Lecture – 1
(20 March, 2017)
Design of a Helical-Bevel Gear Box
Part-I

For

Design of Machine Elements Practice (ME39602)

Students

Design of Machine Elements Practice (ME39602)

3rd. Design Assignment :

Design of an Industrial General Purpose Reduction Gear Unit

(Monday Group : Spring Semester 2017)

[Duration (5 days) x 3 hours between – Mar 20 to Apr 17, 2017]

March 16 : PPT Demonstration – Nalanda Complex

March 23 : 1st. Layout Drawing- Drawing Hall MED

(Plan view of all Gears in their respective positions.
Follow the plan view as in problem sheet.
IMP-Do not put any dimension unless instructed.)

March 30 : PPT Demonstration – Nalanda Complex

April 06 : Drawing Continuation - Drawing Hall MED

(Plan view of the whole gear box. As in problem sheet.
Dimensions which are not determined by design or selection of components, are to be taken proportionally following the view in problem sheet.)

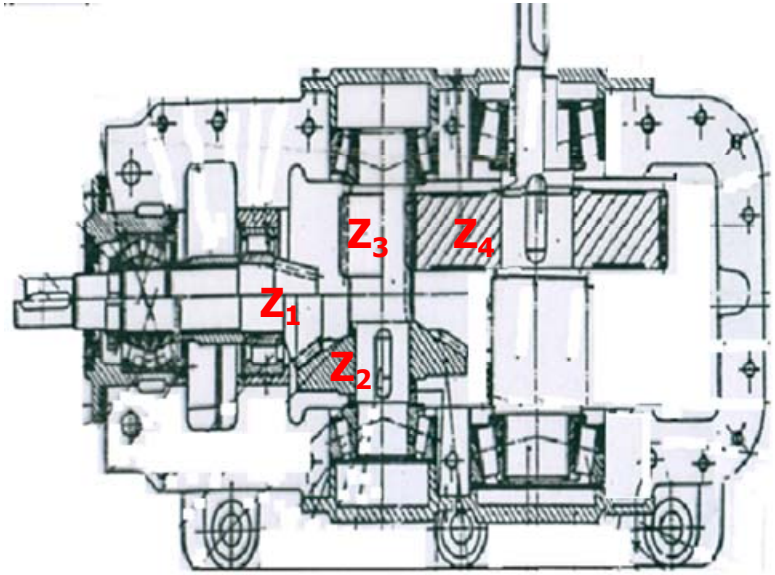
April 13 : Drawing Continuation/Class Test/Viva - Drawing Hall MED

Department of Mechanical Engineering
IIT, Kharagpur

Design of an Industrial General Purpose Reduction Gear Unit :

Tasks :

Photographic view (Example)
Two Stage Bevel-Helical Horizontal Input-Output.



Assembled plan view (Top cover removed)
(Not of the same one as above)

Design all gears and pinions of a two stage general purpose industrial gear box.

Verify the design of the intermediate gear shaft with the helical & bevel - pinion & gear with the following data.

Select the bearings and draw plan, elevation and side views of the assembled gear sets placed in lower housing.

Make a bill of material.

Design of an Industrial General Purpose Reduction Gear Unit :

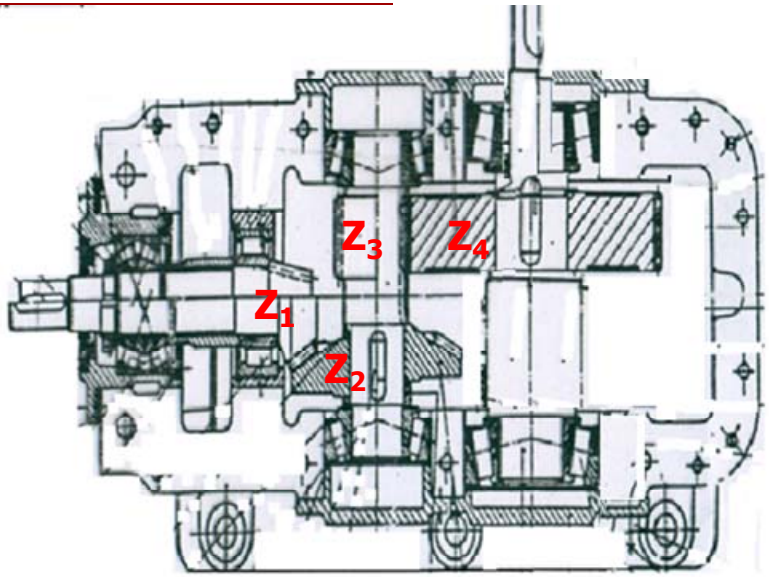
Tasks (contd....) :

Data: The TWO- stage (1st stage Bevel and 2nd. Stage helical) reduction gear box has the following specifications.
(20 to 22 different problems).

GROUP	POWER (kW)	INPUT RPM	OUTPUT RPM	DUTY		OVERHAUL TIME	LUBRICATION
				Sub Group	Description		
I A, B, C, D,	12	1500	170	A,E,I,M, Q, U	Precision, Intermittent, No shock	2 years	Forced
II E, F,G,H	10	1800	200	B,F,J,N,R	General, Continuous, Medium shock		Oil Sump
III I, J, K, L	09	1450	125	C,G,K,O, S, V	General, Intermittent, Heavy Shock		Oil Sump
IV M,N,O,P	07	1200	125	D,H,L,P,T	Precision, Continuous, Medium Shock		Forced
V Q,R,S,T	05	1500	140				
VI U, V	06	950	100	Horizontal input and vertical output (Forced Lubrication)			

In general non co-axial horizontal input and output (except otherwise mentioned).

For helical gear (pinion) number of teeth may be taken as low as 15 & for straight bevel it is 17.



