Study the Need of Designing a Special Purpose Machine to Improve the Production of Engine Block

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Abstract— Special purpose machine tools are designed and manufactured for specific jobs and such never produced in bulk such machines are finding increasing use in industries the techniques for designing such machine would obviously be quite different from those used for mass produced machine. A very keen judgment is essential for success of such machines. A special purpose machine is needed to be designed and manufactured at a Company which found beneficial in increasing production quantity & reducing manpower. The company sponsored the project to be undertaken and need of SPM machine is to be studied under this sponsorship.

Keywords: Special Purpose Machine, Engine Block

I. Introduction

Special purpose machine tools are designed and manufactured for specific jobs and such never produced in bulk such machines are finding increasing use in industries the techniques for designing such machine would obviously be quite different from those used for mass produced machine.

Broadly the special purpose machine tools could be classified as those in which jobs remain fixed in one position and those in which job moves from one station to other (Transfer machine).

In this case the product may be either moving continuously (as in the case of spraying, polishing, sanding etc) or intermittently (the most usual case in machining operation). Rotary intermittently motion Transfer machine is very popular production machine.

It is essential that all movements be completely synchronized in order to obtain desired product it is essential that all tools and units must have completed their operation and come to rest before tools and units begin their work.

II. Literature review

[1] S. Kalpakjian and S. R. Schmid, Manufacturing engineering and technology. Upper Saddle River, N.J: Pearson Prentice Hall, 2006 Due to the increasing demand for new products and greater competition as a result of globalization, manufacturing companies face unpredictable changes in the market. For this reason, manufacturing systems must be designed to meet the factors that enable the companies to remain competitive. These factors are high quality of products, low product cost, and flexible response to changes in the market and consumer needs.

[2] M. Tolouei-Rad and S. Zolfaghari, "Productivity improvement using specialpurpose modular machine tools," IJMR, vol. 4, pp. 219-235, 2009 These factors are very important for achieving greater productivity in manufacturing systems.

[3] U. H. Farhan, "An integrated computer-aided modular fixture design system for machining semi-circular parts," 2013 Traditional machinery was used to carry out manufacturing operations until the beginning of the 1950s. This included lathes, drill presses, milling machines, and other equipment for operations such as shaping, forming, and joining. However, using traditional machinery and equipment was relatively inflexible and a high level of skilled labor was required to operate and produce parts with the required specifications. These disadvantages led to high production costs. Therefore, production cost needed to be reduced by improving the flexibility and efficiency of manufacturing systems.

[4] M. P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing: Pearson Education, Limited, 2014 This led to meeting the requirements of the major factor in manufacturing, which is productivity. In order to improve the productivity of manufacturing systems, some important techniques have been implemented. One of these techniques is automation, which is a process to automate the operation of a machine by following a predetermined sequence of processes.

Automation has various levels, starting with simple hand tools and continuing on to computer numerical control machine tools (CNC) and, ultimately, the implementation of expert systems. Automation has been implemented in many areas, such as manufacturing processes, material handling and movement, inspection, assembly, and packaging.

[5] T.-C. Chang, H.-P. Wang, and R. A. Wysk, Computer-aided manufacturing. Upper Saddle River, N.J: Pearson Prentice Hall, 2006 The main advantages of automation are improving the productivity and quality of products, reducing human errors and work piece damage, arranging machines and other equipment efficiently, and integrating various aspects of manufacturing operations.

III. Design of Parts

Broadly the special purpose machine tools could be classified as those in which jobs remain fixed in one position and those in which job moves from one station to other (Transfer machine). In first case the machine may perform either only one operation or more .In the second case, the product may be either moving continuously (as in the case of spraying, polishing, sanding etc) or intermittently (the most usual case in machining operation). Rotary intermittently motion Transfer machine is very popular production machine and is described in brief bellow.

