DEVELOPMENT OF A NUMERICAL CONTROL DIDACTIC MILL FOR MANUFACTURING PROTOTYPES IN SCALE

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Abstract. *The development and improvement of new products are related to creation of prototypes in scale. With these prototypes are possible, for example, to evaluate design, mechanical properties, aerodynamics, manufacture, performance and functionality. The construction of these prototypes requires mechanical equipment controlled for numerical command. This paper presents the development of a numerical control didactic mill with six axles. The three linear axles (X, Y, Z) are controlled for numerical command, one rotating axle of the end mill (W) and two axles of turn of the support of the end mill in perpendicular plans between itself (B, C) with manual positioning, however with possibility to be also controlled for numerical command. The configuration was router that it provided a bigger area of work. The close loop axis motion control kit was used for controlled the step motors. The system uses a single standard parallel port of the PC computer, with the included software. For at development an equipment of low cost, used trapezoidal thread screws, linear sliding bearings and cylindrical gears trains with the step motors. The structure was constructed with welded profiles makes possible a sufficiently rigid system.*

Keywords*: didactic mill, numerical control, prototype*

1. INTRODUCTION

The development of new products is connected on to the creation and test of prototypes, considering it is the use since the conceptual application until the functional evaluation. These prototypes are used in various areas, such as engineering, architecture, medicine, arts, archaeology, etc. In Engineering, they are applied for evaluation of design, mechanical properties, aerodynamics, manufacture, performance and functionality. The physical prototypes can be manufactured in natural, reduced or expanded scale available for construction and the necessities of the demanded evaluation. In some cases, the elements have that to be made in parts for the fulfillment of the chosen scale. The prototypes are constructed with various material, such as paper, isopor®, wood, resins, waxes, polymers, etc. The prototypes are used in the development of tools applied in preliminary series of parts manufactured for metal stamping and forging, injection and casting. In reverse engineering, the physical prototypes are used for creation and recovery of virtual prototype aiming at alterations and development of new projects with the construction of new physical prototypes (Santos, 2002).

This paper indicates the development of the numerical control didactic mill with six axles. The three linear axles (X, Y, Z) are controlled for numerical command, one rotating axle of the end mill (W) and two axles of turn of the support of the end mill in perpendicular plans between itself (B, C) with manual positioning, however with possibility to be also controlled for numerical command (Wang *et al*, 2006)

2. DEVELOPMENT OF A NUMERICAL CONTROL DIDACTIC MILL

Initially the type of the equipment to be developed was defined through the evaluation of the configuration of movement of the main types of machine tools: mechanical lathes, milling machines, radial drilling machines, among others and types of possible operations of machining with this equipment. The developed equipment was of the type "Router" where the main table is fixed and the support of the end mill cut can to move in the axles (X, Y, Z) and turn manually around axles B and C, conferring bigger possibility in the constructed of complex surfaces (Yang *et al*, 2006).

As the objective one, it was the development of numerical controlled mechanical equipment for production of prototype in scale, mainly didactic applications in laboratories, it was opted to equipment whose area of work made possible the construction of medium size, it could be of easy transport and it is able to be dislocated for other places for demonstration. Thus, the dimensions of the worktable are defined 600 x 1200 millimeters. After a research and analysis of the equipment dimensions of same transport of worktable, it concluded that the compatible height between the end mill and the base of the worktable would be of the 300 millimeters.

The axis motion control kit uses three step motors with encoders, logical controller in closed loop and software CNC of the MaxNC® (Kwon *et al*, 2006). The system uses a single standard parallel port of the PC computer, with the included software. For at development an equipment of low cost, used trapezoidal thread screws, linear sliding bearings and cylindrical gears trains with the step motors. The structure was constructed with welded profiles makes possible a sufficiently rigid system (Gordon and Hillery, 2005).

