The importance of the research programs of reverse engineering in engineering teaching education

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Abstract *--- Much of the activities carried out by students in the work world relate to the knowledge of parts, machines or systems which have very little referential information. However, students are not trained in universities with systematic ways allowing the generation, processing, interpretation and use of information from these systems. Reverse engineering is a methodology, taught and used systematically, can contribute, on the one hand, to improve the skills and creativity of students to find out useful information about parts and components and, on the other hand, to motivate technological development based on product innovations. This article presents a description of a method of the reverse engineering which can be useful for teaching engineering. It presents a description of the research programs and models associated with the reference object (Object to reproduce). This article presents a case study related to an industrial mechanical part. Four research programs are applied to the case study: 1) Measuring, 2) Computer aided design CAD, 3) Finite element analysis (FEM or FEA) by CAE (Computer Aided Engineering) and 4) Simulation manufacture in CAM (Computer aided manufacturing) and manufacturing by EDM (Electrical Discharge Machining). Research programs related to the reverse engineering, help students learn and apply different computational and experimental tools to determine systematically, characteristics, relations and properties of reference objects.*

Index Terms --- *Profile Engineering, Engineering Teaching, CAD/CAM/CAE, EDM, FEM, FEA*

Introduction

Many of the activities performed by engineers, in academia, as in the workplace, may be confined within the scope of Reverse Engineering. Similarly, activities such as design, manufacturing and maintenance of parts and components used in one form or another programs and models of Reverse Engineering [1] to achieve its goals. In addition, the reproduction of parts and components is a current need of the industries, because, first, do not always have the parts for repairs or for urgent maintenance of machinery and you have the need to reproduce those parts, and on the other hand, technological innovation based on improvements of existing products, requires the use of reverse engineering to find the products to be systematically improved [2].

However, even despite the great importance of Reverse Engineering in Mexican universities is not taught formally, and in most companies the processes of duplicate parts and components are more empirically (to test and error) than a systematic way.

To be able to develop projects of reverse engineering efficiently and with great potential, it is necessary to have measurement tools, analysis methods, trained personnel and a system of suppliers, from technical services as suppliers of parts and components. In other words, it requires a whole technical system well-organized and specialized for Reverse Engineering. Furthermore, it is necessary to understand that reverse engineering is a legitimate method to recognize parts and components and is not synonymous of piracy. The method is legitimate from the context of research, teaching and technological innovations, since it is one way to recognize and systematize information about the components. Evidence of this is information that is required for the maintenance programs of the machines in a production system. Reverse engineering should be taught in the universities, since many of the activities that makes engineering is precisely to recognize parts and components, machines or systems. Students should be able to understand many of the activities taking place in companies from the context of Reverse Engineering and be trained in the laboratories of the universities [2].

Reverse engineering

The concept of reverse engineering has many definitions. According to [3], the reverse engineering can be described as the process by which an existing part or a physical model is recreated or cloned. This article will consider the following definition [4]:

Reverse Engineering is an analytic-synthetic process that seeks to determine the characteristics and / or functions of a system, a machine or product or part of a component or subsystem. The purpose of reverse engineering is to determine a model of an object or product or system reference.

Reverse Engineering has its primitive elements, ie: the reference object called A, the reproduced object B (called duplicate) and a set of specific relations. The nature of the reference object is [5]:

"A can be a real or virtual object. It is real if it is a physical object with physica propertiesl, chemical, electrical, etc. It is virtual if the object is not physical. It can be an object or part of an object or system or subsystem and is also classified in complete or incomplete. Is complete if given a reference object A satisfies all the characteristics of the reference and is incomplete if at least one of these characteristics fails the reference. Object A is also finite, measurable and admits decomposition".

In the case of the reproduced object it have the following nature:

"B can be real or virtua,l object or, part of the object or, system or subsystem. By nature the object produced B is complete given the reference. The object B also provided a model of A".

On the other hand, according to [4,5], each definition of reverse engineering must have its own method. For the above definition it have the following stops [5].

