AUTOMATED HANDLING DEVICE FOR CILINDRICAL WORKPIECES USED FOR HIGH FREQUENCY INDUCTIONHARDENING EQUIPMENT

Dănuţ Pavel TOCUŢ[1] Adrian BURCA[2]Călin TRIPE VIDICAN[3]
[1]University of Oradea, Faculty of Management and Technological Engineering, MechatronicDepartment, tocutpd@yahoo.com
[2]University of Oradea, Faculty of Electrotechnics and Informatics, aburca@uoradea.ro
[3]University of Oradea, Faculty of Management and Technological Engineering, MechatronicDepartment, tripetrophy@yahoo.com

ABSTRACT:Heating with high frequency induction has a large variety of applications like melting, heating and hardening metals. Heating by high frequency induction can be made in the complex automated manufacturing systems that can increase productivity and quality of the workpieces. Surface hardening of the workpiece is one of the most important application of induction heating. This project has the main goal of the authors to present an automated surface hardening system used for a cylindrical workpiece using the SolidWorks computer aided design software.
KEYWORDS: Cylindrical workpieces, Induction heating, metal heating and hardening, surface hardening, automated device for handling the pieces to the inductor

1. INTRODUCTION

Surface hardening of work pieces is one of the main application of induction heating, which uses the main benefit of the method to concentrate the heat on the surface of the work piece, surface that it is in relation with the frequency of the current. Using higher frequencies ensures high power density and fast concentration of the heat to a defined area. In the end, this area will have a modified metallurgical structure, without affecting the properties of the material. We are pursuing for a higher wear resistance of the surface compared to the other properties of the work piece that will not change during the heating [1, 2].

Thereby, we can see that the work piece subjected for hardening, heats up to hardening temperature of 1100oC in 3-4 second, after that starting the cooling resulting the hardening. All the hardening process takes between 8-10 seconds.

In Figure1, it has presented the 3 dimensional and 2-dimensional drawing of the work piece, manufactured in mass production, work pieces that are in the end surface hardened using high frequency induction.

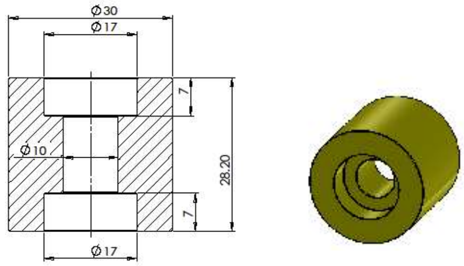


Figure 1 3D and 2D model of the cylindrical work piece subject of surface hardening

Work pieces are made out of C45 steel. Initially, they are made through lathing being manufactured in mass production, being follow by the heat treatment. The pieces are introduced into an automated device for continuous feed for the induction heater. Using the SolidWorks software, we designed the workpiece, presented in Figure 2, and used the programs application to found out the geometrical volume of the work pieces.

2. THEORETICAL ASPECTS REGARDING 3D DESIGN OF THE CONTINUOS FEED AUTOMATED DEVICE FOR HIGH FREQUENCY INDUCTION HARDENING

Using SolidWorks software, our main goal was to design, using the 3-dimensional model of the work piece a version of a continuous feed automated device that delivers the work pieces to a high frequency induction-hardening machine.

The goal of our design was finding out a constructive and functional optimization of the handling device. In Fig. 3a) and 3b) are presented 3 dimensional and 2 dimensional models of the continuous feed device assemble. Through the two images, we can distinguish the main components and working principle of the device. The cylindrical work pieces are feed alternatively in an automated layout by the help of a software. Because of the automated program the work pieces are positioned precisely near the inductor, follow by the quick cooling in the fluid reservoir.

