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Design and Development of PLC Operated Special Purpose Machine for Face Milling Operation on Connecting Rod

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***Abstract*—Special Purpose Machines is a high productivity machine, with specially designed tooling and fixture, dedicated for mass producing the same component day in and day out. A judicious combination of limit switches, sensors, logic controls, automatic job clamping etc. is the essence of a SPM. SPM perform special or particular task only for which it is designed. So the SPM perform the face milling operation on both sides of the connecting rod at a time. This will ultimately lead to reduction in the cycle time of the existing conventional milling machine which has large cycle time and which consumes more power. To fix the connecting rod at one place so that its position is fixed while the face milling operation is carried out the fixture unit is designed and developed. The convention milling machine is hand driven which ultimately leads to human errors. To overcome this problem the SPM will be interfaced with the PLC which will carry out the entire operation.The aim of this project is to design and development discrete component of special purpose machine**

Keywords*— Connecting rod, Spindle, Fixture Unit, PLC Programming

I. INTRODUCTION

The Special Purpose Machines (SPM) have crucial role in manufacturing industries to enhance the productivity. In most of the operations are performed differently for each end of side of connecting rod i.e. for small end and big end. Earlier work has been done by considering two distinct processes for two different ends. In this dissertation work an attempt is made to combine operations to enhance the productivity. In this special purpose machine two work pieces will bored simultaneously. This will save time and as well as increase the productivity. The spindle shaft used in this machine is critical part so static and modal analysis of spindle shaft will be done to know stress distribution.

The Special Purpose Machines (SPM) And Automatic Machines are designed to Operate Continuously for 24 hours a day, with Minimum Supervision. The Special Purpose Machines are Generally Product Specific & they are required to be Designed & Developed for each Specific Requirement. Sometimes it May be Possible to Cater to the Jobs having Similar Features but Differing in Dimensions by Using Change Tooling Concept. This Special Purpose Machines (SPM) is either Cam Operated Machine or they use Hydraulics & Pneumatics as Actuating Elements or Combination of all the three of them. Many times a Dedicated Programmable Logic Controller is used in Conjunction with Positional Sensors & Transducers, to give Commands to the Actuating Elements some Times Different Special Motors like Stepper Motor & Servo Motors are used as Actuating Element. The Productivity Achieved after all these Efforts is very high. Productivity of 3 to 10 times is Achievable. However to Fetch the Fruits of these Highly Specialized Machines the Pre-Condition is that the Input to the Automatic Machine must have Strict Quality Control.

II. FIXTURE UNIT

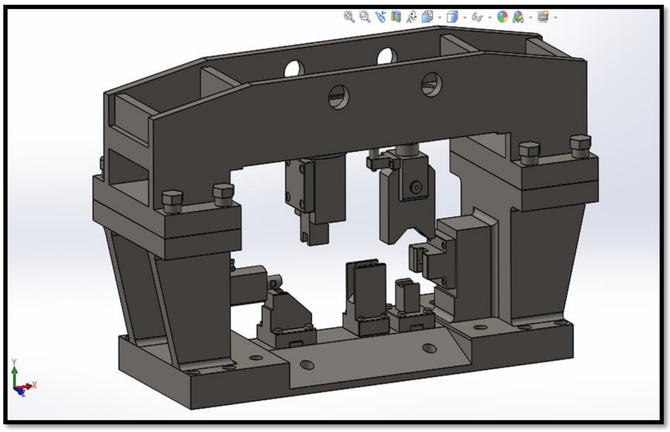

Fig No.1 CAD model of Fixture Unit

A. *Component side resting pad*

It is made up of O.H.N.S (Oil hardening Non-shrinking Die steel) which is mainly used for highly stressed machine parts which are intended for cementation with high strength and core toughness. Since, the connecting rod one side is going to rest on it so special care is taken while selection of the material.

