DEVELOPMENT OF A LOW COST CNC PLASMA CUTTING MACHINE

João Carlos Oliveira Pena, pena.ufmg@gmail.com
Frederico Alevato Ramalho Filho, fcnc05@gmail.com
Jordano Fernandes Cordeiro, jordano.f@gmail.com
Kássio Maciel Kienitz, kassio.kienitz@gmail.com
Emanuel Barbosa Silva, emanuelribeiro@gmail.com
Eduardo José Lima II, ejlima2@yahoo.com.br
Alexandre Queiroz Bracarense, bracarense@ufmg.br
Universidade Federal de Minas Gerais, Departamento de Engenharia Mecânica, Av. Antônio Carlos, 6627 – 31270-901, Belo Horizonte, MG, Brazil

Abstract. *The plasma cutting of parts in a sheet metal is an excellent method to manufacture parts that doesn't need very high precision and have small to medium batches. The advantages are high productivity, no need for minimal batch being cost effective even for single parts, flexibility for cutting small gauges to several inches thick metal plates, different materials and everything with good precision and a reasonable cut quality. The Plasma cutting, along with LASER cutting and Oxi-fuel, all have advantages and disadvantages, but the CNC Plasma system is particularly interesting because it can cut thick metals with great productivity and low cost, like the Oxi-Fuel, but also can provide precision parts with complex shapes like the LASER. But in order to extract the full potential of a plasma cutting system, it has to be coupled to a good CNC machine, capable of providing the optimal cutting speed for each material and thickness, good acceleration in order to maintain constant speed in corners, with minimum rounding, rigidity and precision, in order to avoid vibrations and oscillations during the cutting. In order to achieve all these characteristics, it is necessary to use quality components in a sophisticated design, and coupled with the necessary electronics, the final price of a CNC cutting system may end up being much higher than an oxi-fuel system, although smaller than a LASER system. The major problem is that only a small fraction of this price is the actual plasma cutting machine, and if a system could be designed in order to reduce the cost of the machinery and electronics involved, the final system could have a final price much lower than what is being offered by the industry. This paper proposes through a case study a novel construction system and design methodology capable of reducing drastically the price of the structure, and coupled with a modular electronics that can bring the final price down by a significant amount.*

Keywords*: Plasma Cutting, Design Methodology, CNC, low cost*

1. INTRODUCTION

In 1995, under the coordination of Professor Alexandre Queiroz Braga, PhD, was implanted the "Grupo de Robótica, Soldagem e Simulação", the GRSS, with the objective of contributing to technical and scientific improvement of professionals in the field of automation of welding processes, in the development and implementation of new technologies, in addition to providing service in robotics, welding and simulation. With the support of companies from the productive sector and government agencies was built the Laboratório de Robótica, Soldagem e Simulação (LRSS), a laboratory of latest generation the offers to GRSS the necessary and sufficient conditions for teaching jobs, researches and consulting in several areas. (LRSS UFMG, 2010)

To perform the prototyping of robots in the LRSS the laboratory needed to outsource the laser cutting and as the LRSS already had a plasma cutting machine (manual), it was interesting to automate de process.

The table was designed to be laser cut so that could be built as cheaply as possible, using the technique LOD (Laminated Object Design). The design of the table was based on a project performed by the laboratory to build a CNC mini-mill also using the LOD technique, taking into account the protection of the motors, spindles and pulleys, keeping them away from possible splashes and from plasma dust, a highly abrasive material.

Automation is the technology on which a process or procedure is performed via programmed instructions usually combined with an automatic control response to ensure proper execution of the instruction (Groover, 1994).

In automatic control systems with a closed loop system , a sensor measures the response, which will be compared to the reference input. As the controlled signal is fed back and compared to a reference input, an active signal which depends of the difference between the input and output is sent to the entire system to correct the error, thus providing a more accurate control (Rosário, 2005).

According to Lima II (2007), "Automation is the set of techniques based on machines and programs in order to perform tasks previously programmed by humans and control sequences of operations without human intervention". Lima II (2007) also classifies automation into three types: fixed, programmable and flexible automation.