For the end mill, the variable speed rotary tool Dremel® was used (capacity 130W, rotation of 5000 up to 35000 rpm), with electric independent feeding and fixed in the mobile headstock of the numerical control didactic mill. The Figure 1 illustrates the numerical control didactic mill for construction of prototype in scale.

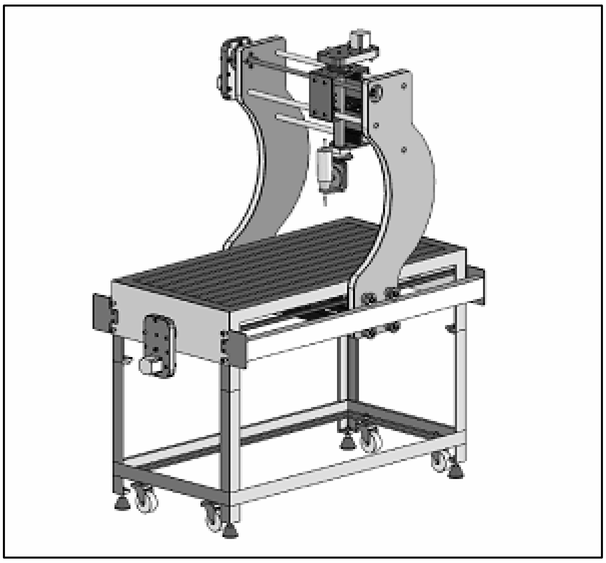

Figure 1. Numerical control didactic mill for construction of prototype in scale

2.1. Development of the worktable

The worktable was constructed with the dimensions 600 x 1200 millimeters, and was adopted a utile course 450 x 950 millimeters, with height compatible height between the end mill and the base of the table would be of 300 millimeters.

The support for movement of the numerical control didactic mill was developed in such a way, thinking about its transport and movement, how much about the option of being used as base for the worktable. Being fixed by means of screw, this support can be removed and the didactic mill can be placed of the workbench. The same welded corn was placed 04 casters where the height could be regulated. Thus, when it desires to put into motion the didactic mill it regulates the casters these if to support in the soil. It was used the "vibra stop®" for eliminated the vibration. The Figure 2 presents the configuration of the worktable and the support for movement of numerical control didactic mill.

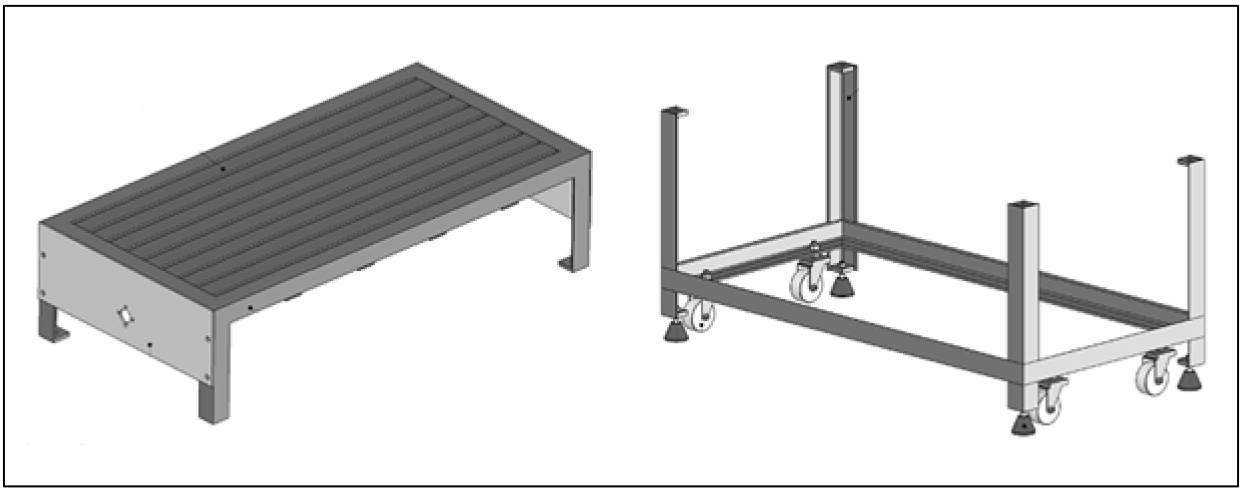

Figure 2. The worktable and the support for movement of numerical control didactic mill

2.2. Development of the lateral structures and inferior structure support of the axle X

The lateral structure is responsible for the sustentation of the three guides of circular profile of the mobile headstock, the bearing of screw the axle Y and set the system of transmission of the axle X.

