CHAPTER 3

FINE BORING MACHINE

3.1 INTRODUCTION TO DESIGN OF FINE BORING MACHINE

While designing the fine boring machine the following factors are considered. The specified accuracy, shape and dimension of work piece produced on the machine together with the required surface finish must be obtained consistently and as for as possible independently of the skill of the operator.

In order to be competitive in operation it must show high technical performance with economic efficiency. Technical performance includes both quantitative performance (e.g. rate of metal removal, and maximum diameter to be bored) and qualitative performance such as obtainable degree of accuracy and surface finish.

The factors responsible for easy installation control and maintenance requirements are considered. The maintenance or repair work must be possible without undue difficulty and in a minimum time. Parts which are subjected to heavy wear and are likely to require frequent repair and replacement are designed in such away that it is easily accessible and interchangeable. The life expectancy is predicted and suitable replacement policy is carried out. Standard parts are used wherever possible. The performance of the machine tool depends not only upon the design and manufacturing of the machine itself, but also upon the design of the work piece, the selection of the operational
procedure the type and design of the cutting tool, the cutting conditions, the performance of the clamping devices for tools and work pieces. These factors are considered.

The power capacity and desired qualitative performance of the machine determine the requirement of static and dynamic stiffness of the structure while the size and shape of the work piece and the cutting process together with the operating and loading conditions affect the shape and the layout of the design.

The layout of the structure as well as the shapes and sizes of its components therefore so designed to ensure not only that satisfactory conditions exist for the operation and maintenance of the machine but also working stresses, the deformation deflection and displacements under working stresses, remain within specified limits. The design of base, table power screw etc, are explained next and the above mentioned stresses are checked. It is often difficult if not impossible for the machine which has to work over a wide speed range to be so designed as to keep its natural frequency below the frequency of the minimum working speed. On the other hand if natural frequencies is above the working speed, this may ensure not only freedom from resonance vibration of the structure but also satisfactory working of high performance control devices.
The basic machine consists of

1. Base
2. Table
3. Unit bridge
4. Spindle and boring unit
5. Motor bridge
6. Main motor
7. Idler pulley
8. Brake motor
9. Slow feed motor
10. Centralized lubrication
11. Chip tray
12. Electrical cabinet
13. Control stations

The figure 3.1 shows 2 views of the fine boring machine.

Elevation and plan are clearly shown and the parts are numbered as shown.

3.2 THE SPECIFICATION OF THE FINE BORING MACHINE

1. Size of the bore to be machined from 8mm to 350mm dia.
2. Cutting speed of the spindle: 90m/min
3. Diameter of the spindle bearing: 80 inside diameter and 140 outside diameter.
FINE BORING MACHINE

Fig. 3.1
4. Speed range: Spindle speed 300 to 3000 rpm.
5. Working area of table: 400 x 500 mm
6. Maximum working stroke: 630 mm
7. Feed electro mechanical. Feed range: 8 to 1076 mm/min by pick off gears 45 steps.
8. Rapid traverse rate: 4600 mm/min
9. Feed motor power: 0.75 kw

The fine boring machine mainly consists of base, table, spindles main motor, brake motor and slow feed motor.

The spindle rotates by the power received from main motor through idler pulley. The Table reciprocates on guideways which is integral with the bed. The brake motor and slow feed motor are required to get the table feed at rapid rate and slow feed. Table moves by the power transmitted from brakemotor through power screw. The design of table, power screw etc are explained in the next chapter.

Fine boring machine is used to do rough boring and finish boring. The job is fixed on the fixture which is kept on the table. Fine finish can be obtained by reducing the feed to a bare minimum. The lowest feed vary depending on the type of feed system used. There are four spindles in the fine boring machine. The spindles get power from main motor. The boring units are kept on unit bridges. The job is indexed through an indexing fixture to do boring operation in different position. 2 or 4 jobs can be done in one set up one by one. We have designed the feed unit for 2 jobs one at left side and one at right side. A fine finish can be obtained at low feed with a high tolerance.
3.3 THE BASE

The 3D view of the main base is shown in Figure (3.2). The main base is a sturdy cast iron construction. It is held rigidly on the ground, by foundation bolts. It is 700mm wide and 2100mm long. It has ribs of approximately 30mm thick.

