Design and Development of Tap Loading System for MFX3 CNC Square Grinding Machine

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*Abstract–***The study is focused on development of a solution for loading of taps on a MFX3 CNC square grinding machine. The problems faced were operator fatigue and low productivity. It also includes study of the previous solution to the problem and eradication of the arising problems. The developed system now has increased accuracy and effectively reduced the operator fatigue.**

***Keywords*-MFX3 CNC, pneumatics, automation, ratchet and pawl, indexing mechanism, job loading system**

I. INTRODUCTION

The CNC is the most widely known application inspired by Automation. With the growing demands of the customers, and the limited time allotted for delivery of products, CNCs are the go-to for most of the manufacturing industries. Compared to conventional machines, CNCs provide us with higher accuracy and higher degree of uniformity, as CNCs eliminate chances of human errors as all the machining operations are carried out by the machine itself. Though most of the operations on these CNCs are automated, in some cases there is still need of an operator for loading of the jobs. This gives way to some amount of human errors, and also slows down the process causing an increase in overall cycle time. This is why many industries, nowadays, choose to install a custom, application-specific loading system. The desired features of these systems are,

1) Robust design,
2) Detachability,
3) Adaptability to various types of jobs,
4) Light weight,
5) Simple in construction,
6)Cost efficient.

Based on this study, we aim to design and develop a semi-auto loading system for MFX3 CNC machine which performs square grinding of taps.

II. PROBLEM STATEMENT

The concerned machine is aspecial purpose square grinding machine in the taps and blanks department of the Sandvik Asia Pvt. Ltd., which grinds taps ranging from size M4 to M12. It has a magazine which holds maximum 40 taps at a time. Under ideal conditions machine is expected to complete 100 jobs (size M8) in one hour. But after every 40 jobs, an operator needs to load the job manually in magazine. The efficiency of the machine which increases cycle time and results in less number of jobs done than it ideally should. To reduce these losses, operator fatigue and in turn increase efficiency, they need to build a mechanism which holds large number of taps and helps to load them in the magazine one by one automatically as per requirement. Also, for certain conditions, like machining of asymmetrical taps, maintenance of machine and changing of grinding wheel the mechanism should be easily detachable, and should fit in less area such that it does not interrupt any other machines and walkway around the machines.

The solution to this problem resulted in development of a system which had a vertical rigid frame to support the tap holding tray and the mechanism. The system was indexed using Geneva mechanism with the help of stepper motor synchronized with the CNC. This solution posed the following problems:

1) Difficult to maneuver,
2) Angular inaccuracy arising from cumulative inertial error,
3) Interruption in walkway.

Fig.1: previous loading system

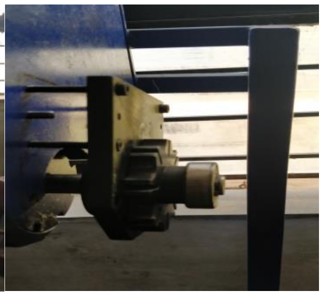

Fig. 2: indexing mechanism for previous loading system

The following study is based on fulfilling the requirements and rectification of the problems faced by the previous iteration.

III. Studies and Findings

The basic solution to this is to build an external unit, which will hold many jobs at a time, and refill the magazine as and when required. Also a system, which will be the link between the CNC and the external unit holding the jobs, that refill the magazine only when required. Also, the system should be detachable (in case the machine is required to perform a different job).
Keeping this in mind, the components of the system can be broadly categorized as:

a) A unit to hold the extra jobs,
b) A system that will fill the jobs in the right time and place,
c) A frame to support the above two components.

The first step of methodology we adopted was to study and understand the existing systems in the industry. We reviewed many research papers related to this topic, which provided us with many ideas.
The study introduced us with the following:

1. Installation of robotic arm,
2. Use of linear tool indexing mechanism for tool loading and unloading [1],
3. Use of turret tool indexing mechanism for tool loading and unloading [2],
4. A gripper and swinging arm system operated using servo or stepper motor [3],
5. Pick and place mechanism [4].

Apart from these common solutions, we thought of some solutions like, using a slotted cylinder, in which, the jobs from the tray will fit one by one, and drop on the magazine. The cylinder can be given precise angular motion using:

1. A custom made cam and follower mechanism,
2. Geneva mechanism,
3. Ratchet and pawl mechanism.

Ratchet and pawl mechanism was finalised due to simpler design and high accuracy. To run the above mechanism in synchronisation with the CNC, we can time the mechanism, using a pneumatic or hydraulic circuit or an electric circuit (as in case of stepper or servo motors). The company has permitted us to take an input from the dead end pneumatic cylinder of the CNC, hence to avoid complexity, we choose to keep the system purely pneumatic.
We also need a strong frame to support the mechanism. Also, the frame should be easily detachable when not needed.
Considering these requirements, we thought of a few solutions like:

a)A rigid vertical frame, which will slide to the side when not in use,
b) A combination of links, normally placed on top of the CNC, and pulled down as and when required without much effort put in.

