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Design and Development of Gear Test Rig

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Abstract - *Gears are the crucial element of any transmission system which generally used for power transmission along with other applications depending upon working requirements. Such type of component must be check by using highly accurate methodology in order to assess its functional performance in advance. The inspection methodology of gears should be accurate with less time consuming procedure for its inspection. This objective is easily obtain by using Gear Test Rig. This Test Rig check the gear in least time which leads to reduction of non-productive time and improve plant efficiency.*

Key Words: Gear Test Rig, Functional Inspection, Composite Errors, Transmission errors

1. INTRODUCTION

Any power transmission system of any machine consist of Gears which perform the task of power transmission. The inspection methodology of such vital element plays important role in its functional performance. The test rig can be developed for checking different parameters at a time instead of checking individual error which consume lots of time for inspection. Mainly gear test rig used for functional inspection method which involve checking of gears running with other gear which consider as a master gear. The result of this testing method is in terms of Composite error. The working principal of this test rig is similar to Parkinson Gear Tester in which gear to be tested is rotated with the gear having very closed dimensional accuracy called as master gear. This type of Gear Test Rig can be Developed for any type of gear box having vertical axis of rotation in its working condition.

1.1 Gear Test Rig

Gear test rig is such arrangement which make the task of inspection so easy that it can be performed within few minutes. Simultaneously it saves the labor time and cost associated with it with other different advantages.. In gear test rig all the gears are mounted on a plate which may be fixed or stationary as per requirement of measurement. While measuring the one gear remaining act as a master gear. This will help in finding the composite errors. Any error during its inspection make that one gear defective which may be taken as a scrap or send for rework for error removal process. This entire process of gear inspection is quick with clear result of acceptance or rejection of gear.

1.2 Composite Error

In general, any error that includes two or more sources; specific meaning is generated by naming the sources. The composite error is nothing but combination of geometric errors. It is the error which includes Profile errors, Tooth thickness error, Backlash, Run out, Pitch error etc.

2. CONSTRUCTION OF GEAR TEST RIG

This Gear Test Rig have been designed for a Gear box which is used in Ginning machine. This gear box has an arrangement of six helical gears. As this gear test rig is work on the principal of Parkinson's gear tester all the gears in this gear box must be in meshing condition; it have been placed as per the arrangement in actual gear box. In this assembly a rectangular plate is used as a platform plate on which whole assembly of gear is mounted. This plate is well machined, ground and hardened. On this plate three movable plates will be mounted with the help of particular linear guide ways. The movement of the plate with reference to fix plate wills response the error in gear.

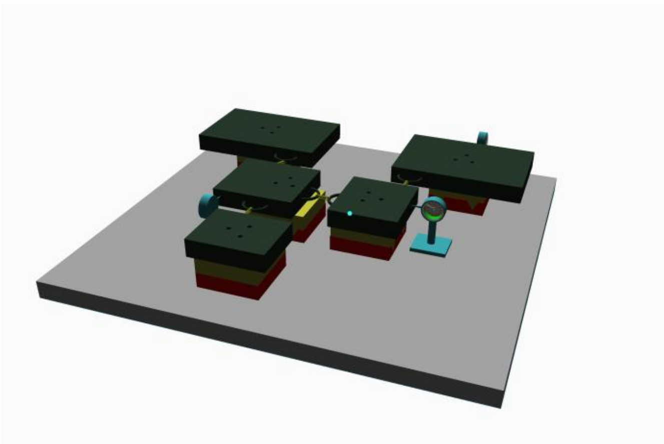

Fig - 1: Arrangement of plates in Test Rig

With three movable plates, two fixed plates are also there. These plates are connected with each other with the help of extension springs. Total foure springs are used for connecting all plates together. On the movement plates and fixed plates there is an arrangement for mounting of gears. Shaft having particular shapes are used for mounting all gears. The shaft are fixed on plate with three dowel pins for getting more accuracy.

Now for measuring the errorsin terms of deflection, we used dial gauge indicators. These are mounted according to the movements of moving plates on the base plate. Specifically the pointer of it will in touch in with moving plate So as to measure deflection in centre to centre distance. The following explode view is giving idea about the construction of test rig.