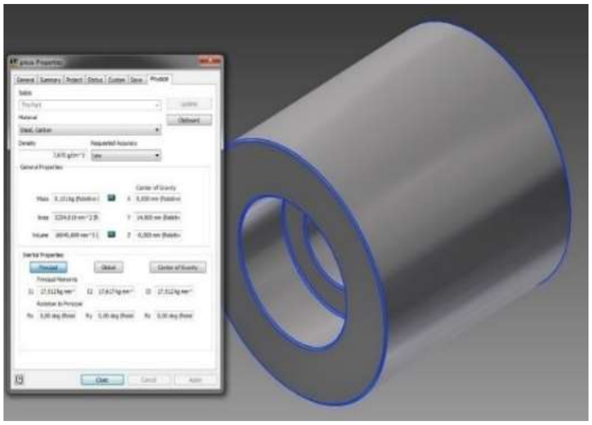


Figure 2 3D design of the workpiece using an application of the SolidWorks software

3D and 2D design of the automated feed devices bunker [3, 4].

Bunkers are components of automated handling devices which contain the workpieces in a disordered manner. The main characteristics of the bunker are given.

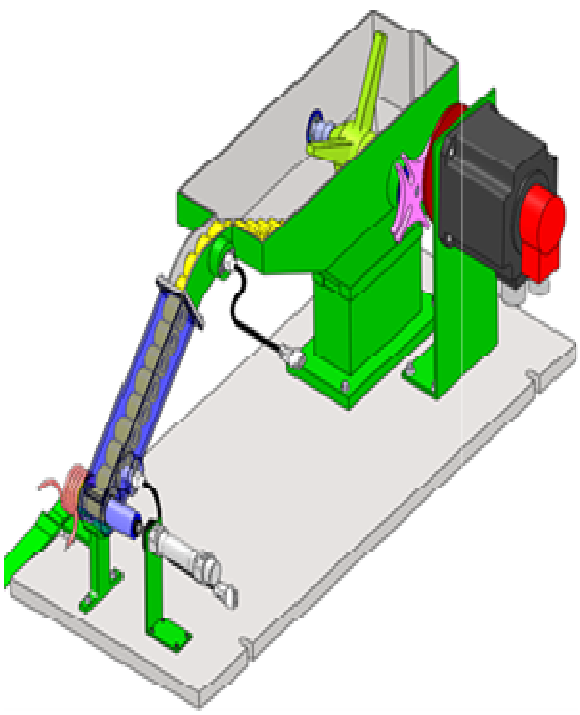


Figure 3a). 3D model of the automated feed device used for workpieces to be sent to the high frequency induction hardening machine

The SolidWorks [4, 5] computer aided design software used by us facilitates, with the help of an internal application, to determine the geometric form and the volume of the designed bunker. In Fig..4 we can see a screen shot of the 3D designed bunker and also the numerical values related to total volume of the bunkers tank.

The volume of the designed stationary bunker is 788791 mm^3, and the volume of one cylindrical workpiece that will be contained in 16640 mm^3. Comparing the values, it results that in the bunkers containment tank will fit up to approximate of 50 workpieces.

From the 3D model presented in Fig. 5, represented through an isometric view, we can see the geometric form of the bunker, the way the workpieces are positioned in a scattered position and also the way these are carried through an internal bent drain. The wrongly placed workpieces will be put out from the drain back to the bunkers tank with the use of a limiter.

The catch and draw system for the workpieces from the stationary gravitational bunker it's made of a stellar rotor with 4 blades which is fixed on a cylindrical spindle, cased with radial bearing and gyrates alternatively with the help of a gearmotor and a Maltese cross mechanism also known as a Geneva drive.

The speed of the gearmotor (which is actuated by a continuous current electric motor) can be modified depending of the systems requirements via an electronic speed variation, ensuring the adjustments for an optimal processing speed. The speed is directly correlated with the heating period, the feed frequency being the frequency of heating and ejection from the inductor.

