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Design And Development Of Gearbox For Multi-Spindle Drilling Machine (SPM)

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Abstract

This project emphasis will be given on designing, modelling (AutoCAD) and developing of gearbox which operate the multi-spindle drilling machine for drilling operation of counter bore of ø5 mm, ø6.8 mm and ø14.4 mm for a cylinder block.

Gearing selection for power transmitting (at high rotational speeds) from prime movers and driven units and different factors affecting gear performance are studied. To overcome that problem and to maximize the efficiency as well as profits by increasing the production rate without scarifying quality with decrease in time frame, labouring cost, rejection of part etc., Special Purpose Machine are introduced which plays an vital role in heavier production, and which to be achieved by developing gearbox which operates to different types maximum numbers of drilling tools at a time.

Keywords: *Multi-spindle drilling machine, Gearing.*

1. Introduction

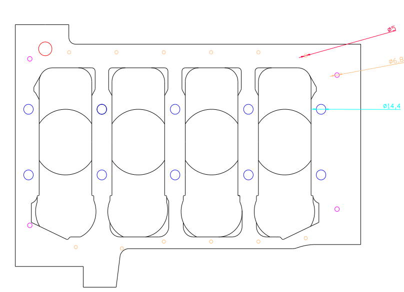
Gearing is one of the most important components between prime movers and driven units. If gearing is not selected properly, it can cause many problems. Gearing transmits great power at high rotational speeds. The major factors affecting gear performance include pressure angle, helix angle, tooth hardness, scuffing prediction, gear accuracy, bearing types, service factor, gear housing, and lubrication.

In most operations carried out on grey cast iron automotive components like break drum, cylinder blocks (Single,2,3,4,6,8,12) and cylinder heads(3,4,6) ,conventional machines are used which has limitations to improve productivity. To overcome that problem and to maximize the efficiency as well as profits by increasing the production rate without scarifying quality with decrease in time frame, labouring cost, rejection of part etc., Special Purpose Machine are introduced which plays an vital role in heavier production, and which to be achieved by developing gearbox which operates to different types maximum numbers of drilling tools at a time.

And gear box designing is taksplace on product base (Cylinder block) requirement. It include gear selection, types of Gear Failures and their Causes like Wear, Normal wear and abrasive wear, Scoring, Tooth breakage, Corrosion, Spoiling, and Interference.

Present cylinder block-

Made up of cast iron, Grade=FG 260,Tensile Strength = 260 N/mm^2 (depends on wall thickness), Wall thickness (In mm) = 25-40, Hardness Range=190-230 BHN, Chemical Composition- C= 3.3 -3.45 %, Mn=0.6 -0.9%, P=0.15 %(Max.), S= 0.15 % (Max.)
Cu = 0.3 - 0.7 %, Cr = 0.1-0.25 %, Iron =Remainder.



This is a cylinder block contain various sizes total 26 numbers of drill & which as listed below-

Ø5 mm = 12 nos., Ø6 mm = 4 nos., Ø14.4 mm = 10 nos.

This project concerns design & develop a gear box which carried out this drilling operation at a time on product (**product based design**).

Aims and objectives of the present work-

In this dissertation work it is proposed to carry out designing, developing and testing of gearbox for Multi-spindle drilling machine (SPM).

Objectives-

- To design a gear box by considering spindle speed is 650 rpm (Due to Universal joint).
- To develop a model of gear box in 'AUTOCAD'
- Develops a gear box (Manufacturing and assembly of different parts) as per the drawing in AutoCAD.
- Testing of gear box which operate Multi-Spindle Drilling machine of different diameter drill tools having sizes ø5mm, ø6.8mm and ø14.4mm, which simultaneously propagate on job at a specific speed and feed.

2. Estimation of Power and force requirement -

The first basic step of any engineering design is to calculate the power requirement enhance the appropriate electrical motor selection. To carry out the necessary motor selection it is mandatory to evaluate the thrust forces, speed calculations, and strength analysis design.

By taking initial inputs like numbers of spindles, speed (i.e. 650 rpm), size of the drill and material of component where operation is to be takes place to Estimation of Power and force is calculated. Here operations are carried out on cast iron component.

