

Customised Speed Reduction for SB CNC 60N Lathe

R. Rangarajan¹, Ferguson Aissac Fredric², Mohamed Shaheen³, Mansoor Khan V B⁴, Galil Johnson⁵,
Vishnu H⁶.

DGM (Design & Development), HMT Ltd. Kalamassery, Kerala, India¹.

Assistant Professor, Department of Mechanical Engineering, KMEA Engineering College, Edathala, Kerala, India²

U.G. Students, Department of Mechanical Engineering, KMEA Engineering College, Edathala, Kerala, India^{3,4,5}

U.G. Student, Department of Mechanical Engineering, Mahendra Institute of Technology, Salem, Tamil Nadu, India⁶

ABSTRACT: The SB CNC 60 N lathe is a new lathe produced by HMT Ltd Kalamassery. It has a spindle power of 22KW and a speed range of 50-2500rpm. The constant power 22KW is not obtained at lower speeds for the existing machine and it is prone to spindle run out due to development of heat. The solution is to design a separate gear box so that the power can be transmitted to spindle through a belt pulley arrangement. The design phase consists of the design of input and output shaft with splines, gears, belts, bearing, pulley and key. The gear design was carried out based on the ray diagram which was derived so that a constant torque of 1850Nm is obtained at 150 rpm. The ray diagram has been derived following the R20 series. It was found that at least a minimum of 28 kW motor has to be used to get a minimum rpm of 150. The Fenner and Bando catalogue was used in design of V belt, Fag catalogue for the design of bearings, and Siemens catalogue was used for selection of motor to satisfy the industrial standard. The design of other components had been carried out by referring various reference texts, data books and journal papers. Accuracy and stability has been increased by designing an optimal gear ratio and also implementing high precision bearings.

KEYWORDS: Speed Reduction, Two Stage Gear Box, V-Belt, Constant Torque.

I. INTRODUCTION

SB CNC 60 N is a new CNC lathe manufactured by HMT Ltd Kalamassery. It has a rapid traverse of 24m/min for both X and Y axis with linear movement guide ways and a 22 kW spindle motor. It has 12 turret indexing positions (Bi-directional Random). It has a slant bed which makes 20° angle to the vertical axis. It has a swing over bed diameter up to 600mm and maxing turning diameter of chucking jobs up to 550mm. It has a weight of 12000kg. It has a spindle speed range of 50-2500rpm. It has a feed range of 1-8000mm/min. It uses a Sinumerik 828D CNC Control system with diagnostic for fault identification. It can do turning, contour making, drilling, boring, threading (both internal and external). It has accuracies of following: 1. Positioning: X-Axis 0.015mm, Z-Axis 0.015mm 2. Repeatability: X-Axis 0.007mm, Z-Axis 0.007mm.

The machine needed to produce 1850 Nm @ 150 rpm so that threading and bigger diameter jobs can be done with acceptable accuracies. We found that a minimum of 28 kW motor has to be used to satisfy the above requirement. To reduce the speed at constant power we adopt for a two stage gear box. Faisal S. Hussain^[2] has described how to optimise the gear reduction unit through ray diagram. He focuses on developing a design space which is based on module, pinion and teeth by using simple logical statement in computer software. Puttapaka Nagaraju^[3] has investigated the characteristics of an involute helical gear system mainly focused on bending stress using solid works simulation. He also explains about basic steps for the modelling and design of 2-stage gear box. Bader Abuid and Yahya Muhammed Ameen^[4] have explained how to optimise the design of a two stage spur gear system. They have given various optimum values for various constants and other constituents used in the design procedure. S Mahendran, K.M Eazhil, L.senthil kumar^[5] has explained the use of different materials and their composition for the use of gear

design .The comparison of different materials and studying the impact analysis for cast iron and composite material.S Khurumi^[6] has well explained the basic design details for manufacturing process in his book on machine design. He has also given the steps for manufacturing of various parts like spur gear, bearing etc. R K Benzal ^[7] has also explained about the basic design details and load calculation to find the reaction and support loads at each point on shafts and journals. V B Bhandari ^[8] has explained the basic design procedure and the steps for manufacturing of various parts required like shafts, keys etc. In his book “Design of Machine Elements” most of the formulae’s and assumptions used in our design process is taken from this book and also referring PSG data book. L.T.C. Rolt ^[1] has given a detailed description of the history of machine tools and their working is also explained in his book “A short History of Machine Tool”.