The lateral structure was composed for two steel sheets with thickness of 5 millimeters and entered this wood sheet (MDF) with thickness of 25 millimeters for to increase the rigidity. It is not increasing the weight very and thus creating a structure of lower cost. The lateral structure of each side of the worktable was considered. The geometry of the lateral structure was developed of such form that the center of the end mill coincided with the center of the joint box-nut of axle X. Moreover, was developed a profile that prevented the interference of the variable speed rotary tool with the lateral structures in situations of turn of axle C.

The two lateral structures are put into motion by means of the system of transmission, what it becomes necessary a structure that fixes them jointly. The nuts of axle X is located in the center enters the two lateral structures of the equipment. The four welded corn shelf were adopted to establish connection and to fix the two laterals of the machine and, between them, it develop two supports in profile type "U", that it possess regulation by means of oblong punctures for the setting of the nut of axle X. This configuration made possible the rigidity sufficiently satisfactory; moreover, it is of easy construction and assembly. The Figure 3 represents the assembly of the inferior structure with the lateral structures of the didactic mill.

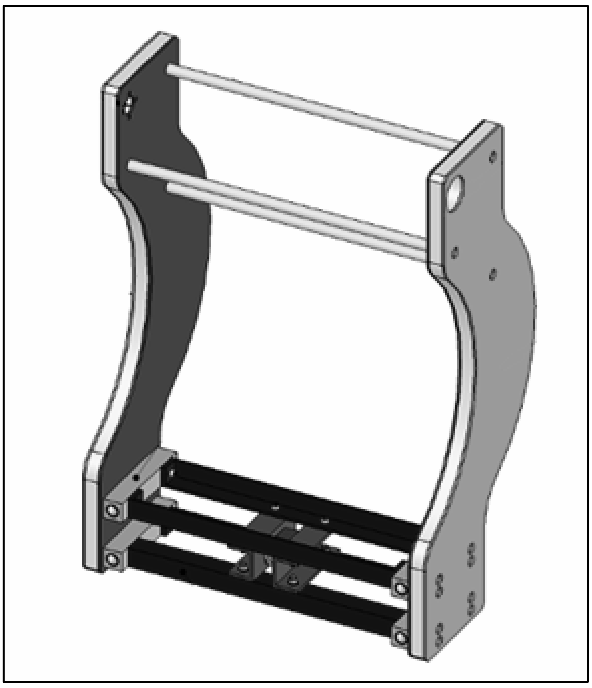

Figure 3. Assembly of the inferior structure with the lateral structures of the didactic mill

2.3. Development of the translation guides system

The translations guides with circular geometry had adopted, because had the easiness of construction and low cost. The linear sliding bearing in bronze was used. However to improve the rigidity of the lateral structures of the equipment, a structural profile the type "U" in the system of translation of axle X was used. The ball bearings with eccentric axles that were fixed in the lateral structures of the milling machine would be guided by this profile. Two steel sheets were fixed in the faces of the profile type "U" to make possible the assembly in the didactic mill. The Figure 4 presents the assembly of the set ball bearing with eccentric axles and profile type "U" in the lateral structure of the didactic mill.

