4.1 SPECIFICATION OF FEED UNIT

Table working area 400 x 500mm$^2$
Max traverse height from table top 630 mm
Boring unit bridge 155 mm
Feed range 8-1076 mm/min
Rapid traverses rate 4600 mm/min
Maximum working stroke 630 mm
Power of Motor 0.75 Kw

Feed motions are obtained by means of suitably designed independent feed units which have their own drive motors. High production rates can only be obtained if movement at feed rate is restricted to the cutting length, while all idle distances are travelled at rapid traverse rates.

Feed Unit is equipped with 2 motors one (brake motor) for rapid traverse and the other (standard motor) for feed. As the brake motor is used for rapid traverse, the table can be stopped instantaneously and slow feed stroke can be minimized to the bare minimum. This reduces idle time. Brake motor will also act as overload safety during machining.
4.2 GEAR ARRANGEMENT (Ref. Fig.4.1)

The gear box is designed for transmitting power from brake motor to lead screw via sun and planet gear during rapid advance and transmitting power from slow feed motor to lead screw via change gear, bevel gears and sun & planet gear during slow feed. By varying the change gears during slow feed as many as 45 feeds can be obtained.

First when the brake motor rotates it transmits power to gear A. From gear A power is transmitted to B (spur gear). The speed reduces. The power is transmitted to Gear C (sun gear) and C to D (planet gear) D to 9, 9 to 10 and 10 to 8. From 8 power is transmitted to lead screw 12 via 10A and 11 as shown in figure.

Now the lead screw rotate at rapid feed rate. When the lead screw rotates table gets linear motion and moves towards the spindle. When it reaches near the spindle, the brake motor is switched off and slow feed motor is switched on. The power is transmitted from standard motor (slow feed motor) to change gear 1. From spur gear 1 power is transmitted to spur gear 2 and speed is reduced considerably. Again the speed is reduced by transmitting via gears 3, 4, 5 and 6. Bevel gear 7 is fixed at the other side of spur gear 6. From bevel gear 7 power is transmitted to bevel gear 8 in perpendicular direction. From bevel gear 8 power is transmitted to lead screw 12 and table gets slow feed.
ELECTRO MECHANICAL FEED MECHANISM.

(GEAR ARRANGEMENT)

Fig. 4.1
4.3 POWER SCREW DESIGN

The power screw at the end of feed units explained earlier transfer motion to the table through nut.

It has the following distinguished features.

1. Possible to obtain slow travel of the operative element in the feed train.

2. Simple design and compactness.

3. High load carrying capacity.

4. Uniform and accurate moment.

The screw material is taken as structural steel IS 1570.

The nut material is taken as bronze.

The true square thread with zero included angle has least friction and maximum efficiency and extents minimum radial or bursting pressure on the nut. However it is difficult and expensive to manufacture and is therefore rarely employed in practice. The ISO METRIC TRAPEZOIDAL Screw thread as per IS (7000 - 1973) is taken.

From CMTI databook,
For a 36mm nominal dia of screw
Pitch = 8mm
Major dia of nut = 37 mm
Minor dia of screw = dm = 29 mm
Pitch dia dp = d - 0.5 p
= 36 - 0.5 x 8
= 32 mm
(α) included angle = 15°

4.3.1 Design for wear resistance

The wear resistance of power screw depends primarily upon the average pressure on the working surface of the thread. The design condition is

\[ \text{Pav} < [\text{Pav}] \]

Where Pav - average pressure on the thread surface.

\[ [\text{Pav}] \] - permissible average pressure on the thread surface.

\[ \text{Pav} = \frac{2 \times 500}{\pi \times 3.2 \times 13} = 7.65 \text{ Kgf/cm}^2 \]

\( < 30 \text{ Kgf/cm}^2 \) for a steel screw, bronze nut pair of precision feed mechanism. So design is safe.
4.3.2 Design for Strength

Power screws are designed for strength in accordance with the theory of maximum shearing stress. The design condition can be written as

\[ T_{\text{max}} < [T] \]

Where \( T_{\text{max}} \) = maximum shearing stress in screw

\( [T] \) = Permissible shearing stress of the screw material.

