16th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2012, Dubai, UAE, 10-12 September 2012

DESIGN OF PORTABLE CARVING MACHINE

Damir Ciglar, Toma Udiljak, Miho Klaić
University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
Ivana Lučića 5, 10000 Zagreb, Croatia

Tihomir Mulc
SAS strojogradnja
Ulica domovinskog rata 1, 23000 Zadar, Croatia

ABSTRACT
Although the manual mode of stone carving is still quite frequent, modern world's need faster and more precise production of engraving and stone surfaces. Today, the stone market has become more selective and demand for special product and service is greater. Big problem in stone branches is large surface area, large dimension and weight of the stone workpiece that can't be produced by typical machine for stone engraving. In these situations portable stone carving machine can solve that problems, because the machine has less mass and easier to put the machine on the workpiece than the workpiece on the machine. It will also greatly reduce work time and increase productivity. This paper gives the design of portable carving machine which can be used for machining the engravings on large and non movable stone surfaces.
Keywords: Portable machine, stone engraving, modular design

1. INTRODUCTION
Stone-masonry is an occupation that in all the historical and stylistic periods had the same goal: with the power of spirit, will and skill, breathe life into amorphous stone. Starting from the self-taught stonecutter and mason gradually were gained conditions for versatile and organized learning of this noble profession. In various regions and cultures, depending on the characteristics [1], the stone is processed in various ways that have outgrown into traditional methods of processing. Stone carving may be manual and machine, and the increasingly frequent use is in restoring ethno villages, ethno houses or in building our own homes [2,3]. Manual carving requires full concentration of stonemason who is mostly exposed to adverse conditions, because he is working in standing or the bow position, and sometimes crouching or kneeling, Figure 1.

Figure 1. Forced positions of stonemasons

Machining of stone developed in the late 60's with the arrival of the machine for engraving stone, popularly known as "Pantograph". Italian company INCIMAR was first company that has placed such machines on the market [4]. First pantographs were manually controlled by a rigid memory, or template, according to which the needle slip and thus copied the shape on the stone surface, Figure 1a. A major drawback of this process is need for having the large databases of rigid templates. Also, due to the slip of copied needle each treatment reduces the lifetime of templates because of occurrence of increased wear. It is important to note that each new desired shape should be followed by other procedures to create desired templates for that shape and after that approach to machining of stone.

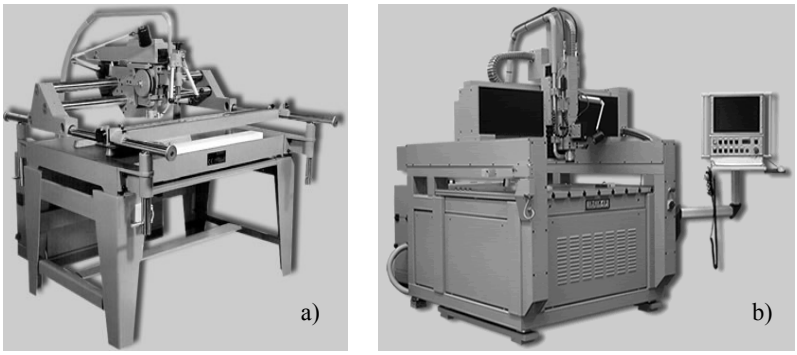

Figure 2. a) Hand engraving machine for stone INCISOGRAFO MC 1000,
b) Numerically controlled machine for engraving stone INCISOGRAFO MH

Commercial development of computers and all their frequent use in the work and supervision of machinery, leads to the development of NC machines for engraving in stone, Figure 2b. It was a great improvement in relation to the current technology of making stone reliefs. The development of CAD / CAM system greatly expanded the horizons for new forms and the appearance of desired new shapes. These machines can also consist of X, Y and Z axes that are driven by step motors, and later servo motors, which have formalized precise steps. This has largely save employers money and simplifies the database, because now complete archive of various forms is located in the computer. The process of machining means simply selection of desired shape and adjusting to the default size and then implementation of engraving on stone.
In the machining the stonemasons face with the problem of manipulation of the workpieces often large size and weight, and also hard to reach. It can be a large variety of monuments, various stone facades of buildings, lined with stone floors, the walls, the existing signs which had to be restated or supplemented. Of course, manual processing is the solution but it is too slow, inaccurate and very demanding for the stonemasons. Machining is another solution but it is possible to manufacture a workpiece only at the machine that has large working dimensions. All previous versions of existing NC machines for stone carvings have a common disadvantage that they are very expensive and complex, and it is impossible to work with them on outdoor. Depending on the size the price of the machine may be over 15000 €.