The Fixed automation is characterized by using equipment specific to a particular type of part. The programmable automation is used to produce a wide variety of products and can be reprogrammed to produce different parts. Flexible automation, flexible manufacturing systems (FMS) is characterized by allowing the processing of products with different specifications through automatic exchange of equipment programs, as well as changing the sequence of processes and equipment to be used.

Although automation can be used for a wide variety of tasks it is commonly associated in manufacturing projects.

In the sector of industrial production in 70 years, the goal was to perform automated tasks, robots and Computer Numeric Control (CNC), a combination of hardware and software that had as its main objective to increase the flexibility of the system. In the following decade the priority was the automation of processes, and the connection of individual tasks resulted in CAD and CAM processes in CNC and FMS machines.

It was a time of great advances in industry modernization. In 90 years the automation of factories involved the automation of various processes, which started to run a simple process chain, according to a predetermined model, involving a greater integration of electronic components (VLSI) and microcontrollers, and the integration of communication networks to the system. The decentralization has increased the interdependence of sectors control and the flow of production and factory management.

Industrial automation is what could be called of integrating technology of three areas: the electronic, which has an electronic platform using of hardware; the mechanical, in the form of mechanical devices (actuators), and informatics, where the operations programs are made, the management and involved communication (software). (Rosário, 2005)

Some advantages of automation can be highlighted:

- Increased efficiency of processes;
- Quality improvement;
- Lower costs;
- Increasing competitiveness and the level of requirement;
- Greater control and safety of operation.

2. COMPUTER NUMERIC CONTROL

The Computer Numeric Control (CNC) is an electronic equipment that receives information in the way in which the machine will perform an operation, through its own language or specific command, such as the G-Code, processes this information and return them to the system through electrical impulses. The electrical signals are responsible for the activation of the engines that will give the machine the desired movements, performing the operation in the programmed sequence without operator intervention.

The utilization of CNC allows the production of complex parts with great accuracy, especially when combined with CAD / CAM. It has been widely used in the machining area with machines such as lathe, milling, plasma cutting and welding machines, drilling, among others.

Ramalho Filho (2003) mentions that there are basically two kinds of numerical control units: the autonomous units, dedicated or start-alone, where the control of the machine is done by an embedded computer, and the CNC of open architecture in which the control unit is outside the machine frame. These units can be seen in Figure 1 and Figure 2.

Figure 1 - CNC machine of proprietary architecture

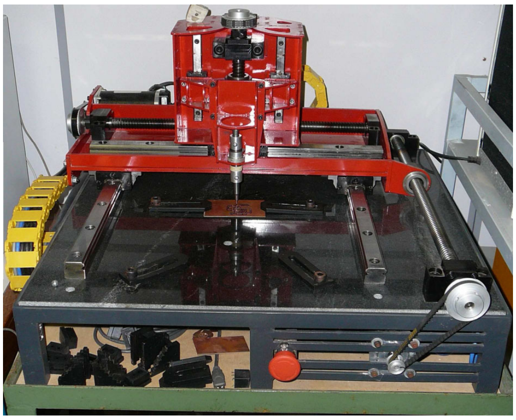
Figure 2 – CNC machine of open architeture

The numerical control is the part responsible for reading the sequence of tasks to be performed, and produce the appropriate signal. Among the functions performed by the control unit, Ramalho Filho (2003) highlights:

- The control of rotation speed of the machine;
- The control of the tool paths;
- The action of the switch tools;
- Turning on and off the flow of coolant;
- Lock or release the part to be machined;
- Chip Remover;
- Trigger Automatic feeder of raw material;
- Make the simulation of tool path.

The introduction of CNC in the industry has radically changed the industrial processes. Curves are easily cut, complex structures in three dimensions are relatively easy to produce and the number of steps in the process with the intervention of human operators is drastically reduced. The CNC also reduced the number of human errors (which increases the product quality and reduces rework and waste), sped up the assembly lines and made them more flexible, because the the same assembly line can now be adapted to produce another product in a much shorter time than with traditional processes of production. Accompanying the development of informatics technologies and a tendency for increased interactivity with the user, code and machine language also evolved.