The minor diameter cross section of a power screw is subjected to biaxial stress consisting of a tensile or compressive stress \( \sigma \) due to an axial pulling force and a shearing stress \( T \) due to torque. The maximum shearing stress in a biaxially stressed member is given by

\[ T_{\text{max}} = \frac{1}{2} \sqrt{\sigma^2 + 4T^2}, \quad d_m = 2.9 \text{ cm} \]

Normal Stress \( \sigma \) = \( \frac{4Q}{\pi d_m^2} \)

\[ \sigma = 4 \times \frac{500}{\pi} \times 2.9^2 = 75.6 \text{ Kgf/Cm}^2 \]

Shearing stress

\[ T = 16 \frac{M_t}{\pi d_m^3} \]

\[ M_t = \frac{Q dp \cos \alpha \tan \lambda + \mu}{2 \cos \alpha - \mu \tan \lambda} \quad \text{(Ref. N.K.Metha)} \]

\[ \alpha = 15^\circ, \lambda = \tan^{-1} \frac{\text{Pitch}}{\pi dp} \]

\[ = \tan^{-1} \frac{8}{\pi} \times 32 \quad \mu = 0.1 \]

\[ = 4.5 \]

\[ M_t = \frac{500 \times 3.2 \times \cos 15^\circ \times \tan 4.5 + 0.1}{2 \cos 15^\circ - 0.1 \tan 4.5} \text{ Kgf cm} \]

\[ = \frac{121.7/1.924 = 63.25 \text{ Kgf cm}}{2 \cos 15^\circ - 0.1 \tan 4.5} \]
The allowable shearing stress for screw material IS1570 is 3.1 kgf/mm² = 310 kgf/cm² so design is safe.

4.4 DESIGN OF TABLE

Table width = 400 mm
Table length = 1000 mm
Table working area = 400 x 500 mm
Max. working stroke = 630 mm
(Data given by HMT)

The table unit consists of a cast iron moving table which slides on hardened and ground steel guide way one rectangle and one trapezoidal. Feed screw gives movement to the table thro bronze nut. The screw and nut arrangement gives a shock free positive movement to the table which is essential when the table is used for fine boring operations.
The table is considered a box in which a vertical normal force is acting on the plane as shown in Figure (4.2)

The cutting force acting normal to the table (on which the fixture is fixed and work piece is clamped on the fixture) is calculated as below (Ref. PSG data book)

\[
\text{Axial Thrust} = 630 \text{ k} z (D-d) S^{0.85}
\]

K for BHN 110 - 140 - 0.66
K for BHN 140 - 190 - 0.83

take the BHN is 140 - 190 so, K = 0.83

D - d = 10
D - Dia of bigger bore
d - dia of smaller bore

We assume D - d = 10 (maximum depth of cut is taken as 5.mm)

Z = 1 for single point cutting tool (Z - no of cutting points)

\[
S = \text{Feed/blade/Rev}
\]

\[
= \frac{300}{\text{blade/3000}}
\]

(Since boring tool has only one edge or blade to cut, number of blade=1)

\[
S = 0.1
\]

\[
\text{Axial Thrust} = 630 \times k z (D-d) S^{0.85}
\]

\[
= 630 \times 0.83 \times 1 \times 10 \times 0.1^{0.85}
\]

\[
= 738 \text{ N}
\]

\[
= 74 \text{ Kgf}
\]
TABLE

Fig. 4.2
The weight of fixture + Table self weight is 30 + 120 = 150 Kg. We assume a total force of 150 + 74 = 224 acting vertically.

= 224 Kgf

Also the Force due to power screw which makes the table to move towards and away from boring head is acting as a force of torsion (shear force) on the table. These two forces are considered acting on the table in mutually perpendicular direction. So the bending stress due to normal force and shear stress exerted by power screw is calculated and the max principal stress due to these stresses is calculated as max principal stress

\[
\sigma = \frac{\sigma}{2} + \sqrt{\frac{\sigma}{2} + T^2}
\]

Where \( \sigma \) is the maximum bending stress and \( T \) is the pressure in the power screw.