3.3.1 The Design Criteria for Machine Tool Base

Consider a simple machine tool bed with two side wall, which may be represented as a simply supported beam loaded by a concentrated force P acting at its centre (Fig. 3.3). The maximum normal stress acting on the beam is given by the expression.

\[ \sigma_{\text{max}} = \frac{M_{\text{max}} Z_{\text{max}}}{I_y} \]  \hspace{1cm} (3.1)

Where, \( M_{\text{max}} = \frac{P l}{4} \) = Maximum bending moment
\( Z_{\text{max}} = \frac{h}{2} \) = Distance of outermost fibre from the neutral axis
\( I_y = \frac{b h^3}{12} \) = Moment of interia of the beam section about the neutral axis

Upon substituting these values in Eq.(3.1), we get

\[ \sigma_{\text{max}} = \frac{\frac{P l}{4} \frac{h}{2}}{\frac{b h^3}{12}} = \frac{3}{2} \frac{P l}{b h^3} \]
BED SUPPORTED AT ENDS

Fig. 3.3
If the permissible normal stress under tension for the beam material be denoted by \( \sigma \), then

\[
\sigma_{\text{max}} = \frac{3Pl}{2bh^2}
\]

or

\[
V_\sigma = bhl = \frac{3P}{2(\sigma)} \left( \frac{l^2}{h} \right)
\]  

(3.2)

Where \( V_\sigma \) is the minimum volume of metal required to ensure sufficient strength of the beam.

The maximum deflection of the simply supported beam is given by the following expression (see any text on Strength of Materials)

\[
\delta_{\text{max}} = \frac{Pl^3}{48EI_y}
\]  

(3.3)

Where \( E \) = modulus of elasticity of the beam material.

If the deflection of the beam is not to exceed a permissible value, denoted by \( \delta \), then

\[
\delta_{\text{max}} = \frac{Pl^3}{48EI_y} = \frac{Pl^3}{48E.bh^3}
\]

or

\[
V_\delta = bhl = \frac{P}{4E(\delta)} \left( \frac{l^2}{h} \right)^2
\]  

(3.4)
Where $V_a$, the minimum volum metal required to ensure that deflection of the beam under load does not exceed the specified value. The condition of optimum design is $V_a = V_s$

\[
\frac{3}{2} \frac{P}{(\sigma)} \left( \frac{l^2}{h} \right) = \frac{P}{4E(\delta)} \left( \frac{l^2}{h} \right)^2
\]

wherefrom,

\[
\frac{l^2}{h} = \frac{6E(\delta)}{(\sigma)}
\]  \hspace{1cm} (3.5)

(equating $V_a$ and $V_s$ for condition of optimum design)

Equation 3.5 indicates that for every structure there exists an optimum ratio $l^2/h$ depending upon.

1. Operation constraints expressed in this case through $(\delta)$ and
2. The material of the structure expressed in this case through $(\sigma)$ and $E$.

If we consider two beams of mild steel and cast iron with mechanical properties for mild steel,

- $E = 2 \times 10^4$ kgf/mm$^2$ \hspace{1cm} $\sigma = 1400$ kgf/cm$^2$
- $[\delta] = .002$ mm, for cast iron
- $E = 1.2 \times 10^4$ kgf/mm$^2$ \hspace{1cm} $[\sigma] = [300]$ kgf/cm$^2$
- $\delta = .002$ mm
For steel beam

\[
\left( \frac{l^2}{h} \right)_{\text{opt}} = \frac{6 \times 2 \times 10^4 \times .002}{14} = 17.14
\]

For cast iron beam

\[
\left( \frac{l^2}{h} \right)_{\text{opt}} = \frac{6 \times 1.2 \times 10^4 \times .002}{3} = 48
\]