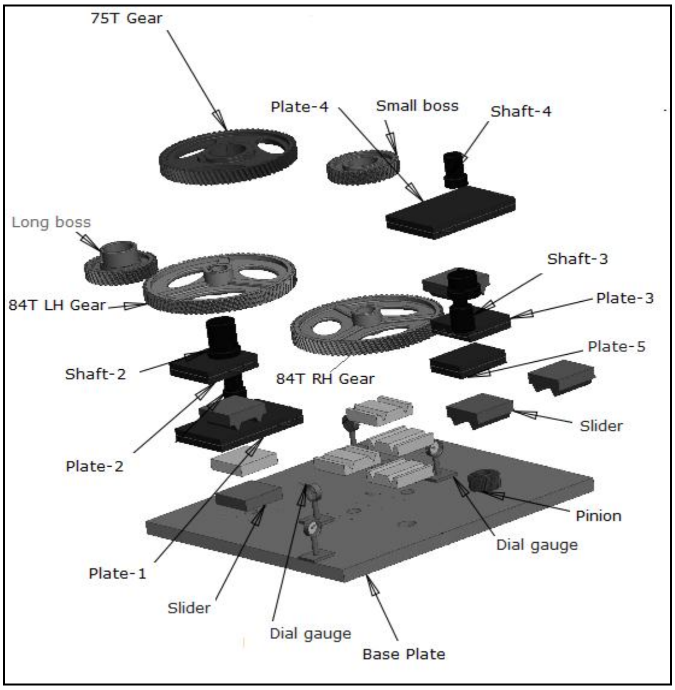

Fig - 2: Explode view of Test Rig

Table -1: Part List

PART NO.	PART NAME	QTY.	MATERIAL
1.	Base plate	01	M.S.
2.	fixed plate-1	01	M.S.
3.	Movable plate-2	01	M.S.
4.	Movable plate-3	01	M.S.
5.	Movable plate-4	01	M.S.
6.	Movable plate-5	01	M.S.
7.	Shaft	05	M.S.
8.	Linear guide ways	03	QHH15CA
9.	Pinion	01	
10.	84 teeth RH gear	01	
11.	84teeth LH gear	01	
12.	39 teeth Small boss gear	01	
13.	39 teeth Long boss gear	01	
14.	75 teeth gear	01	
15.	Spring	05	Stainless steel [EN10270-3-1.4310 CAT No.3709]
16.	Dowel pin M8x30	15	Stainless steel
17.	Allen bolt M4x16	09	Stainless steel
18.	Allen bolt M4x5	12	Stainless steel
19.	Dial Gauge	03	steel
20.	Stop plate	04	M.S.

3. WORKING

The main principle of working of the test rig is based on principle of 'Parkinson's Gear Tester. It is nothing but the rolling test of gear. In this test the master gear (highly accurate) is meshed and rotated with the gear to be check, then it gives the variation in centre to centre distance of the gears if any deflection is there and the this displacement is measured using some measuring instrument viz. Dial Gauge Indicator, and this way the error in a testing gear can be detected. The test rig is having the same arrangement of gears as that of the actual gearbox of the machine as mentioned in the construction.

All the gears used in the gear box are helical gears, and therefore same are used in the test rig. The test rig consists of pinion having 16 teeth's (16t) which is in contact with the gear having 75 teeth's (75t) and on the same shaft of 75t gear, the long boss having 39 teeth's (39t) is located, which is in contact with 84 teeth's Left handed gear (84 t LH), and the 75t gear which is on the upper side of long boss meshes with small boss gear having 39 teeth's (39t) which in turn rotates 84t right handed gear. In this way the power is transmitted to all five gears and they start rotating. Variation in the centre to centre distance of the gears, they are mounted on the plates, some of them are fix and some are movable with the help of guide ways. The 84t LH gear is mounted on plate 1 which is fixed plate. Long boss and 75t gear is on plate 2. Small boss is on plate 3. Plate 4 has 84T RH and pinion is on plate 5. All these plates are mounted on the base plate through linear guide ways for avoiding friction and are connected to each other with the extension springs.

This test rig will mainly check the Composite errors, Proper rotation of all gears in meshing condition. The composite error can be checked by rotating the testing gear master gear. Both gears are mounted on plates, one of the plates will be fixed i.e. the plate 1, and another will be moving. The moving direction of the plate is restricted in only one direction by using linear guide ways. If there is any error in the testing gear, then it varies the centre to centre distance between the two gears and it is detected and measured by the Dial Gauge indicator, which is mounted on base plate and having pointer contact with the last edge of moving plate. Value displayed will be measurement of composite error in testing gear. The 2nd purpose can be done by mounting all the gears at their places and running the test rig. The running of the test rig will be same as that of actual gear box of ginning machine, and due to that, we can get the performance of the gear under the working conditions. The locking and jamming of the gears can be easily detected from this technique.