3. LOD (LAMINATED OBJECT DESIGN)

The Laminated Object Design, LOD was developed by the Laboratório de Robótica, Soldagem e simulação, LRSS, through the study of three techniques for product design, DFM, DFA and LOM. In the LOD the concept of shape of the machine is translated into steel plates in the initial phase of the project. Each part of the machine can be subdivided into two-dimensional plates that can be laser cut from a single plate of steel. These plates can be mounted through specific type male-female slots and welded to form the components of the machine. Each sub-component is designed taking into account the process of laser cutting in order to avoid any further processing in the assembly, such as cleaning or grinding. The Figure 3 illustrates an assembly using the LOD technique.


Figure 3 - Application of the LOD method - Support of the plasma cutting torch

The use of male-female slots, as in Figure 4 allows when being welded, the part formed do not need any type of setting and remain free of distortion or thermal stress. (Ramalho Filho, 2003)

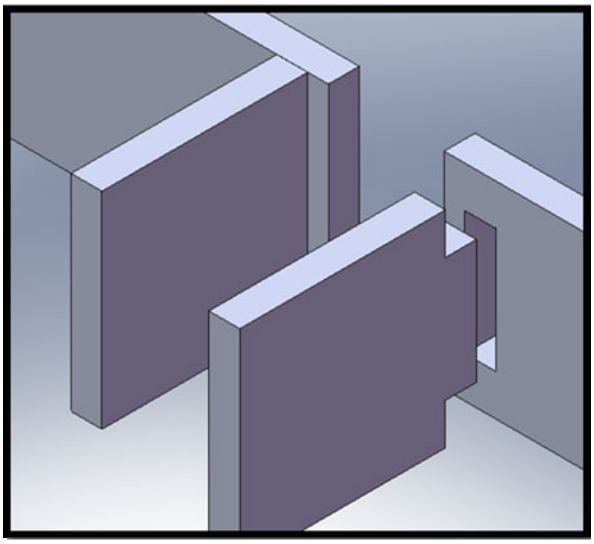

Figure 4 - Male-female slot

3. METHODOLOGY

3.1. Table Assembly

In this step, it was used a project of structure developed by the LRSS based on another project used to create a mini-mill CNC, with some modifications in its structure due to the need for greater rigidity and protection of motors, spindles and pulleys.

The table size was determined by the size of the spindle, which had availability in the laboratory. All other measures necessarily derive of the size the spindle used, 700 mm.

The whole structure of the table was conceived through the technique LOD (Laminated Object Design) to allow a faster and cheaper manufacturing.

3.2. Operationalization of the Table

After completion of the structure of the table, it moved to the process of operationalization. This step consisted in studying the operation of the CNC plasma cutting table, using it in applications and solving all the little details inherent in to the process to make the equipment functional.

3.3. Software Choice

The software is the computational element that connects a design to the piece being cut. The software should be able to produce or receive a file CAD / CAM and transform it into G-code so that the system understands. This step consisted in determine the best software to be used taking into account the objectives above and its functionality.

3.4. Study of applicability in the plasma cutting process

In order to improve the use of a CNC table for plasma cutting process, it is inevitable to study the process of plasma cutting. In order to understand what is the best speed to cut a certain type of metal at a certain amperage with a specific thickness. A study of the effects of plasma dust, a very abrasive material, and its effects on the system becomes highly desirable.

4. RESULTS

4.1. Table Assembly

During assembly of the table were found some factors that required improvements in the project. One of these factors was manufacturing of the "water table" that would serve as support for the plates to be cut. As the cut would not be realized in free span the use of a container of water was required, and should be done so that the plate to be cut would be placed over pallets.

Then studied a possibility for the water table, and it was concluded that the use of removable pallets would be a good option, since they would be consumables in the process of plasma cutting, making the water table itself more durable. It can be seen in Figure 5 how is done the fixing of the pallets on the table.

