Unit-3

Design of Gear Box

Laws of stepped regulation of speeds in multi-speed gearbox

- Arithmetic Progression
- Geometric Progression
- Harmonic Progression

Sr.No	Comparison Parameter	Arithmetic Progression	Geometric Progression	Harmonic Progression
1	Definition	In arithmetic progression, the difference between any two successive spindle speeds is constant.	In geometric progression, the ratio of any two successive spindle speeds is constant.	In harmonic progression, the difference between reciprocal of any two successive speeds is constant.
2	Z^{th} Spindle Speed	$n_z = \frac{n_{max} - nmin}{(z-1)}$	$\emptyset = \left[\frac{n_{max}}{n_{min}}\right]^{\frac{1}{z-1}}$	$nz = \frac{n_{min}}{[1-(z-1)Cn_{max}]}$
3	Good in	High spindle speed range	High spindle speed range	Low spindle speed range
4	Poor in	Low spindle speed range	Low spindle speed range	High spindle speed range

Design procedure of gear box (sliding gear type)

A. For designing a stepped drive

- Following informations are necessary

- ✓ Highest output speed
- ✓ Lowest output speed
- ✓ Number of steps (Z)
- ✓ Number of stages to achieve the required number of speed steps.

B. Break up of speed steps

- The number of steps (Z) should be so selected that it can be broken into the multiples of 2 & 3. Thus, selected values of Z are : 6,8,9,10,12,14,16 & 18.

C. Structural diagram

- It gives the information about
  - Number of shafts in the speed box
  - Number of gears on each shaft
  - The order of changing transmission in individual groups to obtain the desired speed.
  - Transmission range
  - Group characteristics

While drawing the structural diagram, following points should be considered

a) Number of gears on the last shaft should be as minimum as possible.

b) The speed reduction between the spindle and preceding shaft should be as maximum as possible.

c) Number of gears on any shaft should not be more than three. It can be four in exceptional case.

d) $i_{max} \times imin = 1$ is for least radial dimensions of gear box. This is possible by making the axes of adjacent shafts coincident i.e., co axial

- $i_{max} \times imin = 1$ is possible when maximum speed reductions equals the maximum speed increase.

- But considering the importance of reduction of axial dimensions of gear in machine tool with a traversing spindle head, the above point does not favour it, because small axial dimensions of traversing units are critical.

- Structural formula represented by the special form of graphs is called as structural diagram.

Method of drawing structural diagrams

1. If n= no of transmission groups then draw(n+1) vertical lines at a convenient distance. Here the first vertical line represents the transmission from motor shaft, and the rest represents the transmission group of speed box.

2. Draw an any of horizontal lines intersecting the vertical lines at a distance of logØ from each other. The number of horizontal lines are equal to the number of speed steps(Z). The spacing between the horizontal line should be equal so that interval between the spindle speeds is content. In practice the distance between adjacent horizontal lines is taken equal to Ø, but not log for convenience.

Cont…

3. Draw a line joining the first shaft of known speed & the second shaft for calculated input speed. The speed reduction between the first and second shaft is usually through belt derive.

4. From second shaft at the input speed point of diverging lines joining the third shafts. The number of lines will be equal to the number of transmission. The maximum spacing between the lines on third shaft, will be according to the calculated transmission range between these two shafts say $Ø^1$ $Ø^2$ $Ø^4$ $Ø^6$ ......etc.

5. From the third shafts for all groups draw the diverging lines, having maximum spacing on the fourth shaft as per calculated value of transmission range of groups.