2.4. Development of the transmission system

The movement of the mobile headstock and the lateral structures used a transmission system with the trapezoidal thread screws with air gap reduced part. The transmission system was bi-supported for axles X and Y, being used the ball bearing. The cylindrical gear train was used in the transmission system of the axles X, Y and Z to increase the capacity of transmission of the lateral structures and the mobile headstock. Amongst the cylindrical gear trains were adopted straight lines for the biggest easiness of construction and minor cost. The relation of reduction was of the 1:25.

The Figure 5 presents the assembly of the transmission system indicating the trapezoidal thread screws and cylindrical gear train.

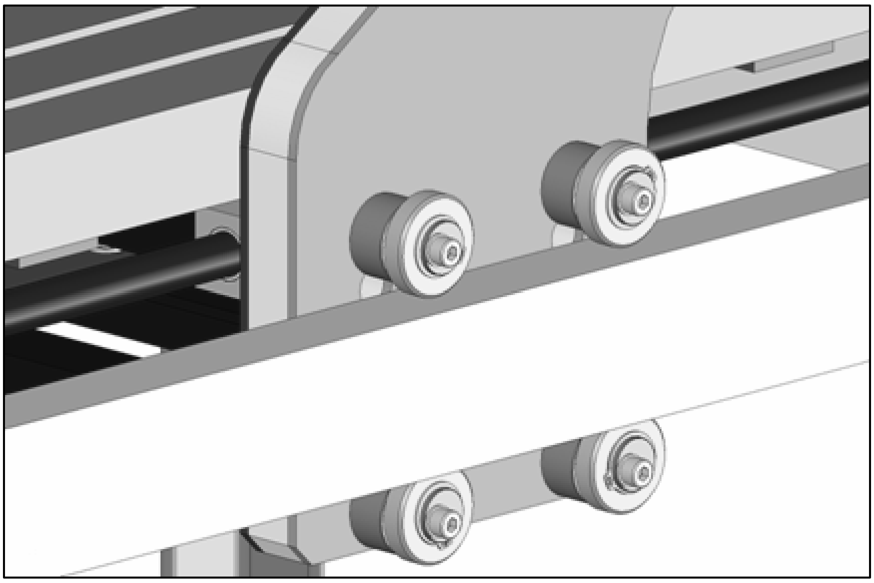

Figure 4. Assembly of the set ball bearing with eccentric axles and profile type "U" in the lateral structure

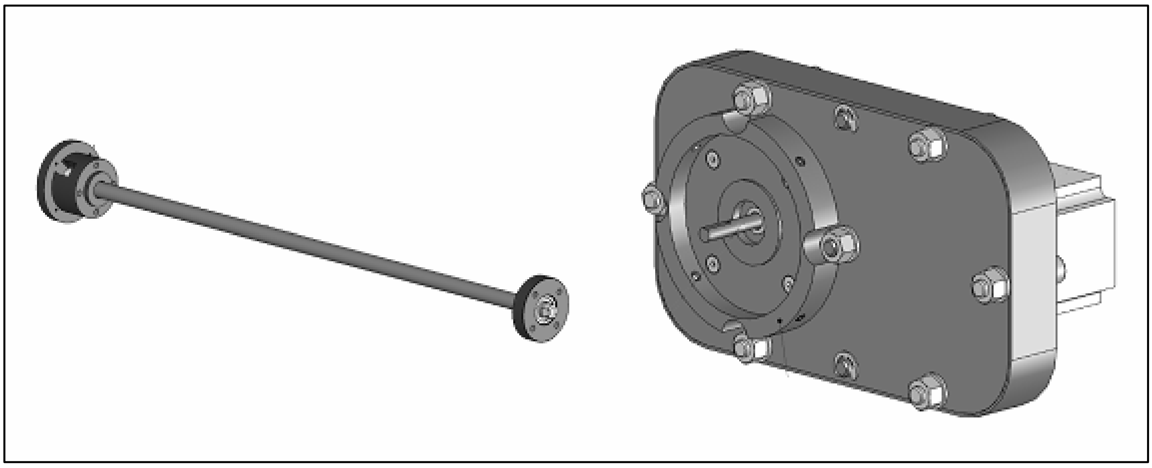

Figure 5. Assembly of the transmission system indicating the trapezoidal thread screws and cylindrical gear train

To guarantee greater precision in the movements, it developed the air gap reduced assembly. A box with two bronze nuts was developed with a spring between them with the objective to keep always in contact the nuts with the screws and thus to eliminate the air gap, guaranteeing a bigger precision in the displacement of the mobile parts of the didactic mill. The Figure 6 presents the air gap reduced assembly.

