CHAPTER 7
COMPARISON OF FEED MECHANISM OF FINE BORING MACHINE
AND PREDICTING THE OPTIMUM BASED ON COST ANALYSIS

7.1 SUMMARY OF 3 FEED MECHANISMS

The main functions of the feed mechanism is the following:

1. 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.

In Electro Mechanical feed the fast and slow movements are obtained with 2 motors one brakemotor for rapid traverse and one standard motor for slow feed. These two motors are fixed perpendicular to each other. During rapid traverse power is transmitted from brakemotor to lead screw via sun and planet gears as shown as explained in Chapter 4.

After the table has travelled fast the idle distance, brake motor will be switched off and standard motor will be switched on. Now power will be transmitted from standard motor to lead screw via change gears. During slow feed as many as 45 feeds can be obtained by varying the change gears. When
different feeds are required the gears are changed by operator by opening the gear box and change done as required.

Hydraulic drive is designed on the principle of hydraulic stepless drive. Hydraulic stepless drive with the flow control valve is selected. In hydraulic feed mechanism the table is moved by piston connected with table and rapid advance rapid return slow feed takes place by control of valves.

There are four solenoid operated valves four check valves and four flow control valves. Solenoid operated valves change the direction of fluid, check valves allows the fluid to flow in only one direction and flow control valves are used to control the flow thereby varying feed. The sequence of operations were explained in Chapter 5. At first Sol 3 is in on position. Table moves at High speed forward from left to right, and table decelerates after the idle distance is covered by making the Solenoid valve 3 in off position. At this time the fluid is made to pass through a check valve and table moves in forward direction only. When table comes near the left side spindle Solenoid 1 is in on position. Solenoid 1 is meant for slow feed forward. Table moves slowly towards right side spindle and boring takes place. At this time the fluid is made to pass through a flow control valve and speed can be varied by controlling flow. After that Solenoid 1 is in off position. Table stops. Similarly operations like rapid return slow feed at left side takes place by the operations of valves 4 and 2. So all the operations like rapid advance (RA) slow feed at right side (SF), rapid return (RR) slow feed at left side, table returns to home position takes place by the control of valves. Various parameters like cycle time, cylinder bore,
pump discharge, power of motor, pipe size, oil type, tank capacity, filter capacity pressure gauge pressure limit, pressure switch, etc were designed.

In CNC feed the table is moved by a ballscrew which gets power from AC servomotor. The complete numerically control drives consists of AC servo motor, drive unit and mechanical transmission system.

The characteristic of AC servo motor are

(a) High power density with low weight.
(b) Low rotor inertia.
(c) Constant continuous torque and constant overload capacity over the full speed range.
(d) Additional cooling of the motor is not required.

The motor speed is directly proportional to the frequency of AC mains.

\[ n = \frac{120 f}{P} \]

where

\[ n = \text{motor speed} \]
\[ f = \text{frequency of supply} \]
\[ P = \text{no. of poles}. \]
Thus if the number of poles of the motor is constant speed of the AC motor is directly proportional to the frequency. Hence by varying the frequency speed control can be achieved.

Fig. 6.25 shows the drive unit. When motor is switched on, speed is reduced to 1 : 2 ratio in speed reduction unit. The ball screw rotates at output speed and table move. This is how power transmission takes place.

The torque and speed of motor were designed as discussed in Sec. 6.5 and rated torque is found to be 18 nm and speed of motor 2000 rpm. The sequence of events like table moved from left to right fast, rapid advance, slow feed SF at right side, rapid returns, slow feed at left side takes place in CNC feed by adjusting the speed of motor to run set maximum rated speed during rapid advance and rapid return. The motor is run at slow feed during the boring taking place at left and right side boring heads.

At slow speed the motor runs at constant torque and feed is varied infinitely by varying the frequency as explained earlier. During rapid advance and rapid return motor runs at constant power.

7.2 CYCLE TIMES IN FEED SYSTEMS

1. Cycle time in electro mechanical feed

\[
\text{Cutting speed} = \frac{\pi \text{DN}}{1000} = 90 \text{ m/min for material cast iron & cutter carbide tip}
\]

\[
\text{Cutting speed} = 90 \text{ m/min}
\]
Details of the Component Bored in
Fine Boring Machine

Material: Cast Iron
Component name: Cylinder for IC engine

Fig. 7.1

All dimensions are in mm
Dia of bore \( D \) = 50mm

\[
N = \frac{90 \times 1000}{\pi \times 50} = 600 \text{ rpm.}
\]

Feed rate for fine boring 0.05mm/rev.

Feed / min = 600 x 0.05 = 30mm/min

Bore length = 70mm

Machining Time = \( \frac{70}{30} \times 60 \) = 140 secs.

Rapid rate = 4600mm/min

Rapid travel = 300 mm

\[
\text{Time for rapid travel} = \frac{300}{4600} \times 60 = 4 \text{ sec.}
\]

**Time for Feed**

Table from home position to right = 4 secs.

Right side boring = 140 secs.

Right to left = 8 secs.

Left side boring = 140 secs.