Assembled plan view (Top cover removed)
(Not of the same one as below)

Photographic view (Example)
Two Stage Bevel-Helical Horizontal Input-Output.

(Monday Group : Spring Semester 2017)

[Duration (5 days) x 3 hours between – Mar 20 to Apr 17, 2017]

Formation of Group & Problem Distribution.

- **Each Group to be of 4 Students (Not less than 3 & Not more than 4).**
- **You would write name & roll number of all members (one of them to be mentioned as group leader) in a piece of paper and drop in my locker (No. 32, MED) by 22nd. March, 2017 (Wednesday).**
- **A list mentioning problem code against the name of group leader will be send to you THROUGH ERP by 23th. March.**

You would complete gear calculations before coming to the class on 27th. March. (Also, you have to submit a free hand sketch (as in problem sheet- Fig.-3), one copy per group, of plan view of the whole gear box, as in the problem sheet. Dimensions which are not determined by design or selection of components, are to be taken proportionally following the view in problem sheet

Design of an Industrial General Purpose Reduction Gear Unit : Gear Design:

Module (m, in meter) can be estimated as:

For helical gear:

$$m_{helical} = \sqrt[3]{\frac{2T\cos\beta}{\frac{S_d}{c_v c_w} ZY\psi}}$$

For straight tooth bevel gear:

$$m_{bevel} = \sqrt[3]{\frac{2T}{\frac{S_d}{c_v c_w} ZY\psi(1-\psi_o)}}$$

Photographic view (Example)
Two Stage Bevel-Helical Horizontal Input-Output.

c_v **= Velocity factor,**

= 1 for precision gears & no shock,
1.2 for general purpose gear.

c_w **= Wear load / Lubrication factor,**

= 1 for force lubrication &
1.5 for sump/splash lubrication

Where:

T = Torque (Nm),

Z = Number of teeth,

S_d **= Allowable design strength (Pas),**

$$S_d = Yield\ strength / 2.5\ to\ 3$$

***For selecting material and other information follow any machine design book*.**

Design of an Industrial General Purpose Reduction Gear Unit : Gear Design:

(contd….)

Module (m, in meter) can be estimated as:

For helical gear:

$$m_{helical} = \sqrt[3]{\frac{2T\cos\beta}{\frac{S_d}{c_v c_w} ZY\psi}}$$

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$$m_{bevel} = \sqrt[3]{\frac{2T}{\frac{S_d}{c_v c_w} ZY\psi(1-\psi_o)}}$$

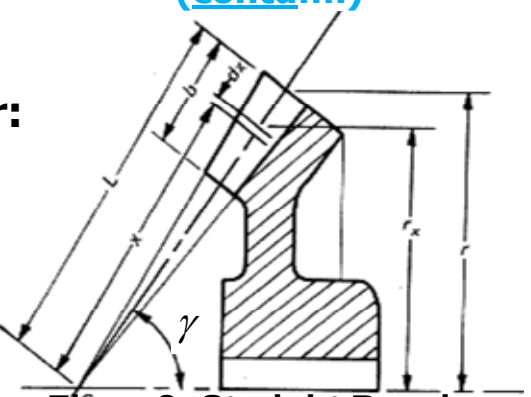

Fig.- 2: Straight Bevel.

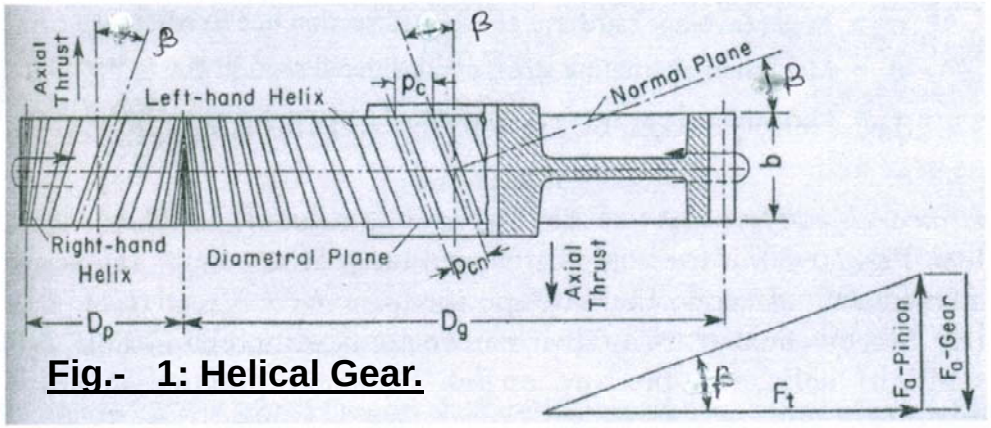

Fig.- 1: Helical Gear.

Where:

$\beta =$ **Helix angle (degree),**

ψ **= Width factor [active width (b) of gear/module],**

$\psi_o = b/l$ **for bevel gear (See Fig. -2), usually 1/3 or less,**

Modified Lewis form factor

$$Y = \pi(0.154 - 0.912/Z')$$

For helical gear formative number of teeth, $Z' = Z/\cos^3\beta$

and for straight bevel gear ,

$Z' = Z/\cos\gamma$ $\gamma =$ **pitch cone angle (see Fig.- 2).**

Pitch Circle Diameter, PCD (Helical) =

$$Z \times m_{helical} / \cos\beta$$

Mean PCD (Straight Bevel)

$$= 2 \times mean\ r = Z \times m_{bevel}$$

Design of an Industrial General Purpose Reduction Gear Unit :

Tasks (contd....) :

GROUP	POWER (kW)	INPUT RPM	OUTPUT RPM	DUTY		OVERHAUL TIME	LUBRICATION
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I A, B, C, D,	12	1500	170	A,E,I,M,Q, U	Precision, Intermittent, No shock	2 years	Forced
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V Q,R,S,T	05	1500	140				
VI U, V	06	950	100	Horizontal input and vertical output (Forced Lubrication)			

IMPORTANT NOTICE:

(i) A group should be of 3 /4 students (Strictly not more than 4).