2. CONCEPTUAL DESIGN AND SELECTION OF MODULES

Portable carving machine should be easy to handle, must have sufficient stiffness, the lower weight and must be resistant to corrosion. Having this in mind, as basic structural elements are taken the finished aluminum profiles thus creating a compact design with satisfactory precision. The whole machine is based on modular concept, because „These days modular principle is a very popular metod in design of the tools machine“[5]. It consists of several modules shown in Figure 3., and the modules are: Frame, Modul X axis, Modul Z axis, Main spindle and Vacuum module.
The base module of the machine is frame, which is composed of two parallel linear rails located on the left and right sides of the frame, thus creating a Y-axis. Rails are connecting with aluminum profile 80x20, thus creating a rectangular frame. The frame is important because it defines the working surface of machine, but also defines the functionality of the machine in terms of portability. The

machine must have sufficiently large dimensions of the working surface, so it does not have to constantly move on the workpiece surface, but should not be too big for the setting up and machining capabilities.

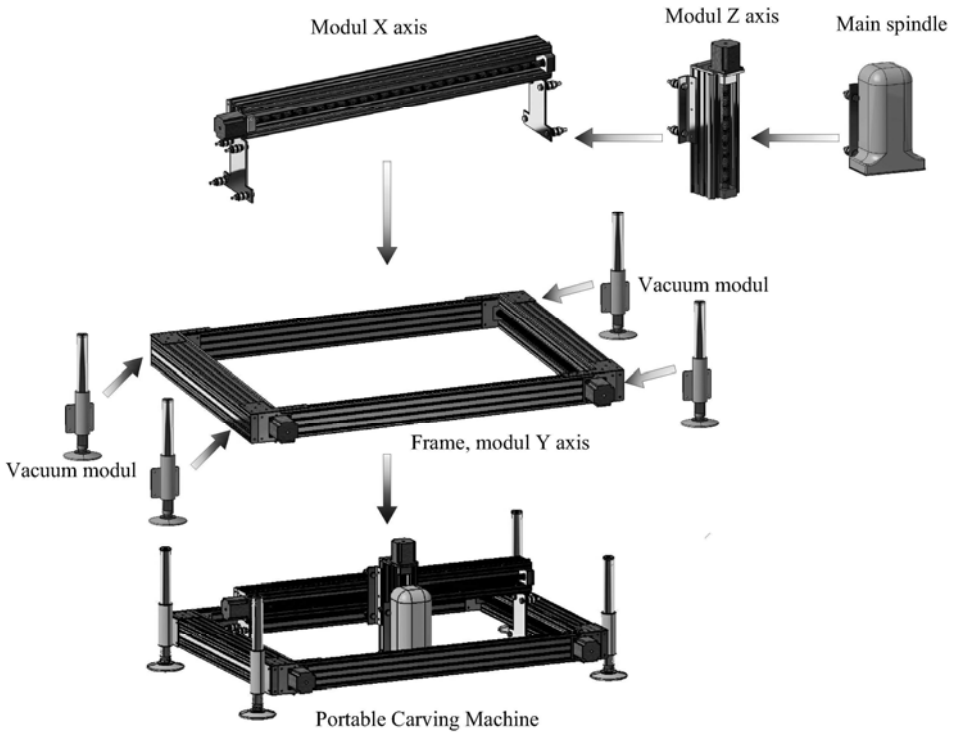

Figure 3. Main modules of portable carving machine

To the top of the frame, to the left and right rail, is placed finished module for the X axis. On this axis is then set the module for the Z axis, and it contains the Main spindle module Bosch GGS27 (600W, rotation up to 19000 1/min). This conceptual design and selected modules [6] give to the Main spindle module the option of straight-line motion in three mutually perpendicular X, Y, and Z axes.
On the frame corners are four Vacuum modules, Figure 4, for adhesion the machine on workpiece surface. It consists of the guide housing that have a plate with four holes by which it is fixed to the frame.

