International Journal of Current Engineering and Technology

E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Analysis and Modeling of Gear Roll Tester

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Accepted 01 Oct 2016, Available online 05 Oct 2016, **Special Issue-6 (Oct 2016)**

Abstract

Gear roll testers are used to measure and analyses functional performance of gears. Gear testing is a technique that has been used in the gear industry to identify potential manufacturing defects in the design intent of the gear. It is a practical, fast and effective screening tool that can identify when the gear manufacturing process has deviated from an ideal condition that could result in a change in backlash, or an unwanted noise and vibrations in a gear mesh therefore, in the present work it was decided to develop a gear roll tester to analyze effects of different types of defects in gear on its functional performance in terms of run out, pitch errors, backlash, profile errors, noise and vibration. For the present work a spur was selected with the specifications matching with the gear used in automobiles. A test rig was designed and developed for the functional testing of spur gears. Various components were designed and selected according to the standard design procedure. The test rig was fabricated with very high accuracy. Gears with different types of defects were tested on the test rig to ensure the accuracy of it. This test rig is an important tool to the gear manufacturer to test the gears for their functional performance. The test rig can be used further to analyses noise and vibrations along with a Fast Fourier Transform (FFT) analyzer.

Keywords: *gear, noise, vibration, error, conjugate, Analysis.*

1. Introduction

Today world requires speed on each and every field. Hence rapidness and quick working is the most important. Now a day for achieving rapidness, man manufactures various machines and equipments. The engineer is constantly conformed to the challenges of bringing ideas and new design in to reality. New machines, equipments and the techniques are being developed continuously to manufacture various products at cheaper rates and high quality. The Gear Roll Tester is compact and portable equipment, which is skillful and is having something precise in testing the gears being manufactured. Gears are machine elements that transmit rotary motion and power by the successive engagements of teeth on their periphery. They constitute an economical method for such transmission, particularly if power levels or accuracy requirements are high (Omkar B Agashe, 2015).This Gear Roll Tester is the equipment useful to improve the quality of the gear being manufactured and can be made in less time.

2. Experimental Setup

To operate the testing machine, electric motor (prime mover), which is torque motor having 5 Kg.cm torque capacity, is used to rotate the master gear against the gear to be tested. Also an another motor of the same capacity is used to rotate the paper rolling drum to pass the recording paper against the vibrating pen and stylus due to the improper tooth geometry provided. The gear to be tested is installed on the trolley gear shaft using the fasteners as the nut and bolts. The trolley being spring loaded is in continuous close contact with the master gear. The master gear shaft is extended and is coupled with the driving torque motor using a coupling. When the pair of master gear and the gear to be tested is rotating and if there is any mis-run of the gear to be tested then the stylus and pen arrangement will deflect and the appropriate amount of variation in the graph which is recorded on the moving paper is being recorded. Thus the operation of gear testing machine is done. A Schematic diagram of the Experimental Setup is shown in Fig. 1.

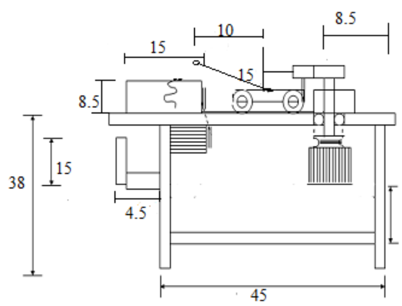

Fig.1 Schematic diagram of the Experimental Setup

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3. Experimental Work

It works on the principle of measurement of the miss-run of the smooth running of the precisely meshing gears (when rotated with respect to each other) with any variation in the geometry of the gear tooth profile due to the wear and tear by the periodic use or the faulty manufacturing. Gears are machine elements that transmit rotary motion and power by successive engagements of teeth on their periphery. They constitute an economical method for such transmission, particularly if power level or accuracy is high.

Fig.2 Experimental setup

4. Experimental Design

Design consists of application of scientific, principles, technical information and imagination for development of new or improvised machine or mechanism to perform a specific with maximum economy & efficiency. Hence a careful design approach has to be adopted. The total design work has been split up into two parts;

1. System design
2. Mechanical Design and Analysis

System design mainly concerns the various physical constraints and ergonomics, space requirements, arrangement of various components on main frame at system, man + machine interaction, No. of controls, position of controls, working environment of machine, chances of failure, safety, measures to be provided, servicing aids, ease of maintenance, scope of Improvement, weight of machine from ground level, total weight of machine and a lot more.

