Design and Development of a Special Purpose Machine with PLC Control for Face Milling of Connecting Rod

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Abstract - *Special purpose machines are extremely productive machines that are used to create the same part in huge quantities on a daily basis. They have fixtures and tooling that are specifically developed for them. A carefully selected collection of limit switches, sensors, logic controllers, automatic job clamping, etc., form the foundation of an SPM. SPM only finishes the designated tasks for which it is designed. Consequently, the SPM grinds the connecting rod's face simultaneously on both sides. This will ultimately lead to a decrease in the long and energy-intensive cycle time of the existing standard milling machine. unit is made and planned. People can make mistakes since the conventional milling machine is manually operated. To address this problem, the SPM will be interfaced with the PLC, which will handle the entire procedure. The design and development of a discrete special purpose machine component is the aim of this project.*

KeyWords: Connecting rod, Face Milling, Spindle, Fixture Unit, PLC Coding.

1.INTRODUCTION

In order to increase productivity, Special Purpose Machines (SPM) are essential in the manufacturing sector. The majority of the operations are carried out differently for the small and big ends of the connecting rod. Previous research has considered two different methods for two different purposes. An attempt is made to consolidate activities in this dissertation work in order to increase productivity. This particular equipment is designed to simultaneously bore two work pieces. Time will be saved, and production will rise as well. Because the spindle shaft in this machine is a crucial component, a static and modal analysis of the spindle shaft will be performed to determine the distribution of stress.

The Automatic and Special Purpose Machines (SPM) are made to run continuously for 24 hours a day with the least amount of supervision. Generally speaking, special purpose machines are product-specific and must be developed and designed to meet each unique requirement. Using Change Tooling Concept, it may occasionally be possible to cater to jobs with similar features but different dimensions. These Special Purpose Machines (SPM) are either cam-operated, employ hydraulic and pneumatic elements as actuators, or combine all three. Positional sensors and transducers are frequently employed in conjunction with a dedicated programmable logic controller to provide commands to the acting elements occasionally. Actuating elements include various special motors, such as servo and stepper motors. After all of these efforts, a very high level of productivity was achieved. Three to ten times as much productivity is achievable. Strict quality control must be applied to the automatic machine's input in order to reap the benefits of these highly specialized machines.

2. FIXTURE UNIT

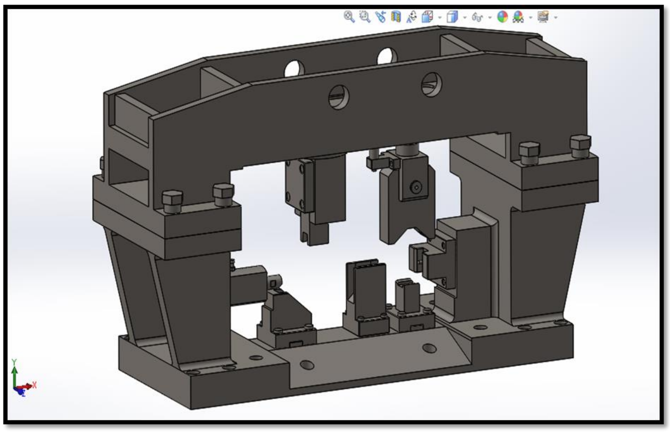


Fig No.1 CAD model of Fixture Unit

A. *Component side resting pad*

It is composed of O.H.N.S. (Oil Hardening Non-Shrinking Die steel), which is mostly utilized for heavily stressed machine parts with high strength and core toughness that are meant to be cemented. Particular care is taken while choosing the material because one side of the connecting rod will rely on it.

B. *Component Resting Piece*

The primary purpose of the component resting piece is to provide appropriate support for the connecting rod during the face milling process. The material used to make it is WPS (Die steel 1.2080/D3), which has good hardenability, resistance to plastic deformation, wear resistance, and compressive strength.

C. Hydraulic Cylinder MTG. Bracket (Top)

The hydraulic cylinders that are placed atop the fixture unit are held in place by a bracket. The bracket's job is to support the hydraulic cylinder properly, guide it in the right direction, and hold it there so that it can hold the connecting rod securely enough to support the face milling operation.