Pressure in the power screw is

\[
T = \frac{2Q}{\pi d l}
\]

\[
= 2 \times 500 / \pi \times 3.2 \times 13 = 7.65 \text{ Kgf/Cm}^2
\]

Where \( d \) is the pitch dia of thread=3.2 Cm and \( l \) is the length of nut=13 Cm.

\[
\sigma_{\text{max}} = \frac{M_{\text{max}} \times Z_{\text{max}}}{I_{\text{yy}}}
\]

\[
M_{\text{max}} = \text{Bending moment acting in X Z Plane}
\]

\[
= 224 \times 50
\]

\[
= 11200 \text{ Kgf.Cm}
\]

\[
Z_{\text{max}} = 16/2 = 8 \text{ cm}
\]
Moment of Inertia $I_{yy}$

$$I_{yy} = \frac{40 \times 16^3}{12} = 13653 \quad Z_{max} = 16/2$$

$$\sigma_{max} = \frac{11200 \times 8}{13653} = 6.56 \text{ Kgf/cm}^2$$

Principal Stress

$$\sigma = \frac{\alpha}{2} + \sqrt{\left(\frac{\alpha}{2}\right)^2 + T^2}$$

$$= \frac{6.56}{2} + \sqrt{(6.56/2)^2} + 7.65$$

$$= 11.6 \text{ Kgf/cm}^2$$

The allowable stress for Table castiron material is 80 to 90 Kgf/Cm$^2$

So design is safe.

4.5 DESIGN OF DIFFERENT FEEDS IN ELECTRO MECHANICAL FEED SYSTEM

The gearing arrangement for Feed Mechanism of fine boring machine is shown in fig.4.1 and 4.4.

The working of feed mechanism based on figure 4.1 was already explained. Here in this section the method of calculation of rapid feed rate and 45 slow feed rates are explained.
4.5.1 Rapid Feed

The rapid rate is got from Brake Motor rotating at 1500 rpm. The power is transmitted from brake Motor to lead screw 12 via C,D,9,10,10A,11 as shown is figure 4.1.

From figure 4.1 the gear ratio for rapid

\[
\text{rate} = \frac{Z_A}{Z_B} \times \frac{Z_C}{Z_D} \times \frac{Z_{10}}{Z_{11}} \times \frac{Z_{10A}}{}
\]

This is calculated as follows. Ref fig.4.4.

The gear ratio = \[\frac{26}{51} \times \frac{20}{13} \times \frac{13}{22} \times \frac{22}{53}\]

= 0.192378

Pitch of Screw = 8

No. of Start = 2

Multiplying the gear ratio by 1500, rpm of brake motor and pitch of lead screw thread and no.of start

We get rapid rate

= 0.192378 \times 1500 \times 8 \times 2 \text{ mm/min}

= 4617 \text{ mm/min}

= 4.6 \text{ m/min}

So the rapid rate at which the table will be moving is 4.6 m/min. During rapid rate only the brake motor will be switched on. The slow feed motor will
be switched off. So there will be no power transmission to the gears meant for slow feed.

Slow feeds obtained from slow feed motor. Power is first transmitted from slow feed motor to gear 8 via, gears 1,2,3,4,5,6,7 (ref fig. 4.1). From gear 8 power is transmitted thro sun and planet gears CD,9,10, then from 10 to 10A and 11 and to 12 lead screw. The function and advantage of sun and planet gears are explained next in detail.

4.5.2 Planetary Gearing

Planetary gearing consists of a system of gears in which two coaxial gears are connected by a number of equally spaced gears or gear assemblies called planets mounted on a carrier which is also coaxial with the first two gears.

Planetary gearing is classified as

i. Simple planetary trains
ii. Compound planetary trains

A simple planetary train has four basic elements namely (i) an external gear called, sun wheel (ii) An internal gear called annulus (iii) planet carrier (iv) planets. The sun wheel the annulus and the planet carrier are coaxial. Each one of these could be used as input, output or reaction member.
Compound planetary trains are obtained by combining two or more simple planetary trains such that two members of each train are connected to two members of another train. In the case of compound planetary trains internal gears could be replaced by external gears.

Planetary trains could be used as (i) fixed ratio drives or as (ii) differential drives. In a fixed ratio drive one of the three coaxial shafts is locked and the other two are used as input or output member as desired. In differential drive all three coaxial members are allowed to rotate with any one of them as the driver and other two as followers or vice versa.