Speed chart

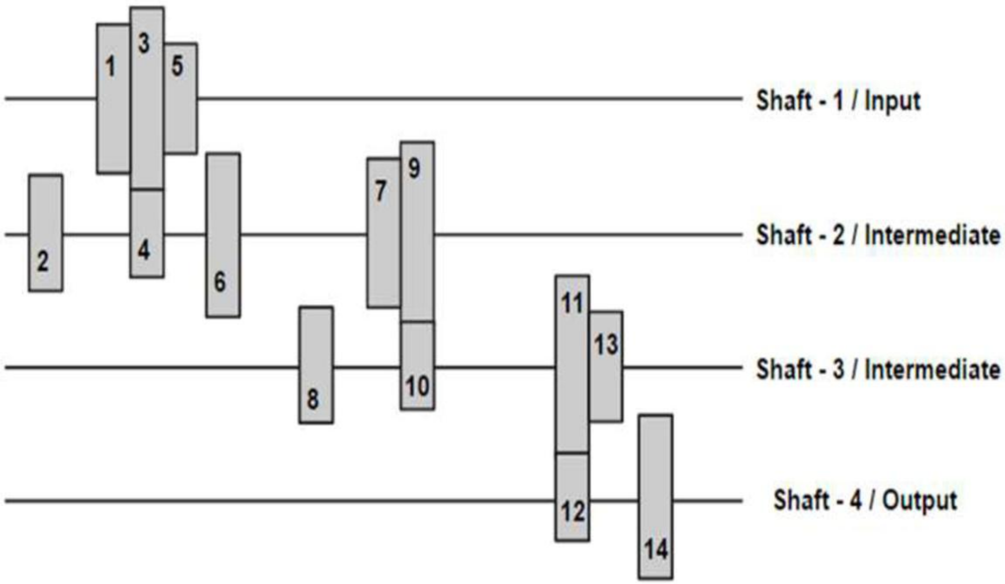
- The speed chart depicts the transmission ratios. The structural diagram depicts only range ratio so speed chart must be plotted to depict the transmission ratios

- Horizontal line corresponds to transmission ratio, i = 1. (no speed)
- Line inclined upwards corresponds to transmission ratio, I >1 (increase in speed)
- Line inclined downwards corresponds to transmission ratio, i <1 (decrease in speed)

- While plotting the speed chart it is desirable to have minimum transmission ratio i.e maximum speed reduction in the last transmission group. The remaining shafts run at relatively higher speed and so subjected to less torques.

Kinematic Diagram

- A kinematic layout is a pictorial representation of gearbox, describing the arrangement of gears.
- It provides information like number of stages, number of shafts used, number of gear pairs and its arrangement.



Ray diagram

- A ray diagram is a representation of structural formula. It provides information such as speed in each stage, the transmission ratio in each stage, The total number of speeds and its values.

- As seen in fig. (a) the maxi speed and minimum speed both are higher for shaft. This requires smaller size of shafts due to reduced torque. But as fig(b) the maximum speed and minimum speed both are lower which requires lager size of shaft due to increased torque. The version indicated in fig(c) is the middle situation. One will definitely prefer the version(b) , but if the machine cost of shafts is not a criterion , then version(a) is preferred.