Left to home position = 4 secs.

\[
\text{Total} = 296 \text{ secs.}
\]

**Cycle time for fine boring using Electro Mechanical feed** = 296 secs.
2. **Cycle time for hydraulic feed**

Cutting speed\[=\dfrac{\pi DN}{1000} = 90 \text{ m/min}\]

Dia of bore D = 50 mn

Spindle speed\[=\dfrac{90 \times 1000}{\pi \times 50} = 600 \text{ rpm}\]

Feed rate for fine boring\[= 0.05 \text{ mm/rev.}\]

Feed/min = 600 x 0.05\[= 30 \text{ mm/min}\]

Machining time\[= \dfrac{60}{30} \times 70 = 140 \text{ sec}\]

Rapid rate\[= 3000 \text{ mm/min}\]

Rapid travel\[= 300 \text{ mm}\]

Cycle time for rapid level\[= \dfrac{300}{3000} \times 60 = 6 \text{ sec}\]

Table from home position to right\[= 6 \text{ sec}\]

right side boring\[= 140 \text{ sec}\]

right to left\[= 12 \text{ sec}\]

left side boring\[= 140 \text{ sec}\]

left to home position\[= 6 \text{ sec}\]

Total\[= 304 \text{ sec}\]

**Cycle time for fine boring using hydraulic feed = 304 secs.**
3. **Cycle time for CNC feed**

Cutting speed = \( \frac{\pi DN}{1000} = 90 \text{m/min} \)

Dia of bore D = 50mm

Spindle speed = \( \frac{90 \times 1000}{\pi \times 50} = 600 \text{ rpm} \)

Feed rate for fire boring = 0.05mm/rev.

Feed/min = \( 600 \times 0.05 = 30 \text{mm/min} \)

Machining time = \( \frac{70}{30} \times 60 = 140 \text{ sec} \)

Rapid rate = 10000mm/min

Rapid travel = 300mm

Cycle time for rapid travel = \( \frac{300}{10000} \times 60 = 1.8 \text{ sec} \)

Table from home position to right = 1.8 sec

Right side boring = 140 sec

Right to left = 3.6 sec

Left side boring = 140 sec

left to home position = 1.8 sec

**Total** = 287.2 sec

Cycle time for fine boring using CNC feed = 287.2 secs.
There are two pieces done at a time one at left side boring head and one at right side boring head. Time taken for loading, unloading, fixing the jobs on fixture etc.

= 10 minutes for each Pcs.

and 20 minutes for one setup

Total time taken for fine boring a hole for electro mechanical feed

= $20 \times 60 + 296$

= 1496 sec

Total time taken for fine boring a hole for hydraulic feed

= $20 \times 60 + 304$

= 1504 sec

Total time taken for fine boring a hole for CNC feed

= $20 \times 60 + 287.2$

= 1487.2 secs.

7.3 COST OF FEED MECHANISMS

1. Cost of electro mechanical feed

1. Raw material cost Rs. 47530
2. Bought out Rs. 28150
3. Imported Rs. 3295
4. Sub Contract Rs. 1960

Labour Cost

5. Manufacturing Rs. 1,02160
6. Assembly cost Rs. 25520
7. Pattern cost Rs. 25000
Production cost $= 1 + 5 + 6 + 7 = 200210$

Factory cost $= Rs. 200,210$

Cost price 10% added $= Rs. 220,231 (200,210 + 200,21)$

Bought out + imported + sub contract $= 33405$

Total cost $= Rs.253636$

| Cost of Electro Mechanical feed mechanism | $= Rs. 2,53,636$ |

2. Cost of Hydraulic feed mechanisms
   1. Raw material $Rs. 34130$
   2. Bought out $Rs. 35550$
   3. Manufacturing $Rs. 71750$
   4. Assembly $Rs. 19140$
   5. Pattern $Rs. 25000$

   $1 + 3 + 4 + 5$ Factory cost $Rs. 150020$

   Cost price $Rs. 165022$

   Bought out $Rs. 35550$

   Total $Rs. 200572$

| Cost of hydraulic feed mechanism | $= 200572$ |

3. Cost of CNC feed mechanism

   Cost of system $Rs. 1,50,000$
   Ball screw $Rs. 50,000$
   Gearbox and others $Rs. 50,000$

   Total $Rs. 2,50,000$

| Cost of CNC feed Mechanism | $= Rs.2,50,000$ |
The details of cost of each feed mechanisms was worked out with the help of HMT. Giving full details about material cost manufacturing cost of each component will make the thesis book bulky, hence avoided.

7.4 MACHINE HOUR RATE FOR 3 TYPES OF FEED MECHANISMS

1. Electro mechanical feed system

Cost of feed system = Rs.2,53676
Estimated life = 10 years

We assume 300 working days in a year and 2 shifts per day with 14 hours effective time of working.

(16 hours shift - 1 hour for lunch and personnel matters and 1 hour for getting tools and objects from store etc.)

So estimated life in hours

\[ = 10 \times 300 \times 14 \]

\[ = 42,000 \text{ hrs.} \]

Estimated working hours per annum = 300 \times 14

\[ = 4,200 \text{ hrs.} \]

Estimated scrap value = Rs.10000
Estimated hours required for maintenance = 200 hrs.
Cost of repair and maintenance = Rs. 6000 per annum
Power required for motor = 1 H.P.

\[ = 0.736 \text{ kw for 1 hour} \]
Wages of operator converted to fine boring operation alone Rs.500 per month. over heads converted to fine boring operation alone Rs.300 per month.