4. PART DETAILS

4.1 Plates

4.1.1 Base Plate

The whole of the test rig assembly is mounted on the base plate, and due to that some operations are required for mountings of guide ways and other components such as dial gauge etc. Therefore the dimensions of base plate are important.

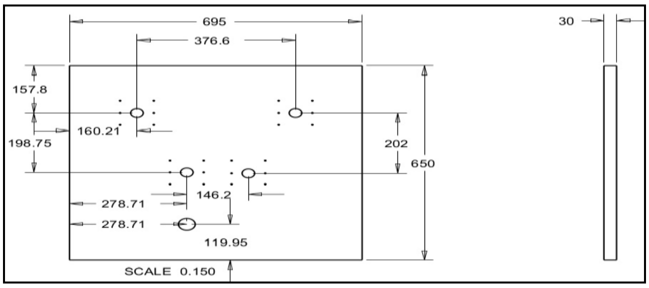

Fig 3: Dimensional details of Base plate

4.1.2 Plate -1

The plate 1 of the test rig is fixed to the base plate. There are 3 holes on the plates for fitting of the shaft with help of dowel pins to get proper alignment. And the arc is welded at the down right corner of the plate for spring attachment. The 84 teeth's left handed gear is mounted on plate 1.

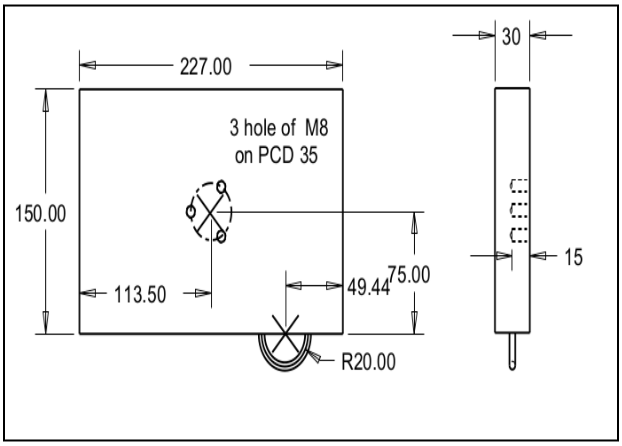

Fig-4 : Dimensional details of Plate 1

4.1.3 Plate 2

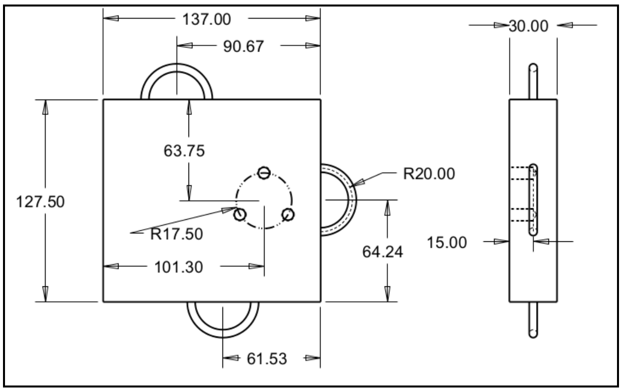

Fig-5: Dimensional details of Plate 2

Plate 2 is moving plate, and it will be in contact with the plate 1 by spring. Shaft 2 is mounted on the plate with dowel pins. The long boss having 39 teeth and gear having 75 teeth will mount on that plate. This plate will be restricted to move in only downward direction by guide way.

4.1.4 Plate 3

Plate 3 is moving plate, connected with plate 2 from down- left corner by spring and with plate 4 from up-left corner plate. The plate will be restricted to move in left-right linear motion. The small boss having 39 teeth will be mounted on it with shaft 3.

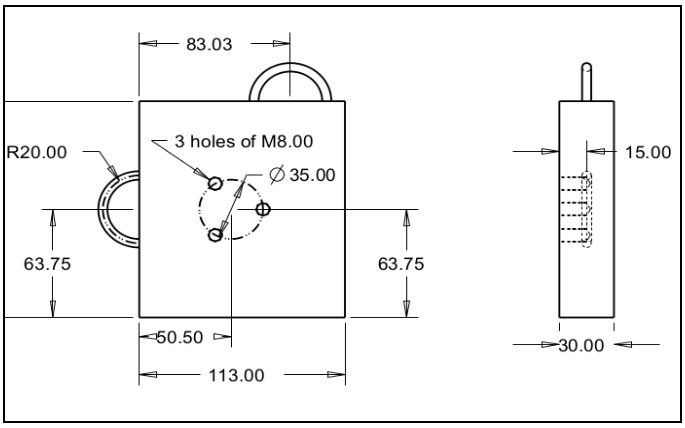

Fig-6: Dimensional details of plate 3

4.1.5 Plate 4

Plate 4 is moving plate connected to the plate 3 by spring from down-left corner of plate and will be restricted to move in vertical linear motion. The 84 right handed teeth gear will mount on this plate.