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

The complete fixture unit rests on the Hydraulic Cylinder MTG.Bracket for Bracket, which resembles a bottom C plate. It is one of the most significant and important components of the fixture unit and has a vital job to play. It is composed of Cast Iron FG-260, which is reasonably priced and has an excellent tensile strength. Cast iron is the recommended material for the Hydraulic Cylinder MTG Bracket since it undergoes a number of machining operations.

E. Hydraulic Cylinder MTG. Bush

It is also a crucial component of the fixture unit, serving the dual purpose of supporting the connecting rod and providing input to the PLC via a sensor installed along the bush. It has a cylinder-shaped part and a bush that are attached to the front of the device along with the sensor. Cast iron FG-260, which is reasonably priced and has strong tensile strength, makes up the Hydraulic Cylinder MTG Bush.

3. POWER CALCULATIONS

A spindle in machine tools is the machine's rotating axis, which frequently has a shaft at its center. Although the name "spindle" refers to the shaft itself, in shop floor practice it is commonly used metonymically to refer to the full rotary unit, including the bearings that are mounted to the shaft as well as the shaft itself. Usually, the largest spindle is the main one. A group of four, six, or even more main spindles can be found in some machine tools that are designed for high volume mass manufacturing.

Cutting Speed (V) = (3.14*D*N)/1000

= 3.14*125*750/1000

= 294.5

Metal Removal Rate (Q) = b*t*Sm/1000

= 80*1*350/1000

= 28

Power at Spindle (N) = U Q

= 69* *1.57*1.21*28

= 5 Kw.

Power of Motor = 6 Kw.

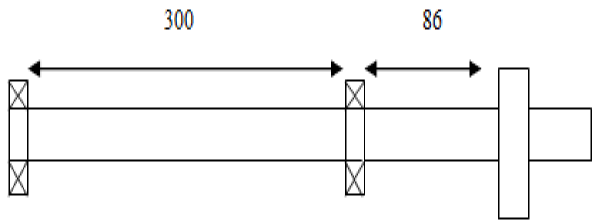
A. Design of Belt and Pulley

Because the motor is positioned above the spindle housing, there is less space between the spindle and motor shafts, making the V belt and V pulley a better choice for power transmission. Spindle shaft radial load is applied by belt tension during power transmission. Thus, while designing a shaft, the bending moment caused by belt strain should be taken into account. The following formula is used to find the belt and pulley values that correspond:

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 extends 86 millimeters beyond the closest bearing center. The graphic below displays the shaft and bending moment diagram configuration.



The total upward force acting at the pulley's center line is thus given by, and the bending moment on the shaft caused by the belt tension is calculated below. Regarding a 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

Torsional, bending, and axial loads are all taken into account when designing the spindle shaft. In cases where the shaft experiences axial load in addition to torsion and bending load, it is necessary to add the axial load stress to the bending stress. Since the shaft is composed of ductile material, the maximum shear stress hypothesis is used in this design.

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

= Maximum permissible shear stress

F.S. = Factor of safety

Shaft is made up of SAE 8620 material having ultimate tensile strength is 660 N/mm² and yield tensile strength is 385 N/mm².

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

Pulley is keyed on the shaft hence, τ_{max} = 0.75 × 64.16 = 48.12 N/mm²

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

The ASME code shaft design states that in order to account for shock and fatigue in the shaft during working conditions, the bending and torsional moments should be multiplied by factors Kb and Kt, respectively. Therefore, the greatest shear stress(τ_{max}) is,

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

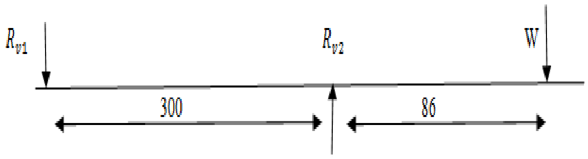
$${d_o}^3 = \frac{16}{3.14 \tau_{max} (1-C)^4} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