The total unit consists of 13numbers of drilling spindles in which drill sizes ø5mm, ø6.8mm and ø14.4mm, which simultaneously propagate on job at a specific speed and feed and where parameters like S-feed per revolution, material factor (k) is depend upon work piece material.

2.1) Cutting speed (V)-

a) For Ø 5 mm $V = \frac{\pi \times D \times N}{1000} = \frac{\pi \times 5 \times 650}{1000}$ = 10.210 m/min.

b) For Ø 6.8 mm = 13.885m/min.

c) For Ø 14.4 mm = 28.588/min.

2.2] Select the suitable feed (S) - which is depends upon the type of the material of the Work piece (C.I.). S-feed per revolution (mm/min),For the cast iron it is S= 65 mm/min.= 65/650 = 0.1mm/rev.

2.3] Select material factor (k) = 1.5

2.4] Power (P) in (kw) and force coming up on the spindle.

a) For Ø 5 mm drill having 6 nos.

$$P = \frac{1.25 \times D^2 \times k \times N\,(0.056 + 1.5\,S)}{10^5} = 0.0627 \text{ kw}$$

= 0.0627/0.746 = 0.08414 hp

Power for **6 nos.** of drill= (0.08414 × 6) = 0.5048 hp.

b) For Ø 6.8 mm drill having 2 nos. = 0.3112 hp.

c) For Ø 14.4 mm drill having 5 nos. = 0.3.4893 hp.

Therefore, total power required = 0.504816+0.3112+ 0.69785 = **4.3053 hp**

By considering 80% efficiency of whole system of gear box, Total power required = 4.3053/0.8 = **5.3816 hp**.

2.5] Torque (T) (kgf.m)= $\frac{975 \times P}{N}$

= 63.355 N.m

a) Ø 5 mm drill(6 nos.)- (1.238 × 6 nos. = 7.428 N.m).

b) Ø6.8 mm drill(2nos.)- **(**2.289 × 2 nos. =4.579 N.m)

c) Ø 14.4 mm drill (5 nos.)- (10.268 × 5 nos. =51.34 N.m)

2.6] Thrust force coming on the spindle, $= 1.16 \times k \times D \times (100 \times 0.15)^{0.85}$

a)Ø 5 mm drill=852.836 N

(For 6 nos. of spindle = 86.93 × 6 = 521.58 kg.f)

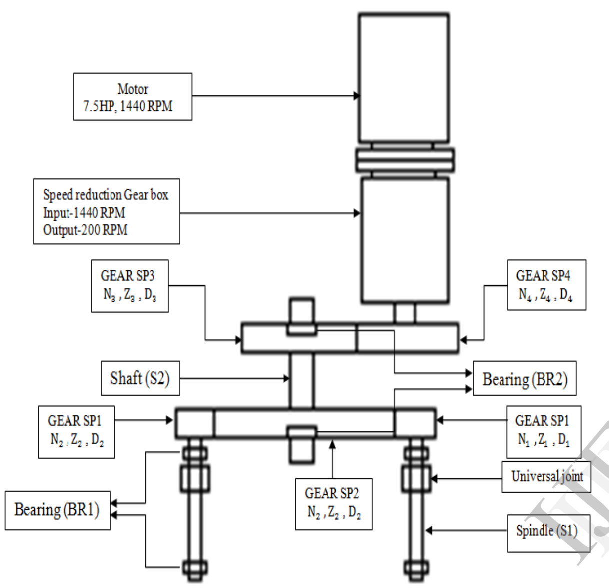
b) Ø 6.8 mm drill(2nos.)= 236.46 kg.f)

c) Ø 14.4 mm drill(5 nos) =1251.85 kg.f)

Total Thrust force = 2009.89 kgf

3. Selection of Motor- 3 phase induction motor of 7.5 hp and 4 poles at 1440 r.p.m.

4. Proposed Structure of Gear Train (one unit)



4.1 Meshing Gear Pair Design-

The motor which is selected on the basis of power require to drive all mechanism and it transmits to driven gear The motor speed is comparatively more than speed required for drill tools. So it is need to reduce the speed of motor and which is achieved by speed reduction gear box

There are total 13 number of spindles rotating with same speed (650 r.p.m.) with the help of main gear (SP2), Hence we have to consider diameter of the two gears .

Terminology used -

N = speed req. at spindle output= 650 r.p.m.