The design phase consists of the various sections. First one is the selection of motor. Second one is the selection of V-belt and pulley. The final sections 3, 4, & 5 deals with the design of gears, shafts, bearings & keys respectively.

II. DISCUSSION

The proposed system is as follows

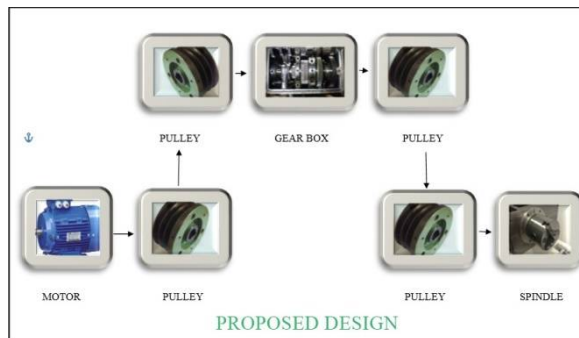


Fig. 1: Proposed system.

Selection of motor is carried out by using the equation

$$P = \frac{2\pi NT}{60} \tag{1}$$

Where,

T=18750 Nmm. and Minimum speed=150 rpm.

Minimum motor power obtained is 28KW

A motor is selected from SEIMENS catalogue as given in fig 2.

Rated speed	Shaft height	Rated power	Rated torque	Rated current	Rated voltage	Rated frequency	Operating speed during field weakening, max. ¹⁾	Speed, max. ²⁾	1PH8 asynchronous motor Forced ventilation
n_{rated} rpm	SH	P_{rated} kW (HP)	M_{rated} Nm (lb _f -ft)	I_{rated} A	U_{rated} V	f_{rated} Hz	n_2 rpm	n_{max} rpm	Order No.
Line voltage 400 V 3 AC, Smart/Basic Line Module									
1000	160	22 (29.5)	210 (155)	55	300	34.2	2800	6500	1PH8163-1 D... 1
		28 (37.55)	267 (197)	71	292	34.2	4600	6500	1PH8165-1 D... 1

SIEMENS synchronous motor Catalogue

Fig. 2: SEIMENS synchronous motor catalogue.

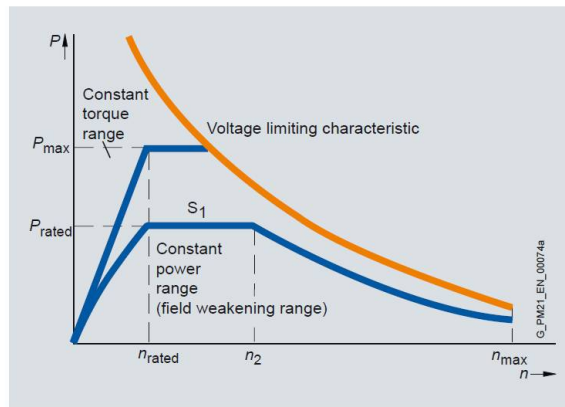


Fig. 3: Speed characteristics curve of motor.

From the speed characteristics of motor, the constant power and speed range are obtained as 1000 to 4600rpm. In order to reduce the above rpm to our required range, a two stage gear box is introduced by drawing a suitable ray diagram through iteration.