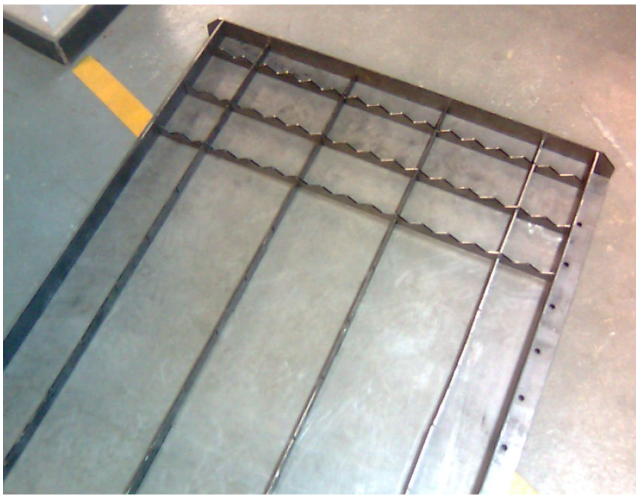

Figure 5 - Fixing of the pallets in the water table

4.2. Operationalization of the Table

After completing the process of assembling the table, It was studied the process of its operation. Several cuts were performed to understand principles such as Offset and Kerf. The offset is the quality characteristic of the region in which the cut is being performed, the offset side is the part with better quality, it was noticed that the best offset quality is produced with cuts in anti-clockwise. The Kerf is a parameter related to cutting thickness, and varies with the material that is being cut, this way before performing a cut in which a higher precision is required, it is necessary to make a cut of a body of test of pre-established dimensions so that it can be calculated the value of Kerf.

Other collected data were about the speed and current used in the cutting process. Several tests were made by varying these parameters and their effect on the cut. It was decided to use existing tables of a brand of plasma cutting consumables indicate according to the metal type and thickness, which is the best speed and current that should be used.

4.3. Software Choice

The choice of the software was based on the following characteristics:

- The software should be able to produce or receive a CAD/CAM file;
- Transform the CAD/CAM file into G-code;
- Being easy to understand;
- Have a user-friendly interface.

Softwares already used previously in the design of the CNC milling, as ArtCAM and EasyCAM were tested, despite being effective in the requirement of movement, they had no specific support for the plasma. After a careful study about softwares used in the market in the area of plasma cutting, it was discovered that the software SheetCam, not only had a precise support for cuts in plasma and laser, but had a friendly interface and it was easy to understand.

The SheetCam receives directly a file of the type drawing of CAD programs like AutoCad and SolidWorks and plots the best route to cutting the piece, as shown in Figure 6. The software also allows that this route to be edited to suit the required process. Then he transforms this route in a G-code to be read by a CAM program, responsible for movement of the CNC.