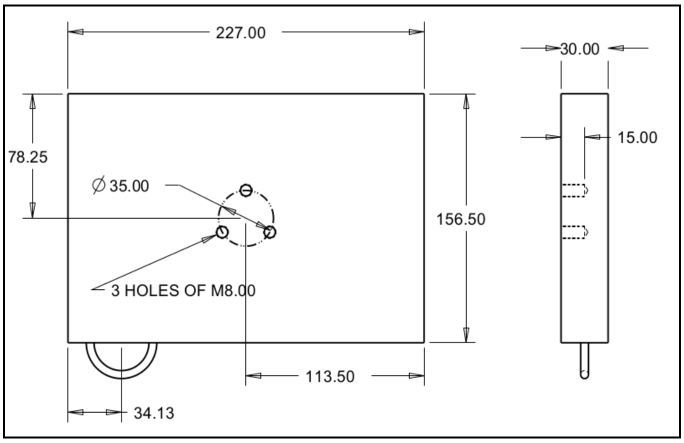

Fig 7: Dimensional details of plate 4

4.1.6 Plate 5

Plate 5 is moving plate connected to the plate 2 by spring from up-left corner of plate and will be restricted to move in vertical linear motion. The pinion of gearbox will be mounted on it.

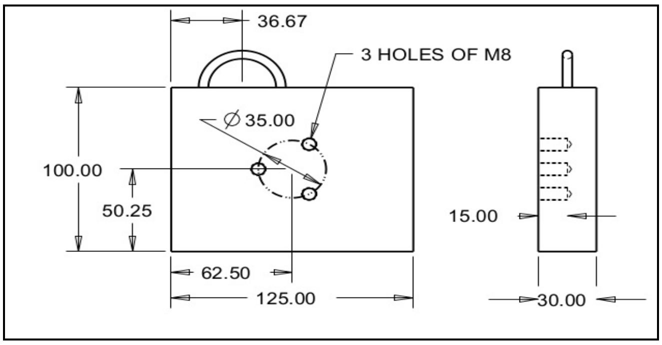

Fig-8: Dimensional details of plate 5

4.2 Shaft

The test rig is using total 5 mild steel shafts for mounting 5 gears on them. All the shafts are fixed on the plates by 3 dowel pins for each shaft to get accurate alignment. The shafts required are stepped shafts. For less friction, there should be clearance between the base plate and the gear to be mounted on shaft, therefore clearance is kept there by making step of particular dimension on the each shaft. The dimension of the each shaft varies according to the requirement of gear.

4.2.1 Shaft 1

Shaft 1 will be mounted on the fixed plate1.The 84 teeth left handed gear will be mounted on shaft 1.

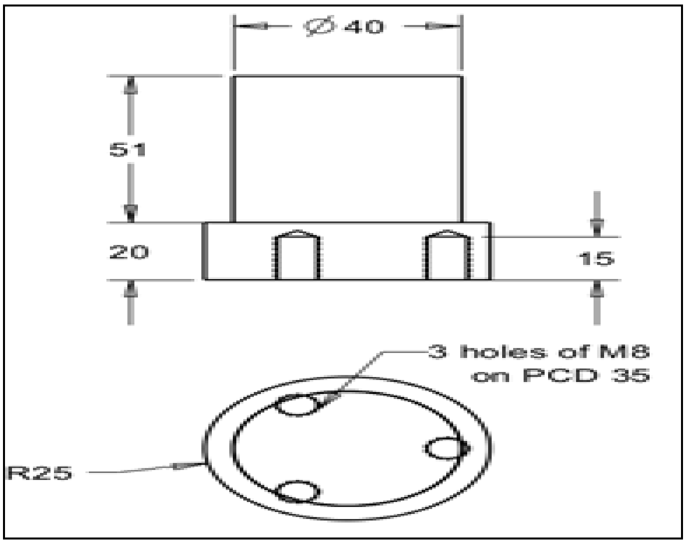

Fig-9: Shaft 1

4.2.2 Shaft 2

Shaft 2 will be mounted on the movable plate2.The 39 teeth long boss and 75 teeth gear will be there on shaft2.

