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AUTOMATING THE FEEDING OF A COORDINATE MEASURING MACHINE

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Abstract: *The main objective of this paper is to solve a problem within a company regarding the optimization of a measurement process of a work-piece on coordinate measuring machines. This has been tried by automating the machine's feeding process, as well as by designing and constructing a part clamping device on the machine, in order to eliminate the measurement errors encountered and to shorten the fixing time of the part. By connecting the gripper to a robot, the human error was eliminated, which was one of the main problems and the whole measurement process was simplified. To achieve the following, the proper gripper needs to be chosen through calculating the gripping force, together with dimensioning the gripper's jaws and designing the clamping device for the work-piece.*
Key words: *Coordinate measuring machine, gripper, process automation, clamping device.*

1. INTRODUCTION

Nowadays, industrial automation has massive importance and impact in all technological fields by increasing work quality and productivity.

Scientific analysis of an experiment is based on a series of entities and each entity is characterized by quality and quantity. Through measurement, we obtain quantitative data regarding properties of an object and it can be performed using simple measuring equipment such as calipers, or complex measuring equipment such as Coordinate Measuring Machines [1][5].

In all workable applications of metrology, there is always an amount of uncertainty regarding precision in measurement. In order to minimize uncertainty, we are eliminating human errors through automating the process and fixture errors through creating a new clamping device for the work-piece [2][4].

Current state

The present paper presents the automation and optimization of a process for measuring a work-piece on coordinate measuring machines, within a company from Transylvania area.

Presently, the clamping device for the part to be measured is composed from two screw vices, as we can observe in Fig.1. The clamping device is fixed on the coordinate measuring machine table through flange system with two bolts.

The principal disadvantage and the main problem of the current clamping device are represented by uncertainty in measurement precision, given by assembling the screw vices and by the inaccurate positioning of the work-piece by the operator.

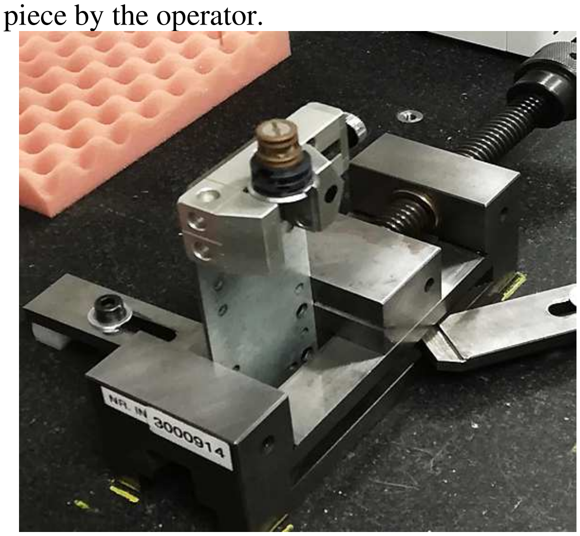

Fig. 1 Existing clamping device

2. PROCESS AUTOMATION

2.1 Calculus for selecting the gripper

The first step for identifying the proper gripper is to calculate the required gripping force, gripping point and the maximum allowable load. In order to calculate, we must know the mass of the work-piece and the material used in manufacturing the part [3].

The following formulas were used:

F: Gripping force [N]

μ: Coefficient of friction between the attachments and the work-piece

m: Work-piece mass [kg]

g: Gravitational acceleration (= 9.8 m/s^2)

mg: Work-piece weight [N]

- Gripping force:

$$F = \left(\frac{mg}{2\mu}\right) 4\ [N] \qquad (1)$$

- Conditions under which the work-piece will not be dropped:

$$2\,\mu F > mg \qquad (2)$$

- Gripping point distance (L) and amount of overhang (H) are chosen using operating pressure (P) and the gripping force already calculated above.
- Allowable load:

F = (max. allowable moment/ L x 0.001) [N] (3)

With all information regarding gripping task, material of the work-piece, gripping force, the proper gripper can be chosen.