2.5. Development of the mobile headstock

The mobile headstock is a structure made in steel sheet of the thickness 5 millimeters and is responsible for the translation in axle Y and rotation of the support of the variable speed rotary tool around axle B. For the rotation of the support a composed mechanism for a tube with flange in an extremity was developed, where in its interior move the axle Z, guided for two keys, set in motion for the of axle Z. The mechanism has supported of the variable speed rotary tool is fixed in this axle of movement Z. If it turns the tube, by means of its flange, the axle of movement Z also turns due to the keys. The flange of the tube was fixed in the sheet of the mobile headstock. This sheet of mobile headstock possess circular rip that, allows the tube to turn on axle B. If it turns the axle Z, it turns the support of the variable speed rotary tool. The Figure 7 indicates the mechanism of rotation around axle B.

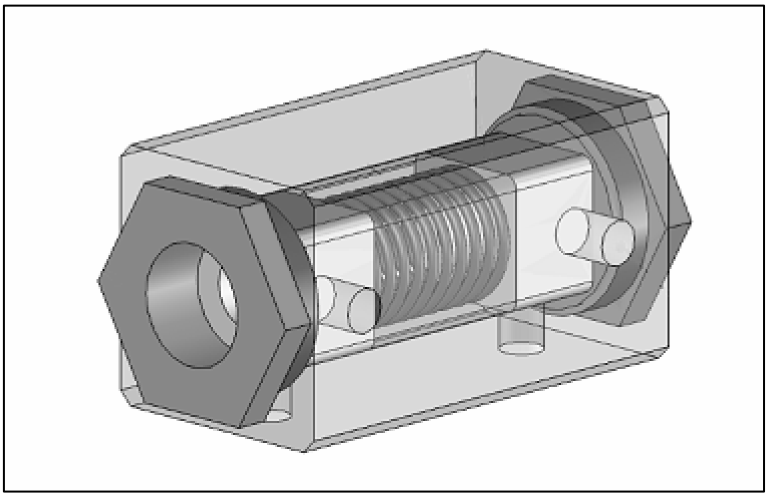

Figure 6. The air gap reduced assembly

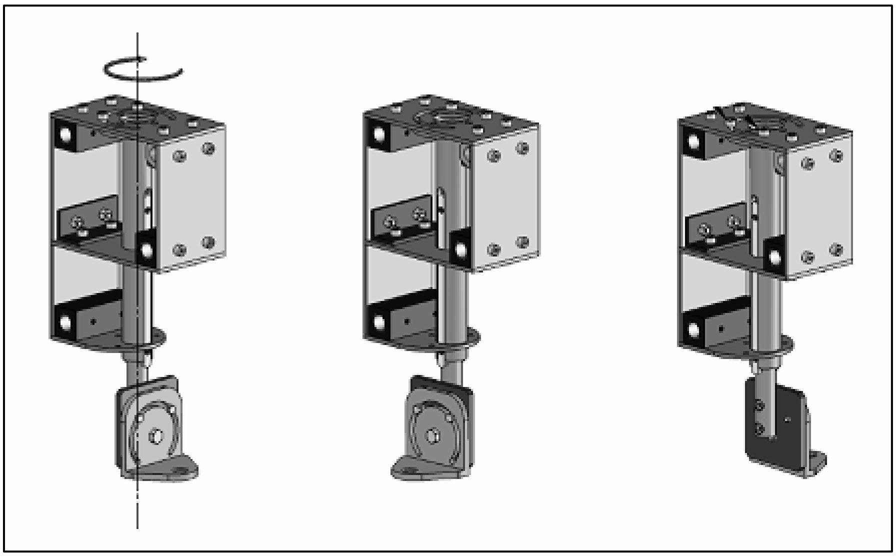

Figure 7. The mechanism of rotation around axle B

To improve the rigidity of the axle of movement Z, sliding linear bearing made in nylon was mounted in the inferior sheet of the structure of the mobile headstock. Thus, if the axle Z is moved, beyond to be guided by the tube, it also is guided by this sliding linear bearing. The Figure 8 illustrates the assembly of the sliding linear bearing and the cylindrical gear train in the mobile headstock.