B. *Component Resting Piece*

The main function of Component resting piece is to give proper support to the connecting rod when the face milling operation is carried out. It is made up of WPS (Die steel 1.2080/D3) material which provides good wear resistance and compressive strength, resistance to plastic deformation, Good hardenability.

C. *Hydraulic Cylinder MTG. Bracket (Top)*

It is Bracket which is used to hold the Hydraulic cylinders which are place on the top of the fixture unit. The function of

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the bracket is to give proper support to the Hydraulic cylinder and give proper direction and hold the cylinder in fixed proper direction so that it can hold the connecting rod tight enough while the face milling operation is carried out.

D. Hydraulic Cylinder MTG.Bracket for Bracket (Bottom)

The Hydraulic Cylinder MTG.Bracket for Bracket is a bottom C plate like structure on which the entire components of the fixture unit rest. It is one of the largest and critical part of the fixture unit which plays very crucial role in the Fixture unit. It is made of Cast Iron FG-260 which is having good tensile strength and is cheaply available in the market. Also lot of machining operation is also carried on the Hydraulic Cylinder MTG.Bracket for Bracket so the cast-iron material is preferred.

E. Hydraulic Cylinder MTG. Bush

It is also one of the important part of the fixture unit which has important function of holding the connecting rod along with sensor which fitted along the bush to sense the connecting rod and gives input to PLC. It is having the cylinder like component along with the bush which is attached on the front side along with the sensor. The Hydraulic cylinder MTG. Bush is made up of Cast Iron FG-260 which is having good tensile strength and is cheaply available in the market.

III. POWER CALCULATIONS

In machine tools, a spindle is rotating axis of the machine, which often has a shaft at its heart. The shaft itself is called a spindle, but in shop floor practice, the word often is used metonymically to refer to the entire rotary unit, including not only shaft itself, but its bearings are also attached to it. The main spindle is usually biggest one. Some machine tools that specialize in high volume mass production have a group of 4,6 or even more main spindles.

Cutting Speed (V) = (3.14*D*N)/1000
= 3.14*125*750/1000
= 294.5 $^{m}/_{minute}$

Metal Removal Rate (Q) = b*t*Sm/1000
= 80*1*350/1000
= 28 $\frac{cm^3}{mim}$

Power at Spindle (N) = U$K_h K_f$Q
= 69*10^{-3}*1.57*1.21*28
= 5 Kw.

Power of Motor = 6 Kw.

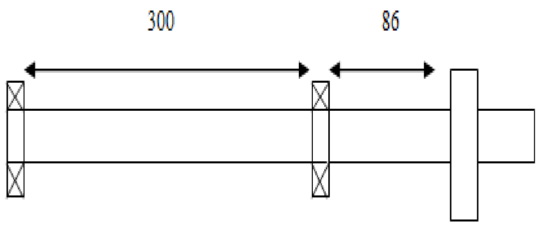
A. Design of Belt and Pulley

Motor is mounted above spindle housing hence distance between spindle shaft and motor shaft is less, so it is preferable to select V belt and V pulley for power transmission. During power transmission, belt tension acts radial load on spindle shaft. So, bending moment due to belt tension should be considered during design of shaft Corresponding values of belt and pulley are calculated as follows,

Sr.No.	Properties	Values
1	Mass of belt	0.1144 Kg/m
2	Velocity of belt	7.22 m/s
3	Centrifugal tension in belt	5.96 N
4	Maximum tension in belt	260 N
5	Tension in tight side	254.04 N
6	Angle of contact of belt over pulley	3.02 rad
7	Tension in slack side	19.48 N

B. Calculation of Bending Moment

The driven pulley is overhang to extent of 86 mm from the nearest bearing center. The layout of shaft and bending moment diagram are shown in figure below.