The volume of the two beams with optimum \(l^2/h\) values will be in the ratio.

\[
\frac{\text{VCI}}{\text{VMS}} = \frac{3}{2} \cdot \frac{P}{3} \cdot \frac{.48}{17.14} = \frac{P}{4 \times 2 \times 10^4 \times .002} \times 17.14^2
\]

\[
= 13.07
\]

(Ref N.K. Mehta)

It is evident from Fig.3.4 that for \(l^2/h\) less than optimum corresponding to the point of intersecting, the structure should be designed from consideration of strength while for \(l^2/h\) values exceeding the value (48) the design should be guided by stiffness consideration.
CURVE SHOWING OPTIMUM VALUE OF $l_{\theta}/h$

Fig. 3.4
In our design of fine boring machine base \( l = 2100 \text{ mm} \)
\[
\begin{align*}
  h &= 490 \text{ mm} \\
  \frac{l^2}{h} &= \frac{2100^2}{490} = 900 \text{ cm} \quad 900 > 48
\end{align*}
\]

So \( l^2/h \) is greater than optimum value. Consequently the stiffness and
not the load carrying capacity of the structure is the decisive factor which is
considered for design.

### 3.3.2 Why choose cast iron

The steel structure is light deeper and thinner than a cast iron structure
of equivalent strength is obvious. However since structure are mostly designed
from stiffness consideration the actual economy of metal consumption by using
steel instead CI may be much less than 13.07 times because steel must be
provided with stiffening ribs. This not only increases the weight of steel
structure but adds to the labour costs.

More over cast iron has higher inherent damping properties, and better
sliding property. Because of these reasons castiron is selected.

The provision of power transmissions by means of shafts and levers and
the requirement of assembly often demand opening which result in the
weakening of the structure. The stiffness of such beam can be increased by
suitable ribbing which may be essential if larger thin walled section are
employed whose wall needs stiffness to prevent undesirable deformation and vibration of individual panels.

The wall thickness is detided by the size factor.

\[ N = \frac{2L + B + H}{4} = \frac{2 \times 2.1 + 0.42 + 0.700}{4} = 1.5 \]

(Refer N.K.Mehta)

For a size factor of 1.5, the rib thickness recommended from data books is 25mm we have taken 28mm.

3.3.3 Selection of Profile of base structure

During the operation of the machine tool a majority of its structure are subjected to compound loading and their resultant deformation consists of torsion, bending and tension or compression. Under simple tensile or compressive loading the strength and stiffness of element depend only upon area of cross section.

However the deformation and stress elements subjected to torsion and bending depend additionally upon the shape of cross section. A certain volume of metal can be distributed in different ways to give different values of the moment of inertia and section modules. The shape that provides the maximum
moment of inertia and section modules will be considered best as it will ensure minimum values of stress and deformation.

The stiffness of four different section of equal cross sectional area are compared Table 3.1.

It is evident from Table 3.1 the box type section has the highest torsional stiffness and in the overall assessment seems best suited both in terms of strength and stiffness. The additional advantage that goes in its favour is ease of proper mating with other surface. All consideration combined point towards the overwhelming superiority of the box type profile over other.

In most of the case the machines tool Base must be provided with aperture for free flowup chips and other maintenance purposes. This weakens the structure. To avoid this certain special provision to be made for example if there is a hole in wall then a boss can be provided to avoid aperture effects.

3.4 BORING UNITS

There are 4 spindles in the machine as shown in fig.3.1 having 4 boring tools which will be useful in boring many holes in one setup by indexing the fixture. The boring units are mounted on unit bridges.

