Design Analysis of Gear in Horizontal Milling Machine

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Abstract- In this paper, speed changing system for Horizontal Milling Machine (low speed position) is designed. In machine tool applications, the variety of speed are very important because of the cutting conditions. Cutting conditions, specially cutting speed, and feed speed depend mainly on the machined material properties and the surface finish accuracy. The purpose of a gearbox system is to convert input speed and torque into a different output speed and torques. The transmission consists of a train of gears of different size contain in a case. This paper emphasizes on the design consideration of speed changing system of gearbox for horizontal milling machine which has three speed two steps gear ratio. This gearbox is designed to transmit the power of motor. The maximum power is 2.2 kW at 1430 rpm. In this paper, the analyzing and designing of gears results are expressed. In gear design, the number of teeth, face width, gear teeth features and pitch diameter are calculated by using Lewis equation.

Keywords— horizontal milling machine, gearbox, transmission, gear teeth.

I. INTRODUCTION

A milling machine is a power driven machine that cuts by means of a multitooth rotating cutter. The mill is constructed in such a manner that the fixed workpiece is fed into the rotating cutter. Varieties of cutters and holding devices allow a wide range of cutting possibilities.

Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting tool, which is called a milling cutter and the cutting edges are called teeth. Unlike lathes, which have been known for thousands of years, milling machines are less than two hundred years old. Because they require much more power than hand-driven lathes, their introduction had to wait for the invention of industrial water and steam power. Also, all their mechanical components had to first be made available, such as accurately fitted slides, large castings to resist cutting forces, calibrated leadscrews, and hardened steel cutting tools. Mills are classified on the basis of the position of their spindle. The spindle operates in either a vertical or horizontal position. The amount of horsepower the mill is able to supply to the cutter is also often important.

II..HORIZONTAL MILLING MACHINE

Horizontal milling machine have a spindle or cutters mounted on a horizontal arbor above an X-Y table. Some horizontal mills have a table, known as universal table that features a rotary function for machining at different angles. Horizontal mills are optimal for machining heavier pieces because the cutters have support from the arbor, as well as a bigger cross-section area than a vertical mill. The design of the horizontal milling machine allows for the rapid removal of material off of the piece one is machining. These types of milling machines can range in size from something small enough to fit on a tabletop to room-sized machines".

1.1 Milling Machine Operation

Milling is the removal of metal by feeding the work past a rotating multitoothed cutter. In this operation the material removal rate (MRR) is enhanced as the cutter rotates at a high cutting speed. The surface quality is also improved due to the multicutting edges of the milling cutter. The action of the milling cutter is totally different from that of a drill or a turning tool. In turning and drilling, the tools are kept continuously in contact with the material to be cut, whereas milling is an intermittent process, as each tooth produces a chip of variable thickness.

1.2Horizontal Milling Machine Gearbox

In speed changing system of horizontal milling machine gearbox is used six speed two step gearbox (multispeed gearbox). In this gearbox consists of three shafts, input, counter and output shaft. They are parallel. The motor power is sent to the input shaft. The main point to be noticed is that the gears on the input shaft are fixed to the shaft but the gear on the counter shaft can slide across the shaft on splines horizontally. The gears can be moved using the selector fork mechanism that pushes the gears. In this gearbox first, second and third speed sliding mesh type. For all speed high and low speed gears are fixed on the output shaft