A. Design of Spindle Unit:

The operational capability of a machine tool in term of productivity as accuracy and finish of machining parts largely depends upon the extent to which these function is qualitatively satisfied. They also determine the important design requirement to spindle unit.

The following recommendations for selecting spindle material may be formulated:

- For normal accuracy spindles, plain carbon steels C45 and C49 (AiSi C1050 and C1050) hardened and tempered to RC =30.
- For above normal accuracy spindles –low alloy steel 40Cr 1 Mn 60 Si 27 Ni25(AiSi5140) induction hardened to Rc 50-56;if induction hardening of above accuracy spindles difficult due to complex profile then low alloy steel 50 Cr 1 Mn 60 Si 27 Ni 25 (Aisi 5147) is used with hardening to Rc =55-60.
- For spindle of precision machine tools, particularly those with sliding bearing –Low alloyed steel 20 Cr Mn 60 Si 27 Ni25 (Aisi 5120) case hardened to Rc =63-68.
- For hollow, heavy –duty spindles –grey cast iron or spheroidal graphite iron.

B. Forces on Spindle Shaft:

1) Inputs:

- Shear strength (fs) = 5.3kgf /mm^2

= 51.67 N /mm^2
D = diameter of gear on spindle shaft =90;
T= Number of teeth on gear = 30
Module (m) = 3;
Torque (T) = p ×60 /2π n = 1.89 kgf-m;

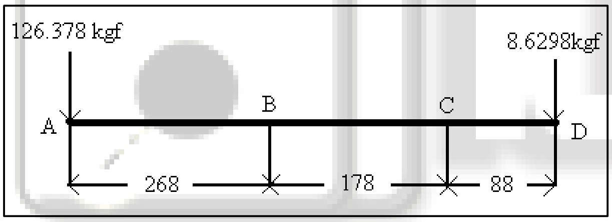
- Tangential component of force acting on gear (Pt)

Pt × PCD = 2 × Torque =23.682 kgf

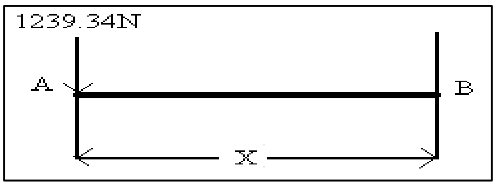
- Radial component of force acting on gear (Pr)

Pr = Pt×tan 20 = 8.6198kgf

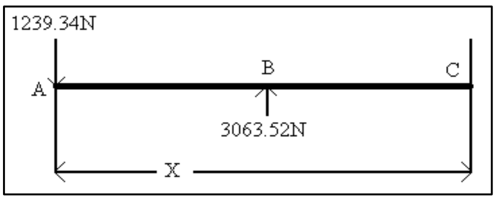
C. Vertical Loadings:



Free body diagram for vertical loading diagram of spindle shaft
RB+RC =134.99kgf;
RB=312.39kgf;
RC=177.39kgf.
Bending Moment Calculations:
a) SECTION AB 0<X<268:

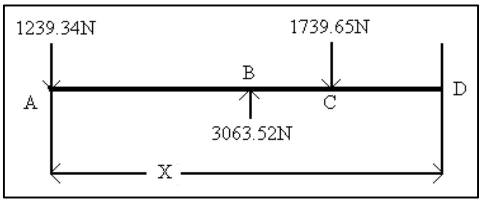


Bending moment at (X=0) =0; B (X=268) = 33869.16 kgf-mm
b) SECTION BC 268<X<446:

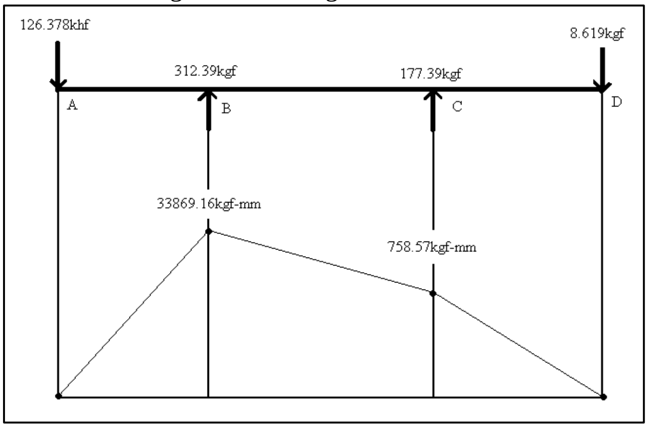


Bending moment at B(X=268) =33869.16 kgf-mm; Bending moment at C (X=446) = 758.57 kgf-mm

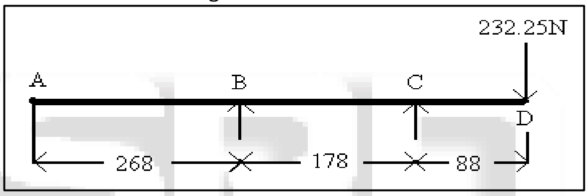
c) SECTION CD 446<X<534:



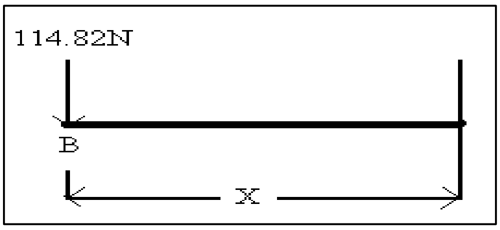
Bending moment at C (X=446) =758.57 kgf-mm; Bending moment at D (X=534) =0
Vertical Bending Moment Diagram:



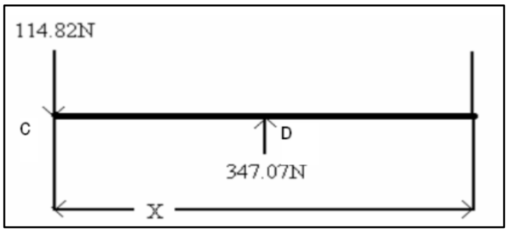
2) Horizontal Loading:



Free body diagram for horizontal loading diameter of spindle shaft
RB+RC=23.68 kgf;
∑MB =0
RC=35.39 kgf; RB= -11.70 kgf
Negative sign indicates that direction of RC is opposite and should be changed from ↑ to ↓
Bending Moment Calculations:
a) SECTION BC 0<X<178:



BENDING MOMENT AT B (X=0) = 0;
BENDING MOMENT AT C(X=178) = 2084.09 kgf-mm
b) SECTION CD 178<X<266:



BENDING MOMENT AT C (X=178) = 2084.09 kgf-mm;
BENDING MOMENT AT D (X=266) =0;

BENDING MOMENT AT A=0

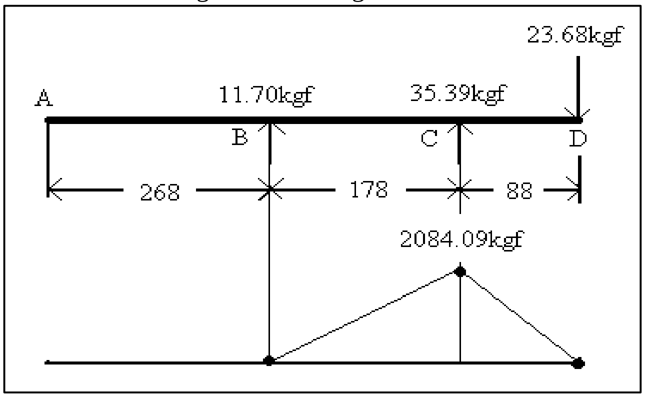
BENDING MOMENT AT B = $\sqrt{(R_{BV}^2+R_{BH}^2)}$
=33869.16Kgf-mm.