(ii) One of the group members should act as group leader.

(iii) Form your own group and write your name & roll number in a small piece of paper and drop in my locker (No. 32, MED) by tomorrow (March 22, 2017).

A Typical General Purpose Industrial Gear Box (Speed Reducer):

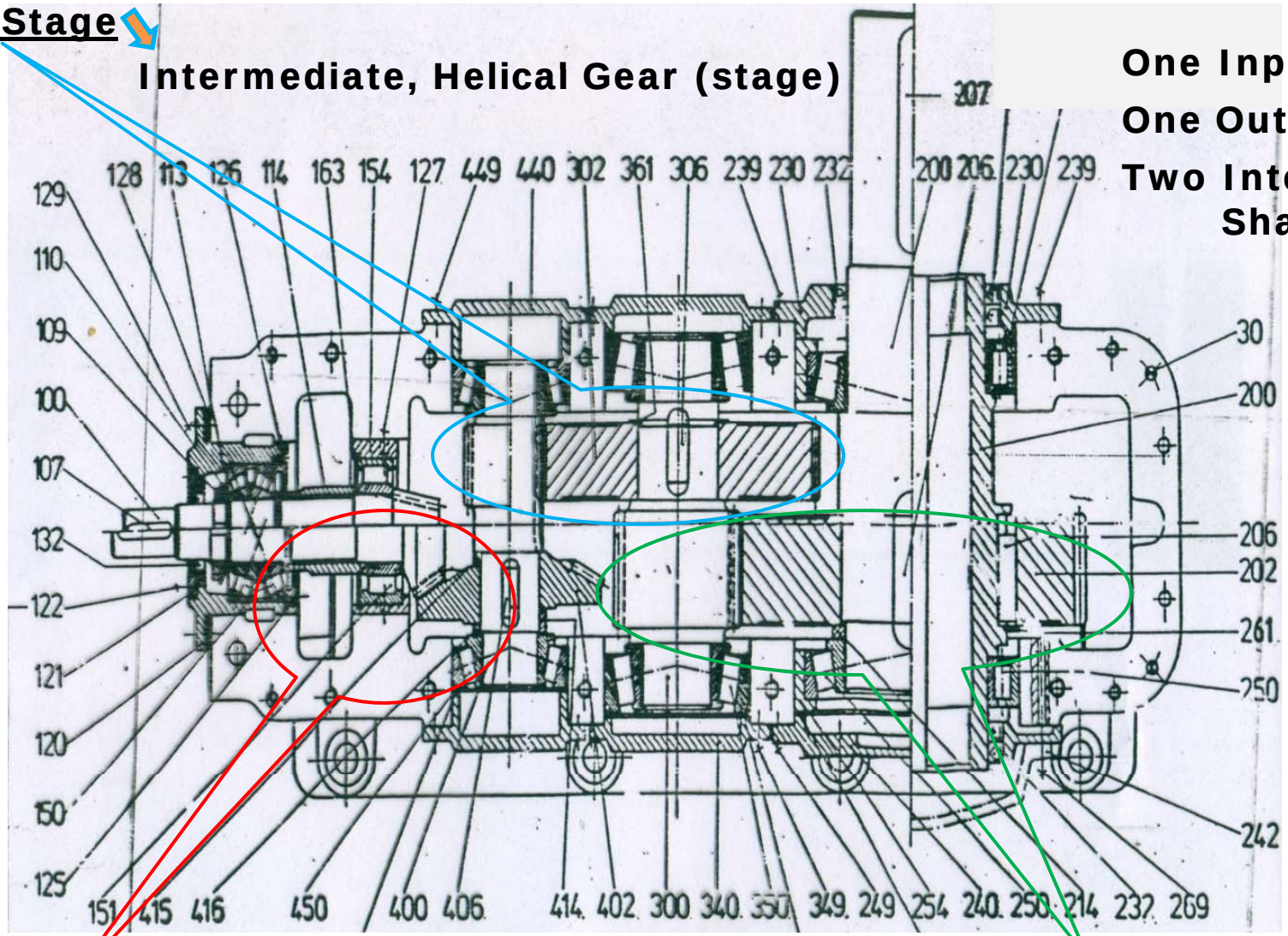
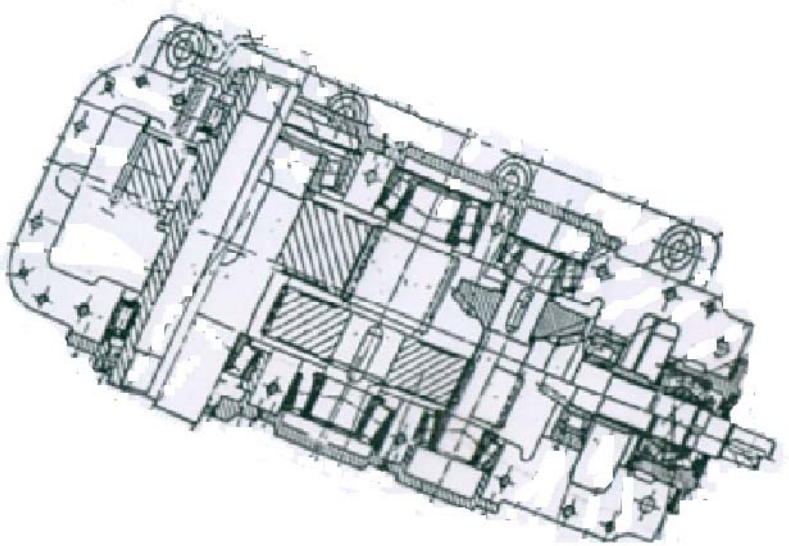
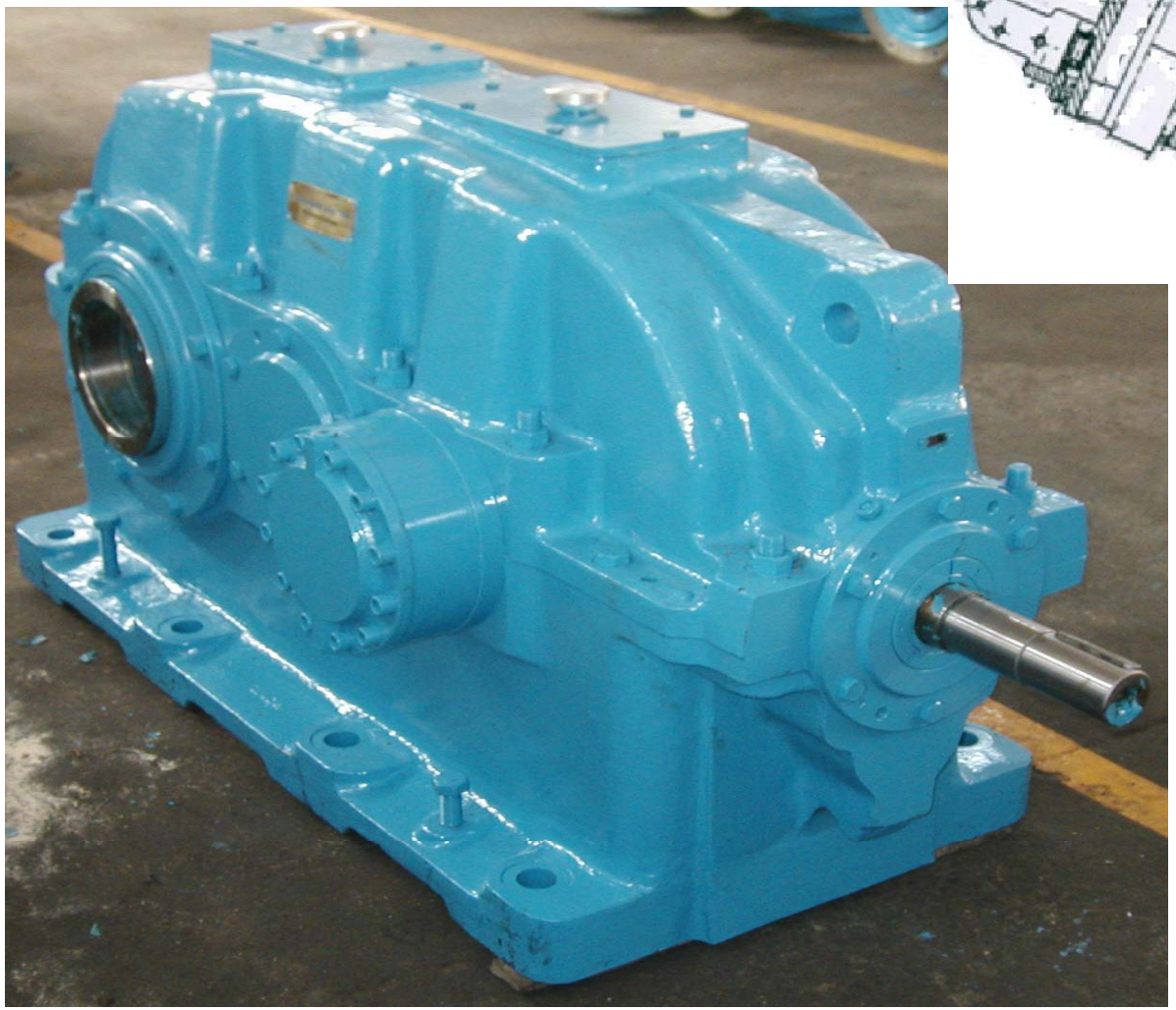