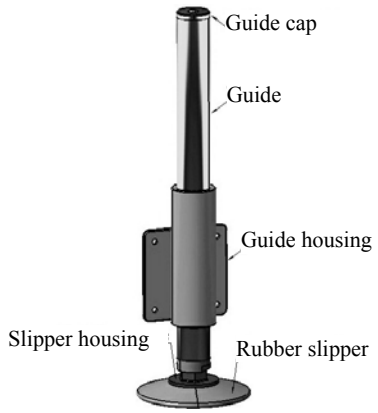

Figure 4. Vacuum module for adhesion the machine on workpiece surface

Throughout the guide housing goes the cylindrical guide, and to it underside is attached the carrying element – rubber slipper [7]. Vacuum modules are independent and each can be moved and fixed on desired position along the rectangular frame module. This design of vacuum module ensures the positioning of portable machine in any position and also the securely adhesion to the stone surface with no possibility of movement during machining. It is important to note that the other solutions were also investigated but because of irregularities in processing stone surface and the surface structure (cracks and pores), the taken solution gave the best results.

3. TESTING OF PORTABLE CARVING MACHINE

After the conceptual design and selection of component modules, the prototype of a portable carving machine is developed. Testing was performed on horizontal and vertical position of portable carving machine, Figure 5, and the processing is carried out on the stone and granite workpiece surfaces. Adhesion of the machine with vacuum modules and processing itself was excellent in both positions on the workpiece surfaces that were previously processed by sawing, grinding or polishing.

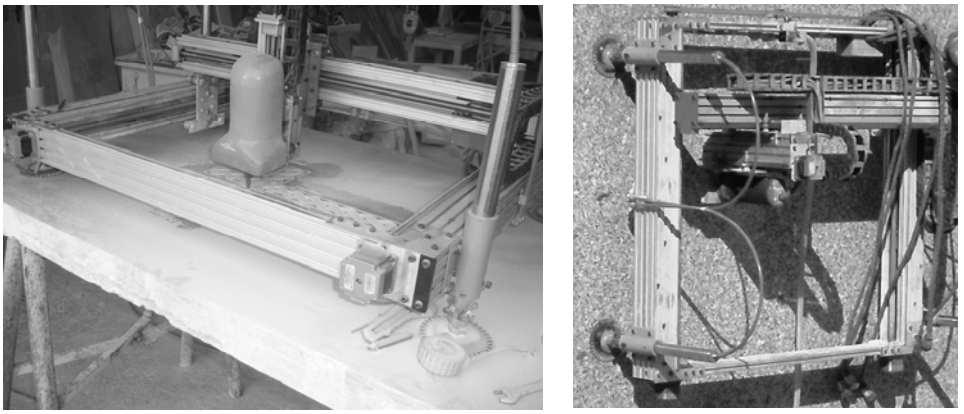

Figure 5. Horizontal and vertical position of portable carving machine

4. CONCLUSION

This paper gives the modular design of portable carving machine which can be used for machining the engravings on large, heavy and non movable stone surfaces. The machine is composed of finished purchasing modules that together form a triaxial portable carving machine with working area X=600mm, Y=500mm and Z=120 mm. Vacuum modules have proven very good, and provide excellent adhesion of machine on sawed, grinded or polished workpiece surfaces in the horizontal and vertical position. The machine is relatively simple and inexpensive solution with high reliability and satisfactory results in the processing accuracy. The price of these prototype of portable carving machine is about 5000 €, and that is no much because the time of making problematic engravings and reliefs had significantly reduced. From human point of view, the other advantage is that portable carving machine preserved the stonemasons of adverse conditions in manual processing.

5. REFERENCES

[1] Tomašić, I., Kršinić, A.:Some important facts for estimation of natural stone deposits during the exploration, Klesarstvo i graditeljstvo, Vol. XXI No.3-4, prosinac 2010. p. 5-15.

[2] Buble, S., Gamulin, A. : Spatial planning in rural cores, Klesarstvo i graditeljstvo, Vol. XXII No.1-2, svibanj 2011. p. 91-103.

[3] Elpel, T.J.: Living Homes, Publisher's Cataloging in Publication Data, ISBN 978-1-892784-32-2, sixth edition, may 2010.

[4] http://www.incimar.com/

[5] Yoshimi, I.: Modular Design for Machine Tools, Mc Graw-Hill, New York, 2008.

[6] http://www.isel-germany.de/products/product.php?lang=en&ID=p33

[7] http://www.festo.com/pnf/hr_hr/products/catalog?