2.2 Dimensioning the gripper jaws

In order to design and dimension the gripper „fingers" is used the 3D model of the work-piece and the 3D model of the gripper. In the previous step were calculated all the elements for the gripper and was chosen the proper gripper for the specific task.

To design the gripper jaws it must be taken into consideration functionality of the work-piece and as well, functionality of the machine.

Starting on the basis, due to work-piece's mass which is in our case only 13,49 [g] and the conical shape of the part with two holes on the sideways, we considered that the best way to grip the part is like in the Figure 3.

Due to conical shape of the holes located on the sideways, gripper jaws were designed with bevels on corners. Gripper jaws are assembled on the gripper body using two screws.

Fig. 2 Gripper's jaw

In the next figure it can be observed that the jaw is designed to cover and to fix precisely the work-piece.

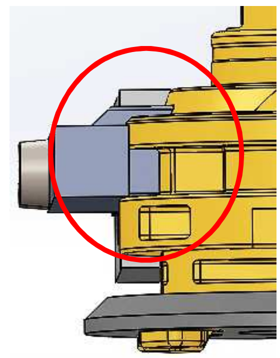

Fig. 3 Fixing the part with the gripper

After dimensioning the jaws, a worst case scenario simulation was accomplished with maximum allowable load obtained from calculus, taking into account the next concerns:

- Excessive deformation;
- Excessive stresses;
- The effect of load/unload cycles.

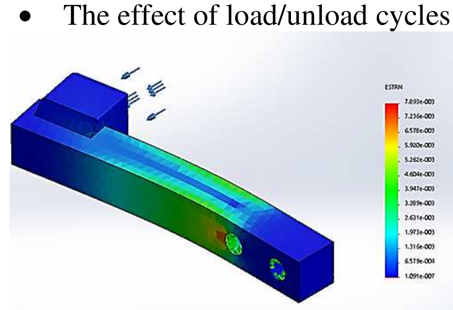

Fig. 4 Static strain test

In the following figure is represented the whole assembly of the dimensioned gripper, together with the work-piece and jaws.

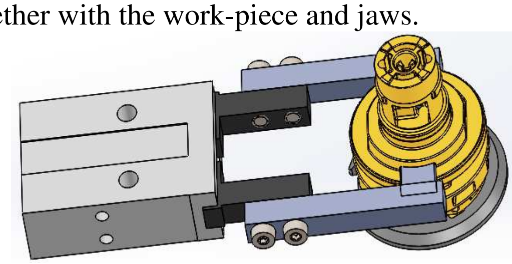

Fig. 4 Gripper with the work-piece

3. DESIGNING THE CLAMPING DEVICE

Some aspects must be considered when a part is fixed and oriented in order to be measured:

- The part must be clamped on the machine table in such way that the features that will be measured are accessible;
- The part must be fixed in such way that is neither distorted or loose;
- We must find the proper position to measure all features from one clamping because the part cannot be unclamped and moved for the same measurement program;
- All degrees of freedom must be blocked.

The main disadvantage of the current clamping device within the company is represented by the higher possibility of machine collision.

To design the clamping device is used the 3D model of the work-piece and SolidWorks software.

The developed solution for the clamping device is presented in figure 6. The device is fixed on the machine's table using screws and bolts.

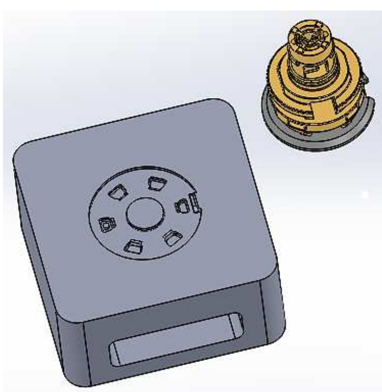

Fig. 6 Clamping device

3.1 Dimensioning the electromagnet

During the measurement process, the trigger force of the stylus might push the part and it might fall off the device.

In order to prevent this possibility, an electromagnet was used. The bottom of the work-piece is made by steel alloy, so an electromagnet can be designed that can fit in the middle of the device. In this way, the work-piece will be gripped properly with no chances of falling off.