Therefore, bending moment on the shaft due to the belt tension is calculated below, the total upward force acting at the center line of pulley is given by, For single belt,

$F_1 = T_1 + T_2 = 257.2 + 24.85$ = 282.05 N

Two V belts are used so total force = F_1 *2 = 282.05*2
= 564.1 N

C. Calculation of Torsional Moment

$$M_t = \frac{60 * 10^6 * Kw}{2 * 3.14 * N}$$

= 70063.69 N–MM

D. Design of Shaft on Strength Basis

The spindle shaft is designed by considering axial, bending and torsional load. When the shaft is subjected to an axial load in addition to torsion and bending loads, then the stress due to axial load must be added to the bending stress. Shaft is made of ductile material; hence here Maximum shear stress theory is applied for design of shaft.

Kb = Combined shock and fatigue factor applied to bending moment

Kt = Combined shock and fatigue factor applied to torsional moment

di = Inner diameter of shaft

do = Outer diameter of shaft

C = Ratio of inside diameter to outside diameter

τ_{max} = Maximum permissible shear stress

F.S. = Factor of safety

Shaft is made up of SAE 8620 material having ultimate tensile strength is 660 N/mm^2 and yield tensile strength is 385 N/mm^2.

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$$\tau_{max} = \frac{0.5\, S_{yt}}{FS} = 64.16\ \text{N}/mm^2$$

Pulley is keyed on the shaft hence, τ_{max} = 0.75 × 64.16 = 48.12 N/mm^2.

Assume $C = \frac{d_i}{d_o} = 0.6$

According to ASME code shaft design, the bending and Torsional moments should be multiplied by factors Kb and Kt respectively, to consider for shock and fatigue in shaft during operating condition. Hence, maximum shear stress (τ_{max}) is,

$$\tau_{max} = \frac{16}{3.14 {d_o}^3 (1 - C)^4} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

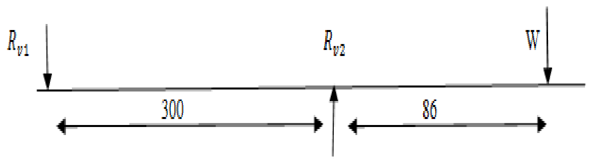
$$ {d_o}^3 = \frac{16}{3.14 \tau_{max} (1 - C)^4} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Considering available diameter of adapter which fits into inner diameter of spindle, selection of do = 30 mm, di = 18 mm, d1 = Shaft diameter where pulley fits = 55 mm.

E. Bearing Selection

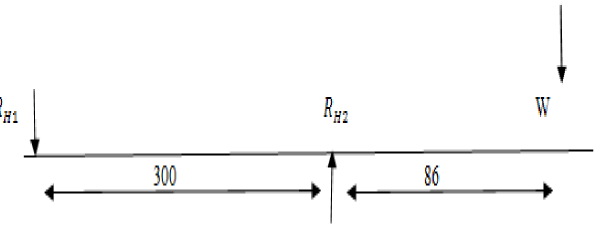
Radial load is exerted by pulley and there is no any axial load is exerted because of absence of gear mechanism in operation. These radial is transferred on bearing through spindle. Thus, it is suitable to select bearing such that it carry radial load. Hence the single row deep groove ball bearing is selected. For selecting bearing following forces are taken,

For vertical plane



R_{v1} = 95.47 N, R_{v2} = 428.52 N.

For horizontal plane



R_{H1} = 80.85 N, R_{H2} = 362.90 N.

Bearing life calculation

$$L_{10} = \frac{60 n L_{10h}}{10^6}$$

= 2700 million rev.

Dynamic load carrying capacity

$$C = P (L_{10})^{\frac{1}{3}}$$

C_1 = 1741.98 N and C_2 = 19547.93 N.

So, 61810 and 61812 single row deep groove ball bearing is selected.

Machining time calculations

Machining time (T_m) = $\frac{L+A+O}{f_r}$

Where, L = Feed length in mm, A = O = Approach distance

f_r = Feed rate (mm/minute)

$$T_m = \frac{5.70 + 2.46 + 2.46}{92.94}$$

= 9 sec.

Slide rapid movement = 9 seconds.