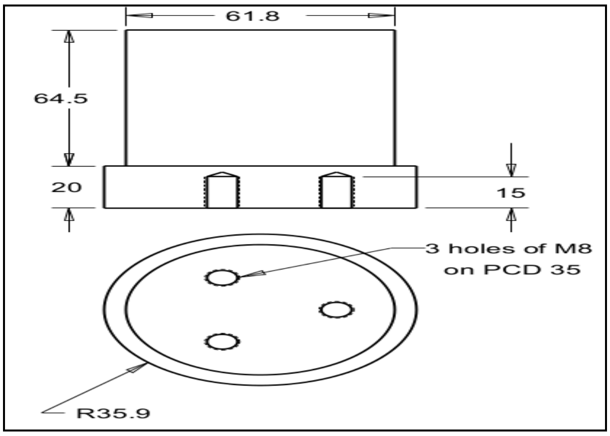

Fig 10: Shaft 2

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4.2.3 Shaft 3

Shaft 3 will be mounted on the movable plat32.The 39 teeth short boss will be mounted on the shaft 3.

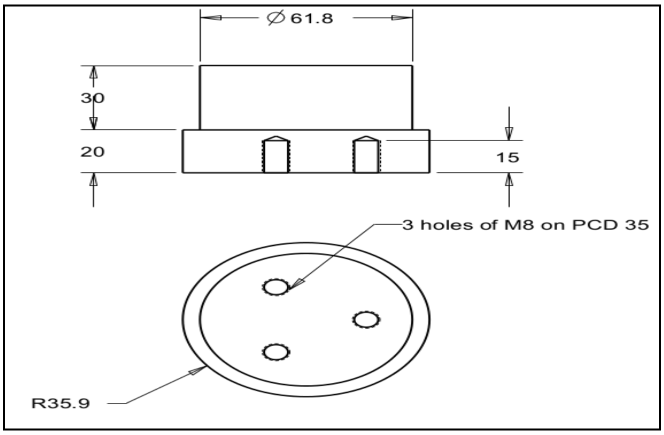

Fig -11: Shaft 3

4.2.4. Shaft 4

Shaft 4 will be mounted on the movable plat4.The 84 teeth right handed gear will be mounted on shaft 4.

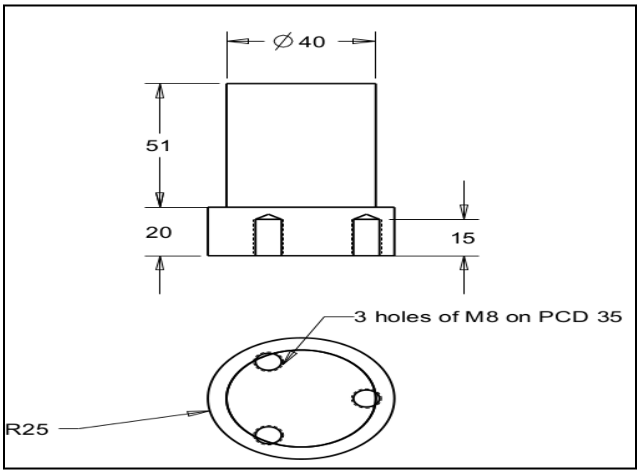

Fig -12: Shaft 4

4.2.5. Shaft 5

Shaft 5 will be mounted on the movable plate 5.The 16 teeth pinion gear will be mounted on shaft 5.

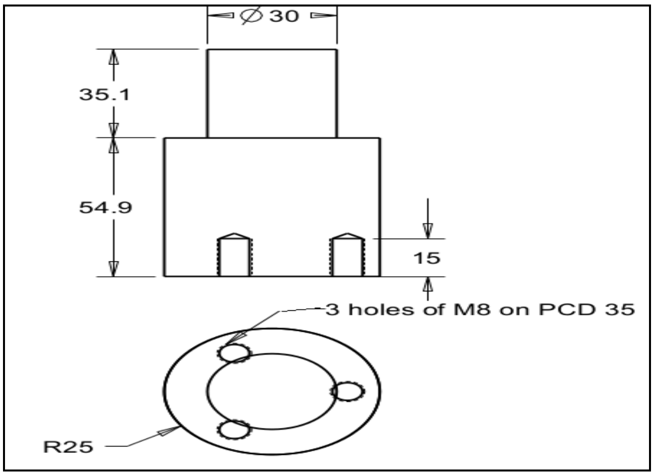

Fig -13: Shaft 5

4.3. Spring

The springs are used for perfect meshing of the gears which we have to check. Due to the springs we can get the accurate deflection of the movement of the plate without slack error.