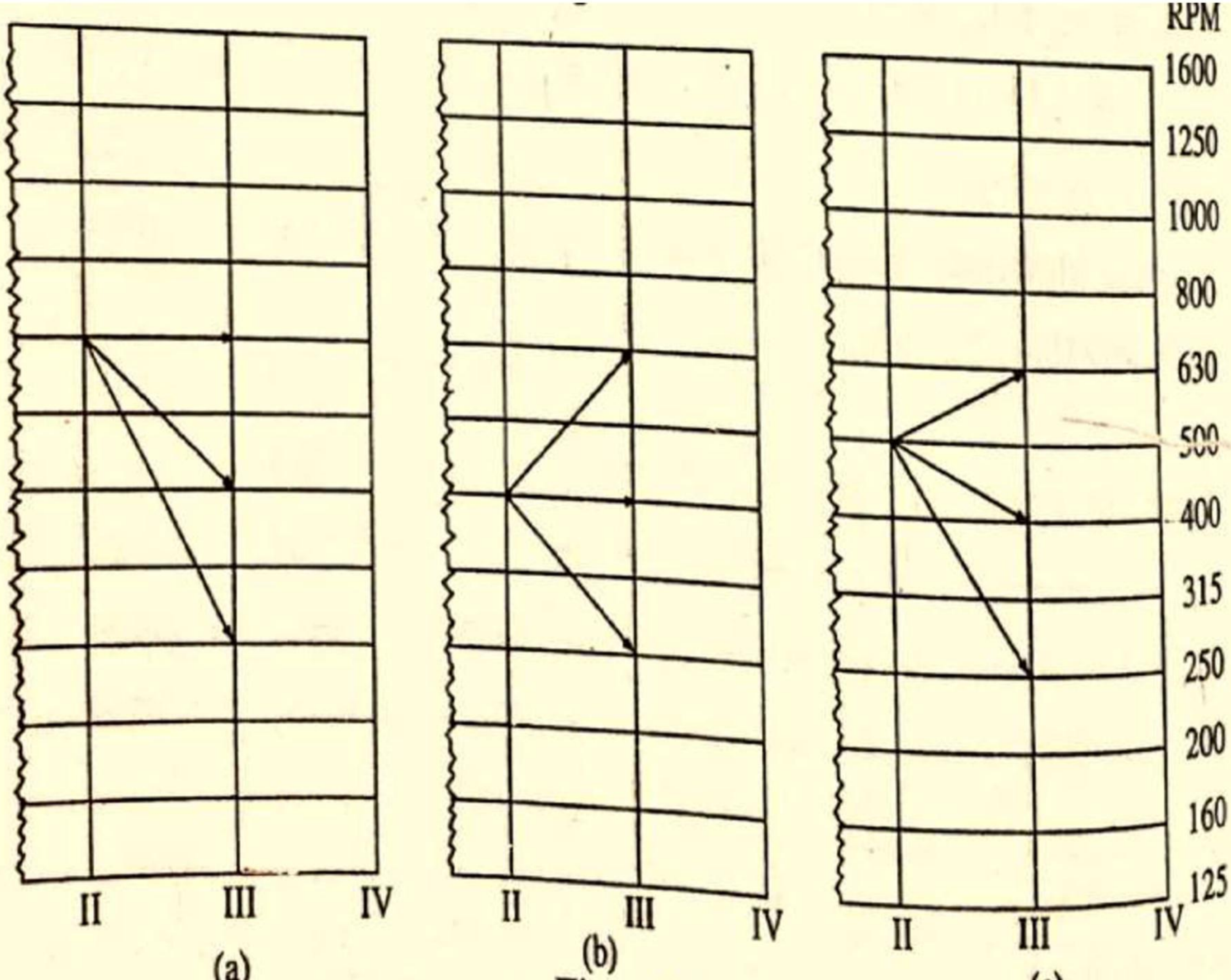

RPM
1600
1250
1000
800
630
500
400
315
250
200
160
125
II
III
IV
(a)
(b)
(c)

Fig. : 2.4

Example

- Design a gear box for a head stock to give 16 speeds ranging from 50 rpm to 1600 rpm. The power is supplied by an electric motor of 10 kw, running at 1440 rpm, through a V-belt drive with a speed reduction of 2:1

  Find
  (I) No. of teeth on each gears.
  (II) Percentage variation in speed.

Solution

1. Selection of standard speed

$N_{max} = 1600$
$N_{min} = 50$
$Z = 16$

$$\emptyset = \left[\frac{N_{max}}{N_{min}}\right]^{\frac{1}{Z-1}}$$

$$\emptyset = \left[\frac{1600}{50}\right]^{\frac{1}{16-1}}$$

$$= 1.259 \approx 1.25$$

2. From $\emptyset = 1.25$, the standard speeds are

50, 63, 80, 100, 125,
160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600 rpm