1) Presented the referente object A.
2) Define the references.
3) Define the objectives.
4) Steps 2 and 3, designs the research's process.
5) Product design of step 4) is a plan or operational research program.
6) P is applied to object A.
7) The result of step 6) is information of A.
8) It is considered step 3) and with results of step 7) B is generated.
9) B is a model.
10) Is verified, according step 3), if B is equivalent to A.
11) Conclusions are given.
12) B is revalued.
13) B is applicable.

One of the functions of Reverse Engineering is the systematic retrieval of useful information and reliable of the reference object, this information is obtained through the method described above. Note that step 5) according to the procedure above, refers to research programs. According to [6], a research program on Reverse Engineering, is a series of planned steps applied to the reference object and / or models related to that object. The outcome of any research program of Reverse Engineering is a collection of models related to the reference object. A model in the context of reverse engineering is a representation of a set of features and / or properties and / or related functions, implicitly or explicitly with the reference object. Moreover, the application of analysis programs at the reference object generates analysis models and the application of synthesis programs generates synthesis models. The main objectives of the analytical programs are:

1) Obtain reliable data and information, functional and objective of the reference object.
2) Transform the data into manageable information model.

Under this context, it can say that one of the most important activities of Reverse Engineering is the design of research programs, since depend on them the quality, reliability and representativeness of the obtained models. In addition, other important aspects related to Reverse Engineering programs are, first, the good condition of tools, devices and machines used to perform the tests and on the other hand, a correct domain of the theories and methods used for interpretation and modeling results [6].

Case study

In this section it present the synthesis of four research programs applied to an object reference. It applies the procedure described in the previous section. Here's development [7]:

To start the process of reverse engineering is necessary to make a short description of the reference object. That is:

1) Presented the referente object A.

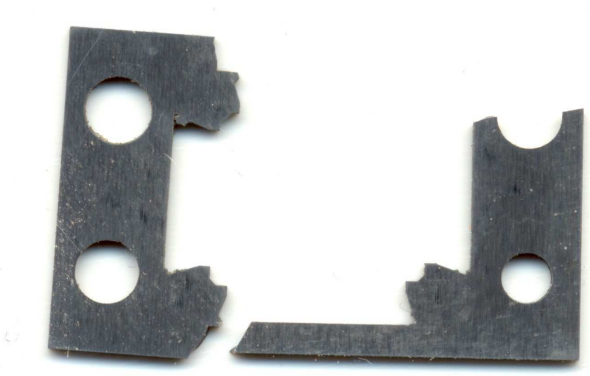

FIGURE 1
Reference object

Description: A is a real object and is a component. A it is incomplete, since it does not know the maps of manufacture. Is finite and measurable and it is considered that supports decomposition in the sense of being analyzed subpart by subpart (circles, arcs, surfaces including subparts). The reference object under study is a part (Clamp) important for a machine to separate the semiconductor from frame.

2) Define the reference (C_{FR}).

The reference object A shown in Figure 1 is of class: Extensive Content Reference (ECR). That is, the piece is certainly known and have already developed methods of analysis among other things, so A $\in$ ECR.

3) Definen the objectives (C_{OE}).

Having described the object of study and references about whether if that object is much or little known, the next step is to define the objective, that is, it want to reach once applied the analysis. In the case of this article, the goal is didactic and consists in obtaining the real dimensions of the object, draw in a CAD software, make a stress analysis and manufacture through the EDM wire process.

4) With C_{FR} y $C_{OE,}$ is designed the research process.

5) Product Design of Step 4) is a plan or program of operational research (P).

The research programs were applied to the object of study are below:

1). Manual Measurement (Program P1)
   a) Digitization process of the case study
   b) The reference model of geometric primitives
   c) Model of primitive digitized
2). CAD Model (Program P2)
   a) Manufacturing drawings of the case study
   b) Solid model
   c) Transfer model

3) CAE Model (Program P3)
   a) Primitives model
   b) Mesh model
   c) Results model (stress, displacement, etc.)
4) CAM Model (Programa P)
   d) Primitives model
   e) Paths model
   f) Tools model

Note that for reasons of space only will show a synthesis of the above programs.

6) P is applied to object A.

Synthesis of program P1:

The program P1 is primarily to obtain measures of the piece shown in Figure 1. We used a digital vernier and a gauge slots. Figure 2 and Table 1 shows the primitives and final measures of each.