3. MALTESE CROSS MECHANISM (GENEVA DRIVE) KINEMATIC ANALYSIS

The alternative rotation of the rotor with the 4 blades it's done with the help of a Maltese cross mechanism, also known as a Geneva drive. The 3D model of the Maltese cross is presented in Figure 6, and it's made of the drive element (1) a washer with the role of a crank, that has in its extremity a roll, which every time a rotation is done it goes inside the notch of the driven element (2) represented by the Maltese cross. For every complete rotation of the drive element, the driven element rotates with 90°

For this drive the complete rotation time ***(T)*** it is defined:

$$\boldsymbol{T = t_m + t_r = \frac{2\pi}{\omega_1}} \qquad (1)$$

In which:

t_m = moving period (when the main element drives the driven element)

t_r = stopping period of the Maltese cross

ω_1 = angular speed of the gearmotor

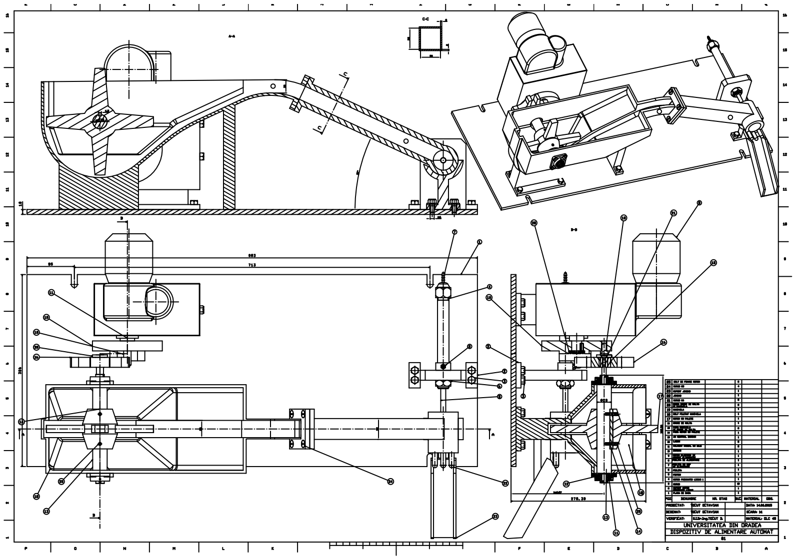
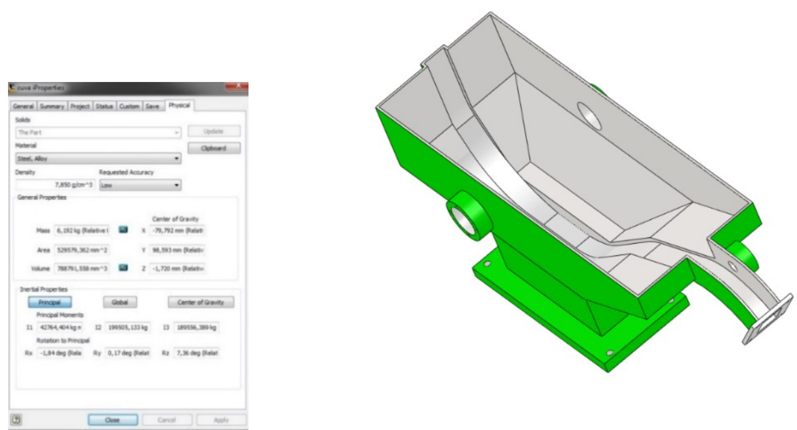