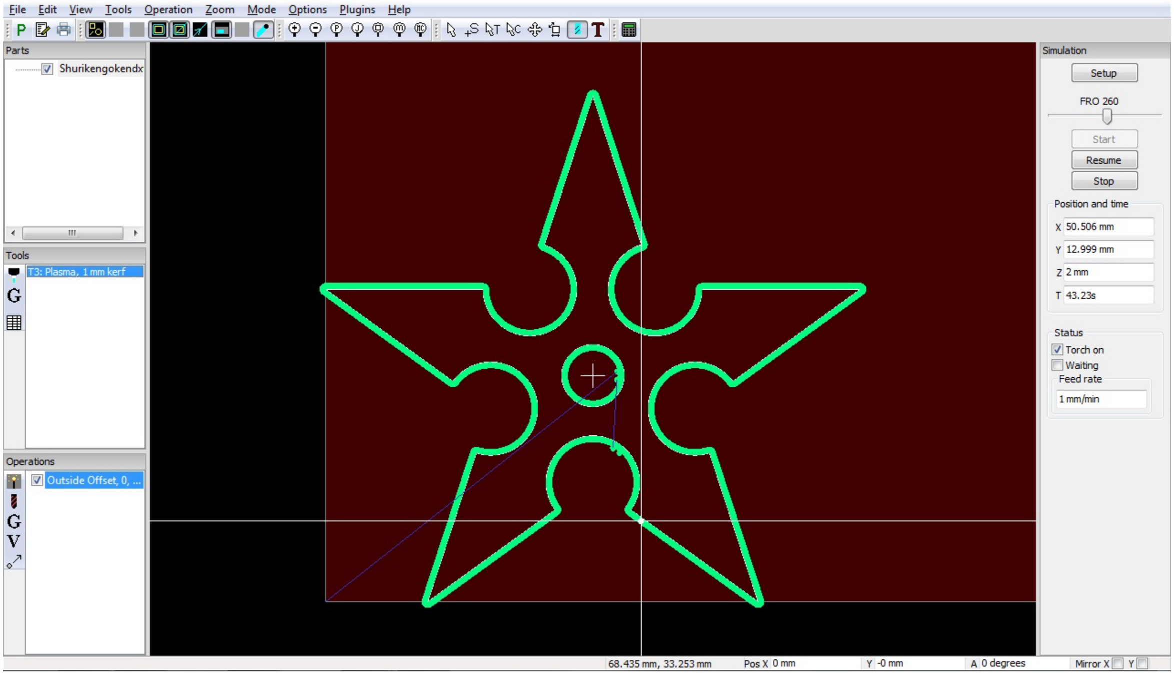

Figure 6 - SheetCam software, responsible for G-code generation.

The CAM program chosen was the same that was used in the design of the CNC milling, the Mach3. Its choice was based on previous knowledge of its handling and the wide use of the product on the market.

4.4. Obstacles Found

During the use of the table, some obstacles were encountered, that somehow will influence future projects of other CNC. Such obstacles are described below along with the solutions found.

4.4.1. Water Table

Initially the water table was a single piece, all pallets were welded to a bottom, forming a sort of form. It was noticed that soon the pallets would be consumed by the cutting process, and the whole table would need to be restored. In response to that, it was projected a water table where the pallets could be detached, and replaced individually as needed.

Another significant issue regarding the water table was about the deposit of scoria. Even with independent platforms and removable the cleaning and maintenance of the table showed to be troublesome, and future projects of the table provide ways to facilitate this cleaning and the use of canals beneath the removable pallets.

4.4.2. Splashes and Plasma Dust

The plasma cutting is a process that uses pressurized gas, and due to the presence of water in the process, splashing are inherent to the process. These splashes in contact with the dust released in the process form a dense layer of dirt that becomes clearly visible around the structure of the table. To prevent that such splashes reach the electronic components of the table and soiling around the it, an acrylic dome will be projected to involve the table and protect the environment and other components.

4.5. Cut Parts

Figures 7 to 12 show the developed machine cutting parts and Figures 13 and 14 show the aspect of cut parts.

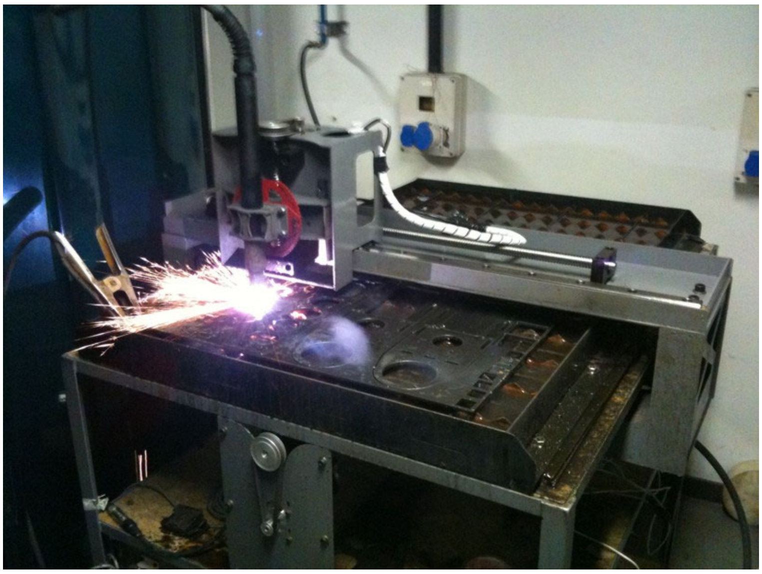

Figure 7 – Plasma cutting.