As the use of the variable speed rotary tool, a support for setting of the tool was developed and making possible the rotation in axle C. A steel sheet in "L" was used and for the rotation in axle C, a fixed steel sheet was used with central axle, where the support in "L" can turn manually of 90 degrees in clockwise or the counter-clockwise one. The development of the support of the variable speed rotary tool and the mechanism of turn in axle C is indicated in the Fig. 9.

3. Results

The Figure 10 indicates the final development of the numerical control didactic mill for construction of prototype in scale. The first tests with the equipment had presented satisfactory results. Due the low power of the variable speed rotary tool were opted in developing the tests with isopor® using abrasive end mill. The Figure 11 indicates the sequence of the process milling of the prototype and Fig. 12 shows to the result of this physical prototype.

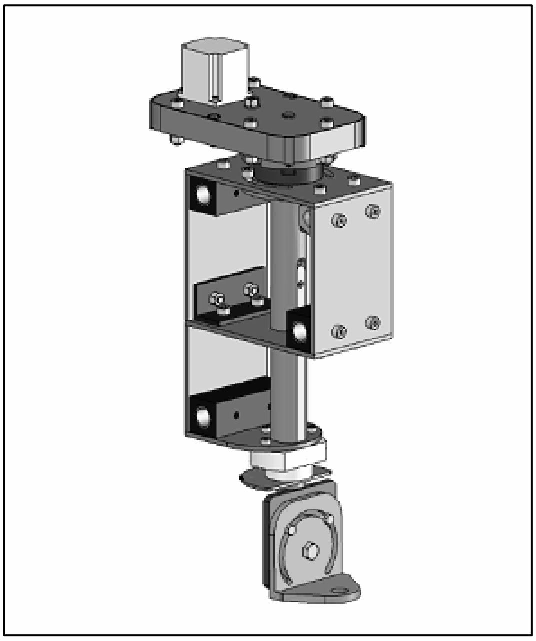

Figure 8. Assembly of the sliding linear bearing and the cylindrical gear train in the mobile headstock

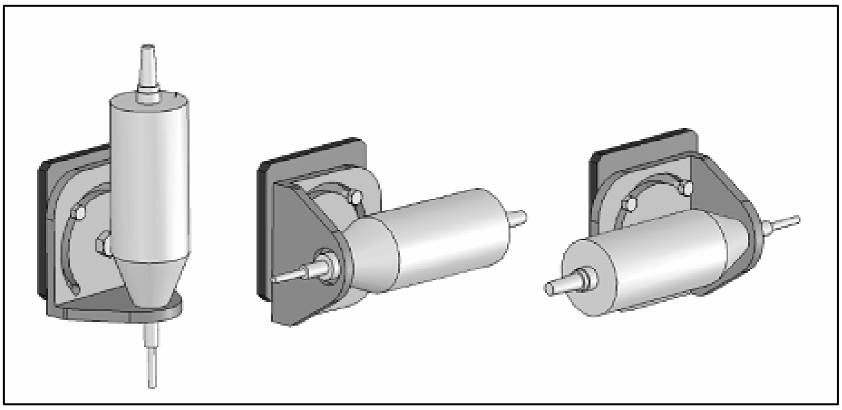

Figure 9. Development of the support of the variable speed rotary tool and the mechanism of turn in axle C