Fig. G02-1: A Typical 3-stage Gear Box

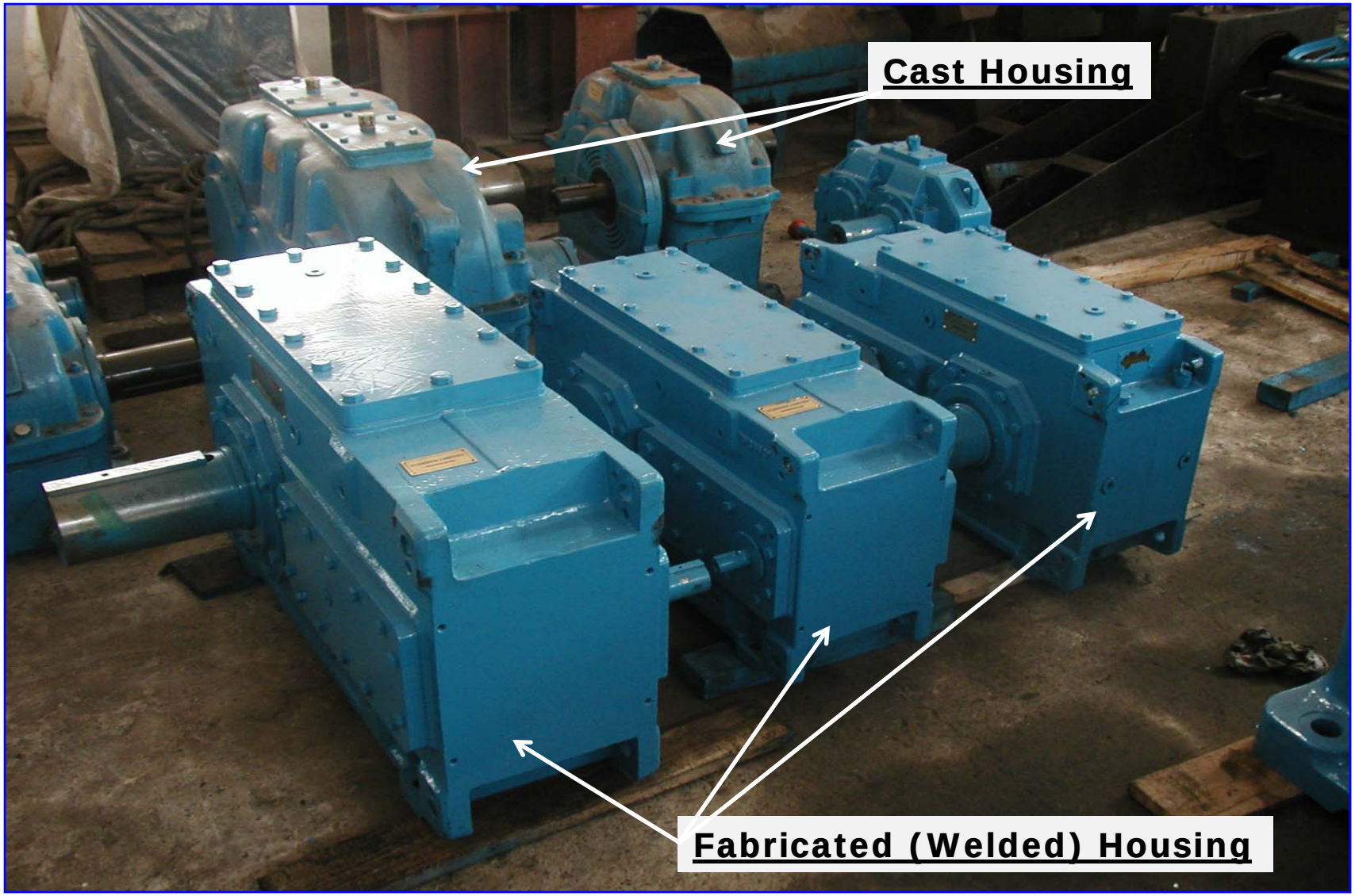
Typical General Purpose Industrial Gear Box (Speed Reducer) Contd…:

How it looks like?