Cont…

3. Structural Diagram

here $Z=16 = 2*2*2*2$

$P_1=P_2=P_3=P_4=2$

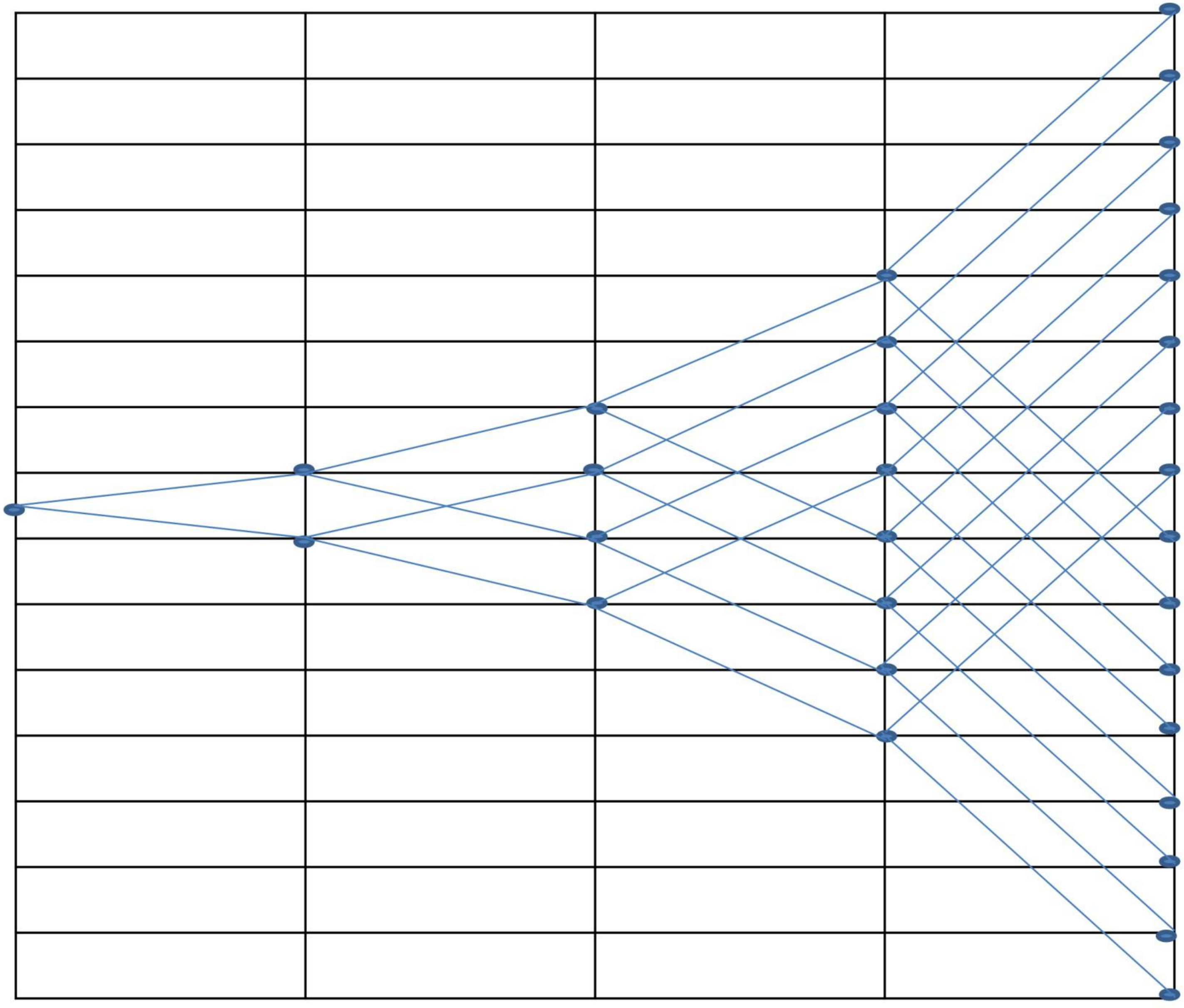
here $X_1=1$, $X_2=P_1=2$, $X_3=P_1P_2=4$

$X3=P_1P_2P_3=8$

∴ Structural Formula

$Z= 2(1)\ 2(2)\ 2(4)\ 2(8)$

Z = 2(1) 2(2) 2(4) 2(8)