N_1= speed of smaller (SP1) gear & N_2 = speed of larger (Main - SP2) gear.

For the selection of gear material the desirable properties considered are-

-The gear material should have sufficient strength to resist failure due to breakage of tooth.

-The gear material should have sufficient surface endurance strength to avoid failure due to destructive pitting (surface failure).

-The material should have a low coefficient of friction to avoid failure due to scoring (thermal destruction).

Considering above factor above factors in mind the design experts from industries and design organization select the material of the gear as **EN36**, having Sut = 800 Mpa.

As per standard design data and experts from industry selected gear profile is 20˚ FDI (Full Dept of Involutes profile). For 20˚ pressure angle minimum number of teeth i.e. Z_{min}.(Theoretical) is 17 and Z_{min}. (Practical) is 14.

Due to required speed of spindle, the gear speed is also 650 r.p.m. i.e. N_1 and motor power is 5.595 kw.

-Pitch circle diameter (P.C.D.). of SP1 = 48 mm

-Pitch circle diameter (P.C.D). of SP2 = 195 mm

-Considering gear pitch circle dia.(D_1) is 48 mm

-Considering minimum numbers of teeth **(Z_1) = 18**.

a) Pitch line velocity(v)-

$$v = \frac{\pi \times dp \times Np}{60 \times 1000} = 1.6336 \text{ m/s}$$

b) Velocity factor (Cv)-for ordinary and commercially cut gear, $Cv = \frac{3}{3+V}$ = 0.6474

c) Estimation of module is based on beam strength-

A] Here the gear is considered as the beam hence module is based on beam strength.

Assume Cs = service factor =1.5

Fs = factor of safety

Zp = teeth on pinion

Np = speed of pinion in rpm

b / m = 10 (std.)

Y = Lewis form factor for 20˚ FDI system.

$$m = \left\{\frac{(60\times10^6\times P\times Cs\times Fs)}{(\pi\times Zp\times Np\times Cv\times(b/m)\times(Sut/3)\times Y)}\right\}^{(1/3)}$$

m = 2.733, Hence preferred **module is 3**.

Based on the module the face width, addendum, deddendum, clearance, tooth thickness is evaluated as given below:

d) Face width (b) = m $\times$ 10 = 3 $\times$ 10 = 30 mm

e) Data

1) For **Gear SP1**-Number of teeth on pinion.

$Z_1 = Z_p = D_1$/ m = 48/3 =**16,** Speed(N_1) = 650 r.p.m.
PCD(D_1)=48mm

2) For **Gear SP2**-

Z_2 = Zg = D_2 / m = 195/3 = 65

Speed (N_2) =160 r.p.m., PCD (D_2) =195 mm

3) For **Gear SP3**-

Gear SP2 & SP3 are coaxial (as shown in figure).

$N_2 = N_3$= 160 r.p.m., PCD (D_3) =165mm

Numbers of teeth (Z_3) =55.

4) For **Gear SP4**-

By using ratio, $N_3 \times D_3 = N_4 \times D_4$

N_4= 200 r.p.m., PCD (D_4) =132 mm

Numbers of teeth (Z_4) = (D_4 / m) = 44.

f) Addendum = 2 $\times$ m = 6mm

g) Deddendum = 1.25$\times$m = 3.75mm

h) Tooth thickness = 1.5708$\times$m = 4.7124mm

i) Fillet radius = 0.4$\times$m = 1.2mm

4.2 Gear Pair Design-

A) Consider between gear SP4 and gear SP3-

From power requirement, torque and thrust forces calculations motor selection is done also speed reduction is taksplace with help of speed reduction gear box and getting output speed i.e. 200 r.p.m.

A_1) Static Load on Gear-

a) Now it is require to calculate Torque transmitted (Mt) by gear SP4,

$$Mt = [\frac{(60\times10^6\times P)}{(2\times\pi\times Np)}] = 267141.57 \text{ (N.mm)}$$

b) Tangential load (Pt)

$$Pt = \frac{(2\times Mt)}{D_4} = \frac{(2\times267141.57)}{(132)} = 4047.59\ N$$

The above values of tangential component, therefore, depend upon rated power and rated speed. In addition to this there is dynamic load. There are two methods to account for dynamic load approximate estimated by means of velocity factor in primary stage of gear design and precise calculation by Spotts equation in final stages.