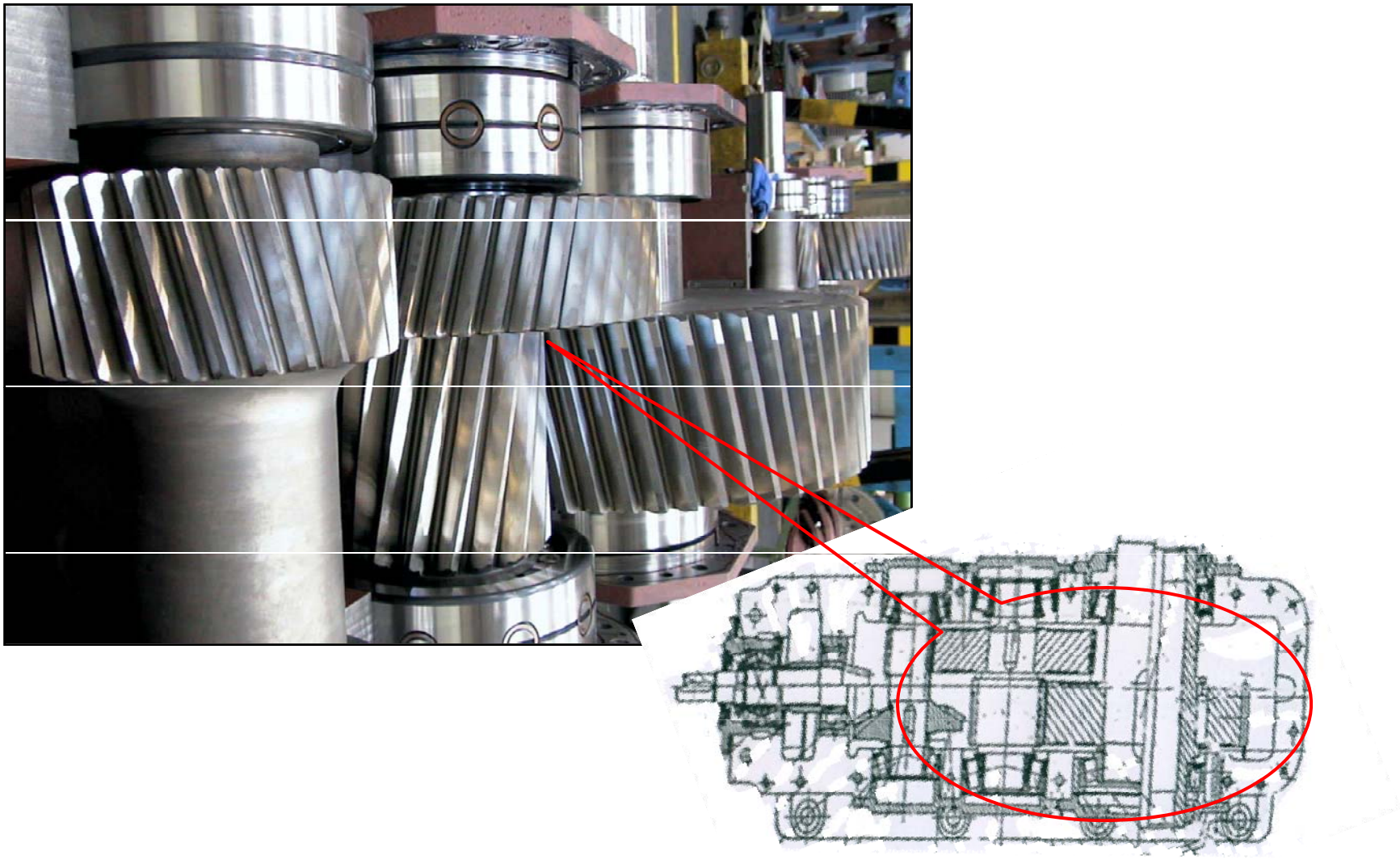




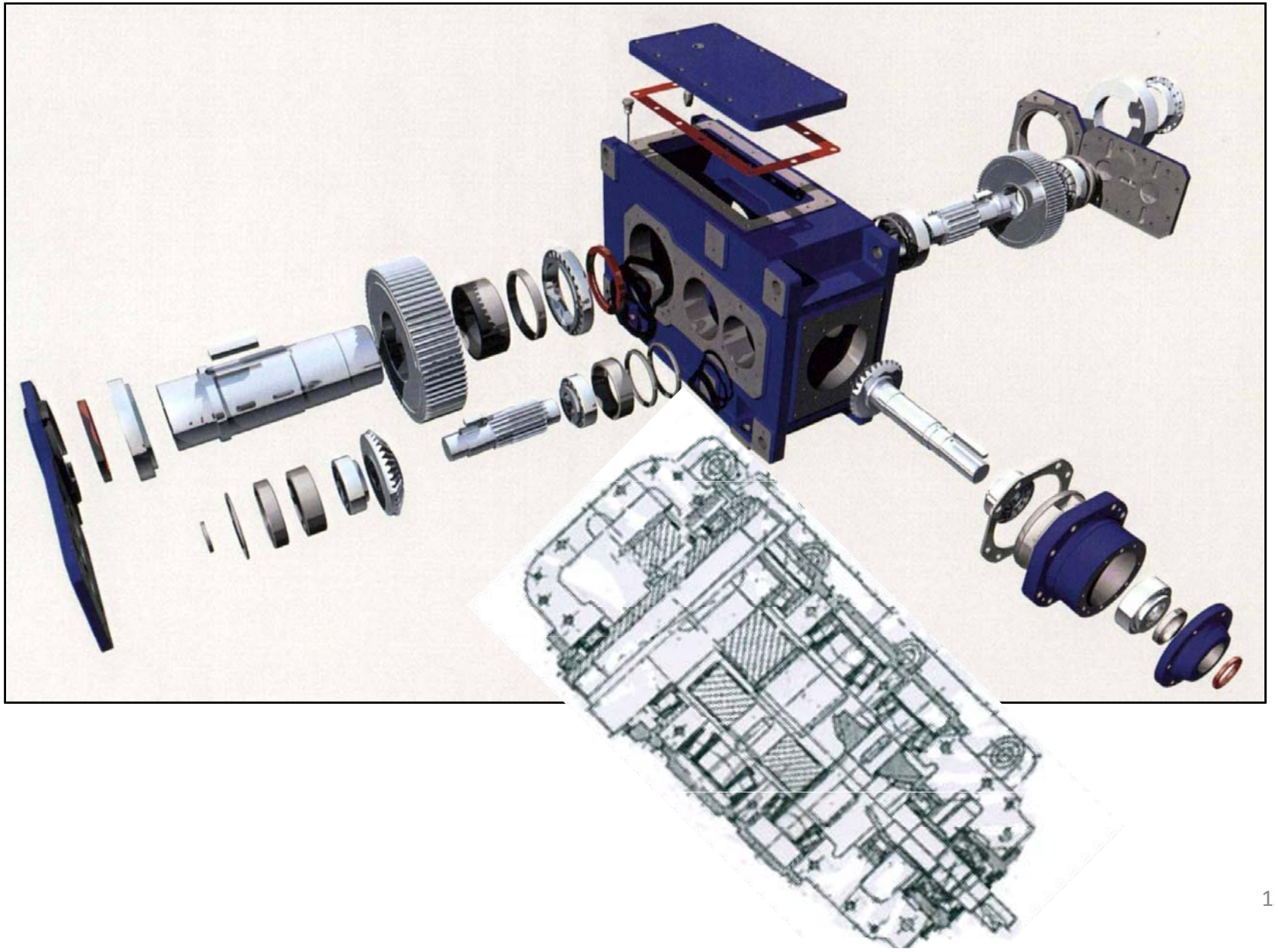
Typical General Purpose Industrial Gear Box (Speed Reducer) Contd…:



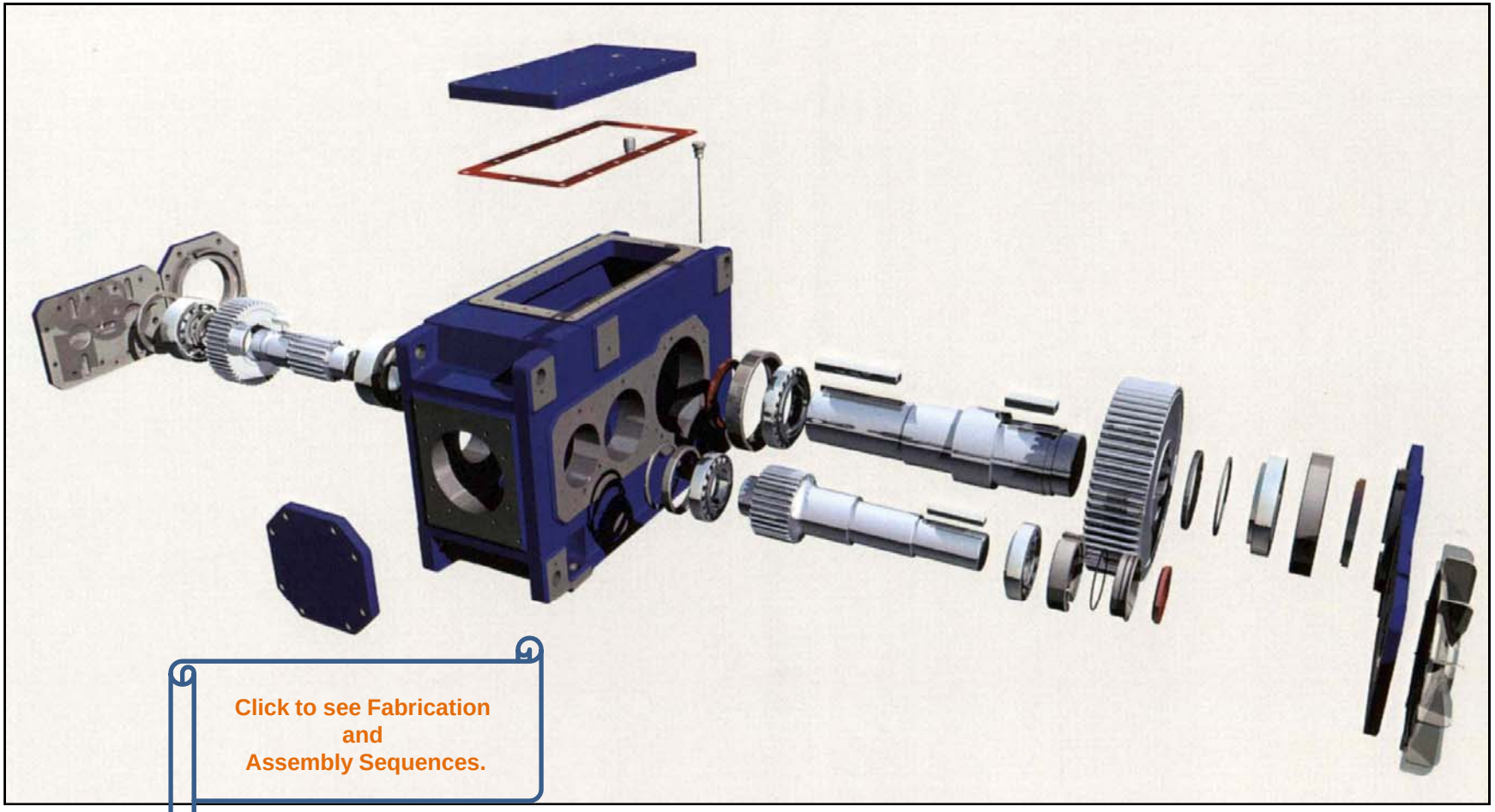
Typical General Purpose Industrial Gear Box (Speed Reducer) Contd…:



Welded Housing- (Single Piece) – GB Exploded View (3 Stage- Bevel & Helical)



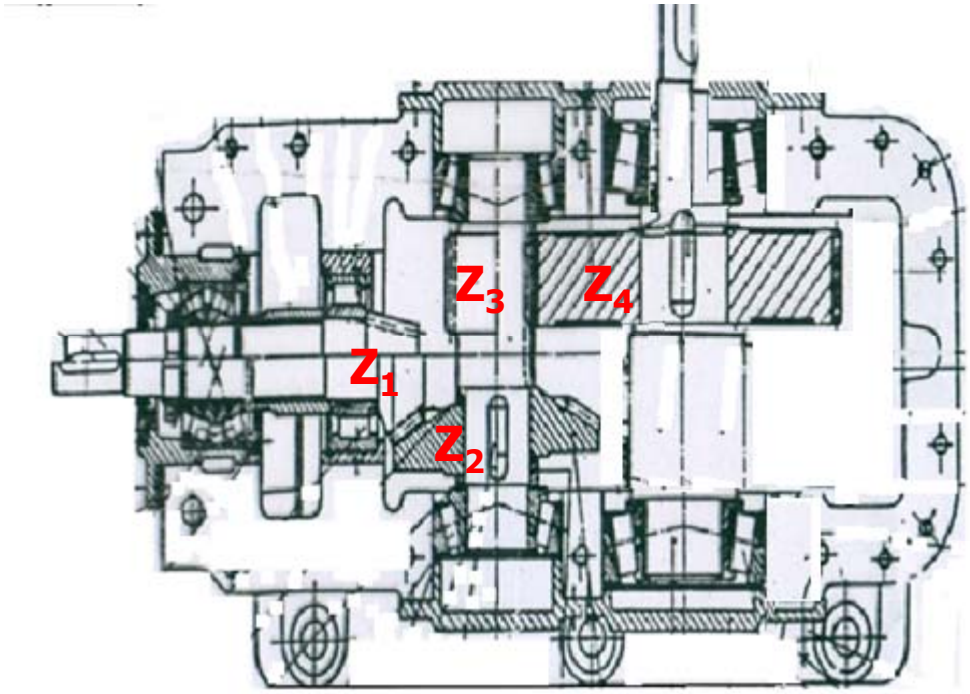
Welded Housing- (Single Piece) – GB Exploded View (2 Stage Helical)



Click to see Fabrication and Assembly Sequences.

HEAT TREATMENT

Preliminary Layout of Gear Box :



Step-1

Knowing the direction of Input & Output Selection of ratios, type of Gears & teeth numbers.

Rules and Limitations:

Stage ratio should not be more than 6.