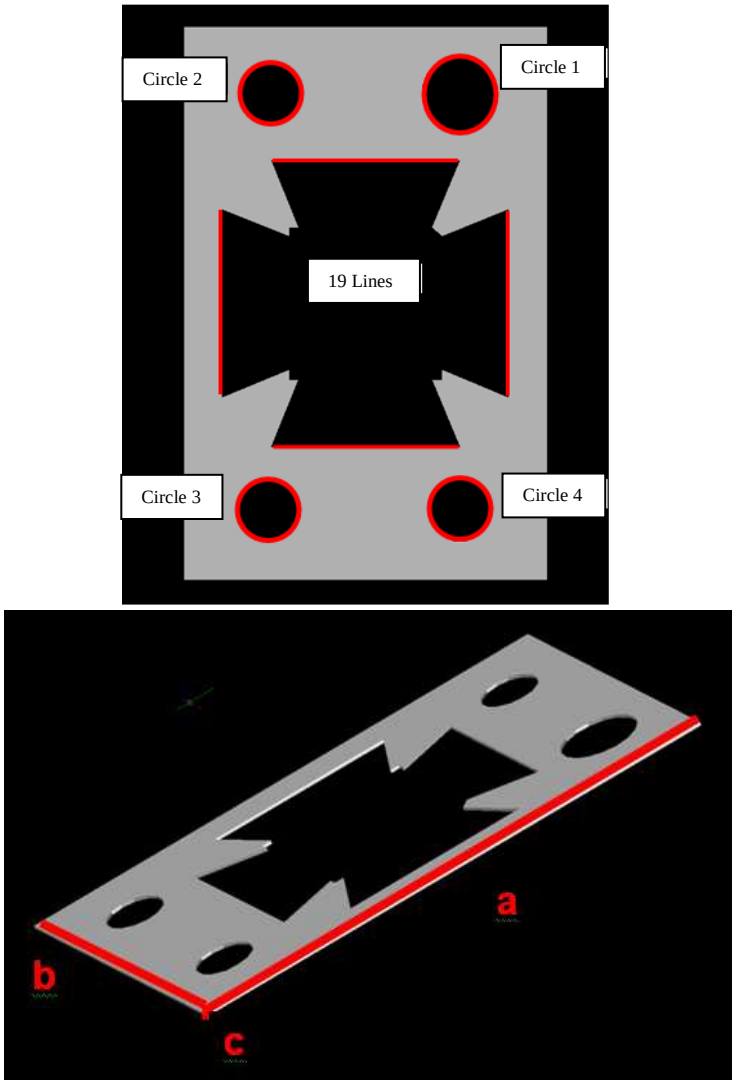

FIGURE 2
Case of study geometric primitives

Geometry	Measurement 1	Measurement 2	Measurement 3	Average
a	5.43	5.43	5.43	**5.43**
b	3.56	3.56	3.56	**3.56**
c	0.03	0.03	0.03	**0.03**
Circle 1	0.748	0.748	0.748	**0.748**
Circle 2	0.5607	0.5607	0.5607	**0.5607**
Circle 3	0.5607	0.5607	0.5607	**0.5607**
Circle 4	0.5607	0.5607	0.5607	**0.5607**

TABLE 1
Primitives measures

Synthesis of program P2:

The objective of this program is to obtain CAD computer models of the piece being studied. Autocad 2007 was used to generate the manufacturing drawing (see Figure 3) and a solid modeling component (see Figure 4).