Cost of over head per annum = 300 x 12
Cost of wages per annum = 500 x 12

Total

Working hours per annum 4200-200 = 4000 hrs
Fixed expenses per hour 9600/4000 = Rs. 2.4

Depreciation charges = \( \frac{2,53,676 - 10000}{42000} \)
= Rs.5.8

Cost of repair & maintenance per hour = \( \frac{6000}{4000} \) = 1.5

Cost of Power

Electricity charges for hour per unit = Rs.3.25

We take 1 Hp motor = 0.736 kw/hr

But the time taken for fine boring operation is only 296 sec (The time at which the motor is operated)

Cost of power = \( 1 \times 0.736 \times 3.25 \times \frac{296}{60 \times 60} \)

= 0.2 Rupees / hour

Machine hour rate

= 2.4 + 5.8 + 1.5 + 0.2
= Rs. 9.9

Machine hour rate for electro mechanical feed mechanism = Rs.9.9/hr.
2. **Machine Hour rate for Hydraulic feed systems**

Cost of feed system = Rs.2,00,572

Estimated life = 10 x 300 x 14 hr = 42,000 hr

Estimated scrap value = Rs.8000

Estimated working hours per annum = 14 x 300 = 4200 hrs

Estimated hours required for repair and maintenance = 200 hr

Cost of repair and maintenance = Rs.6000 per annum

Power required = 2 HP

(Motor power 2 HP)

\[ 2\text{HP} = 0.736 \times 2 = 1.472 \text{Kw}. \]

Over head charge converted to fine boring operation = Rs. 350 per month

Wages converted to fine boring operation alone = Rs.400/month

Annual over head charges 350 x 12 = Rs.4200

Wages annual 400 x 12 = Rs.4800

Total annual fixed charges = Rs.9000

Fixed expenses per hour = 9000

\[ \frac{4000}{9000} = \frac{400}{900} \]

= 2.3
Depreciation charges/hr

\[
\frac{200572 - 8000}{42000} = \text{Rs. 4.5}
\]

Electricity charges for the cycle time of 304 sec.

\[
= 0.736 \times 2 \times 3.25 \times \frac{304}{60 \times 60}
= \text{Rs.0.4/hr.}
\]

Cost of repair maintenance

\[
= \frac{6000}{4000} = 1.5/\text{hr.}
\]

Machine hour rate

\[
= 2.3 + 4.5 + 0.4 + 1.5
= 8.7
\]

Machine hour rate for hydraulic feed = Rs.8.7

3. Machine hour rate for CNC feed system

Cost of feed mechanism = 2,50,000

Estimated life = 10 years

= 10 \times 300 \times 14 \text{ hrs.}

= 42,000 \text{ hrs.}

Estimated scrap value = Rs.20,000
Estimated working hour per annum = 14 x 300 = 4200 hrs.

Estimated hours required for maintenance = 200 hrs in a year

Cost of repairs maintenance = Rs.3000 per annum

Power = 3.77 kw. of motor

Total power spent = 3.77 kw/hour

Over heads converted to fine boring operation = 600/month

Wages converted to fine boring operation = Rs.800 per month

Over head per annum = Rs.600 x 12

= Rs.7200

Wages per year = 800 x 12

= 9600

Total = 16800

Estimated working hours = 4200 - 200

= 4000 in a year

Fixed cost/hour = $\frac{16800}{4000}$ = Rs.4.2

Depreciation = $\frac{2,50,000 - 20,000}{42,000}$

= 5.476/hr.

Cost of repair & maintenance = $\frac{3000}{4000}$ = Rs.0.75/hr.
Cost of power

\[
\text{Cost of power} = \frac{3.77 \times 3.25 \times 287.2}{60 \times 60} = \text{Rs.1/hr.}
\]

Machine hour rate

\[
\text{Machine hour rate} = 4.2 + 5.5 + 1 + 0.75 = \text{Rs.11.45}
\]

Machine hour rate for CNC feed mechanism = Rs.11.45

7.5 COST OF COMPONENT

1. Cost of component in electro mechanical Feed mechanism

Cost of component

\[
= \text{Machine hour rate} \times \text{Time spent on the machine for fine boring operation.}
\]

Cost of component electro mechanical feed

\[
= 9.9 \times \frac{1496}{60 \times 60} + 10\% \text{ profit} = \text{Rs.4.5}
\]

Cost of machining component in Electro Mechanical feed = Rs.4.5

2. Cost of component in hydraulic feed

Cost of components in hydraulic feed

\[
= 8.7 \times \frac{1504}{60 \times 60} + 10\% \text{ profit} = \text{Rs.4.00}
\]

Cost of machining component in hydraulic feed = Rs.4.00
3. **Cost of component in CNC feed**

Cost of component in CNC feed = \( 11.45 \times \frac{14872}{60 \times 60} \) + 15% profit

= Rs.5.5 (Since quality is high 15% profit added)

| Cost of machining the component in CNC feed system = Rs.5.5 |

### 7.6 REVENUE EARNED IN 3 TYPES OF SYSTEMS

1. **Electro Mechanical feed**

   No. of pieces machined in Electromechanical system per day. Working hours per day = 14 hrs.

   At a time in one cycle 2 pcs. are produced one at right side boring head and one at left side boring head.