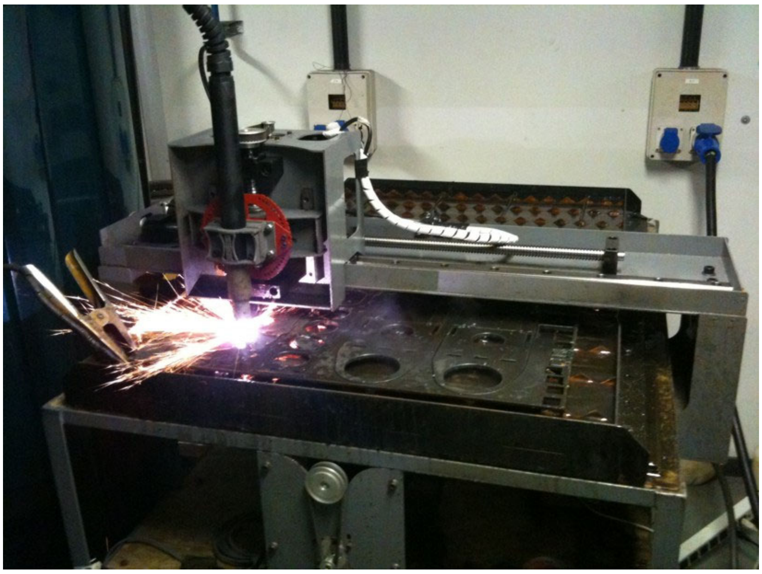

Figure 8 – Plasma cutting.

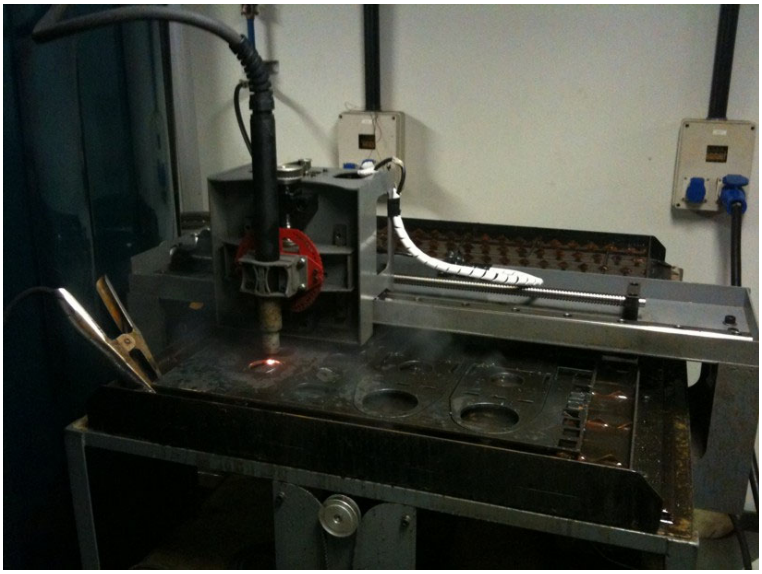

Figure 9 – Plasma cutting.

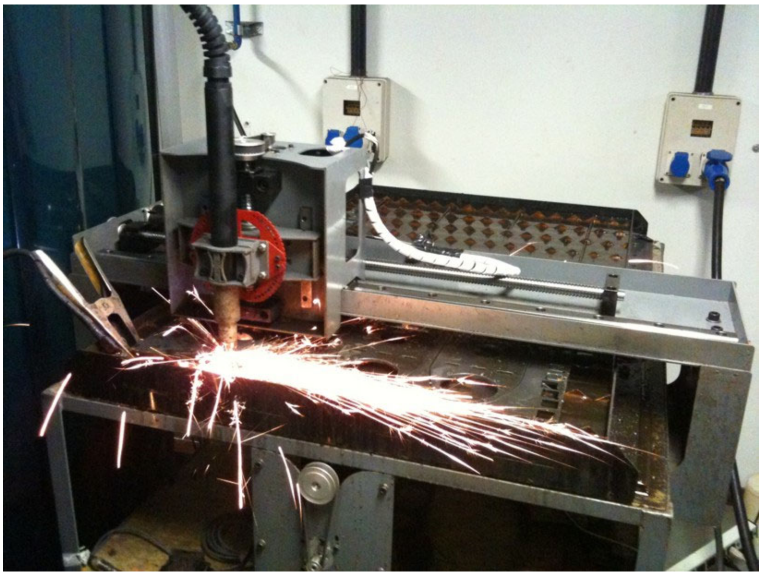
Figure 10 – Plasma cutting.