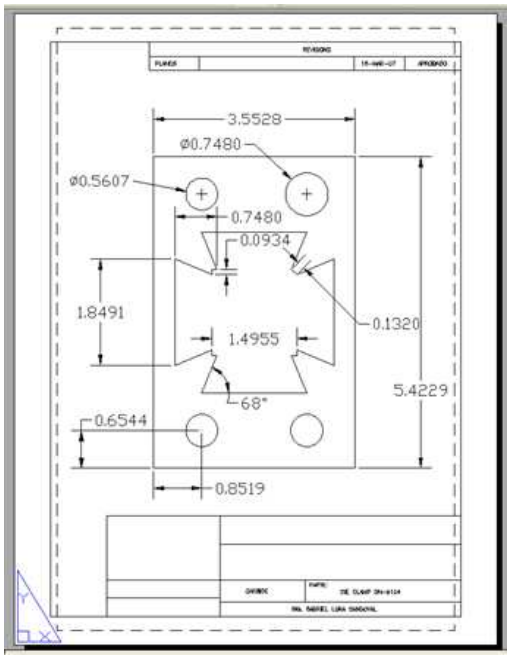

FIGURE 3
Component's manufacturing drawing

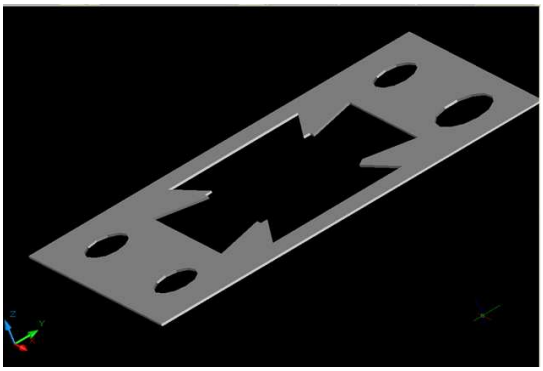

FIGURE 4
Solid modeling of the component

Synthesis of program P3:

The program's goal 3 is to realize a stress analysis to object studied. For this purpose, used GID and ALGOR software. Figure 5 shows a graphical output of the meshing process and Figure 6 shows an output of a stress analysis [8].

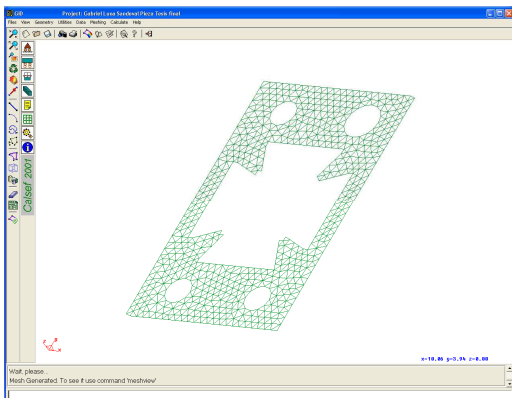

FIGURE 5
GID Meshing of the component

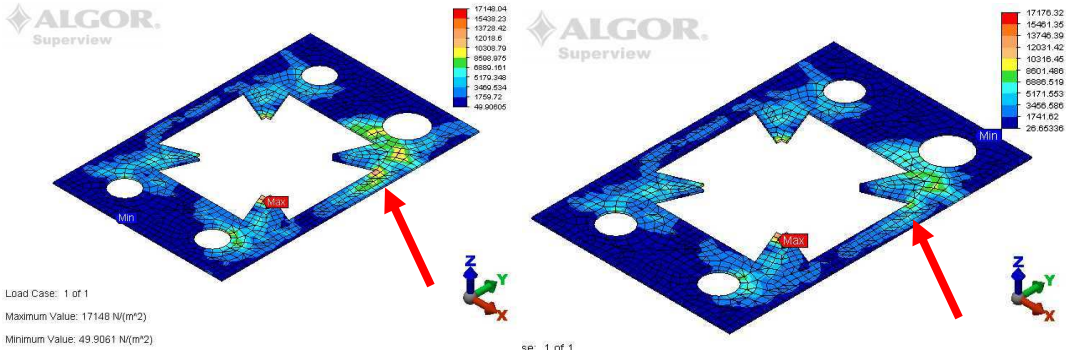

FIGURE 6
Graphical output of a stress analysis, the original part geometry (Left) and new geometry using reverse engineering (Right)

Synthesis of program P4:

The objective of the program P4 is, first, simulating the process of wire EDM machining and on the other hand, manufacture the component. In the case of simulation CNC Simulator software was used and to manufacture a wire EDM machine. Figure 7 shows a graphical output of the simulation and Figure 8 shows the component manufactured using a reverse engineering method.