Speed ratios for the combinations of planetary drives commonly used in machine tools are given in tables. The practical value depends on the space available, power transmission, capacity etc. If the transmission ratio 'i' is preceded by a negative sign it indicates that the driver and follower are rotating in opposite directions, otherwise they rotate in same direction.

Planetary gears have the following advantages.

1. Symmetrical and compact construction with possibility to obtain very high transmission ratio.
2. Co-axial input and output shafts.
3. Load sharing between several pinions.
4. Low weight and efficient space utilisation.
5. Low flywheel effect.
6. Low rolling and sliding velocities at tooth flanks.
7. Silent running.
8. High efficiency.
9. Reduced sensitivity to shock loading.
10. Differential output speeds and torques.
11. Complete balance of static force within the gear train.
12. No resultant tooth loads on the bearing of coaxial shafts when spur gears are used.

4.5.2.1 Simple Planetary Train

General equation of transmission when the system is used as a differential drive is

\[ n_1 = \frac{n_4 (z_1 + z_2)}{z_1} \pm \frac{n_2 z_2}{z_1} \] (Ref. CMTI hand book)

Ref Fig. 4.3(a) negative sign is used if members 2 and 4 rotate in same direction. Positive sign is used when member 2 rotates in direction opposite to that of 4.

4.5.2.2 Compound planetary drive with one sun gear and one internal gear

General equation of transmission when the system is used as a differential drive is

\[ n_1 = n_4 \left( 1 + \frac{z_2 \cdot z_3}{z_1 \cdot z_6} \right) \pm n_2 \frac{z_2 \cdot z_3}{z_1 \cdot z_5} \]
Ref Fig 4.3(b) negative sign is used when members 2 and 4 rotate in same direction. Positive sign is used if member 2 rotates in a direction opposite to that of 4.

4.5.2.3 Compound planetary drive with two sun gears

General equation of transmission when system is used as a differential drive is

\[ n_1 = n_4 \left( 1 - \frac{z_2 \cdot z_3}{z_1 \cdot z_5} \right) \pm n_2 \frac{z_2 \cdot z_3}{z_1 \cdot z_5} \]

Ref fig 4.3(c) positive sign is used for same direction of rotation of members 2 and 4. It members 2 rotate in opposite direction negative sign is used. Refer table 4.1 for fixed ratio drive possibilities.

4.5.2.4 Simple equal bevel gear differentials

Two types of simple equal bevel gear differentials are shown in fig.4.3(d) and 4.3(e). In the type shown in fig 4.3 (d) member F is connected to the planet carrier. In the type shown in fig. 4.3(e) member D is connected to the planet carrier.

For fig 4.3d general equation of transmission when the system is used as differential drive is

\[ n_E = 2n_F + n_D \]

negative sign is used for F and D rotating in the same direction and positive sign is used when D rotates in Direction opposite to not of F.
Fig. 4.3(a)

Simple Planetary Train

1. Sun Wheel Z1
2. Annulus Z2
3. Planet Z3
4. Planet Carrier

Fig. 4.3(b)

Compound Planetary Drive with One Sun Gear and One Internal Gear

1. Sun Wheel Z1
3. Planet Z3
4. Planet Carrier
2. Annulus Z2
5. Planet Z5
COMPUND PLANETARY DRIVE WITH TWO SUN GEARS

Fig. 4.3(c)

SIMPLE EQUAL BEVEL GEAR DIFFERENTIAL TYPE 1

Fig. 4.3(d)

SIMPLE EQUAL BEVEL GEAR DIFFERENTIAL TYPE 2

Fig. 4.3(e)
For fig 4.3(e) general equation of transmission when the system is used as differential drive is

\[ n_E = 2n_D + n_F \ (\text{Ref CMTI Handbook}) \]

Negative sign is used for \( F \) and \( D \) rotating in the same direction and positive sign is used when \( F \) rotates in a direction opposite to that of \( D \).

In the above equation by fixing any one of the member ie by having corresponding \( n = 0 \) the fixed drive relationship is obtained.