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

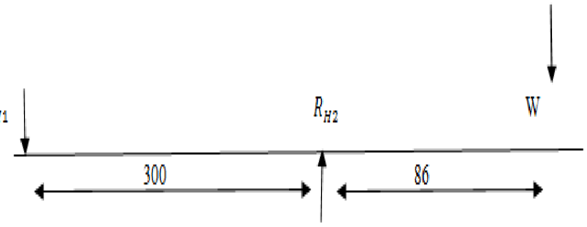
The pulley exerts radial load, whereas the lack of an operational gear system results in no axial stress being exerted. These radials are transmitted through the spindle on a bearing. Therefore, choosing a bearing that can support radial load is appropriate. For this reason, a single row deep groove ball bearing is chosen. The following forces are considered while choosing a bearing

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

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

= 1741.98 N and = 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

4. RESULT

The Shaft's finite element analysis is completed in the following stages: preparation, processing, and postprocessing. Solid Works 2015 is used to generate a three-dimensional model of the spindle, and ANSYS Workbench 18.2 is used for analysis. –

The ANSYS program is used to assess the spindle. Static analysis takes into account a structure's response to stable loading while ignoring inertia and damping effects, such as those brought on by time-varying stresses [13]. Time-varying loads can be roughly comparable to static loads in static analysis, although stable inertia loads like gravity and rotational velocity can also be included. By applying different forces to buildings or components, the von Mises stresses can be found via static analysis. ANSYS imports the spindle 3D model from Solid Works 2015. Standard bearings are chosen and installed at predetermined locations on the spindle. They must have the necessary inner and outer diameters as well as the dynamic and static load carrying capacity determined by the calculated calculation. The shaft is made of SAE 8620 material. The ductile solid material yields, according to distortion energy theory, when the von Mises stress is greater than the material's yield value. Since the von Mises stress is lower than the yield strength, the spindle's design is safer.

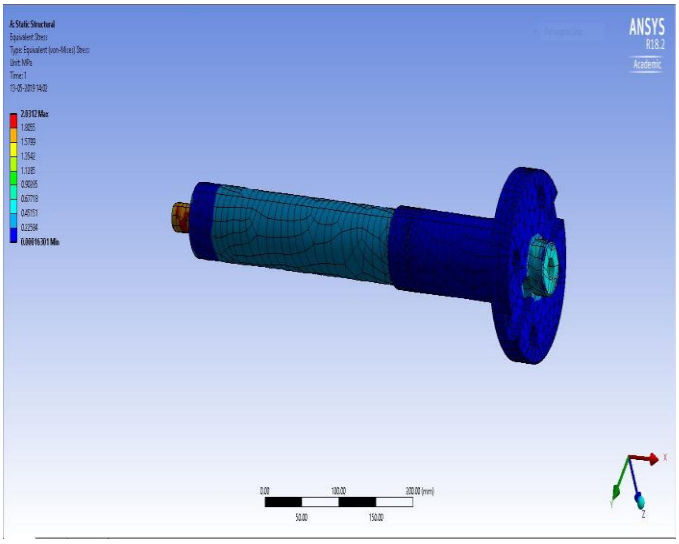


Fig No.2 Analysis of the shaft

PLC Programming

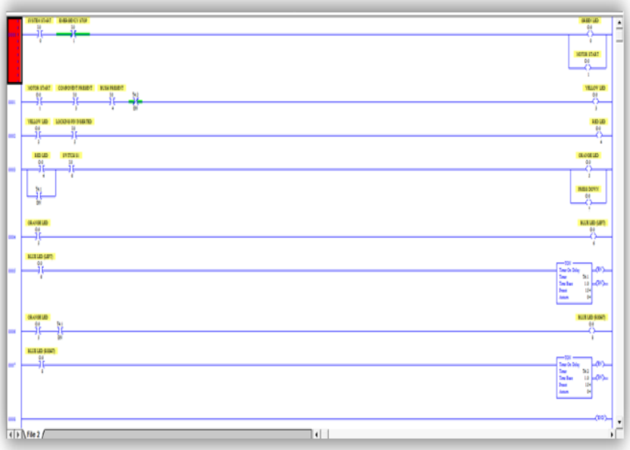


Fig No.3 Ladder Logic

5. CONCLUSION

The design and study of spindles for specific purposes are being done in current research. Face milling, which is used to face mill the connecting rod, was done. The spindle material's yield tensile strength is more than the von Mises stress value that was produced. With only 25 seconds needed for a single task, production has increased and cycle time has decreased.

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