BENDING MOMENT AT C = $\sqrt{(R_{CV}^2+R_{CH}^2)}$
=273213.269 Kgf-mm

BENDING MOMENT AT D = 0;

BENDING MOMENT IS MAX. AT B = 33869.16 kgf-mm

Horizontal Bending Moment Diagram:



3) Calculations of min. shaft diameter:

$\pi/16 \times fs \times d^3 = \sqrt{(Mt)^2 + (T)^2}$

$(D)_{min}$ = 32.59 mm

Multiply $(d)_{min}$ by factor of safety 2

d = 65.18 mm

4) Deflection of Spindle Shaft:

Shafts when subjected to bending loads are subjected to bending stresses. If induced bending stress exceeds the permissible stress values either for compression or tensile, then the shafts undergoes the failure.

The deflection may be calculated by any of the following methods;

– Macaulay's Method
– Area-moment method
– Conjugate beam method
– Castiglione's method
– Graphical integration method

a) Macaulay's method:

The bending moment expression obtained shall be equated to $E \times I\, d^2y/dx^2$

Subsequently the entire expression shall be integrated once to obtain the expression for dy/dx i.e. the slope of beam at any cross section location .it shall be integrated once again to obtain the expression for y, the deflection.

Hence $E \times I\, dy/dx = \int M \times dx$ ----(1)

$E \times I \times Y = \iint M \times dx$ --- (2)

While integrating, the constants of integration shall be coupled with the expression, and shall serve as the constants for entire expression for the valid zones. The constants of the integration C_1 and C_2 shall be solved by applying suitable end conditions as y=0 at X=1 etc. to the basic expression for y. The actual values of y or dy/dx shall be obtained by substituting given value of E and I_{XX}.

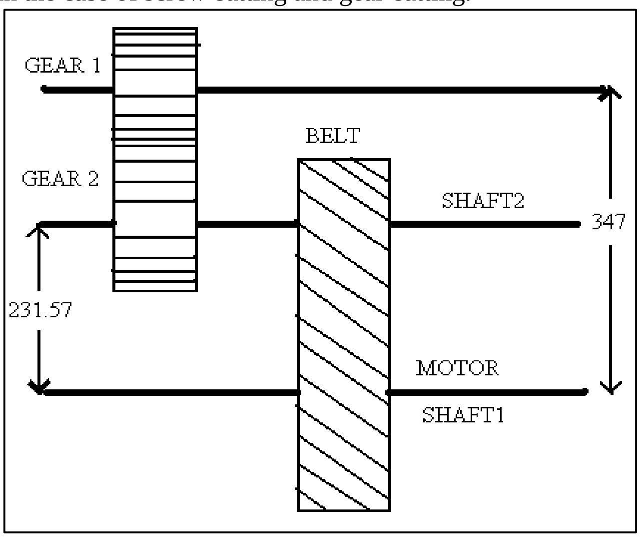
IV. SELECTION OF BEARINGS

The selection of the type of bearing in a particular application depends upon the requirement of the situation and the characteristics of different types of bearing. The guidelines for selecting a proper type of bearing are as follows.

1) For low and medium radial loads, ball bearings are used, whereas for heavy loads and large shaft diameters, roller bearings are selected.
2) Self-aligning ball bearing and spherical roller bearing are used in applications where a misalignment between the axes of shafts and housing is likely to exist.
3) Thrust ball bearings are used for medium Thrust loads whereas for heavy Thrust loads, cylindrical roller Thrust bearings are recommended. Double acting Thrust bearings can carry the Thrust load in either direction.
4) Deep groove ball bearing, angular contact bearing and spherical roller bearing are suitable in application where the load acting on the bearing consists of two components- radial and Thrust.
5) The maximum permissible speed of the shaft depends upon the temperature rise in the bearing. For high speed applications, deep grove ball bearings, angular contact bearing, and cylindrical roller bearings are recommended.
6) Rigidity controls the selection of bearings in certain application like machine tool spindles. Double row cylindrical roller bearing or taper roller bearings are used under these conditions. The line of contact of these bearings, as compared with the point of contact in ball bearings, improves the rigidity of the system.
7) Noise becomes the criterion of selection in application like household applications. Under these circumstances, deep groove ball bearings are recommended. Knowledge of the design characteristics of different types of bearing and proper appreciation of the needs of application enables the designer to select a proper type of bearing.