Connecting rod Mounting = 5 seconds

Total cycle time is 25 seconds

IV. RESULT

Finite element analysis of the Shaft is carried out in following steps preprocessing, processing, post processing. Three dimensional model of spindle is created by using Solid works 2015 and analysis is done on the ANSYS Workbench 18.2.

Analysis of spindle:-

The spindle is analyzed by using ANSYS software. In static analysis the effect of steady loading on a structure is considered while inertia and damping effects, such as those caused by time varying loads are ignored [13]. Static analysis can include steady inertia loads such as gravity and rotational velocity and time varying loads can be approximated as equivalent to static load. The static analysis is used to determine the, von Mises stresses by applying various forces in structures or components. The spindle 3D model is imported in ANSYS from Solid works 2015. Standard bearings with required inner and outer diameter and having dynamic and static load carrying capacity as per designed calculation are selected and mounted at specified location on the spindle. Material of the shaft is SAE 8620. According to distortion energy theory the ductile solid material yields when the von Mises stress exceed the yield value exceeds the yield stress value of the materials. The von Mises stress is less than the yield strength; hence design of spindle is on safer side.

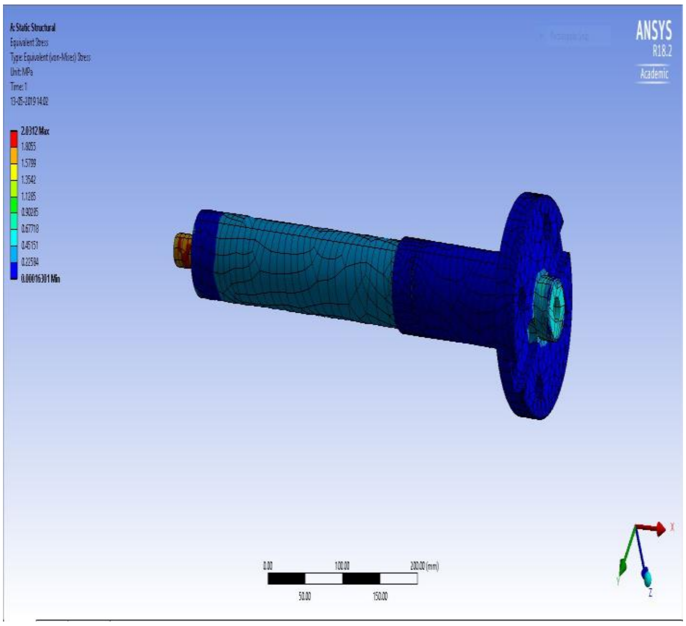


Fig No.2 Analysis of the shaft

PLC Programming

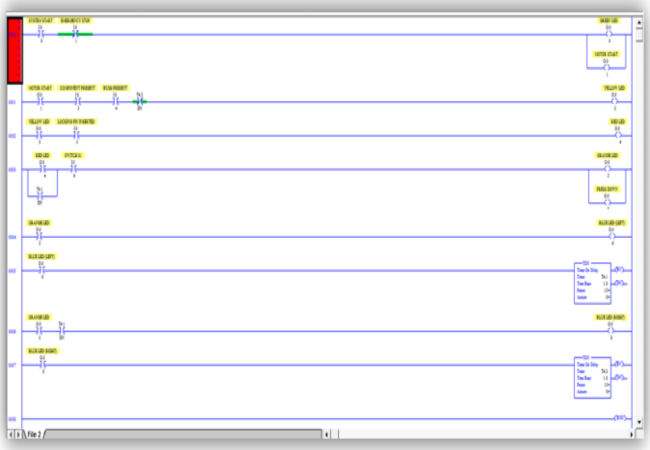


Fig No.3 Ladder Logic

CONCLUSION

In current research work, design and analysis of spindle for special purpose Face milling was carried out which is used for face milling of the connecting rod. The obtained value of von Mises stress is less than yield tensile strength of the spindle material. Time required for single job is 25 seconds so productivity has got increases and cycle time has also been got reduced.

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