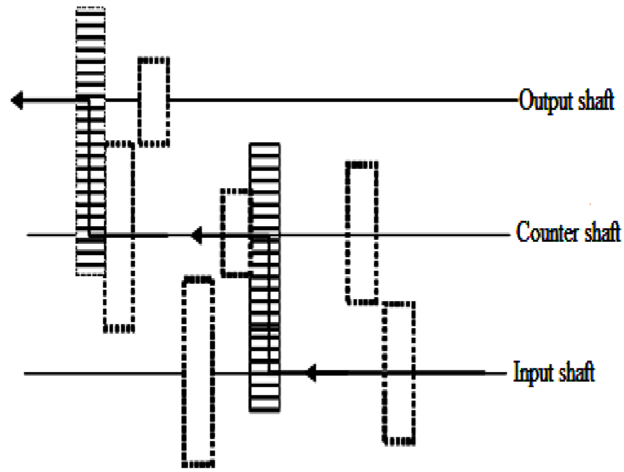

Fig.1 First Gear Low Speed Position

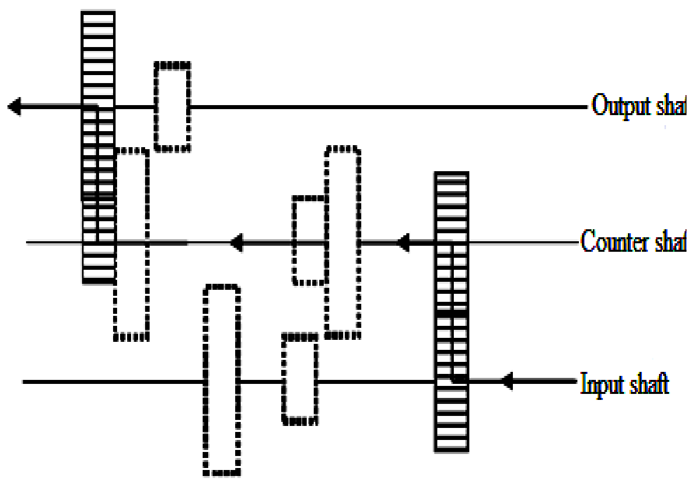

Fig.2 Second Gear Low Speed Position

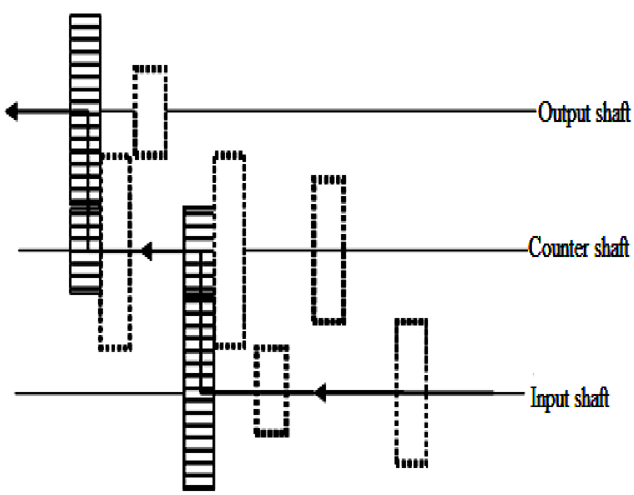

Fig.3 Third Gear Low Speed Position

III. DESIGN ANALYSIS IN GEAR

Type of gear = Spur gear
Teeth depth, Ø = 20°
Velocity ratio, VR = 1.966
Pinion speed, p = 340.476 rpm
Number of teeth of pinion, np = 29
Ultimate strength, Su = 2220 MP_a

Yield strength, Sy = 2170 MP_a

Endurance strength, S_0 $= \frac{S_u}{3} = 740$ MPa

Module of elasticity, E = 207 GPa
BHN = 627

All gears and pinion are made up of AISI 5160 OQT 400 (same material). The design weak occur on pinion. Therefore design is based on pinion.

Transmission power = 2.2 kW

Torque , $$M_t = \frac{9550 \times kW}{rpm}$$
=61.7 Nm

Unknown diameter case,
n_p =29, y = 0.113

Induce stress, $$S_{ind} = \frac{2M_t}{k\pi^2 ynm^3}$$

$$= \frac{0.954}{m^3}$$

$$S_0 = \frac{1}{3} S_u$$

$$= 740 \times 10^6 \text{ Pa}$$

$$S_{ind} = \frac{S_0}{2}$$

$$= \frac{740 \times 10^6}{2}$$

$$370 \times 10^6 = \frac{0.954}{m^3}$$

m =1.37 mm

Standard Module Series
Preferred ; 1,1.25,1.5,2,2.5,3,4,6
Second choice; 1.125,1.375,1.75,2.25,3.5,4.5,5.5
Try m = 1.375 mm

$$\frac{D_p}{n_p} = 1.375$$

D_p = 39.875 mm

$$V_p = \frac{\pi \times D_p \times N_p}{60}$$

= 0.71 m/s < 10 m/s

$$S_{all} = S_o \left[\frac{3}{3+V} \right] \text{ for velocity } < 10\text{m/s}$$