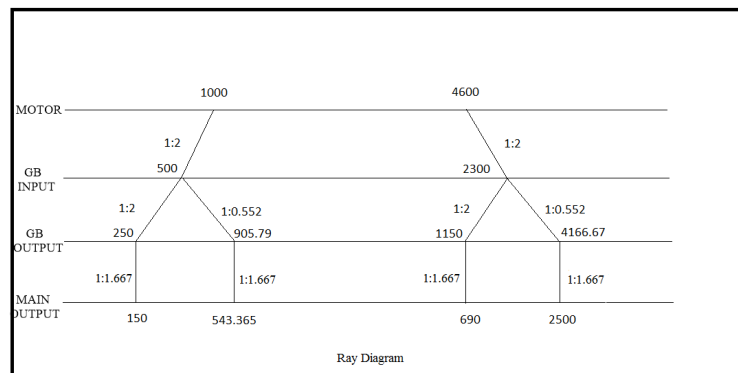


Fig. 4: Ray Diagram

From the above Ray diagram, V-Belt pulley assembly is used to provide a speed reduction of 1:2 from motor to gear box. In gearbox there are two speed ratios (1:2 and 1:0.552) to vary the speeds. There is another V-Belt pulley assembly to provide speed reduction from to gear box to spindle with a ratio of 1:1.675.

III. METHODOLOGY

Design of Gear Box

The gearbox consists of two gear pairs, input and output shafts, bearings and also the design of V-Belt and pulley should be done to complete the driving mechanism from motor to spindle.

GEAR PAIRS

The design of gear pairs to give the desired speed ratio should be done carefully. The various parameters like number of teeth, module, pitch diameter, clearance, whole depth etc. are calculated by referring PSG Data book and the Design of Machine Elements by V.B. Bhandari.

$$^{[10]} \text{Module, } M = 1.26 \sqrt[3]{\frac{[Mt]}{y \cdot \sigma \cdot \phi_m \cdot Z_2}} \tag{2}$$

Where y, ϕ_m are selected from PSG data book
 From above equation, module is obtained as 4mm.

Table 1: Specifications of gear pair 1

	Wheel	Pinion
Material	40NiCr1Mo25	40NiCr1Mo25
Diameter	244mm	124mm
Number of Teeth	61	31
Module	4mm	4mm
Addendum	4mm	4mm
Dedendum	5mm	5mm
Face width	27.6mm	27.6mm
Clearance	1mm	1mm
Tooth Thickness	6.28mm	6.28mm
Whole Depth	9mm	9mm

Table 2: Specifications of gear pair 2

	Wheel	Pinion
Material	40NiCr1Mo25	40NiCr1Mo25
Diameter	236mm	132mm
Number of Teeth	59	33
Module	4mm	4mm
Addendum	4mm	4mm
Dedendum	5mm	5mm
Face width	27.6mm	27.6mm
Clearance	1mm	1mm
Tooth Thickness	6.28mm	6.28mm
Whole Depth	9mm	9mm

SHAFT

The shaft designing is carried out based on different loads acting on it. The optimum diameter is calibrated by finding out the bending moment at each point.

$$^{[8]} \text{Permissible shear stress } \tau_{max} = \frac{16}{\pi d^3} \sqrt{(k_b + M_b)^2 + (k_t M_t)^2} \tag{3}$$

The input shaft diameter is obtained as follows

Table 3: Shaft Parameters

Type of shaft	Diameter
Input Shaft	50mm
Output Shaft	60mm

Consideration for spline shaft is also accounted for when designing input shaft.

V-Belt

The designing of v-Belt is carried out by referring FENNER and BANDO catalogue.

The number of belt is obtained from the equation

$$^{[12]} \text{Number of belt} = \frac{\text{Design Power}}{\text{Belt Power}} \tag{4}$$

$$^{[13]} \text{Belt Length, } L = 2C + 1.57(D + d) + \frac{(D-d)^2}{4C} \tag{5}$$

Table 4: Specification of V-Belt

	V-Belt Motor to Gearbox	V-Belt Gearbox to Spindle
Type of Belt	SPB	SPB
Pitch Diameter	Pulley Pitch diameter(D)=300mm Minimum Pulley Diameter(d)=150mm	Pulley Pitch diameter(D)=300mm Minimum Pulley Diameter(d)=180mm
Centre Distance	C=494.56mm	C=494.56mm
Number of Belts	6nos	12nos