Figure 3 b) – 2D drawing of the automated feeding device



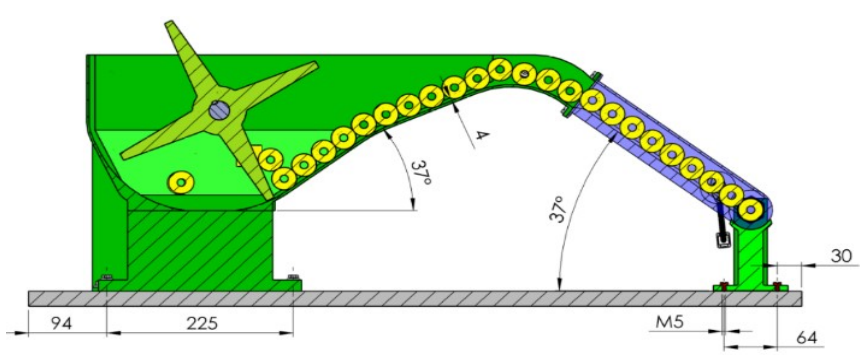
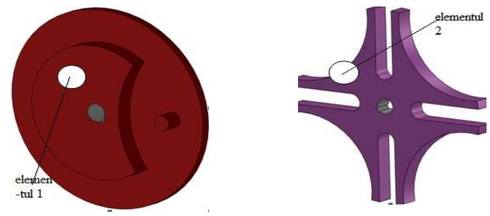


Figure 4 – Screen shot of the bunker and references to its properties via the SolidWorks application

Figure 5 – 3D design of the feed mechanism viewed in a longitudinal section

To establish the operating conditions of the mechanism, we will refer to Fig.6 a) and b), marking with z the number of notches of the Maltese cross and with $2\varphi_2$ the angle between two neighbor notches.



a) b)

Figure 6 a), b) – 3D design of the active elements of the Geneva drive

For a movement period, the value of the angle is:

$$2\varphi_2 = \frac{2\pi}{z} \qquad (2)$$

The angle of rotation of the drive element (1) in this period will be:

$$2\varphi_2 = 2\left(\frac{\pi}{z} - \varphi_2\right) = \pi\left(1 - \frac{2}{z}\right) \qquad (3)$$

The corresponding angle for the stopping period of the driven element will be:

$$2\pi - 2\varphi_1 = 2\pi - \pi\left(1 - \frac{2}{z}\right) = \pi\left(1 + \frac{2}{z}\right) \qquad (4)$$

The moving period t_m and the stopping period of the cross is:

$$t_m = \frac{2\varphi_1}{\omega_1} = \frac{\pi}{\omega_1}\left(1 - \frac{2}{z}\right) = \frac{20}{n_1}\left(1 - \frac{2}{z}\right) \qquad (5)$$

$$t_r = \frac{2\pi - 2\varphi_1}{\omega_1} = \frac{\pi}{\omega_1}\left(1 + \frac{2}{z}\right) = \frac{30}{n_1}\left(1 + \frac{2}{z}\right) \qquad (6)$$

Where:

n_1 – speed of the motor gears spindle [rot/min]

In addition, we define the movement coefficient *km* and pause coefficient *kr*, the ratio between the moving period and stopping period, and the duration of a complete rotation, as follows:

$$k_m = \frac{t_m}{T} = \frac{1}{2} - \frac{1}{z} \qquad (7)$$

$$k_r = \frac{t_r}{T} = \frac{1}{2} + \frac{1}{z} \qquad (8)$$

The ratio $k = \frac{k_m}{k_r} = \frac{z-2}{z+2}$ (9)

It knows as the processing time coefficient, being mandatory for automation drives with recurrent turn off and start.

4. DEPICTION OF THE AUTOMATED FEED MECHANISMS OPERATION

- In the integrated automated hardening system, this device ensures the feed with work pieces to an inductor, which is component of a high frequency induction-hardening machine ensuring the automation of surface hardening process.

Cylindrical work pieces are handling automatic by the device, draw out from the gravitation drain by a side pusher actuated pneumatically and put inside the inductor, after the heating to an adjusted temperature, the work pieces are cleared through a drain into a cooling bath resulting the hardening.

This automated system of hardening operates due to a software program, which has the following sequences: extraction from the storage bunker of a work piece, transfer of the work piece through a linear motion towards the inductor, where the work piece is maintained and heated, the release of the work piece from the inductor into the bath with coolant. Depending of the type of hardening that is required, on the surface or in depth, with some calculations, we can know how much to hold the work piece in the inductor. Thereby, the work piece positioned previously into the inductor is removing by a new work piece, falling into the cooling bath, filled with water or oil, where the hardening process itself happens.