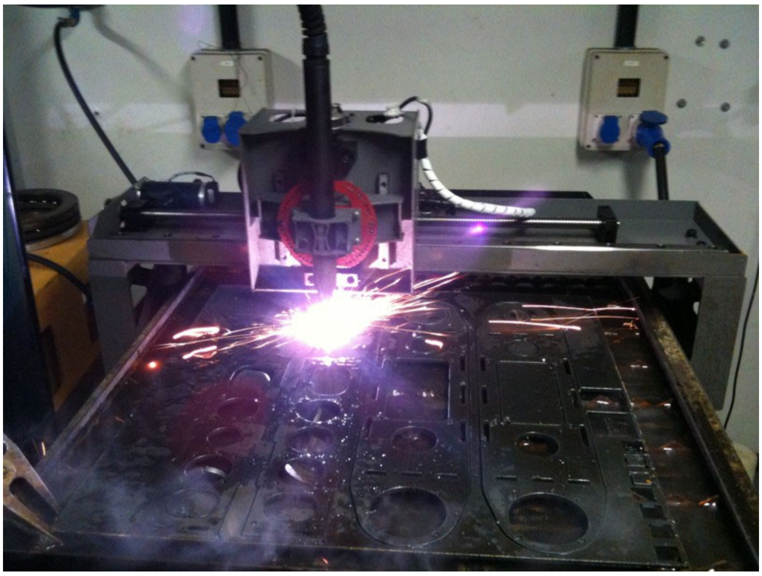
Figure 11 – Plasma cutting.

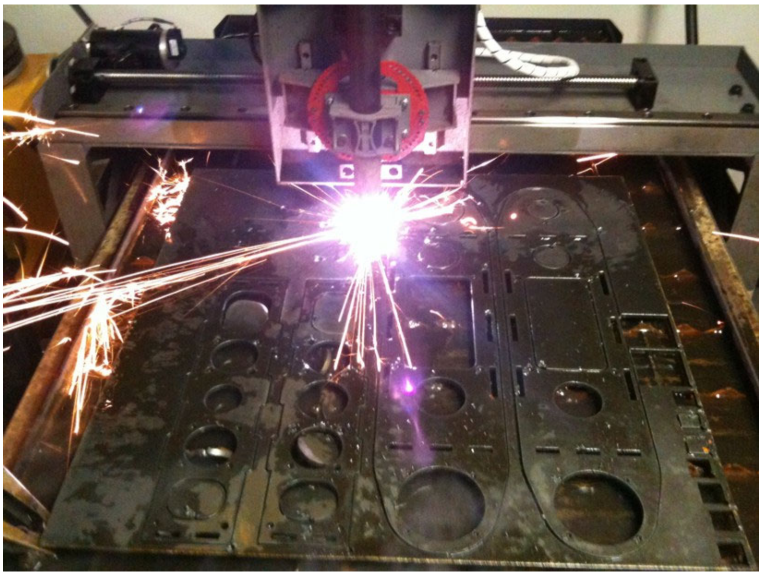
Figure 12 – Plasma cutting.

Figure 13 – Cut parts.

Figure 14 – Cut parts.

5. CONCLUSIONS

In this project it was concluded the possibility of the production of a CNC Plasma cutting machine, with low cost and industrial level in the environment of the LRSS, being able to attend projects in other areas of the Mechanical Engineering Department of UFMG, and produce its own structural pieces for potential new projects.

The results obtained with the production of this table have proved to be very satisfactory and there is a future interest to use this project to produce other tables to other laboratories within the UFMG or companies active in the market.

6. REFERENCES

Cordeiro, J.F., Kienitz, K.M., Ramalho Filho, F.A., Lima II, E.J., Bracarense, A.Q., 2009. Design tools for developing low cost CNC machines, “Proceedings of COBEM 2009”.

Groover, M. P., “Handbook of Design, Manufacturing and Automation”, Edited by Richard C. Dorf e Andrew Kusiak, John Wiley & Sons, Inc., 1994.

Lima II, E.J., 2007. “Projeto de sistemas seqüenciais de automação utilizando CLPS”, Universidade Federal de Minas Gerais, 2007.

Rosário, J.M., 2005. “Princípios de Mecatrônica”, Prentice-Hall, 2005.

Ramalho Filho, F. A., 2003. “Desenvolvimento de Interface Operacional CNC”, Trabalho de Graduação, Curso de Engenharia Mecânica, Universidade Federal de Minas Gerais, 2003.

7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.