   Number of Pcs. machined per day = 2 x \( \frac{\text{Total working time per day}}{\text{Total time taken in one cycle (set up time + cycle time)}} \)

   = \( 2 \times \frac{60 \times 60 \times 14}{1496} \)

   = 67.3796 Pcs. per day.

   Revenue earned per year for electro mechanical feed mechanisms

   = Cost of machining one component x no. of component machined per day x total no. of working days per year

   = 4.5 x 67.37 96 x 300

   = Rs.90 962.5 per year

| Revenue earned per year for electro mechanical feed mechanism = Rs.90 962.5 |
2. **Revenue earned in hydraulic feed mechanism**

No. of pcs machined at a time = 2
(one each at left and right boring head)

Number of working hours = 14 hrs.

Total time taken for machining = 1504 secs.

Number of components machined per day

\[
\frac{14 \times 2 \times 60 \times 60}{1504} = 67 \text{ Pcs. per day.}
\]

Revenue earned in hydraulic feed mechanism per year

\[
\text{Revenue earned per year for hydraulic feed mechanism} = \text{Rs.80,400}
\]

3. **Revenue earned in CNC feed mechanism**

No. of pieces machined at a time = 2

No. of working hours = 14

Total time taken for one cycle = 1487.2 Secs.

No. of components machined per day

\[
\frac{2 \times 14 \times 60 \times 60}{1487.2} = 68 \text{ Pcs.}
\]
Revenue earned per year for CNC feed = \[ 5.5 \times 68 \times 300 \]
= Rs.112200

7.7 RETURN ON INVESTMENT (REF. 80)
i. Average rate of return method

1. Electro mechanical feed mechanism

Initial investment = Rs.253636
Average book earnings = Rs.90962.5

Average rate of return = \[ \frac{90962.5}{253636} \] = 35.8%

2. Hydraulic feed

Initial investment = Rs. 200572
Average book earnings = Rs. 80400

Average rate of return = \[ \frac{80400}{200572} \] = 40.08%

3. CNC feed

Initial investment = 2,50,000
Average book earnings = 1,12,200

Average rate of return = \[ \frac{1,12,200}{2,50,000} \] = 44.8%

Comparing the above three values average rate of return is highest for CNC feed.
The principal virtue of average rate of return is its simplicity; it makes use of readily available accounting information.

The principal shortcomings of the method are that it is based on accounting income rather than on cash flows and it fails to take account of the timing of cash inflows and outflows.

ii. Pay back period method (Ref. 80)

The pay back period of an investment project payment tells us the number of years required to record our initial cash investment. It is the ratio of initial fixed investment over the annual cash inflows for the recovery period.

1. Pay back period for Electro mechanical feed

\[
\frac{253636}{90962.56} = 2.78 \text{ year}
\]

2. Pay back period for hydraulic feed

\[
\frac{200572}{80400} = 2.49 \text{ year}
\]

3. Pay back period for CNC feed

\[
\frac{25,0000}{1,12,200} = 2.228 \text{ year}
\]

The shorter the pay back period the better is the feed system. Among the above three feed mechanism, in Electromechanical feed the money is received in 2.78 years and in hydraulic feed system the money is recovered in
2.49 years and in CNC the money is recovered in 2.228 years. Hence CNC feed is the best, next better is hydraulic and next electromechanical feed.

The major shortcomings of the pay back period is that it fails to consider cash flow after the pay back period consequently it can not be regarded as a measure of profitability. Never the less the pay back method continues in use frequently as a supplement to other more sophisticated methods.

The shorter is the payback period supposedly the less risky the project and greater is liquidity.

iii. Internal rate of return method (Ref.80)

Because of the various shortcomings in the average rate of return and pay back methods, it generally felt that discounted cash flow methods provide more objective basis for evaluating and selecting the best out of alternatives. Internal rate of return for an investment proposal is the discount rate that equates the present value of expected inflows. It is represented by the rate.

\[
\sum_{t=0}^{n} \left[ \frac{A_t}{(1+r)^t} \right] = 0
\]

Where \(A_t\) is the cash flow for period ‘t’ whether it be net cash out flow or inflow and \(n\) is last period in which cash flow is expected. If the initial cash outlay or cost occurs at time 0, let \(n = 5\). then,
\[ A_0 = \frac{A_1}{1 + r} + \frac{A_2}{(1+r)^2} + \frac{A_3}{(1+r)^3} + \frac{A_4}{(1+r)^4} + \frac{A_5}{(1+r)^5} \]

1. For electro methanided feed

\[
253636 = \frac{90962.5}{1+r} + \frac{90962.5}{(1+r)^2} + \frac{90962.5}{(1+r)^3} + \frac{90962.5}{(1+r)^4} + \frac{90962.5}{(1+r)^5}
\]

By trial and error method put \( r = 15\% \)

\[
A_0 = \frac{90962.5}{1+.15} + \frac{90962.5}{(1+.15)^2} + \frac{90962.5}{(1+.15)^3} + \frac{90962.5}{(1+.15)^4} + \frac{90962.5}{(1+.15)^5}
\]

\[
= 79097.8 + 68780.7 + 59809 + 52008 + 45224
= 304919.5 \neq 253636
\]
So try with $R = 20\%$

\[
A_0 = \frac{90962.5}{1+.20} + \frac{90962.5}{(1+.20)^2} + \frac{90962.5}{(1+.20)^3} + \frac{90962.5}{(1+.20)^4} + \frac{90962.5}{(1+.20)^5}
\]

\[= 274444.8 \times 253636\]