$= 1042.24\ MP_a$

$$S_{ind} = \frac{0.954}{m^3}$$

$= 366.97\ MP_a$

$S_{ind} < S_{all}$

Design is satisfied

Try m = 1.25 mm

$$\frac{D_p}{n_p} = 1.25$$

$D_p = 36.25$ mm

$S_{ind} < S_{all}$

Design is satisfied

Reduce k, $k_{red} = 4 \times \frac{S_{ind}}{S_{all}}$

$=3.2$

Face width, $b_{min} = k_{red} \times \pi \times m$

$=12.6$ mm

$b_{max} = k_{max} \times \pi \times m$

$= 15.707$ mm

Tangential force, $F_t = \frac{2M_t}{D_p}$

$= 3404.14$ N

V= 0.65 m/s permissible error = 0.16

First class commercial error = 0.05

$C = 570\times10^3$ N/m

Dynamic force ,

$$F_d = F_t + \frac{21V(bC + F_t)}{21V + \sqrt{bC + F_t}}$$

$=4730.91$ N

the endurance load, $F_0 = S_0 by\pi y$

$= 4925.62$ N

$$VR = \frac{D_g}{36.25}$$

$D_g = 71.29$ mm

$$Q = \frac{2D_g}{D_p + D_g}$$

$= 1.32$

$S_{es} = (2.75\times BHN) - 70$

$= 6.46\times 10^6$ Pa

Specification	Gear	Pinion
Material	AISI 5160 OQT	AISI 5160 OQT
Yield strength, S_y (MP_a)	2170	2170
Ultimate strength, S_u (MP_a)	2220	2220
Endurance strength, S_0 (MP_a)	740	740
Module of elasticity, (N/m^2)	207×10^9	207×10^9
BHN	627	627
No of teeth	57	29
Pitch diameter, D (mm)	78.36	31.625
RPM	173.18	340.476
Speed ratio, V.R	1.966	1.966
Module ,m	1.25	1.25
Face width, b (mm)	15.707	15.707

$$K = \frac{S_{es}^2(\sin\phi)}{1.4}\left[\frac{1}{E_p} + \frac{1}{E_g}\right]$$

$=6.45$ MPa

the wear load, $F_w = D_p bKQ$

$= 4636.66$ N

$$\%\ error = \frac{F_d - F_w}{F_d}$$

$= 0.019 = 1.9\%$

Permissible error from velocity = 16%

$= 1.9\% < 16\%$

Table 1.Design Data For First Speed Gear Mesh

Table 2 Strength check and Dynamic check for first speed gear Mesh

Strength check $S_{allowable}$ (MPa) S_{ind} (MPa)	608.22 488.448 $S_{all} > S_{ind}$
Dynamic Check Endurance Force, F_o(N) Wear Force, F_w(N) Dynamic Force, F_d(N)	4925.62 4636.66 4730.91 $F_o > F_d, F_w < F_d$ % error = $\frac{F_d - F_w}{F_d}$ =1.9% < 16%

Table.3 Design Data For Second Speed Gear Mesh

Specification	Gear	Pinion

Strength check $S_{allowable}$ (MPa) S_{ind} (MPa)	 462.5 335.71 $S_{all} > S_{ind}$
Dynamic Check Endurance Force, F_o(N) Wear Force, F_w(N) Dynamic Force, F_d(N)	 5064.239 4688.77 4053.66 $F_o, F_w > F_d$

Material	AISI5160 OQT400	AISI5160 OQT 400
Yield strength, S_y (MP_a)	1790	1790
Ultimate strength, S_u (MP_a)	2220	2220
Endurance strength, S_0 (MP_a)	740	740
Module of elasticity,E (N/m^2)	207×10^9	207×10^9
BHN	627	627
No of teeth	46	40
Pitch diameter, D (mm)	57.5	50
RPM	296.07	340.476
Speed ratio, V.R	1.15	1.15
Module ,m	1.25	1.25
Face width, b (mm)	15	15

Table.4 Strength check and Dynamic check for Second speed gear Mesh

Specification	Gear	Pinion
Material	AISI 5160 OQT 400	AISI 5160 OQT 400
Yield strength, S_y (MP_a)	1790	1790
Ultimate strength,S_u(MP_a)	2220	2220
Endurance strength, S_0 (MP_a)	740	740
Module of elasticity,E (N/m^2)	207×10^9	207×10^9
BHN	627	627
No of teeth	59	27
Pitch diameter, D (mm)	73.74	33.75
RPM	339.69	742.237
Speed ratio, V.R	2.185	2.185
Module ,m	1.25	1.25
Face width, b (mm)	15.7	15.7

Strength check $S_{allowable}$ (MPa) S_{ind} (MPa)	 545.454 323.584 $S_{all} > S_{ind}$
Dynamic Check Endurance Force, F_o(N) Wear Force, F_w(N) Dynamic Force, F_d(N)	 5387.67 5127.75 4410.72 $F_o, F_w > F_d$

Table.5 Result data for third speed gear Mesh

Table 6.Strength check and Dynamic check for Third speed gear Mesh

IV.CONCLUSION

In this paper, the speed sliding mesh gearbox is designed. The maximum power of the motor is 2.2 kW and the maximum revolution of the motor is 1340 rpm. In designing of the gear, design satisfactions of all gear are checked by its dynamic load that induced to gear by the transmitted torque. For the safety of the gears in normal operation condition, the static load and the wear tooth loads of all gears must greater than that of the dynamic load. The strength check wear also carried out to get the gear parameters. The gear designs wear satisfied not only from the strength but also from the dynamic point of view. Gear is designed with AISI 5160 OQT 400 heat treated alloy steel, which has brinell hardness 627, yield stress 1790 MPa and ultimate stress 2220 MPa. The require design calculation of gears can also be calculated through both strength and dynamic check.

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