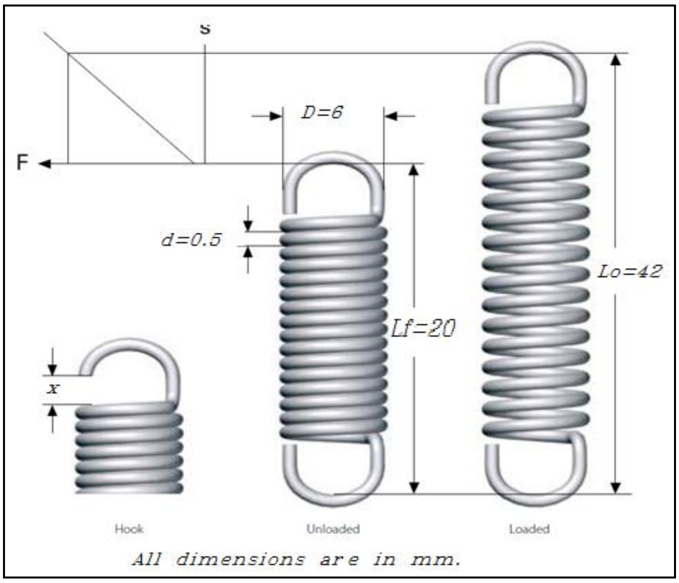

Fig -14: The Extension Springs

4.3.1. Design of springs

For development of the test rig, spring is the important because the design of the plates are depends on the length of the spring. Each spring is designed according to the loads coming on them.The calculations of the spring design are as follows.