A_2) Effective Tooth Load-

c) The preliminary stages Effective tooth load (Peff)-

$$V = \frac{\pi\times D_4 \times N_4}{60 \times1000}, V = \frac{\pi\times 132 \times 200}{60 \times1000}$$

V=1.3823m/s …….. (Pitch line velocity)

$$Cv = \frac{3}{3+V} = \frac{3}{3+1.3823} = 0.6845 \text{ (Velocity factor)}$$

d) Effective tooth load (Peff)-

$$Peff = \frac{Cs\times Pt}{Cv} = \frac{1.5\times 4047.59}{0.6845} = 8869.83\ N$$

e) Beam strength $(Sb) = m\times b\times 6b\times Y$

$= m^2\times$ (b/m) $\times$(Sut/3) $\times$Y = 9528.01 *N*

f) To avoid the tooth failure due to bending

Sb > Peff

Sb = Peff $\times$ Fs, $Fs = \frac{9528.01}{8869.83} = 1.07$

Gear pair Design is safe.

A_3) Dynamic Load on Gear -

In the final stage of equation of gear design, when gear dimensions are known, Error specified and quality is determined. We will select finer grade for the manufacture to reduce the dynamic load because it is essential to get design satisfactory both from stand point of strength and wear. The error depends upon the quality of the gear and method of manufacture. Here assumed that gears are manufacture to meet the requirement of grade 6.

Dynamic load is calculated by Spotts equation,

g) Dynamic load -

$$Pd = \frac{21v((C\times e\times b)+Pt)}{21v+((C\times e\times b)+Pt)}$$

e = error in tooth profile of gear

e = $8 + 0.63\times (m + 0.25\sqrt{D})$= e4 + e3

For gear SP4-

$e4 = 8 + 0.63\times (m + 0.25\sqrt{D_4})$

$= 8 + 0.63\times (3 + 0.25\sqrt{132})$, e4 = 7.3489 (µ)

For gear SP3-

$e3 = 8 + 0.63\times (m + 0.25\sqrt{D_3})$= 7.4845(µ)

e = e4+e3 = 14.83 (µ)

Now,

$$Pd = \frac{21\times 1.3823[(11400\times 14.83\times 10^{-3}\times 30)+4047.59]}{21\times 1.3823+\sqrt{[(11400\times 14.83\times 10^{-3}\times 30)+4047.59]}}$$

Pd = 2125.87 N

Now, Effective load,

Peff = (Cs × Pt) + Pd = (1.25 × 4047.59) + 2125.87

Peff = 8197.25 (N)

And, Sb = Peff × Fs

$$Fs = \frac{9528.01}{8197.25} = 1.1623$$

Gear pair design is safe.

A_4) Surface Hardness -

h) Wear strength (Sw) = Peff × Fs = 8197.25 × 2

Sw = 16394.5(N)

But ,Sw= b×Q×dp×K

$$Q = \text{ratio factor} = 2\times \frac{(Z3)}{(Z4+Z3)} = 2\times \frac{(55)}{(55+44)}$$

Q = 1.1111

And the value of K = 0.16 × $(BHN / 100)^2$

Now equation becomes,

16394.5= 30×1.111×132×0.16 × $(BHN / 100)^2$

BHN= **482.59**

Required Hardness is 482.59.

B) Consider gear pair design between gear SP2 and gear SP1

Static load= 333926.96 N.mm,Pt=3424.89 *N*

Beam strength=10200.01*N*

$$Fs = \frac{10200.01}{7934.78} = 1.2854$$

Gear pair Design is safe.

4.3 Shaft Design

For the selection of gear material, the shaft material should have sufficient strength to resist failure due to breakage, provide rigidity and gives more stability.

Considering above factor above factors in mind the design experts from industries and design organization select the material of the gear as EN353, Hence we have also selected the same material of construction for all the gears of our SPM gear box.

So, for getting more rigidity and stability as well as industrial design experts suggestion we are **taking diameter (D_1) is 30 mm** having 300 mm length and **taking diameter (D_2) is 55 mm** and consider 225 mm length ,also torsional rigidity (G) =79300 N/mm^2. Actual angle of twisting for both shaft is less than 0.25^0.