Figure 10. Final development of the numerical control didactic mill

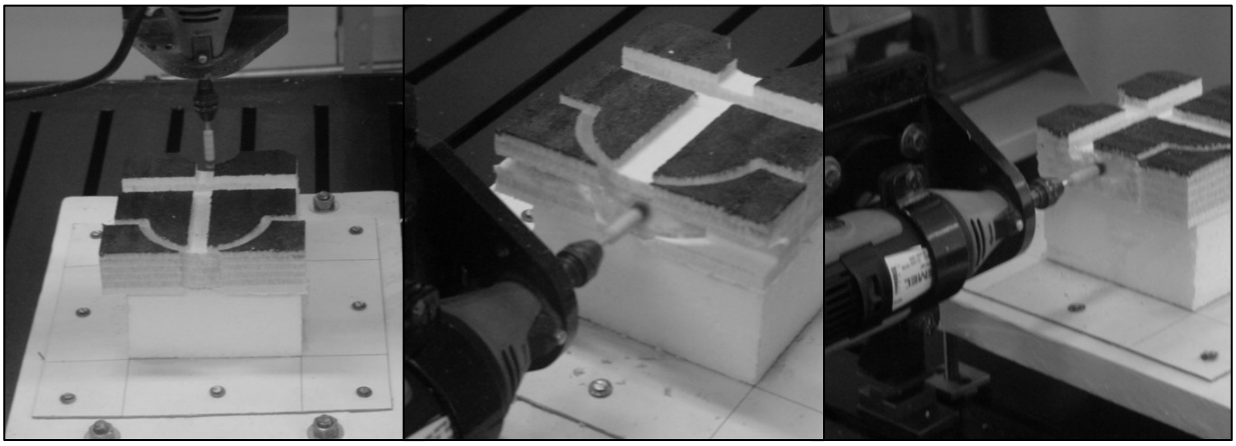

Figure 11. Sequence of the process milling of the prototype

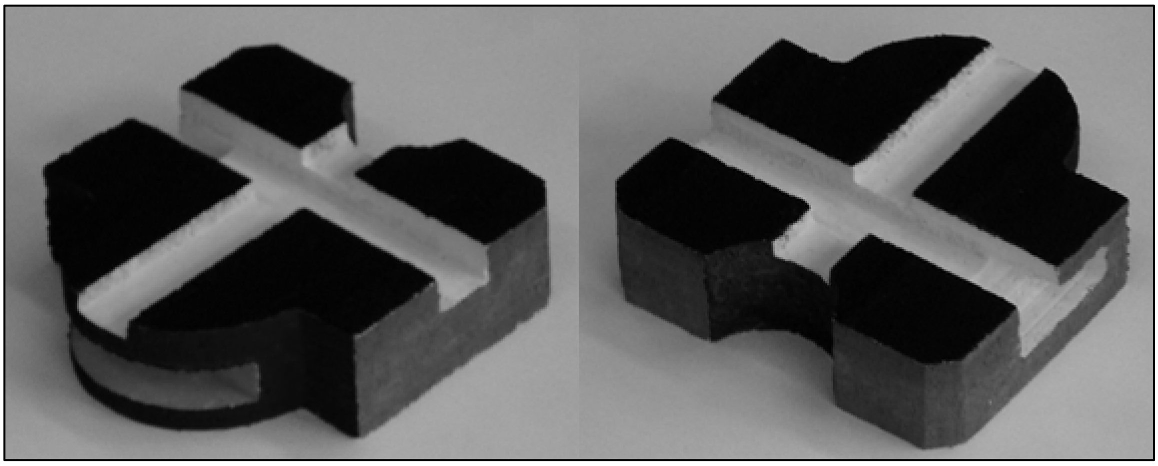

Figure 12. Final result of the physical prototype

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