4.3.1.1 Spring-1:

We know the load

W = 12.88N

Maximum deflection (δ) = 3 m

τ = 437.50 N/mm^2

g = 70 KN/mm^2

Twisting moment,

$$T = W \times \frac{6d}{2}$$

= 12.88 $\times$ 3d

T =38.64

We know,

T= π/16×□×d³

38.64 = π/16×437.50×d³

d = 0.6707 mm

mean diameter(D) = 6d

= 6 $\times$ 0.6707

= 4.02 mm

Outside diameter (D0) = D + d = 4.69 mm

Inside diameter (D1) = D - d = 3.35mm

Maximum deflection, $\delta = \frac{8Wc^3\ n}{g\ .d}$

$$n = \frac{3 \times 70 \times 1ooo \times 0.6707}{8 \times 12.88 \times 6^3}$$

n = 6.32 ≅ 7

free length of spring (L_f) = $nd + (n-1) \times 1$

= 7+ $0.6706(7-1) \times 1$

=11.02 mm

pitch (p) = $\frac{Lf}{n-1}$

= $\frac{11.02}{7-1}$

= 1.83 mm

4.3.1.2. Spring-2:

We know the load W = 12 N

Maximum deflection (δ) = 3 mm

τ = 437.50 N/mm^2

g = 70 KN/mm^2

Twisting moment,

$$T = W \times \frac{6d}{2}$$

= 12 $\times$ 3d

T = 36 d

We know,

$$T = \frac{\pi}{16} \times \tau \times d^3$$

$$38.64 = \frac{\pi}{16} \times 437.50 \times d^3$$

d = 0.6473mm

mean diameter(D) = 6d

= 6 $\times$ 0.6473

= 3.88 mm

Outside diameter (D0) = D + d = 4.53 mm

Inside diameter (D1) = D - d = 3.23 mm

Maximum deflection, $\delta = \frac{8Wc^3\ n}{g\ .d}$

$$n = \frac{3 \times 70 \times 1ooo \times 0.6473}{8 \times 12 \times 6^3}$$

n = 6.55 ≅ 7

Free length of spring (L_f) = $nd + (n-1) \times 1$

= 7+ $0.6473(7-1) \times 1$

= 10.84 mm

Pitch (p) $= \frac{Lf}{n-1}$

$= \frac{10.84}{7-1}$

= 1.80 mm

4.3.1.3. Spring-3:

We know the load W = 9.65 N

Maximum deflection (δ) = 3 mm

τ = 437.50 N/mm^2

g = 70K N/mm^2

Twisting moment,

$$T = W \times \frac{6d}{2}$$

= 9.65 × 3d

T = 28.95 d

We know, $T = \frac{\pi}{16} \times \tau \times d^3$

$$38.64 = \frac{\pi}{16} \times 437.50 \times d^3$$

d = 0.5805 mm

mean diameter(D) = 6d

= 6 × 0.5805

= 3.48 mm

Outside diameter (D0) = D + d = 4.06 mm

Inside diameter (D1) = D - d = 2.90 mm

Maximum deflection, $\delta = \frac{8Wc^3\, n}{g\, .d}$

$$n = \frac{3 \times 70 \times 1000 \times 0.5805}{8 \times 9.65 \times 6^3}$$

n = 7.31 ≅ 7

free length of spring (L_f) = $nd + (n-1) \times 1$

= 7+ 0.5805(7 − 1) × 1

=10.48 mm

pitch (p) $= \frac{Lf}{n-1}$

$= \frac{10.48}{7-1}$

= 1.74 mm

4.3.1.4. Spring-4:

We know the load W = 8 N

Maximum deflection (δ) = 3 mm

τ = 437.50N/mm^2

g = 70KN/mm^2

Twisting moment,

$$T = W \times \frac{6d}{2}$$

= 8 × 3d

T = 24 d

We know,

$$T = \frac{\pi}{16} \times \tau \times d^3$$

$$38.64 = \frac{\pi}{16} \times 437.50 \times d^3$$

d = 0.5285 mm

mean diameter(D) = 6d

= 6 × 0.5285

= 3.1714 mm

Outside diameter (D0) = D + d = 3.69 mm

Inside diameter (D1) = D - d = 2.64 mm

Maximum deflection, $\delta = \frac{8Wc^3\, n}{g\, .d}$

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$$n = \frac{3 \times 70 \times 1000 \times 0.5285}{8 \times 8 \times 6^3}$$

$$n = 8.02 \cong 8$$

$$\text{Free length of spring } (L_f) = nd + (n-1) \times 1$$

$$= 8 + 0.5285\,(8-1) \times 1$$

$$= 11.228 \text{ mm}$$

$$\text{Pitch (p)} = \frac{Lf}{n-1}$$

$$= \frac{11.669}{8-1}$$

$$= 1.67 \text{ mm}$$

4.4. Guide ways :-

In the test rig for detecting the variation of the distance between two gears, the plate movement on which the gear is mounted is necessary, and as we are checking the accuracy, the friction cause due to relative movement between moving and fixed plate should be as low as possible, for that reason the guide ways are used here.

4.4.1. Selection of Linear Guide way :

The standard guide way is selected from the guide ways catalogue which is shown below. The guide way selection is mainly based on the maximum distance which the guide way have to move while testing.

The standard guide way selected is having model no. ***QHH15CA*** .The other specifications of it are given in the following Table

Table 2: Guide way catalogue

Model No.	Dimensions of Assembly (mm)			Dimensions of Block (mm)											Dimensions of Rail (mm)							Mounting Bolt for Rail	Basic Dynamic Load Rating	Basic Static Load Rating	Static Rated Moment			Weight	
																									M_R	M_P	M_Y	Block	Rail
	H	H_1	N	W	B	B_1	C	L_1	L	G	Mxl	T	H_2	H_3	W_R	H_R	D	h	d	P	E	(mm)	C(kN)	C_0 (kN)	kN-m	kN-m	kN-m	kg	kg/m
QHH15CA	28	4	9.5	34	26	4	26	39.4	61.4	5.3	M4 x 5	6	7.95	8.2	15	15	7.5	5.3	4.5	60	20	M4x16	13.88	14.36	0.1	0.08	0.08	0.18	1.45

4.5. Gears :-

Gears are the very important part of the test rig , because the test rig is using the highly accurate master gear to inspect the another gear. Master gears are as a gauge while inspecting with which we can compare the accuracy of the other gear.

As the actual gear box consisting the 6 various helical gears, the test rig is using the same, and in the same fashion. The gears are designed by the engineers. So we need not to design them.

The 3d models of 5 gears of the test rig are given below with their basic information.