**Table 4.1**

**Fixed ratio drive possibilities (Compound planetary drive with two sun gears - Fig.4.3 (c))**

<table>
<thead>
<tr>
<th>Drive No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Member</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Driver</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Driven</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Transmission ratio ( i )</td>
<td>( \frac{\text{rpm of the driver}}{\text{rpm of the driven}} )</td>
<td>( \frac{z_4 z_5}{z_4 z_5} )</td>
<td>( \frac{z_4 z_5}{z_4 z_5} )</td>
<td>( \frac{z_4 z_5}{z_4 z_5} )</td>
<td>( \frac{z_4 z_5}{z_4 z_5} )</td>
<td>( \frac{z_4 z_5}{z_4 z_5} )</td>
</tr>
</tbody>
</table>

**4.5.2.5 Planetary Drive used in Feed System**

For our application we have selected Fig 4.3(c) and Table 4.1 gives details.

Among the fixed ratio drive possibilities the transmission

\[ \text{ratio} \ i = \frac{\text{rpm of driver}}{\text{rpm of driven}} \text{ is got} \]
From Fig 4.4 \( z_1 = 20, \ z_2 = 22, \ z_3 = 13, \ z_5 = 13. \)

The speed ratio after passing thru planet gear is

\[
\frac{22 \times 13}{22 \times 13 - 20 \times 13} = \frac{286}{26}
\]

\[
= 1 : 11
\]

The speed is reduced 11 times as the passing thru sun and planet gear CD 9 & 10. We can get as many as 45 feed rates using change gears and with and without reductor.

4.5.3 Slow Feed

The gear ratio for slow feed can be obtained from Fig.4.1 as

\[
\frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4} \times \frac{Z_5}{Z_6} \times \frac{Z_7}{Z_8} \times \frac{1}{11} \times \frac{Z_{10A}}{Z_{11}}
\]

(the speed ratio after passing through sun and planet gear) \( x \)

In this

\[
\frac{Z_7}{Z_8} \times \frac{1}{11} \times \frac{Z_{10A}}{Z_{11}} \text{ is common for all 45 feeds. They}
\]

are \( \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \), \( \frac{Z_6}{Z_6} \) are
change gears which will be changed each time, when you want different feed.

The different change gears starting from

\[
\frac{15}{67} \quad \text{to} \quad \frac{54}{29}
\]

are shown in Table 4.2

The first 15 feed rates are obtained by without reductor and with PQRS as shown in figure 4.4. They are calculated as follows.

In this

\[
\frac{Z_1}{Z_2} = \frac{41}{41}, \quad \frac{Z_3}{Z_4} = \frac{41}{41}, \quad \frac{Z_5}{Z_6} \text{ is a change gear}
\]

1. \[
\frac{41}{41} \times \frac{15}{67} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500
\]

\[
= 129 \text{ mm/min}
\]

2. \[
\frac{41}{41} \times \frac{18}{64} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

\[
= 162 \text{ mm/min}
\]

3. \[
\frac{41}{41} \times \frac{22}{60} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

\[
= 212 \text{ mm/min}
\]
SLOW SPEED MOTOR

<table>
<thead>
<tr>
<th>HP</th>
<th>RPM</th>
<th>FRAME SIZE</th>
<th>SHAFT DIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1500</td>
<td>80</td>
<td>19x40</td>
</tr>
</tbody>
</table>

**SLOWFEED MOTOR**

1 HP
1500 RPM
FRAME SIZE - 80
SHAFT DIA 19x40

**30° T, 35x8 DOUBLE START**

**BRAKE MOTOR**

1 HP
1500 RPM
FLANGE MOUNTED
SHAFT ø 19x40

**ELECTRO MECHANICAL FEED MECHANISM (RAPID FEED AND SLOW FEED)**

Fig. 4.4
4. \[
\frac{41}{41} \times \frac{41}{41} \times \frac{26}{57} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]
\[
= 263 \text{ mm/min}
\]

5. \[
\frac{41}{41} \times \frac{41}{41} \times \frac{29}{54} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]
\[
= 310 \text{ mm/min}
\]

6. \[
\frac{41}{41} \times \frac{41}{41} \times \frac{32}{51} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]
\[
= 363 \text{ mm/min}
\]

7. \[
\frac{41}{41} \times \frac{41}{41} \times \frac{35}{48} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]
\[
= 421 \text{ mm/min}
\]