The spindles are made of nickel, chrome steel heat treated and stress-relieved and rotate in heavy duty ultra-precision double row cylindrical roller bearings and pre-loaded double row angular contact thrust ball bearing.
### TABLE 3.1

**Comparision of Stiffness of Different Sections Having Equal Cross Sectional Area**

<table>
<thead>
<tr>
<th>SECTION</th>
<th>AREA (mm²)</th>
<th>WEIGHT (kgf/m)</th>
<th>RELATIVE VALUE OF PERMISSIBLE BENDING MOMENT (kgf.cm)</th>
<th>RELATIVE VALUE OF PERMISSIBLE TORQUE (kgf.cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>STRESS</td>
<td>DEFLECTION</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>29.0</td>
<td>22</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>28.3</td>
<td>22</td>
<td>1.12</td>
<td>1.15</td>
</tr>
<tr>
<td>C</td>
<td>29.5</td>
<td>22</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>C</td>
<td>29.5</td>
<td>22</td>
<td>1.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Angular contact ball bearings of special accuracy in matched pairs are made use of in smaller size spindles for high speed applications.

The bearing seats at both ends of the spindles are tapered to match the bore of the roller bearings. The bearings are located close to the work end and the pulley end for extra rigidity.

The spindles are pre-loaded to ensure high axial and radial rigidity. The bearing settings in cast iron housing are lapped to close geometrical accuracies and high surface finish. This ensures longer tool life and high accuracies.

The bearings are lubricated with special grease for life. The spindle can run at high speeds for machining light alloys. Special seals incorporated provide grease retention and protect the bearings from contamination.

The ultra precision tolerances within which all spindle parts are made, plus the special lubrication used results in the spindle operating with very little overheating. It does not need any attention throughout its working life. This ensures thousands of hours of trouble free machine tool operation. The spindle rotates at 300 to 3000 rpm and cutting speed, 90 metres/min.

3.5 DESIGNING GUIDEWAYS

The guideways are integral with the bed. The table moves on hardened and precision ground prismatic and flat guide ways without any stick slip. Table guideways are pressure lubricated and fully protected against dust and chips. The guideways are one rectangular and other trapezoidal.
For a table of A-320mm from CMTI handbook \( H = 12 \) to \( 50 \) in our case it is \( 35 \)mm.

The guideways should have

1. High accuracy and surface finish of guide way surfaces.
2. High accuracy of travel.
3. Durability
4. Low value of frictional forces
5. High rigidity
6. Good damping properties

Slide ways operating under semi liquid friction conditions are distinguished by relatively high co-efficient of friction \( \mu \). The result is considerable wear, reducing life as well as adversely affecting the machining accuracy. For proper function of slide ways it is therefore imperative that friction be kept as low as possible. Certain minimum amount of lubricant is always present between sliding surface. This may be done by automatic means or by the operator who oils the sliding surface from time to time. One of the popular method of increasing the share of liquid friction in slide ways and thus reducing friction at the interface is to provide lubricating groves on the guiding surface.

3.5.1 Material of the guide way

The material used in our design is cast iron. Since the guide way is integral with the bed, it is better to use cast iron. The wear resistance is improved through heat treatment by hardening the guideways. Mostly the guide ways are heat treated by induction hardening process.
3.6 CENTRALISED AUTOMATIC LUBRICATION SYSTEM

This is used for lubricating the guide ways and lead screw nut. It consists of a self-contained oil tank with pump, float switch to indicate the oil level and control unit with two timers for frequency and duration. The frequency can be adjusted up to six hours and the duration up to 30 seconds. Dosing nipples are provided at each lubricating point to control the volume of oil.

3.7 HYDRAULIC POWER PACK

Hydraulic power pack comprising variable displacement pumps, single and dual feed arrangement with temperature and pressure compensated flow control valves for consistency and sufficient cooling system (not to exceed oil temperature of 60°C for 16 hours run) can be provided wherever applicable.

3.8 CONTROL STATION

Operator control station consists of pilot devices like push button, selector switches, signal lamp etc. to enable the operator to run the machine in manual mode for setting purposes, and auto mode.

3.9 PROGRAMME LOGIC CONTROL SYSTEM

Programme logic control used in place of contractor logic, Modular in construction. PLC saves space, ensures high reliability and increases flexibility.