Structural Diagram

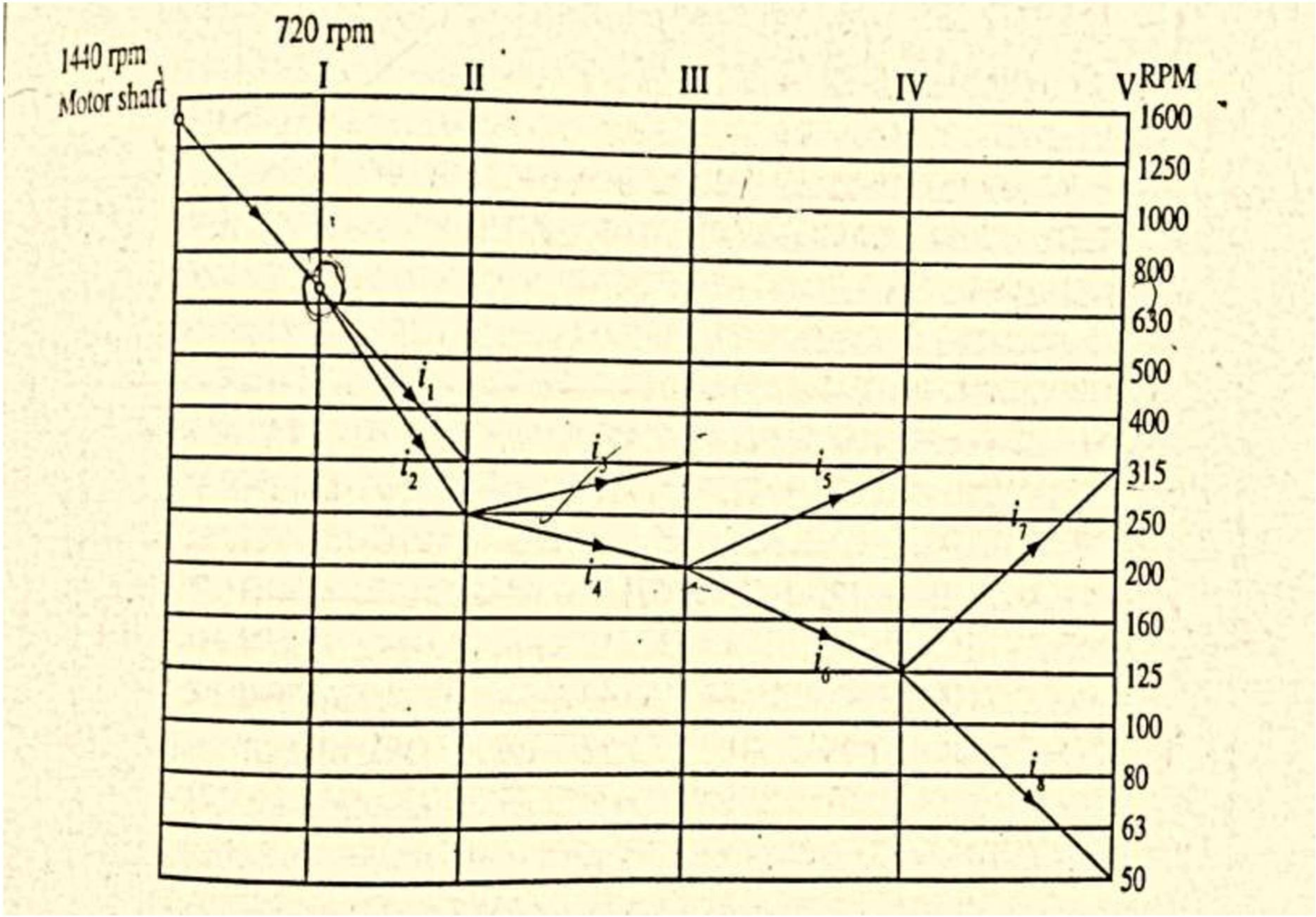
Cont…

4. Speed Chart

Here the power is supplied to input shaft through a belt drive

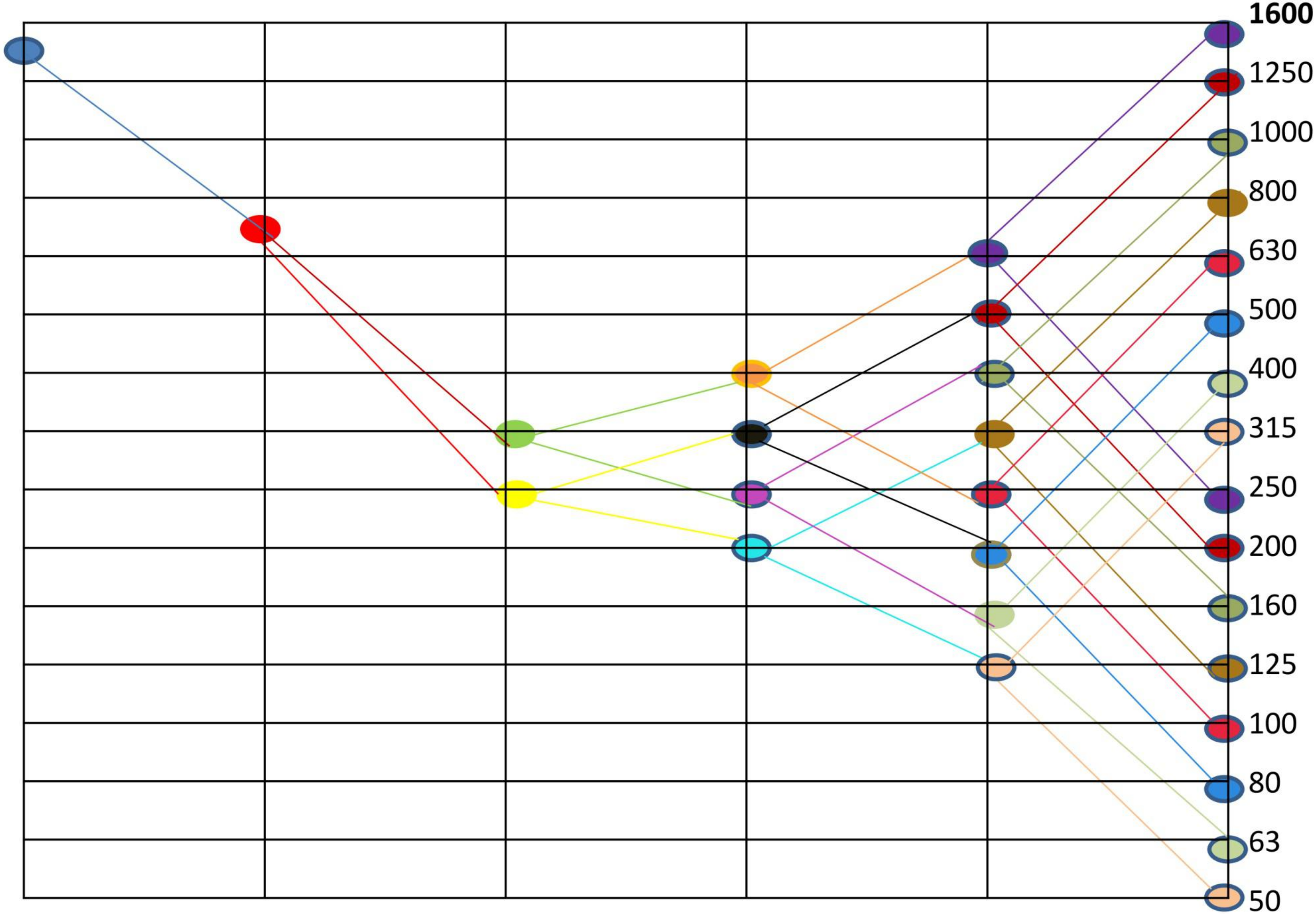
Speed of input shaft

$$= \frac{N_{motor}}{Speed\ Ratio} = \frac{1440}{2} = 720$$



720 rpm
1440 rpm
Motor shaft
I
II
III
IV
V
RPM
1600
1250
1000
800
630
500
400
315
250
200
160
125
100
80
63
50