(Where, The permissible angle of twist for machine tool applications is 0.25˚per meter length)

From above calculation, it is found that **design of shaft S1 and S2 is safe.**

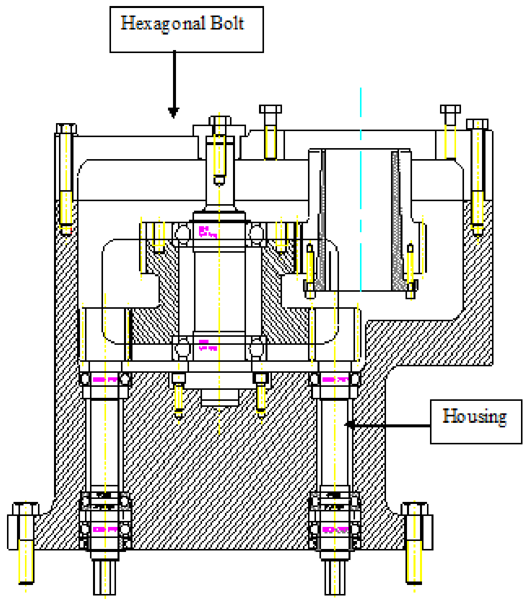


Fig.3 Actual Gear Train

5. Gear Box Housing and Accessories-

Gear box housings or casings are containers in which the internals, namely the gears, shafts, pinion shafts, bearings, oil seals, bearing covers and other components are mounted.

The prerequisites for a reasonably free, long lasting, non-jamming, vibration free and efficient load transmitting gear-drive are proper mounting and alignment of the bearings, maintenance of the correct centre distance and provision of lubricating arrangements ensuring proper and regular supply of lubricants, besides other factors. Closed gear box housings, if properly-designed, can achieve such objectives.

5.1 Material of Gearbox Housing-

- As material for gear box casings, good quality cast iron is used in most of the cases. Steel castings or light metal castings are also popular, but they are used in special cases. Fabricated housings are also not uncommon.

- Cast iron housings have good damping properties and freedom from noise.

- Grey cast irons possess high compressing strength, fatigue resistance and wear resistance.

- Presence of graphite in grey cast irons impart them very good vibration dumping capacity.

- In spite of the fact that patterns are required for such housings, it often pays to use CI castings, even when small numbers are required, because the initial costs for patterns are nullified in the long run.

- Steel castings, which are obviously much costlier than CI housings, are used only in those cases where CI casings are not strong enough to withstand the operational stresses involved Because of their lighter weight, light metal housings are usually used in automotive applications.

Gear housings are also made of fabricated, welded steel plates and sections. Housings of this type are recommended for a single piece or for very small number of pieces. For very big housings, the cost of pattern is saved if fabricated design is used. The welded construction also affords the designer to reduce weight of the housing considerably. Noise & damping property, however, is not as good as that of the CI casting. Fabricated casings are often provided with ribs for extra strength. They must be heated to relieve thermal stresses.

A gear box housing in general consists of two halves—the upper half and the lower half. The plane of separation of the two halves also normally contains the axes of the shafts and bearings. Such arrangement facilitates easy mounting and dismantling of shafts and bearings.

5.2 Gear Box Bearings -

Depending on the type of design, size and operational parameters of the gear box, both antifriction bearings and journal bearings are used. Anti-friction bearings are mainly suitable for gear drives with small and medium loads and speed. These bearings require little maintenance and their starting resistance is negligible. They are lubricated by grease or by gear oil, depending on the overall design. Deep groove ball bearings are mostly used because they can take both radial and axial loads. Cylindrical bearings are suitable when only radial loads are encountered. For high radial and axial loads, self aligning spherical ball or roller bearings as well as tapered roller bearings are generally used.

5.3 Mounting-

Motor & Reduction gear box, design of bolt use for mounting of motor and speed reduction gear box, Assembly of idler shaft in to housing; Oil Seals, External Circlip, Taper lock bush, Idler guide bush etc are mounted at required specific location.

6 Lubrication-

Lubrication selection

Machine tool generally work to high degree of accuracy and are expected sustain this accuracy over a long period. This requires proper control of friction and wear of parts which are in relative motion and cells for the effective lubrication of the vital elements like gear bearing, guide bar, etc.