Bearing

To increase the efficiency of shaft rotation and to withstand all the shaft loads, high precision bearings from FAG catalogue is used.

$$^{[10]} \text{Dynamic Capacity } C = \left(\frac{L}{L_{10}}\right)^{\frac{1}{K}} \times P \tag{6}$$

$$^{[10]} L = \left(\frac{C}{P}\right)^{\frac{10}{3}} \tag{7}$$

Where L is the nominal life

$${}^{[10]}L_h = \frac{16666}{n} \left(\frac{C}{P}\right)^{\frac{10}{3}}$$

(8)

Table 5: Specification of V-Belt

	Shaft Bearing
Input Bearing	Cylindrical Roller Bearing NU1009-M1
Output Bearing	Cylindrical Roller Bearing NU1011-E-M1

2D And 3D Modelling

The design is successfully completed when it is converted it to visual image. 2D and 3D model is obtained by using software solid works and is given below.

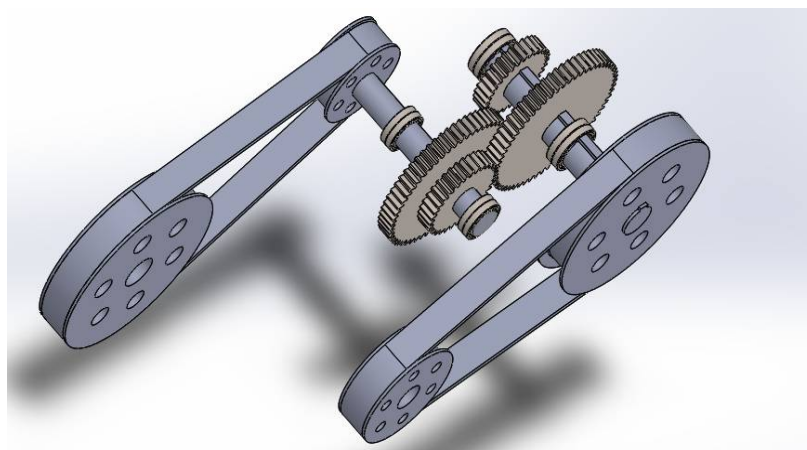
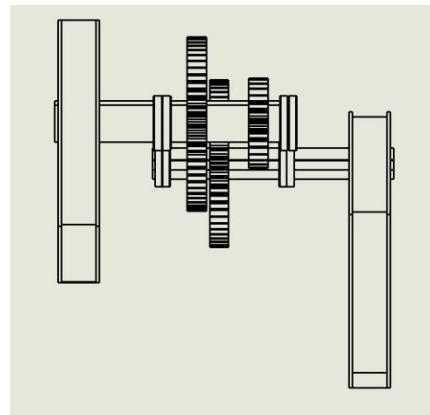


Fig. 5: 2D and 3D Modelling

IV. RESULT

The design is constructed in 2D and 3D model using solid works software. By the above design, machine is able to work at lower rpm and at constant torque. The spindle run out is considerably reduced since the motor is not directly coupled to the spindle. Vibration in working of machine is also reduced by the usage of belt pulley arrangement. We conclude that there is no need for further modification. To increase the efficiency, in design we considered industrial standard equipment's in design such as high pressure bearings from FAG.

V. CONCLUSION

The speed reduced is achieved by incorporating a separate gearbox and is connected to spindle using a belt pulley arrangement. Now the works such as threading, which require the machine to work at very low rpm and at constant torque to get the required finish, can be done with ease. Also we have used the minimum power motor so as to achieve the considerable cost reduction. The factors such as competence, longer service life, etc. is also considered during design phase. The reliability of the design can be increased by choosing factor of safety for each component. To cope with the industrial standards and increase the efficiency of the machine we have used the values of the manufacturers so as to standardise the design

VI. FUTURE SCOPE

The stress concentration at the gear teeth can be reduced by following a study presented by V Rajaprabakaran ^[9], on topic "How to reduce the stress concentration". This study suggested adding different shaped holes on spur gear to reduce stress concentration. Thus the machine life can be further increased.

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