Considering the limited space between adjacent machines, we chose the second option as more appropriate than the first.
Thus, the basic methodology we adopted, was to come up with a solution to the existing problem, keeping in mind the space constraints, weight constraint, feasibility and compatibility of the system for machine, as well as the workers, and the budget.

IV. Design and Analysis

For design consideration the system is divided as follows:

A) Tray

The major parameters to be considered for tray design are:

1. Sufficient tap holding capacity (around 250 of M8)
2. Sufficient strength to support taps and corrosion resistance
3. Variable room for different jobs of different lengths

The final design of the tray is as follows:

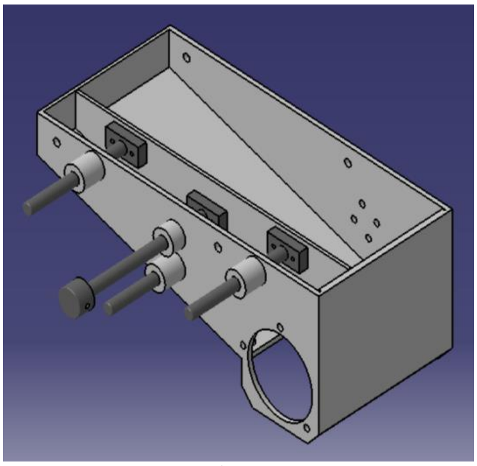

Fig.3:tray for holding taps

Material: Stainless steel 304
Manufacturing Process: Sheet metal and welding

B) Roller

Roller is used to transfer taps from tray to the magazine of the CNC

1. Roller is used to transfer taps from tray to the magazine of the CNC
2. The roller has 4 slots at 90° each other
3. Different rollers will be used for different tap sizes ranging from M4 to M12
4. The roller can be easily replaced from the left face of tray and secured with the help of flanges at both ends

The following diagram shows a roller for M8 taps:

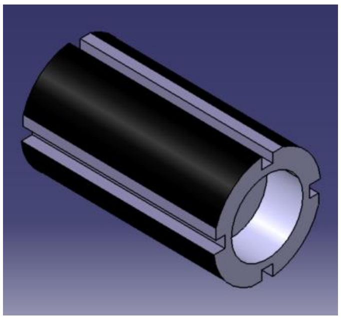

Fig. 4: roller

Material: Stainless steel 304

Manufacturing process: Milling

C) Roller shaft

Roller shaft performs two important functions:

1. It supports the roller and components of the indexing mechanism
2. It transfers the motion from the indexing mechanism to the roller

The following Figure shows the roller shaft:

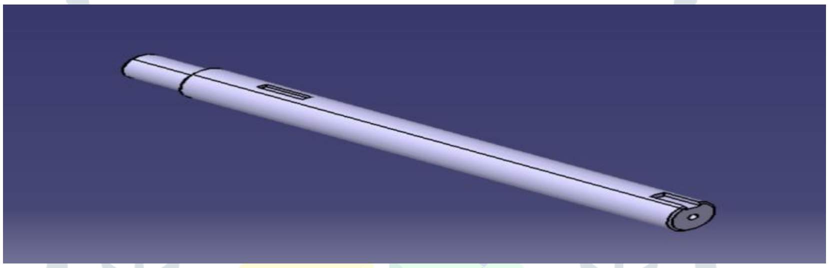

Fig.5: roller shaft

Material: EN24

Manufacturing process: Turning and Milling

D) Frame

The frame supports the tray and the mechanism during the tap loading operation and also detaches it when not in use. The frame design was finalized based on the space constraints and the requirement for easy maneuverability.

During the operation, the frame shaft would be under stress as all the load of the tray with the taps and mechanism falls on it. Hence being the most critical component of the frame, it had to be designed carefully.

The forces acting on the shaft are as follows:

Fig. 6: free body diagram of frame shaft

Fig. 7: shear force diagram

Fig. 8: bending moment diagram

Calculation for minimum safe diameter:

$$d = \left(\frac{32M}{\pi\sigma_b}\right)^{1/3} = 4.86\ mm$$

where,

d – Minimum safe diameter of shaft

d_a - Actual diameter of shaft

σ_b - Maximum bending strength = 150 MPa

M - Maximum bending moment = 1692.225 N-mm

The shaft is selected as follows:

Material: Mild steel

d_a = 10 mm

l - Length of shaft = 298 mm

E) Indexing mechanism

Components of indexing mechanism:

i) Pneumatic cylinder

Specifications:

Model- FESTO DSBC-32-50-PPVA-N3

Maximum pressure- 12 bar

Bore- 32mm

Stroke- 50mm

ii) Rack and pinion

Rack and pinion were selected based on maximum cylinder pressure.