V. DESIGN OF GEAR BOX

Gear box provide for a wide range of cutting speeds and torques from a constant speed power input enabling proper cutting speed or torques to be obtained at the spindle as required in the case of cutting drives and the desired feed rates in the case of fed drives. Gear boxes are also used to affect inter-related motions between the work piece and the tool as in the case of screw cutting and gear cutting.



VI. LUBRICATION & LUBRICANTS

Machine tools generally work to a high degree of accuracy and are expected to sustain this accuracy over a long period. This requires proper control of friction and Wear of parts which are in relative motion and calls for effective lubrication of the vital elements like bearings, gears etc.

Effective lubrication is achieved by using proper lubricants. Lubricants not only reduce the friction and the consequent heat generation, they also aid in transporting the heat generated.

A. Types of Lubricants:

Types of lubricants commonly in machine tools are

1) Oil
2) Grease
3) Oil mist
4) Solid lubricants

Of the above types oil & grease are more commonly used. Mist lubrication is restored to only for very high speed spindles. Solid lubricants are used in situations where lubrication point is increasable or likely to be neglected.

VII. SEALING OF ROLLING BEARING

Seals are be used to retain lubricant and to prevent dirt and other forging matter from entering element .In machine tools the space adjacent to work heads is usually limited , making it may be necessary to have external sealing arrangements in chucks in addition to seals in the bearing housing . Different types of sealing arrangements are in vogue. Rubbing type seals generally provide effective sealing but result in increased friction and heating, thus imposing restrictions on the speed of operation labyrinths or clearance seals on the other hand are suitable higher speeds and can be designed to suit both oil and grease lubrication.

VIII. ASSEMBLY PROCEDURE FOR SPINDLE AND GEAR BOX

A. Assembly Procedure of Spindle unit:

The procedure for assembly of spindle unit is as mentioned below

1) Clean the spindle housing thoroughly by using kerosene and air pressure.
2) Clean the spindle using same method as above.
3) Heat the front side bearing (Φ) in hydraulic /lubricating oil.
4) Insert the front side spacer (no. 1) at the location provided in the spindle housing.
5) Remove the bearing from oil bath after temperature of bearing reaches 60^0 C to 70^0 C.
6) By using tongs lift the bearing from oil bath after temperature of bearing reaches 60^0C to 70^0C
7) Then keep the assembly in open for sometimes so that the temperature of assembly attains the room temperature and bearing fits tightly on to the spindle.
8) Insert the spindle into the spindle housing from front side of the housing.
9) The front side bearing gets located at the correct specified location.
10) Now insert the middle spacer (number 1) spacer are mostly made of EN8 material
11) Insert the 2^{nd} taper roller bearing in hot condition on the spindle (Ø90mm).
12) Again keep the spindle unit assembly in open for sometime so that the temperature of assembly attains the room temperature and bearing fits tightly on to the spindle.
13) Insert the 3^{rd} spacer.
14) Then insert cylindrical rolling bearing in the hot condition.
15) Insert the small spacer (number 2).
16) Fit the oil seal cap using Allan bolt (M6).
17) Then tight it.
18) Fit the oil seal using oil seal cap.
19) Tight the check nut with lock nut Between the two nuts lock washer is to be fitted.
20) Check the run out of spindle using a dial gauge. The total indicating reading (TIP) should be within 0.02 to 0.01.
21) Then start preloading of bearing by means of chuck nut.
22) Lock the washer.
23) Then fit the front side cap.