(Formative) Number of teeth,
$Z_{cr\text{-}min} \geq 2/\sin^2$ (Pressure Angle).

Example:

Let total transmission ratio is 18. Then possible stage ratios are:- 3x6= 18.

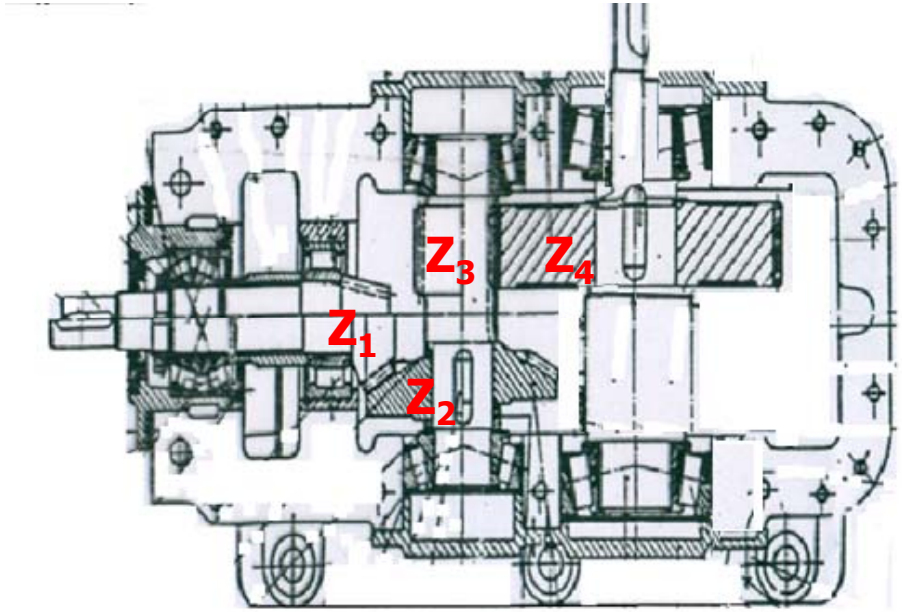
Possible teeth numbers are: $\frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} = \frac{51}{17} \times \frac{102}{17}$

As $Z_{cr\text{-}min} \approx 17$ for 20° Pressure Angle (Involute straight spur Teeth).

Ideally such Numbers of teeth should not have any problem.

However, there are several considerations.

Preliminary Layout of Gear Box (Contd....) :



Step-1 (Contd....)

$$\frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} = \frac{51}{17} \times \frac{102}{17}$$

i) **Is, however, not an optimum (size) selection.**

ii) **Tooth Haunting.**

Say, optimum (size) teeth numbers are: $\frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} = \frac{53}{16} \times \frac{92}{17} = 3.3125 \times 5.412 = 17.926$

This is acceptable as variation in output speed is negligibly small.

Note: Normally helical gears are chosen rather than straight tooth spur gears.

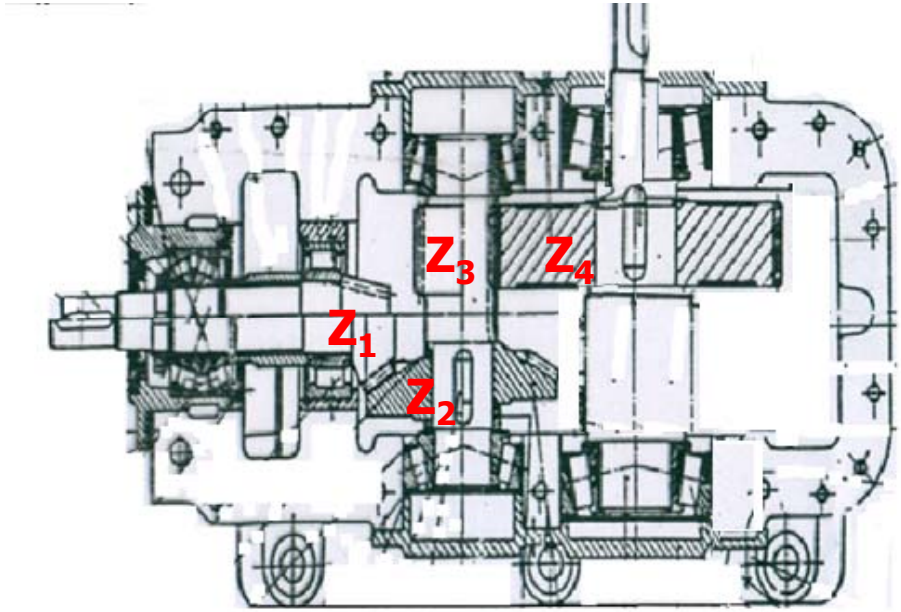
Therefore, we consider formative number of teeth: $Z' = Z / \cos^3\beta$

Where, β **is helix angle which is commonly between** 12^o **to** 20^o **for single helical gear .**

For which considering $Z' = 17$ **,** Z **may be taken as 16 to 14 respectively.**

Considering cutter geometry, speed of gears and manufacturing methods this number my further be lowered.

Preliminary Layout of Gear Box (Contd....) :



Step-2

After selecting teeth numbers i.e.,

$$\frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} = \frac{53}{16} \times \frac{92}{17}$$

Gears are designed.

Step-3

Then first layout is made.

Step-4 Rough shape to the shafts are given.

Step-5 Bearings are selected preliminarily.

Step-6 After putting the bearings in layout load calculations become possible.

Step-7 Lives of all bearings are estimated.

Step-8 If estimated lives are not satisfactory then a new set of bearings are chosen. If necessary shaft(s) dimensions are also altered and lives are re-estimated. Further, gear design may need to be altered.