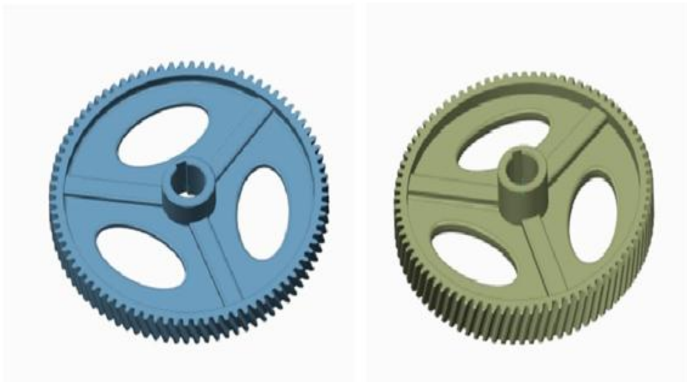

Fig-15: (a) 84 teeth LH gear (b) 84 teeth RH gear

Fig-16: (c) 39 teeth small boss. (d) 39 teeth long boss.

Fig.- 17: (e) 75 teeth gear. (f)16 teeth Pinion

4.6. Dowel pin :-

Dowel pin-A solid, cylindrical semi-permanent pin mainly used to locate machine parts in a fixed position or to maintain alignment. In the test rig the dowel pins are used for fixing of shafts on the plate instead of welding, because in welding there are some chances of inclination of shaft while welding to the plate . ***M8 × 30*** stainless steel dowel pin is used here.

Fig-18: The stainless steel Dowel pins

4.7. Allean bolts:-

Allen bolts are the fasteners used for joining of two components. Allen bolts are selected logically,**M4 × 5** and **M4 × 16** are used here for fitting of guide way and movable plates on the guide ways.

Fig.-19: Allen bolts

4.8. Dial gauge indicator:-

The dial gauge indicator is the mechanical comparator. The working principle of dial gauge indicator is converting the linear motion into angular motion. For that purpose it use the gear train for magnification and scale pointer as indicating device. The following figure shows the actual and 3d model of dial gauge indicator.

Fig.-20: Dial gauge indicator and its 3D model

5. MODELLING OF TEST RIG:

The modeling of the test rig is done in CATIA software. The actual model of the test rig is developed after drawing all subparts of it as mentioned in earlier topics.

The actual model of the test rig is shown below.

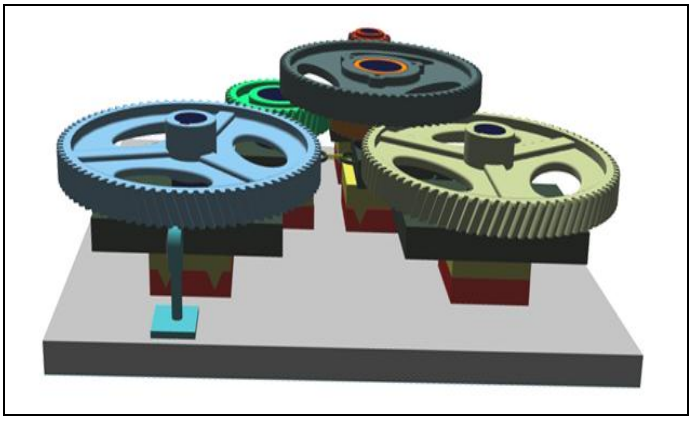

Fig-21: Gear Test Rig Model 1

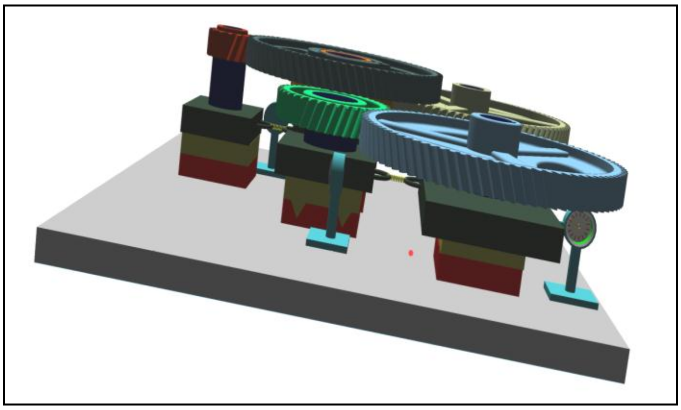

Fig-22: Gear Test Rig Model 2

6. CONCLUSION

The designed test rig offers very convenient and economically viable means of creating the actual working condition for the gears to be tested. The test rig design is totally depends on requirement of testing parameters and errors which we want to check. Due to the use of the gear test rig, functional inspection of the gear can be carried out which is very desirable in industrial use.

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