B. Assembly Procedure for Gear Box:

The procedure for assembly of spindle units is as mentioned below.

1) Insert the key in the keyway on the spindle.

C. Subassembly of Gear and Gear Holding Bush:

1) Gear should be located on bush by using two do Il pins.

D. Assembly of Cluster Gear:

1) Insert the ball bearing on both sides of cluster gear

E. Assembly of Gear Covers Of Gear Box:

1) Insert the baring on the motor gear shaft and fit into the gear box cover.
2) Insert the bush removing spacer into the cluster shaft.
3) Insert the cluster bush. Fit it into round cover on the gear box cover by using 6 bolts.

F. Assembly of Main Gear Box:

1) Place the motor shaft bearing number 2 into the gear box housing.
2) Fix the cluster shaft by using 4 bolts(M12)
3) Insert the gear holding bush sub-assembly.
4) Insert the spacer number 3.
5) Place the circlip.
6) Insert the cluster gear assembly on the cluster shaft.
7) Then fit the circlip.
8) Insert the motor gear shaft into the motor gear shaft bearing number 2
9) Put the gasket with the help of gasket oil.
10) Assemble the rear cover with proper location in the motor shaft bearing number 1 and cluster bush.
11) Tighten the cover assembly with the help of bolt.
12) Fit the drain plug and oil window glass.
13) Pmy the lubricating oil from top tapped plug.
14) Maintain the oil level.
15) Apply grease in the spindle housing and plug it with grease nipple.
16) Fit the motor in position and tighten the 4 bolts.
17) Connect the supply of motor.
18) Run the motor.

19) Paint the spindle as per requirement.

IX. SEQUENCES OF OPERATIONS

A. *Spindle Shaft:*

Sr. No.	Description	Machine	Location/clamping	Tool used	Inspection details
1	Drop forging	Hydraulic press	Die		Visual
2	Grinding of extra material	Portable grinder		Grinding wheel	Visual
3	Milling Ø 40 mm	Centre lathe	3 jaw chuck	ISO 9 P30 2525	Bore gauge
4	Grinding Ø 100 mm	Centre type grinder (plunge grinder)	Between centers	Grinding wheel	Vernier micrometer
5	Grinding Ø 90 mm	Centre type grinder (plunge grinder)	Between centers	Grinding wheel	Vernier micrometer
6	Grinding Ø 85 mm	Centre type grinder (plunge grinder)	Between centers	Grinding wheel	Vernier micrometer

Table 12.1: Sequences of Operation of spindle shaft

B. *Gear Shaft 1*

Sr. No.	Description	Machine	Location/clamping	Tool used	Inspection details
1	Turning Ø35mm	Centre lathe	3 jaw chuck	ISO 2 P30 2525	Vernier caliper
2	Milling keyway	Milling Machine	Vice	Slot mill cutter	Visual

Table 12.2: Sequence of operation for Gear Shaft

C. *Gear Manufacturing Process*

Sr. No.	Description	Machine	Location/clamping	Tool used	Inspection details
1	Gear cutting	Milling Machine	Mounted between two centers with mandrel	Form disc cutter	Vernier Micrometer
2	Broaching a key in a gear center bore	Vertical broaching machine	Broaching fixture	Key way broach	

Table 12.3: Sequence of operation for Gear manufacturing process

X. JUSTIFICATION OF NEW SPM LOCUS CLEARANCE MILLING

Operation	Machine	Total Cycle time In min	No. of Components per month	Operators Per shift	Machining cost per unit	Machining cost per month
1	OLD SPM	17.11	2103	3	20	1,01,880
2	NEW SPM	5.5	6792	1	15	42,060

XI. CONCLUSION

From the overall procedure I followed in designing of the spindle unit and gear box , I conclude that design is safe , accordingly the design could be brought into practice while designing I have successive in keeping the cost factor to minimum total net savings per year after new SPM is Rs.7,17,840

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