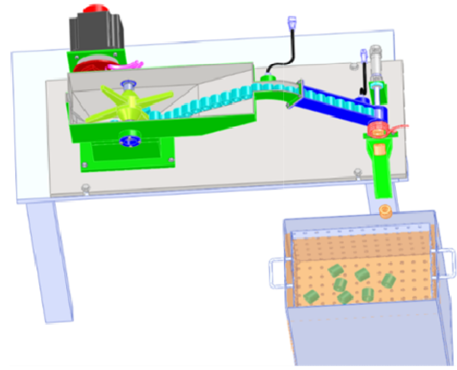


Figure 7 – 3D design of the integrated hardening system with continuous feed

The hardening process is supervised by a trained human operator, which follows it from a defined distance, and periodically feeds up the bunkers tank with workpieces.

In Fig..8, with the help of an isometric 3D view, we can view the approach of assembling the double action pneumatic cylinder, representing the catch and draw system for the work pieces from the storage. On the threaded rod of the cylinder, it's positioned the side push head.

The slow movement of the pneumatic cylinder rod, push head catches individually only one work piece, which will be moved into the inductor of the high frequency induction unit.

In Fig..9 a) with the help of an isometric view of the 3D model, we can see the pneumatic system actuation for feeding the work pieces into the inductor. Thereby, in Fig..9 b) it's presented the pneumatic diagram that corresponds for the stroke end phase of the catch and draw automated system.

The speed of the piston can be adjusted with the help of a one-way flow control valve mounted on the pneumatic circuit, resulting a better and more precise placement of the work piece into the inductor. The work piece is place on three silicon carbide rails, which are positioned symmetrically on a radius ensuring a precise orientation of the work pieceand facilitating an optimal heat transfer from the high frequency inductor to the work piece.

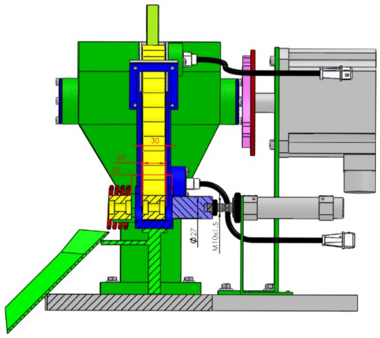


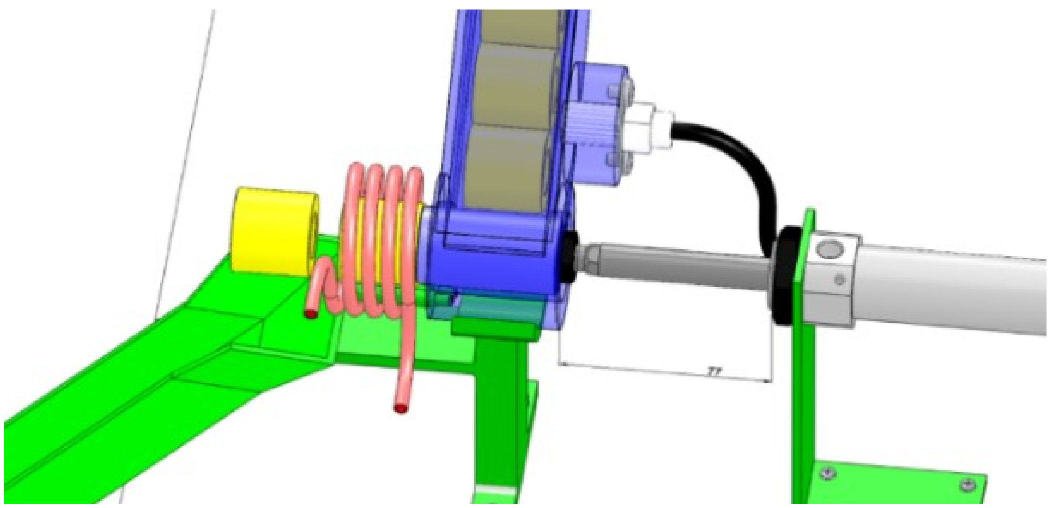
Figure 8 – 3D design of the slow drawing system actuated by the double action pneumatic cylinder