So try with $R = 23\%$

\[
A_0 = \frac{90962.5}{1+.23} + \frac{90962.5}{(1+.23)^2} + \frac{90962.5}{(1+.23)^3} + \frac{90962.5}{(1+.23)^4} + \frac{90962.5}{(1+.23)^5}
\]

\[= 255000 \text{ nearly} \times 253636\]

So try with $R = 23.2\%$

\[
A_0 = \frac{90962.5}{1+.232} + \frac{90962.5}{(1+.232)^2} + \frac{90962.5}{(1+.232)^3} + \frac{90962.5}{(1+.232)^4} + \frac{90962.5}{(1+.232)^5}
\]

\[= 253929 \text{ approximately} \times 253636\]

\[
\text{Hence } r = 23.2\%
\]
2. **For hydraulic feed**

\[ A_0 = \frac{80400}{(1+r)} \]

\[ + \frac{80400}{(1+r)^2} + \frac{80400}{(1+r)^3} \]

\[ + \frac{80400}{(1+r)^4} + \frac{80400}{(1+r)^5} \]

By Trail and Error Method

\[ r = 28.5\% \]

3. **For CNC Feed**

\[ A_0 = \frac{1,12,200}{1 + r} + \frac{1,12,200}{(1 + r)^2} + \frac{1,12,200}{(1+r)^3} \]

\[ + \frac{1,12,200}{(1 + r)^4} + \frac{1,12,200}{(1+r)^5} \]

By Trail and Error Method

\[ r = 34.755\% \]

So comparing above three feed system Internal rate of return is highest in CNC feed.
iv. **Net present value method**

Like internal rate of return method the net present value method is discounted cash flow method. With the net present value method all cash flow are discounted to present value using required rate of return.

\[
NPV = \sum_{t=0}^{n} \left[ \frac{At}{(1+k)^t} \right] = 0
\]

Where \( K \) is the required rate of return. The net present values compared for 3 designs and higher is best design.

1. N.P.V for electromechanical feed at \( K = 12\% \) (Usual rate of return)

\[
= -2,53636 + \frac{90962.5}{1.12} + \frac{90962.5}{(1.12)^2} + \frac{90962.5}{(1.12)^3} + \frac{90962.5}{(1.12)^4} + \frac{90962.5}{(1.12)^5} + 72514.7 + 64745.3 + 57808.3 + 51614.5
\]

\[
= (-253636 + 327899)
\]

\[
= 74263
\]
2. **N.P.V. for hydraulic feed**

\[
\begin{align*}
&= -200572 + \frac{80400}{1.12} \\
&\quad + \frac{80400}{(1.12)^2} + \frac{80400}{(1.12)^3} + \frac{80400}{(1.12)^4} \\
&\quad + \frac{80400}{(1.12)^5} \\
&\quad = -200572 \\
&\quad + 71786 + 64094 + 57227 + 51095 + 45621 \\
&\quad = -200572 + 289823 = 8925
\end{align*}
\]

3. **N.P.V. for CNC feed**

\[
\begin{align*}
&= -2,500,000 + \frac{1,12,200}{(1.12)^1} + \frac{1,12,200}{(1.12)^2} + \frac{1,12,200}{(1.12)^3} \\
&\quad + \frac{1,12,200}{(1.12)^4} + \frac{1,12,200}{(1.12)^5} \\
&\quad = -2,500,000 + 1,00178 + 89445 + 79861 + 71305 + 63665.2 \\
&\quad = (-250000 + 4,04454) = 1,54454
\end{align*}
\]

*If the sum of discount cash flow is positive the proposed is accepted. So all the three projects are accepted.*
But CNC feed is having the highest net present value next higher is hydraulic feed and electrochemical last of the three.

**Profitability Index (Ref.80)**

The profitability index or benefit cost ratio of a project is the present value of future net cash flows over the initial cash outlay. It can be expressed.

\[
PI = \frac{\sum_{t=1}^{n} \frac{A_t}{(1+k)^t}}{A_0}
\]

where \( K \) is the required rate of return as given earlier.

\[
\sum_{t=1}^{n} \frac{A_t}{(1+k)^t} = \frac{327899}{253636} = 1.29
\]

Profitability index for hydraulic feed

\[
= \frac{289823}{200572} = 1.44
\]

Profitability index for CNC feed

\[
= \frac{4,04454}{250000} = 1.61
\]
As long as the profitability index is 1 or greater the investment proposal is acceptable. For any given project the net present value method and profitability index give the same accept reject signal. Highest profitability in CNC feed.

7.8  BREAK EVEN ANALYSIS (REF.79)

Operating leverage is used for operational or profit planning for the same purpose the cost volume - profit analysis or break even analysis is used. Break even analysis indicates the profit or loss at various levels of activity and the extent of margin of safety. It may be mentioned that the reciprocal of margin of safety is the operation leverage. A low margin of safety indicates that a firm has not got enough risk bearing capacity as measured by variation in sales.

7.8.1 Cost volume profit analysis

By analysis of costs volume and profit it is possible to predict the probable effect on profit which may be expected to follow from a change in volume or level of activity. The result of such analysis are generally presented in the form of break even chart.