8. \[
\frac{41}{41} \times \frac{41}{41} \times \frac{37}{45} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]
\[
= 475 \text{ mm/min}
\]

9. \[
\frac{41}{41} \times \frac{41}{41} \times \frac{39}{43} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]
\[
= 524 \text{ mm/min}
\]
10. \[ \frac{41}{41} \times \frac{41}{41} \times \frac{41}{41} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 578 mm/min

11. \[ \frac{41}{41} \times \frac{41}{41} \times \frac{43}{39} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 637 mm/min

12. \[ \frac{41}{41} \times \frac{41}{41} \times \frac{45}{37} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 703 mm/min

13. \[ \frac{41}{41} \times \frac{41}{41} \times \frac{48}{35} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 792 mm/min

14. \[ \frac{41}{41} \times \frac{41}{41} \times \frac{51}{32} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 921 mm/min

15. \[ \frac{41}{41} \times \frac{41}{41} \times \frac{54}{29} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 1076 mm/min
next 15 feed rates are obtained with reductor 18/64 with gear pair $C \times D = 15 \times 67$ and using change gears different feed rates of are obtained.

In this

\[
\frac{z_1}{z_2} = \frac{18}{64}, \quad \frac{z_3}{z_4} = \frac{15}{64}, \quad \frac{z_5}{z_6} - \text{Change gear}
\]

\[
\frac{18}{64} \times \frac{15}{67} \times \frac{15}{67} \times \frac{30}{7} \times \frac{1}{11} \times \frac{22}{53}
\]

$\times 1500 \text{ (rpm of motor)} \times 8 \text{ (pitch of lead screw)} \times 2 \text{ (no.of start -2)}$

$= 8 \text{ mm/min}$

\[
\frac{18}{64} \times \frac{15}{67} \times \frac{18}{64} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53}
\]

$\times 1500 \times 8 \times 2$

$= 10 \text{ mm/min}$

\[
\frac{18}{64} \times \frac{15}{67} \times \frac{22}{60} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53}
\]

$\times 1500 \times 8 \times 2$

$= 13 \text{ mm/min}$

\[
\frac{18}{64} \times \frac{15}{67} \times \frac{26}{57} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53}
\]

$\times 1500 \times 8 \times 2$

$= 16 \text{ mm/min}$
87.

20. \[ \frac{18}{64} \times \frac{15}{67} \times \frac{29}{54} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 19 mm/min

21. \[ \frac{18}{64} \times \frac{15}{67} \times \frac{32}{51} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 23 mm/min

22. \[ \frac{18}{64} \times \frac{15}{67} \times \frac{35}{48} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 26 mm/min

23. \[ \frac{18}{64} \times \frac{15}{67} \times \frac{37}{45} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 29 mm/min

24. \[ \frac{18}{64} \times \frac{15}{67} \times \frac{39}{43} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 32 mm/min

25. \[ \frac{18}{64} \times \frac{15}{67} \times \frac{41}{41} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= 36 mm/min
26. \[\frac{18}{64} \times \frac{15}{67} \times \frac{43}{39} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2\]

= 40 mm/min

27. \[\frac{18}{64} \times \frac{15}{67} \times \frac{45}{37} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2\]

= 44 mm/min

28. \[\frac{18}{64} \times \frac{15}{67} \times \frac{48}{35} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2\]

= 49 mm/min

29. \[\frac{18}{64} \times \frac{15}{67} \times \frac{51}{32} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2\]

= 57 mm/min

30. \[\frac{18}{64} \times \frac{15}{67} \times \frac{54}{29} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2\]

= 67 mm/min
next 15 feed rates are obtained with reductor 18/64 with gear pair C x D = 41 x 41 and using change gears.