According to the 3D isometric view presented in Fig..10 the cylindrical work piece placed inside the inductor for 6 seconds reaches the temperature of 1100^0. Afterwards the incandescent work piece is pushed, and falling freely on a gravitational drain, it goes into the cooling tank and a basket. The cooling medium is made out of water or oil ensuring the cooling of the work pieces thus resulting the surface hardening. Periodically, after filling up to 70% of the tank, the basket with the work pieces it placed on a drain tray and it's changed with an empty one.

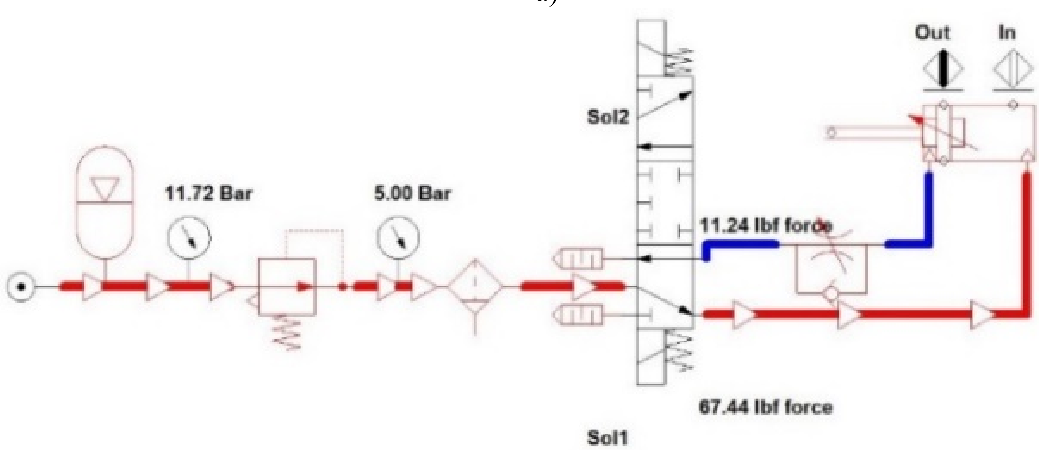
The pneumatic actuation of the catch and draw mechanism in made on a exactly measured time interval, determined mathematically depending of the heat treatment that is prescribed for the work pieces.

To retreat the piston and the piston rod to initial position we commute to a new position of the pneumatic valve presented in Fig..11

The pneumatic valve used in our case is a 5/3 type, as a result of the automation program made on the PLC, ensures based on a newly programed command that the valve being positioned on a new position, presented below, delivers air pressure in the right chamber of the pneumatic cylinder.



a)



b)

Figure 9 a) – 3D design of the stroke end of the slow draw mechanism. Pneumatic diagram

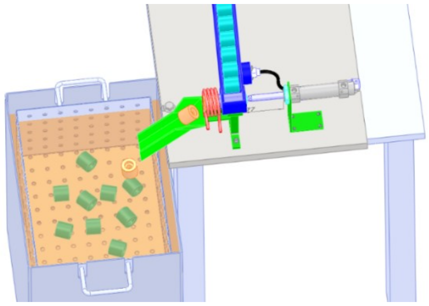


Figure 10 – 3D design of the heat treatment and storage into the basket

Through the pneumatic circuit that does not have a one-way flow control valve the speed of the piston and piston rod it bigger, resulting a much faster reversion of the draw head. After the retreat of the piston, the feed time of one cylindrical work piece into the inductor in 2 seconds, and depending of the hardening prescribed for the work piece, surface of depth hardening, the workpiece reaches optimal temperature in 6-10 seconds.