7.8.2 Break even chart

A break even chart BEC is a pictorial representation of marginal costing. It is an important aid to profit planning. It has been defined as a chart which shows the profitability or otherwise of an undertaking of various levels of
activity and as a result indicates the point at which neither profit nor loss is made. The BEC therefore depicts the following information at various levels of activity.

1. Variable costs, fixed costs and total costs
2. Sales value
3. Profit or loss
4. Break even point i.e. the point at which total cost just equal or break even with sales. This is the activity point at which neither profit is made nor loss is incurred.
5. Margin of safety.

Certain assumptions are required to the made for the purpose of construction of BEC. They are:

1. Fixed costs will tend to remain constant. In other words there will not be any change in cost factors such as change in property tax rate, insurance rate, salaries of staff or in management policy.
2. Prices of variable cost factors i.e. wage rates, price of material suppliers service etc. will remain unchanged.
3. Semi variable costs can be segregated into variable and fixed elements.
4. Product specification and methods of manufacturing and selling will not undergo change.
5. Operational efficiency will not increase or decrease.
6. There will not be any charge in pricing policy due to change in volume competition etc.

7. The number of units of sales will coincide with the units produced so that there is no closing or opening stock. Alternatively the changes in opening and closing stocks are insignificant and not they are valued at the same price or at variable cost.

The most important one by the BEC is the ascertainment of a break even point (BEP) from the chart which is a valuable guide to the management. The BEP can be determined from BEC or can be calculated as follows:

(i) \[ \text{BEP (units)} = \frac{\text{Total fixed costs}}{\text{Unit contribution}} \]

(ii) \[ \text{BEP (sales value)} \]

(a) \[ \frac{\text{Total fixed costs} \times \text{unit selling price}}{\text{Unit contribution}} \]

(b) \[ \frac{\text{Total fixed costs} \times \text{Total sales value}}{\text{Total contribution}} \]

(c) \[ \frac{\text{Total fixed costs}}{1 - \frac{\text{Variables cost}}{\text{Sales}}} \]
7.8.3 Construction of the break even chart

A break even chart is drawn in a graph paper. Costs and revenues are plotted in Y axis and activity of volume is plotted on X axis.

Procedure

1. Represent fixed cost by a line parallel to X axis. Plot variable costs for different levels of activity over fixed cost line. Join the variable cost line to fixed cost line at zero activity level. The resultant will represent total cost line, variable cost having been added to fixed cost.

2. Similarly determine sales value at various levels of activity and plot them on graph paper and join to zero in the graph. This line will represent sales value.

3. The sales line will cut the total cost line at a point which is known as break even point. The break even sales will be determined by dropping a perpendicular to the X axis from the point of intersection and measuring the horizontal distance from the zero point to the point at which perpendicular is drawn. Another perpendicular to the Y axis from the point of intersection will indicate (vertically), the break even sales value.
7.8.4 Details of calculations of profit, break even point etc. for three feed mechanisms

1. Electro mechanical feed mechanism

**Fixed cost for electro mechanical feed system**

Over heads per year converted to fine boring operation alone $300 \times 12 = 3600$

Wages per year for fine boring operation alone $(500 \times 12) = 6000$

Total $= 9600$

Total fixed cost per annum for electro mechanical feed

**Variable cost for electro mechanical feed**

Depreciation charges $= \frac{\text{Initial investment - scrap value}}{\text{Life in hours}}$

Depreciation charges/hr. $= \frac{253636 - 10000}{42000} = Rs. 5.8$

Electricity charges/hr. $= 0.2 \text{ rupees/hr.}$

Cost of repairs Maintenance/hr. $= Rs.1.5$

Variable cost per hour $= 5.8 + 1.5 + 0.2 = Rs.7.5$

Variable cost per component operation. $= \frac{\text{Hour rate x time spend for fine boring}}{60 \times 60} = Rs.3.2 \text{ per component}$
Table 7.1

Unit produced, sales fixed variable cost per annum details for Electro Mechanical feed.

<table>
<thead>
<tr>
<th>Units</th>
<th>Sales cost (4.5 x no. of units)</th>
<th>Fixed cost</th>
<th>Variable cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>Nil</td>
<td>9600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5000</td>
<td>22500</td>
<td>9600</td>
<td>16000</td>
<td>25600</td>
</tr>
<tr>
<td>10000</td>
<td>45000</td>
<td>9600</td>
<td>32000</td>
<td>41600</td>
</tr>
<tr>
<td>15000</td>
<td>67500</td>
<td>9600</td>
<td>48000</td>
<td>57600</td>
</tr>
<tr>
<td>20000</td>
<td>90000</td>
<td>9600</td>
<td>64000</td>
<td>73600</td>
</tr>
</tbody>
</table>

Annual sales = 67 x 300 = 20100

= 20000

Annual sales is 20000 units units sales cost is Rs.4.5

(i) Profit sales value - total cost per year = 90000 - 73600

= Rs.16400

(ii) Contribution = Sales price - variable cost per unit

= Rs.4.5 - 3.2

= Rs.1.3

(iii) P/V Ratio (Profit volume ratio)

\[
\text{P/V Ratio} = \left( \frac{\text{Contribution}}{\text{Sales}} \right) \times 100
\]

\[
= \left( \frac{1.3}{4.5} \right) \times 100
\]