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

The most commonly used lubrication in machine tools-

1. Oil
2. Grease
3. Solid lubricants

A proper choice of lubricants is depends upon the mode of lubrication. Operating conditions like sped, load, lubricant properties surface are governed more by the chemical properties of lubricants rather than the physical properties of lubricants, like viscosity.

The general choice of lubricants is between oil and grease.

Advantage of grease over oil lubricants-

1. Simplicity in system design.
2. Easy sealing arrangements.
3. Easy retain in housing.
4. Low maintenance and initial cost.

Disadvantage of grease over oil lubricants-

1. Poor cooling properties.
2. Not suitable for high speed application.
3. Retain dirt and wear debris.

6.1) Spindle oil- For the spindle the low viscosity member oil corrosion, anticorrosion, anti wear and oxidation properties is used. This is used for all spindle bearings lubrication and suitable for all types of lubrication system.

6.2) Gear oil-

Oil used for gear lubrication must have high viscosity index and adhesion property. The important factor in selection of gear oils its viscosity. Viscosity is decided depending upon pith line velocity. For high speed application low viscosity oil should be and vice versa.

Thicker oil film give higher film thickness that is it can be prevented matal to metal contact their by reducing the possible wear. On the other hand from the point of view of cooling an oil of low viscosity is desired. When a gear box is fitted with number of gear , it is suffer to be based on the selection of lubricants viscosity on the slowest and mostly heavily loaded elements.

6.3) Bearing oil-

Purpose of lubrication –

1. To reduce friction and wear between the sliding part of bearing.
2. To prevent rusting and corrosion of bearing surface.
3. To protect the bearing surface from water, dirt etc.
4. To dissipate heat.

When the temperature is less than 100 C the grease is used, while lubricating oil is suitable when the temperature exceeds above 100 C. Calcium based grease should be used. If there is possibility of moisture content then potassium or sodium based grease may be used.

Another additional advantage of grease is that if forms as eal to keep out dirt of other foreign substance.

6.4) Guide bar and bushes-

The mode of lubrication here is the boundary lubrication. Science the housing and jig plate has to slide to slide smoothing over the guide bar oil.

Advantages of oil lubricants-

- Carries away dirt, wear, debris etc.
- Suitable for wide operation condition.
- Easy to drain and refill.
- Co-efficient of friction and frictional torque s low.

7 Manufacturing & Assembly

7.1) Manufacturing-

While designing the gear box for special purpose machine, designers are applying knowledge based ergonomic system in the design task in order to reduce required machine design time, improve machine design efficiency, and eliminate possible human errors. Ergonomics and human factors researchers have made great contributions to the safety, productivity, ease of use, and comfort of human machine environment systems.

The parts like bearing, bolts, screws, tapper lock bush, circlip etc. are available in standard specifications can produce.

The part like housing, cover plates, gears, spindles, shafts etc. are manufactured as per the drawing specifications by different methods like casting or fabrication.

7.2) Assembly-

All component of machine should be made and assembled considering technical issues. These parts should be sufficiently rigid and equipped with special dampers in order to minimize vibrations resulting from the operation of cutting tools. Generally, thick steel plates and cast iron are used for machine table. Cast irons have good damping character, and therefore, are used for making the machine table to reduce vibrations. In addition, a properly designed coolant system should be used to enhance the lives of cutting tools as frequent tool changes increase machining costs.

Then, based on detailed engineering drawings installation of stands, supports, motor, speed reduction box, gear box, housing, spindles, shafts, machining units, sliding units, indexing table and coolant system are performed. Installation electric power systems for electric power supply to electro-motors and finally, the control systems are all performed at this stage. Upon completion of previous steps, gear box performance is measured by carrying out the operation on product.

6.3) Assembly process-

1. Clean all parts like spindles, gears, plates, housing, spindles, shafts and bearings.

2. Check all parts as per drawing.

3. Mount the motor and speed reduction unit on housing.

4. Place taper bush in between reduction gear shaft and gear.

5. Place the idler shaft where main gear is mounted in gearbox housing.

6. Around the main gear total 13 gears are mounted.

7. Place all gears in housing hub from which spindles are coming towards outside, where external circlip are mounted for lock as well as support to spindles.