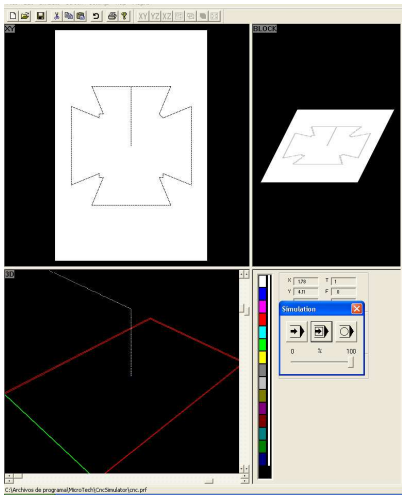

FIGURE 7
Simulation graphical output in CNC Simulator software

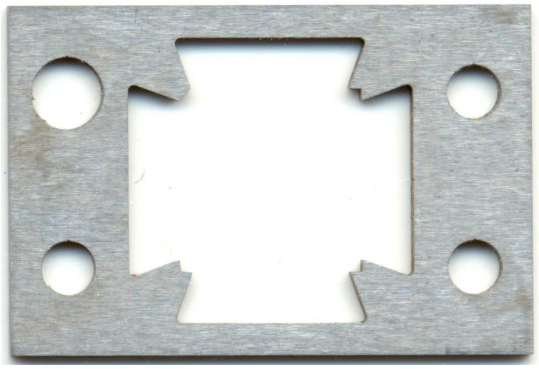

FIGURE 8
Manufactured part using a reverse engineering method

7) The result of step 6) is information of A.

All the data obtained by applying the research programs are transformed into information models. For reasons of space the information gained from reverse engineering is not show.

8) Step 3) is considered and with the results of step 7) B is generated.

The physical duplicate (B) of reference object A is shown in Figure 8. But in reality B are all models of information obtained.

9) B is a model.

This step only shows that B is a set of models of models. That is, it reaffirms the nature of the object reproduced.

10) Verified, according to step 3), if B is equivalent to A.

To verify the equivalence between the object of study A and duplicate B is necessary to establish references. For example, re-measure B or just testing the functionality of the duplicate. For purposes of this article and only tries to show an example of reverse engineering methodology, it will say that in fact B is equivalent to A.

11) Conclusions are given.

In this step it provide some conclusions about the duplicate B. For example, model B is representative of A, or the stress model allowed to identify high concentration of stress.

12) B is revalued.

Once given the final conclusions of the primary process of reverse engineering should revalue B, that means, evaluate each model obtained from the implementation of each research program. This assessment is performed only on B and is to determine the added value of the obtained models.

13) B applies.

This step completes the implementation of the method of reverse engineering and consists of evaluating all possible applications of the model B. For example, the finite element model can be applied to known strains and displacements for different working conditions of the duplicate.

Some considerations for engineering education

Reverse Engineering is a methodology that should be formally taught in the universities, it is the key to knowledge and technology development. However, it is necessary to systematize the teaching, development processes of reverse engineering as is the case of the method described in this article. The research programs form the core of Reverse Engineering, for determining the procedures to follow, computational and experimental tools and measurement equipment required for the analysis of the reference object. The number of research programs and the complexity of them depend on the real needs of the person requesting for reverse engineering, ie: for the customer. In the case of the teaching in engineering subjects in many areas such as Mechanical, Manufacturing and Production Systems Maintenance should consider the Reverse Engineering as a useful method, necessary and powerful which can be used to learn in a systematic form parts, products and systems.

Conclusions

This article has presented a method of reverse engineering which can be useful for engineering education. In addition, was presented 4 research programs related to the analysis of a reference object. The conclusions related to this investigation are summarized in the following points:

- The reverse engineering method presented in this article allowed to analyze a piece in a systematic manner through the application of different research programs. This systematization can be useful for engineering education.
- In the case of the discussed piece in this paper, the applied research programs were demonstrative and didactic, as well as learn and apply various computational and experimental tools to know useful and functional information of the reference object, such as the Finite Element Method and wire-EDM technology.
- The information obtained from the reference object, applying correctly the research programs, can encourage creativity among engineering students, especially for the improvement and product innovation.
- The methodology of reverse engineering should be taught formally and systematically in classrooms, as correctly applied lets know products and systems, also has multiple applications.

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