= 28.89%
(iv) Break even point

\[
\text{Break even point} = \frac{\text{Fixed expenses}}{\text{Contribution per unit}}
\]

\[
= \frac{9600}{7384} = 1.3
\]

\[
= 7384 \text{ Nos.}
\]

(v) Break even point in Rupees

\[
\text{Rupees} = \frac{\text{Fixed expenses}}{\text{P/V Ratio}}
\]

\[
= \frac{9600}{28.889} = 33230
\]

(vi) Margin of safety = Actual sales - Break even sales

\[
= 90000 - 33230 = 56770
\]

2. Hydraulic feed mechanism

Fixed cost for hydraulic feed mechanism

\[
\text{Over heads converted to fine boring operation alone } 350 \times 12 = 4200
\]

\[
\text{Wages annual } 400 \times 12 = 4800
\]

Total \[
= 9000
\]

Total fixed cost \[
= \text{Rs.9000}
\]
Variable cost for hydraulic feed system

\[
\text{Depreciation} = \frac{\text{Initial investment} \ - \ \text{scrap value}}{\text{Life in hours}}
\]

\[
= \frac{200572 \ - \ 8000}{42000}
\]

\[
= 4.5/\text{hr.}
\]

Electricity charges = 0.4/hr.

Cost of repair and maintenance = 1.5/hr.

Total variable cost per hour

\[
= 4.5 + 0.4 + 1.5
\]

\[
= 6.4
\]

Variable cost per Component

\[
= 6.4 \times 1504
\]

\[
= \frac{60 \times 60}{60}
\]

\[
= \text{Rs.} 2.7
\]

Variable cost for hydraulic feed = \text{Rs.} 2.7 per component

Table 7.2

Unit produced, sales, fixed variable cost per annum details for Hydraulic feed

<table>
<thead>
<tr>
<th>Units</th>
<th>Sales cost (4 x no. of units)</th>
<th>Fixed cost</th>
<th>Variable cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>Nil</td>
<td>9000</td>
<td>-</td>
<td>9000</td>
</tr>
<tr>
<td>5000</td>
<td>20000</td>
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<td>22500</td>
</tr>
<tr>
<td>10000</td>
<td>40000</td>
<td>9000</td>
<td>27000</td>
<td>36000</td>
</tr>
<tr>
<td>15000</td>
<td>60000</td>
<td>9000</td>
<td>40500</td>
<td>49500</td>
</tr>
<tr>
<td>20000</td>
<td>80000</td>
<td>9000</td>
<td>54000</td>
<td>63000</td>
</tr>
</tbody>
</table>
(i) Profit = 80000 - 63000

= Rs.17000

(ii) Contribution = Sales price per unit - cost per unit (variable)

= 4 - 2.7

= 1.3

(ii) P/V Ratio = Profit volume ratio

\[
\text{P/V Ratio} = \frac{\text{Contribution}}{\text{Sales}} \times 100
\]

= \frac{1.3}{4} \times 100

= 32.5%

(iv) Break even point

\[
\text{Break even point} = \frac{\text{Fixed expenses}}{\text{Contribution}}
\]

= \frac{9000}{1.3}

= 6923.07 Nos.

(v) Break even point in rupees

\[
\text{Break even point in rupees} = \frac{\text{Fixed expenses}}{\text{P/V Ratio}}
\]

= \frac{9000}{0.325}

= Rs.27692.3
(vi) Margin of safety 
\[ \text{Margin of safety} = \text{Actual sales} - \text{break even sales} \]
\[ = 80000 - 27692.3 \]
\[ = \text{Rs. 52307.7} \]

3. CNC feed mechanism

Fixed cost for CNC feed mechanism

Over heads converted to the fine boring operation alone = 600 x 12
\[ = 7,200 \]

Wages per year 800 x 12 = 9,600

Total fixed charges = 16,800

Total fixed cost = Rs.16,800

Variable cost for CNC feed mechanism

Depreciation/hr = \[ \frac{\text{Initial cost} \cdot \text{scrap value}}{\text{Life in hours}} \]
\[ = \frac{2,50000 - 20000}{42000} \]
\[ = \text{Rs.5.476} \]

Cost of repair & maintenance
\[ = \frac{3000}{4000} = 0.75/\text{hr.} \]

Cost of power
\[ = \frac{3.7 \times 3.25 \times 287.2}{60 \times 600} \]
\[ = \text{Rs.1/hr.} \]
Total variable cost per hour = 5.5 + 0.75 + 1
= 7.25

Variable cost per component
= hour rate x time spent on the machine
= 7.25 x 1487.2
= 60 x 60
= Rs.3

Variable cost of component in CNC feed mechanism = Rs.3

Table 7.3

<table>
<thead>
<tr>
<th>Unit</th>
<th>Sales cost 5.5 x sales</th>
<th>Fixed Cost</th>
<th>Variable cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>-</td>
<td>16800</td>
<td>-</td>
<td>16800</td>
</tr>
<tr>
<td>5000</td>
<td>27500</td>
<td>16800</td>
<td>15000</td>
<td>31800</td>
</tr>
<tr>
<td>10000</td>
<td>55000</td>
<td>16800</td>
<td>30000</td>
<td>46800</td>
</tr>
<tr>
<td>15000</td>
<td>82500</td>
<td>16800</td>
<td>45000</td>
<td>61800</td>
</tr>
<tr>
<td>20000</td>
<td>110000</td>
<td>16800</td>
<td>60000</td>
<td>76800</td>
</tr>
</tbody>
</table>