8. Press ball bearing with pair on main spindle and required locations.

9. Fill gear oil and grease.

10. Fit the all cover plates.

8 Testing Of Gear Box -

8.1) Results and discussion-

For Ø 5mm and Ø 6.8mm drill, operation is carried out by HSS drills i.e. high speed steel drill and Ø 14.4 mm drill operation is carried out by HSCO drills i.e. high steel cobalt drill because of required high cutting speed.

1) Operations on component – SUMP FACE AND CAP DRILLING.
2) Component of material – gray cast iron

PARAMETERS	UNIT	UNIT A	UNIT B	UNIT C
OPERATION	-	DRILLING	DRILLING	DRILLING
TOOL MATERIAL	-	H.S.S.	H.S.S.	H.S.S.
TOOL DIA	mm	5	6.8	14.4
CUTTING SPEED	m/min	10.2	13.885	28.588
SPINDLE SPEED	R.P.M.	650	650	650
TOOL TRAVEL	mm	60	60	60
FEED / REV.	mm	0.1	0.1	0.1
MACHINING TIME	Sec.	55	55	55
TOTAL TIME	Sec.	55	55	55

8.2) Noise and Vibration Measurement-

Prior to the selection and design of control measures, noise sources must be identified and the noise produced must be carefully evaluated. Procedures for taking noise measurements in the course of a noise survey. To adequately define the noise problem and set a good basis for the control strategy, the Following factors should be considered:

- Type of noise
- Noise levels and temporal pattern
- Frequency distribution
- Noise sources (location, power, and directivity)

The need for control or otherwise in a particular situation is determined by evaluating noise levels at noisy locations in a facility where personnel spend time. If the amount of time spent in noisy locations by individual workers is only a fraction of their working day, then local regulations may allow slightly higher noise levels to exist. Where possible, noise levels should be evaluated at locations occupied by workers' ears.

The noise which is generated by gear box and machine is measured with help of digital sound level meter and it's comes in between 70-75 dB.

Vibration measurement-

An active internal gearbox structure is developed and evaluated experimentally to suppress gear pair vibration due to transmission error excitation. The approach is based on an active shaft transverse vibration control concept that was theoretically analyzed in an earlier study and determined to be one of the most feasible methods.

The pair assembly remains one of the major noise and vibration sources in power transmission systems typically used in automotive, aerospace and industrial applications. The gear vibration and noise signatures are often dominated by several high-level tonal peaks that occur at the fundamental gear mesh frequency (given by the product of the shaft speed and number of gear teeth) and its harmonics.

Vibration is tested by using vibrometer. Compact vibrometer is meant for checking vibration level and diagnostics of defects of rotary equipment. It also permits to measure general vibration level. Vibrometer registers signals in dimension of acceleration, velocity and displacement with the help of built in or outside sensor. With the use of outside sensor, which is placed on the controlled equipment by the help of magnet or with the using probe, vibrometer can make a complex measuring. Where vibration coming by machine and gearbox as per allowated range(10 *Hz*-1000 *Hz*) or in safe region.

8.3) Comparison-

Parameters	Conventional Machine	MSD MACHINE
Machining time	high	low compare to CM
Operational time	large	Less (95 sec.)
Job Handling	Required	Not required
Work Quantity	Less in large time	Large in less time
Large Production	Cannot achieved	Can be achieved

Conclusion-

The MSD machine is fabricated and satisfactorily commissioned. Any saving done due to use of advanced manufacturing technique directly contributes to the net profit of the product. The following satisfactory conclusion is drawn after completion design, installation and commissioning of the SPM and which is achieved by gearbox which handle multi-spindle drilling tools.

Due to multi-spindle drilling machine-

1) Smooth or noise less operation due to spur gear box.
2) Reduction in cycle time.
3) As compare with conventional machine less operational time as well as Job Handling is required.
4) Productivity has improved in both ways that is qualitative and quantitative. Special purpose machine is necessary for improving the production.
5) MSD machine produces numbers of holes are drilled on the on same work piece with required accuracy and tolerances to be maintained, which is difficult to obtain by using radial drill machine. Also rate of production justify the additional cost involved in multi drilling machine. Also it has improved the repeatability, accuracy and less rejection, due to accurate automation.

6) This reduces the labour cost. Hence MSD machine increases the production rate; reduced production cost, and reduced labour cost which minimizes the production cost.

It's reflects that gear box which handle MSD machine plays an important role for achieving more production rate within less time, less effort and less handling in right cost.

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