From Fig. 4.1.

\[
\frac{Z_1}{Z_2} = \frac{18}{64}, \quad \frac{Z_3}{Z_4} = \frac{41}{41}, \quad \frac{Z_5}{Z_6} = \frac{41}{41} - \text{ Change gear}
\]

\[
\frac{18}{64} \times \frac{41}{41} \times \frac{15}{67} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 36 mm/min

\[
\frac{18}{64} \times \frac{41}{41} \times \frac{18}{64} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 45 mm/min

\[
\frac{18}{64} \times \frac{41}{41} \times \frac{22}{60} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 59 mm/min

\[
\frac{18}{64} \times \frac{41}{41} \times \frac{26}{57} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 74 mm/min
35. \[ \frac{18}{64} \times \frac{41}{41} \times \frac{29}{54} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= \( 87 \text{ mm/min} \)

36. \[ \frac{18}{64} \times \frac{41}{41} \times \frac{32}{51} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= \( 102 \text{ mm/min} \)

37. \[ \frac{18}{64} \times \frac{41}{41} \times \frac{35}{48} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= \( 118 \text{ mm/min} \)

38. \[ \frac{18}{64} \times \frac{41}{41} \times \frac{37}{45} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= \( 133 \text{ mm/min} \)

39. \[ \frac{18}{64} \times \frac{41}{41} \times \frac{39}{43} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= \( 147 \text{ mm/min} \)

40. \[ \frac{18}{64} \times \frac{41}{41} \times \frac{41}{41} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2 \]

= \( 162 \text{ mm/min} \)
41. \[
\frac{18}{64} \times \frac{41}{41} \times \frac{43}{39} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 180 mm/min

42. \[
\frac{18}{64} \times \frac{41}{41} \times \frac{45}{37} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 200 mm/min

43. \[
\frac{18}{64} \times \frac{41}{41} \times \frac{48}{35} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 222 mm/min

44. \[
\frac{18}{64} \times \frac{41}{41} \times \frac{51}{32} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 259 mm/min

45. \[
\frac{18}{64} \times \frac{41}{41} \times \frac{54}{29} \times \frac{30}{47} \times \frac{1}{11} \times \frac{22}{53} \times 1500 \times 8 \times 2
\]

= 302 mm/min
4.5.4 Operation of Feed System

Figure 4.5 shows cycle of events that takes place from start of brake motor doing useful work and to reach home position.

The fine boring machine has 2 spindle on left side and 2 spindle on right side. The sequence of events take place are

1. The job which is fixed on the table is moved from left to right fast.
2. Boring using right spindle takes place slowly.
3. Table is moved from right to left fast.
4. Boring takes place using left spindle slowly.
5. Table is brought to home position fast.

This is done by means of limit switches. As shown in figure 4.5(a) first rapid advance takes place. Then slow feed. Then dwell takes place. Then rapid return. Then the table moves to home position.

The operations controlled by limit switches are explained below.

First brake motor is switched on. Rapid table movement follows. Spindle motor is also on. Limit switch 1 is on. When table moves right to left and meet limit switch by trip dog brake motor stops. Slow feed motor is on. Table is under slow feed job facing right side spindle. Limit switch 2 is on. When the table moves meets limit switch 2 slow feed motors is off. Spindle also off. With this the first cycle completes the table starts coming towards left spindle.
FIGURE SHOWING TABLE MOVEMENTS

RA - RAPID ADVANCE
SF - SLOW FEED
RR - RAPID RETURN
Brake motor is switched on in the reversed direction. Table under rapid rate. Limit switch 3 is on. When table moving towards left touches limit switch 3 brake motor stops. Slow feed motor is on. Table is under slow feed job facing the left spindle. Limit switch 4 is on when table meets limit switch 4, slow feed is off. Brake motor is on. Table comes to home position. This is the cycle of events that tables place in a fine boring machine feed mechanism under operation.

As per the table 4.2 first 15, feeds are obtained without reductor 18/64 and with PQRS 41/41 x 41/41 and change gears. Next 15 feeds are obtained with reductor 18/64 and gear pair C x D (15/67) and change gear. Next 15 feeds are obtained with reductor 18/64 and gear pair C x D (41/41) and change gear. These gears are changed by the operator manually by opening the gear box and removing old gears and replacement done according to the feed.
Table 4.2
Different Slow Feeds

<table>
<thead>
<tr>
<th>Change Gear A Number of teeth Z</th>
<th>Change Gear B Number of teeth Z</th>
<th>A/B</th>
<th>Slow Feed MM/Min.</th>
<th>Range without Reductor and with PQRS</th>
<th>Range with Reductor with gear pair C x D</th>
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<tbody>
<tr>
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<td>67</td>
<td>15/67</td>
<td>129</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
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<td>64</td>
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<td>162</td>
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<td>45</td>
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