(i) Profit = 110000 - 76800 = 33200

(ii) Contribution = Sales Price per unit - Variable Cost per unit
= 5.5 - 3
= 2.5

(iii) \( \frac{P}{v} \) ratio - Profit - volume ratio
= \( \frac{\text{Contribution}}{\text{Sales}} \) x 100
= \( \frac{2.5}{5.5} \) x 100
= 45.45%
iv) Break even point

\[
\text{Fixed expenses} \quad \text{Contribution} = 16,800 \\
2.5 \\
= 6720 \text{ Nos.}
\]

v) Break even point in Rupees

\[
\frac{\text{Fixed Expenses}}{\text{P/V ratio}} = \frac{16800}{0.4545} = \text{Rs.36963}
\]

vi) Margin of Safety = Actual Sales - Break even sales

\[
= 1,10000 - 36963 = \text{Rs. 73037}
\]

7.8.5 Interpretation of break even chart (Ref. Fig.7.2, 7.3 and 7.4)

The break even chart will give a vivid picture of profit or loss at different levels of activity. For instance where the sales line is above total cost line there is profit and where it is below the total cost line there is loss and where cost equals total sales there is no profit or no loss.
BREAK EVEN CHART FOR ELECTROMECHANICAL FEED

UNIT SALES
Fig. 7.2
BREAK EVEN CHART FOR HYDRAULIC FEED

UNIT SALES

Fig. 7.3
BREAK EVEN CHART FOR CNC FEED

Fig. 7.4
Break even analysis is based on the principle of classifying the operating expenses into fixed and variable. Nowadays it has become a powerful instrument in the hands of policy makers to maximise profit.

The term "break even Analysis" is interpreted in the narrower as well as broader sense. Used in its narrower sense, it is concerned with finding out the break even point i.e. level of activity where the total cost equals to selling price. Used in its broader sense it means the systems of analysis which determine the probable profit at any level of production. The break even analysis establishes the relationship of costs, volume and profits. So this analysis is also known as cost volume profit analysis.

The study of break even analysis can be made by (i) mathematical relationship between cost volume profit and (i) preparing break even chart.

In order to understand mathematical relationship between cost volume and profit it is desirable to understand the following four concepts their calculation and application.

i) Contribution

ii) Contribution / sales (C.S.) or
Profit volume (P/V) ratio

iii) Break even point

iv) Margin of safety
7.8.5.1 Contribution

Contribution is the difference between the sales and marginal cost of sales and its contribution towards fixed expenses and profit.

\[
\text{Contribution} = \text{Selling price} - \text{Marginal cost}
\]

\[
\text{Contribution} = \text{Fixed expenses} + \text{Profit}
\]

\[
\text{Contribution} = \text{Fixed expenses} = \text{Profit}
\]

Contribution is different from the profit which is net gain in, activity or the surplus and remain after deducting fixed expenses from the total contribution. In marginal costing contribution is very important as it helps to find out the profitability of a product.

7.8.5.2 Profit Volume P/V Ratio

\[
P/V \text{ Ratio} = \frac{\text{Contribution}}{\text{Sales}}
\]

The profit volume ratio is one of the most important ratios for studying the profitability of operations of a business and establishes the relationship between contribution and sales. Comparison of P/V ratios for different design can be to find out which design is more profitable. Higher P/V ratio more will be the profit and lower the P/V ratio lessor will be the profit.

In our Analysis, of 3 designs, electro mechanical design the P/V ratio is 28.8% and Hydraulic design 32.5% and CNC design 45.45%. Hence CNC design is more profitable.
7.8.5.3 Break Even Point

A business is said to be break even when its total sales are equal to total costs. It is a point of no profit or loss. At this point contribution is equal to fixed cost. A concern which attain break even at a less number of unit will definitely be better from another concern where break even point is achieved at more units of production.

In our analysis of 3 designs for design (1) Electro Mechanical design the break even point is B.E.P = 7384 units.

Design (2) hydraulic design B.E.P = 6923 Units
Design (3) CNC design B.E.P. = 6720 Nos.
Design (3) is better B.E. P. at less units.

7.8.5.4 Margin of Safety

Margin of safety is the difference between the actual sales and sales at break even point. One of the assumption of marginal costing is that output will coincide with sales, so margin of safety is also the excess production over the break even points output. Sales or output beyond break even point is known as margin of safety because it gives some profit at break even point only fixed expenses are recovered. Margin of safety also can be expressed in percentage.

Margin of safety is that sales or output which is above break even point. All fixed expenses are recovered at break even point. So fixed expenses have been excluded from the formula of margin of safety given above. Margin of
safety is that sales which gives us profit after meeting fixed costs. So formula of its calculation takes only profit.

If margin of safety is large it is an indicator of the strength of the business, because with substantial reduction in sales profit shall be made. On the other hand if the margin is small a small reduction in sales or production will be serious matter and lead to loss. The margin of safety at break even point is nil because actual sales volume is just equal to break even sales.

In our analysis for design (1) Electro mechanical design margin of safety

\[ = \text{Rs. 56770} \]

For design (2) hydraulic design, margin of safety

\[ = \text{Rs. 52307.7} \]

For design (3) CNC design, Margin of Safety = Rs. 73037

CNC design has superior margin of safety.