The electromagnet is important because blocks all degrees of freedom and the work-piece must be properly clamped in order to be measured.

For dimensioning the electromagnet, the trigger force must be taken into account.

The following formulas were used:

- Holding force:

$F\ -\ force\ [N]$

$B\ -\ Magnetic\ field\ [T]$

$A\ -\ Area\ of\ pole\ faces\ [m^2]$

$\mu 0 = 4\pi * 10^{-7}\ [HM^{-1}]$

$$F = \frac{B^2 * A}{2 * \mu 0}\ [N] \quad (4)$$

- If $B > 1.6\ [T]$ a larger core must be used;
- Bolt diameter, nut diameter, air gap, weight of object, pitch are needed;
- In order to hold the part, the following condition must be fulfilled:

F mag > Trigger force*1/friction coefficient [N];

Trigger force = mass/ 100 [N] (5)

- Pole area:

$$A = \pi * \frac{d^2}{4}\ [m^2] \quad (6)$$

- Flux density in the air gap:

B- magnetic flux

A- core area

$$A = 2\pi rl + 2\pi r^2 \quad (7)$$

$$\phi = B * A \quad (8)$$

- The magnetizing force (H) in the air gap:

$$H = \frac{B}{\mu 0}[AT/m] \quad (9)$$

- Magneto-motive force:

$$\mathcal{F} = HL\ [AT] \quad (10)$$

The magneto-motive force is the product of the electrical current that will go round the magnet and the number of turns of the wire that make up the magnet.

If one of the variables is chosen, the other variable can be calculated, thus if the number of turns is chosen to be 1320, then the electrical current in the electromagnet is given by:

- $I = \frac{mmf}{N}\ [A]$ (11)
- Layer perimeter = $\pi * D *$ nr. of turns

From STAS is picked the wire diameter and number of turns.

In conclusion, the holding force necessary for the part equals with 0.0031 [N] and the current in the electromagnet is 0.011 [A].

In the below figure it can be seen where the electromagnet was positioned and in figure 10 is presented the printed model of the device, used together with the electromagnet for testing.

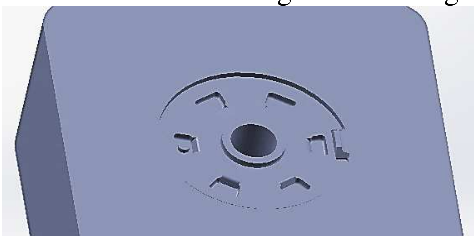

Fig. 9 Electromagnet area

Fig. 10 3D printed model of the device

4. CONCLUSIONS

The process automation was implemented through choosing the proper model of gripper from calculus and through designing the gripper jaws. Based on gripper jaws design and maximum allowable load, a finite element analysis was done in order to check the reliability of the device.

Due to work-piece's characteristics and the current state of the clamping device, a new and much simple device was created based on the bottom model of the work-piece.

An electromagnet, specific for our clamping device was identified.

Through designing the gripping device, which will be linked to a robot and designing the clamping device, the following aspects were improved:

- Time spent on placing the work-piece on the clamping device was reduced;
- Human error was eliminated;
- Increasing work quality and productivity, higher accuracy;
- The process was simplified.

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Automatizarea procesului de alimentare al unei mașini de măsurat în coordonate

Rezumat Obiectivul principal al acestei lucrări este rezolvarea unei probleme din cadrul unei companii cu privire la optimizarea unui proces de măsurare al unei piese pe mașini de măsurat în coordonate. Acest lucru s-a încercat prin automatizarea procesului de alimentare al mașinii, precum și prin proiectarea și construcția unui dispozitiv de prindere al piesei pe mașină, care să elimine erorile de măsurare intâmpinate precum și să scurteze timpul de fixare al piesei. Prin conectarea dispozitivului de prindere al reperului la un robot din dotarea companiei, a fost eliminată eroarea umană care reprezenta una dintre principalele probleme existente iar întreg procesul de măsurare a fost simplificat.

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