Ray Diagram



Speed Chart

Cont…

5. Determination of number of teeth on gears
Between shaft 1 & 2

$$i_1 = \frac{315}{720} = \frac{1}{2.285} = \frac{21}{47.98} = \frac{22}{48} = \frac{Z_1}{Z_1'}$$

$$Z_1 = 22 \;\; Z_1' = 48 \;\; (Z_1 + Z_1' = 70)$$

$$i_2 = \frac{250}{720} = \frac{1}{2.88} = \frac{18}{51.84} = \frac{18}{52} = \frac{Z_2}{Z_2'}$$

$$Z_2 = 18 \;\; Z_2' = 52$$

Cont…

- As the same like above,
  Between shaft 2 & 3

  $Z_3 = 32 \; Z_3' = 25 \; (Z_3 + Z_3' = 57)$

  $Z_4 = 25 \; Z_4' = 32 \; (Z_4 + Z_4' = 57)$

- Between shaft 3 & 4

  $Z_5 = 32 \; Z_5' = 20 \; (Z_5 + Z_5' = 52)$

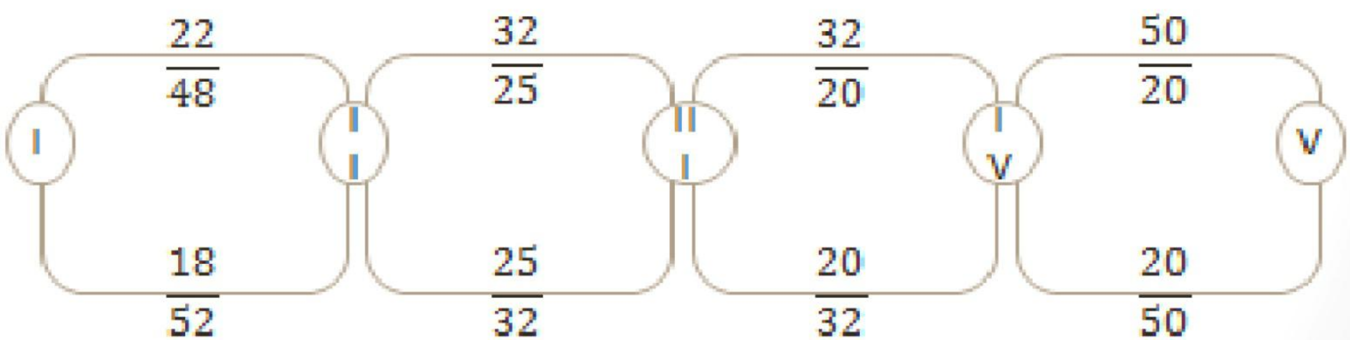
  $Z_6 = 20 \; Z_6' = 32 \; (Z_6 + Z_6' = 52)$

Cont…

- Between shaft 4 & 5

$$Z_7 = 50 \;\; Z_7' = 20 \;\; (Z_7 + Z_7' = 70)$$

$$Z_8 = 20 \;\; Z_8' = 50 \;\; (Z_8 + Z_8' = 70)$$

6. 

7. Percentage Variation in Speeds

Sr No	Available Speed (rpm)	Selected Speed	% Variation
1	$720 * \frac{22}{48} * \frac{32}{25} * \frac{32}{20} * \frac{50}{20} = 1689.6$	1600	+5.06
2	$720 * \frac{18}{52} * \frac{32}{25} * \frac{32}{20} * \frac{50}{20} = 1276$	1250	+2.08
3	$720 * \frac{22}{48} * \frac{32}{25} * \frac{32}{20} * \frac{20}{50} = 270.32$	250	+8.12

Sr No	Available Speed (rpm)	Selected Speed	% Variation
4	204.1	160	+2.05
5	1031.25	1000	+3.125
6	165	160	+3.125
7	778.84	800	-0.145
8	124.6	125	-0.32
9	660	630	+4.76

Sr No	Available Speed (rpm)	Selected Speed	% Variation
10	105.6	100	+5.6
11	498.46	500	-0.30
12	79.75	80	-0.31
13	402.83	400	+0.707
14	64.45	63	+2.30
15	304.2	315	-3.66
16	**48.67**	**50**	**-2.66**

Cont…

8. Now the permissible speed variation

   is $= \pm 10[\emptyset - 1]\%$

   $= \pm 10\ [1.25-1]$

   $= \pm 2.5\%$

   i.e. Maximum 5% variation

Here the percentage variation variation is more or less within

the permissible value.