Calculation:

Maximum tangential force on pinion tooth (F_{tmax}) = $P_{max}*A_{piston}*10^5$

= 965.22 N

where,

P_{max}= Maximum cylinder pressure= 12 bar

A_{piston} = Piston area = $8.044*10^{-4}$ m^2

Hence maximum torque = $F_{tmax}*r_p*10^{-3}$

where,

$r_p = d_p/2$ = Radius of pinion

The rack and pinion pair selected is as follows:

Material: (16MnCr5) AISI5115

Module: 2

Face width: 24 mm

Pitch Circle Diameter: 56 mm

No. of teeth: 28

Torque capacity: 64 (47) N-m

iii) Ratchet and pawl

The pawl is pinned to a plate rigidly mounted on the pinion. It runs a four toothed ratchet which is keyed to the roller shaft. The pawl rotates the ratchet by 100° during the forward stroke of the cylinder and slides over it during the backward stroke, thus exposing one roller slot to the magazine after every cycle.

The strength of ratchet and pawl design is governed by the pin diameter.

The pin is designed weaker, so that if the system load goes beyond the design value, the pin fails and other components are safe from damage.

$$d_{pin(min)} = 2.71 * \sqrt[3]{\frac{F_n}{2\sigma_{ba}}\left(\frac{b}{2} + t_h\right)} = 11.295\ mm$$

where,

d_{pin} = Diameter of pin

$d_{pin(min)}$ = Minimum safe pin diameter

F_n = Normal force at point of contact = 965.22 N

σ_{ba} = Allowable bending stress = 150 MPa
b = Face width = 15 mm
t_h = Thickness of pin hub = 15 mm

Ratchet and pawl pair is selected as follows:
Material: Mild steel
Manufacturing process: Wire cutting / Milling
Pin diameter selected, d_{pin} = 8 mm

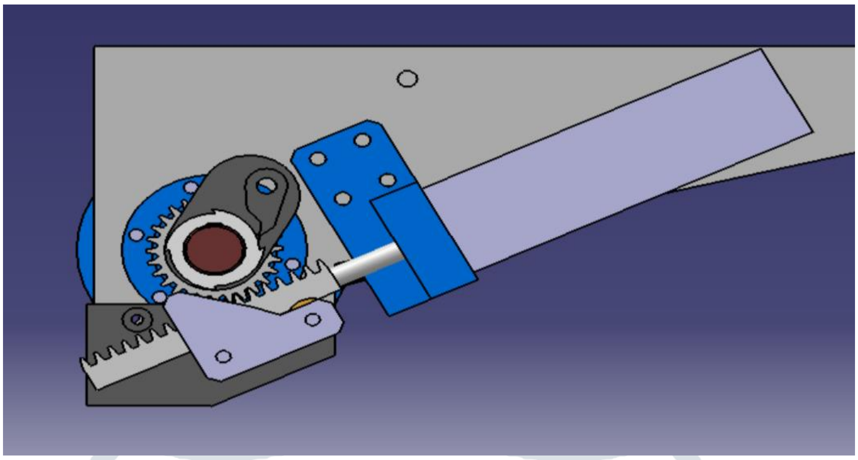

Fig. 9 indexing mechanism

V. CONCLUSION

By building mechanism for loading taps for MFX3 CNC, the cycle time for jobs has reduced which resulted in increase in productivity and decrease in operator fatigue. Prior to installation of tap loading system, manual loading of taps in magazine exploited 5% of the cycle time. This loss is effectively minimised. The frequency of the operator visits required is effectively reduced from one visit every 24 minutes to one visit every 1-2 hours (depending on the tap size)

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REFERENCES

[1] Hailog Tian, Zhaojan Yang, Chuanhai Chen, "Study on Operational Reliability of Tool Magazine and Automatic Tool changer based on Tool pulling force", Proc. of the second International Conference on System Reliability and Safety, Jilin University, Changchun, China, 2017, pp. 195-201.

[2] Jayson P. Rogelio and Renann G. Baldovino, "Development of Automatic Tool Changer (ATC) System for the 3-axis Computer Numerically Controlled (CNC) Router machine", 7th International Conference Humanoid, Nanotechnology, Information Technology Communication and Control, Environment and Management (HNICEM), The Institute of Electrical and Electronics Engineers Inc.(IEEE),Hotel Centro, Palawan, Philippines, 12-16 November, 2014.

[3] Sandeep S. And K.R. Prakash, "Automation of loading and unloading on CNC turning centre", International Journal on Mechanical Engineering and Robotics, 2013.

[4] Rong-Fong Fung, Chin-Lung Chiang and Guo-Ching Wu, “System identification of a pick-and-place mechanism driven by a permanent magnet synchronous motor”, Applied Mathematical Modelling, 2010.