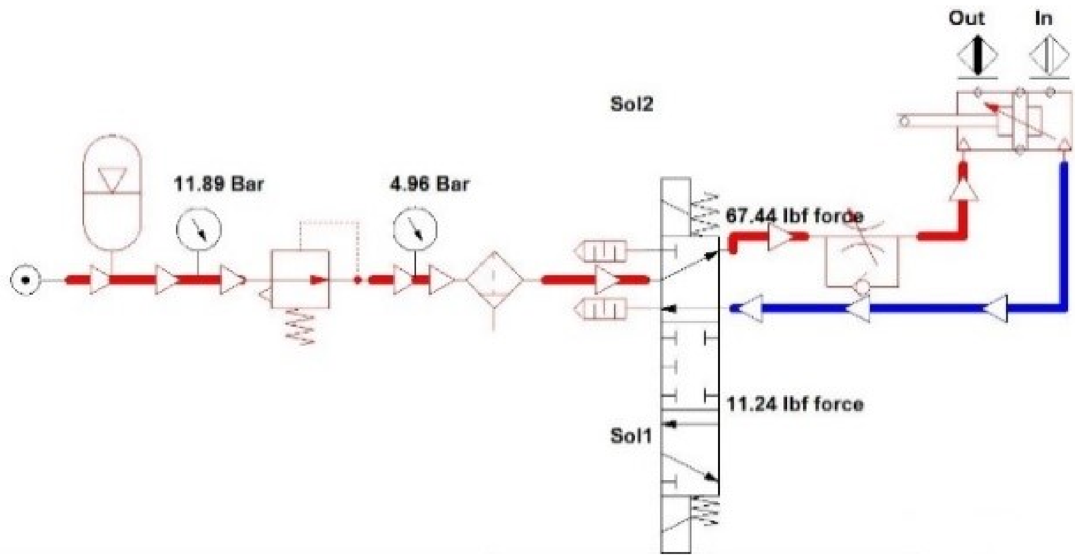


Figure 11 – Fast retreat pneumatic diagram for the double action pneumatic cylinder

5. . CONCLUSIONS

In this paper, we designed and realized an automated device for handling simple cylindrical or spherical work pieces with the purpose of feeding a high frequency induction machine, implemented into a surface or depth hardening system. This system was made due to old concerns regarding our university, University of Oradea, about studying, designing and manufacturing high frequency induction machines.

The authors of this paper designed the handling device, electrical and pneumatically actuation systems. The electric motor is actuated through a H bridge to avoid system gridlocks.

Thereby, the device is provided with sensor for confirming the existence of the work pieces in the work area ensuring at the same time the command of the pneumatic cylinder.

6. REFERENCES

1. Antonescu, O,Antonescu,*Mecansimeşimanipulatoare*.Editura PRINTECH Bucureşti 2006
2. Burca A., "*Analizasistemelorelectrotermice inductive echipate cu invertoare de înaltăfrecvență*", ISBN 978-606-10-1830-7, EdituraUniversităţii din Oradea, 181 pag, 2016.
3. M., Topologeanu, *Assembly automation. Parts supply systems*. University of Oradea Publishing House 2008.
4. Book of Solid Works 2016 Software, 2016.
5. Book of AutoCAD 2016 Software, 2016.
6. P. D. Tocuţ, A. Tripe Vidican, *Devices for manufacturing systems*. University of Oradea Publishing House 2007
7. P. D. Tocuţ, A. Tripe Vidican, C. Tripe Vidican, *Implementation of working and automatization devices in a flexible processing system*, page 1126-1135, ANNALS of the ORADEA UNIVERSITY. Fascicle of Management and Technological Engineering, Volume VII (XVII), 2008.
8. Fluid SIM 4.2