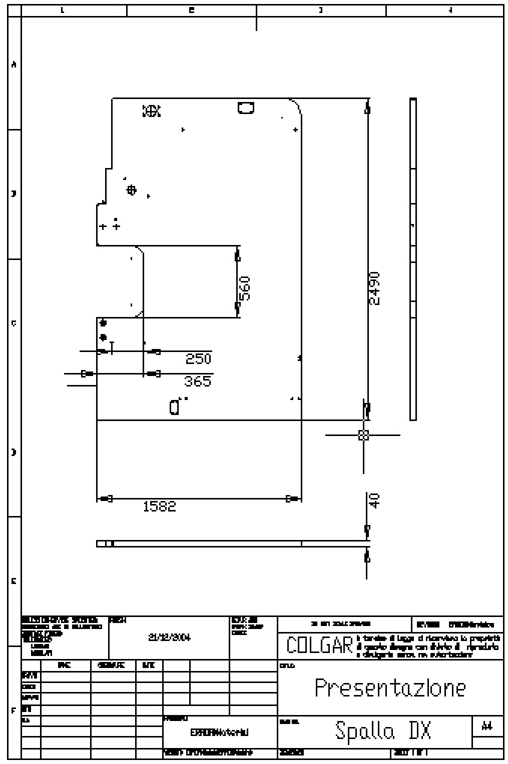

Figure 7. Example of constructive drawing

5 Conclusion

Encouraging results on the prototype evaluation was obtained, and, after this fact, the generalisation of the approach, by developing a more general application to design all family machines, was induced. Given the complexity of such application, we adopted a Knowledge Based system to represent product architecture and design process. The emphasis in this case is focused on product architecture, represented by a tree structure, and design process representation by a programming language. The virtual prototype has been realised with a parametric CAD system; geometric parameters have been used as variables in dimensioning and configuring procedures. The system requires as input only the bending force, maximum length and width of sheet metal and then the application provides to choice and configure parts and assemblies, to define geometric model, BOM and drawings, and to estimate costs.

The fundamental obtained advantages are as follows:

- design time reduction (from 20 days, to ca. 40 minutes);
- easy expandability and configuration possibility;
- easy management of trade information.

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