In mechanical design the components are listed down and stored on the basis of their procurement, design in two categories namely,

1. Designed Parts
2. Parts to be purchased

For designed parts detached design is done & distinctions thus obtained are compared to next highest dimensions which are readily available in market. This amplifies the assembly as well as postproduction servicing work. The various tolerances on the works are specified. The process charts are prepared and passed on to the manufacturing stage. The parts which are to be purchased directly are selected from various catalogues & specified so that anybody can purchase the same from the manufacture. The results of inspection are not only recorded but forwarded to the respective manufacturing department for taking necessary steps, so as to produce acceptable parts and reduce scrap. It also helps to purchase good quality of raw materials tools, equipment which governs the quality of the finished products. It also helps to co-ordinate the functions of quality control, production purchasing and other departments of the organizations.

4.1 System Design

4.1.1 System Selection Based on Physical Constraints

While selecting any machine it must be checked whether it is going to be used in a large – scale industry or a small –scale industry. In our case it is to be used by a small scale industry. So space is a major constrain. The system is to be very compact so that it can be adjusted to corner of a room. The mechanical design has direct norms with the system design. Hence the foremost job is to control the physical parameters, so that the distinctions obtained after mechanical design can be well fitted into that.

4.1.2 Selection Based on Components of Systems

As already stated the system should be compact enough so that it can be accommodated at a corner of a room. All the moving parts should be well closed & compact. A compact system design gives a high weighted structure which is desired. Man Machine Interaction The friendliness of a machine with the operator that is an important criterion of design. It is the application of anatomical & psychological principles to solve problems arising from Man–Machine relationship.

4.2 Mechanical Design and Analysis

Mechanical design phase is very important from the view of designer as whole success of the project depends on the correct design analysis of the problem. Many preliminary alternatives are eliminated during this phase Designer should have adequate knowledge above physical properties of material, loads stresses, deformation, and failure. Theories and wear analysis. He should identify the external and internal force acting on the machine parts. This force may be classified as

1) Dead weight forces
2) Friction forces
3) Inertia forces
4) Centrifugal force
5) Forces generated during power transmission etc.

Designer should estimate these forces very accurately by using design equations. If he does not have sufficient information to estimate them he should make certain practical assumptions based on similar conditions. This will almost satisfy the functional needs. Assumptions must always be on the safer side. Selection of factors of safety to find working or design stress is another important step in design of working dimensions of machine elements. The corrections in the theoretical stress value are to be made according in the kinds of loads, shape of parts & service requirements. Selection of material should be made according to the condition of loading shapes of products environments conditions & desirable properties of material .Provision should be made to minimize nearly adopting proper lubrications methods. In mechanical design the components are listed down & stored on the basis of their procurement in two categories.

1) Design parts
2) Parts to be purchased

For design parts a detailed design is done & designation thus obtain are compared to the next highest dimension which is ready available in market.

This simplification the assembly as well as post production service work. The various tolerances on the work are specified. The processes charts are prepared & passed on to the work are specified. The parts to be purchased directly are selected from various catalogues & specification so that anybody can purchase the same from retail shop with the given specifications.

4.2.1 Design of Shaft

The shaft may be designed on the basis of Strength and Rigidity. The following cases may be considered when shaft designing is on the strength basis

1) Shaft subjected to twisting movement or torque only.
2) Shaft subjected to bending moment only.
3) Shaft subjected to combined twisting & bending moment.
4) Shaft subjected to axial loading in addition to combined torsion bending load.
5) Shaft Subjected To Combined Twisting Moment & Bending Moment

When the shaft is subjected to combine twisting and bending moment then the shaft must be designed on the basis of the two moments. The following two theories are important from design point of view:

1) Max. Shear stress theory. It is used for ductile material such as M.S.
2) Max. Normal stress theory or Rankine's theory, it is used for brittle material such as C.I.

Twisting moment (T) may obtained by using the following relation.

$$P=2\pi nT/60 \tag{1}$$

Where,
T = twisting moment
N= RPM of shaft
P = power transmitted in Watts

When the shaft is subjected to a twisting moment, then the d diameter of shaft is to be obtained by using torsion equation.

$$\frac{T}{J} = \frac{F_s}{r} \tag{2}$$

Where,
T = twisting moment acting upon the shaft
J =Polar moment of inertia of shaft about the axis of relation.
Fs = Torsional shear stress

$$r = \frac{d}{2}$$

We know that for round solid shaft, polar moment of inertia

$$J= \frac{\pi}{32} X d^4 \tag{3}$$

The equation (2) may now be written as

$$\frac{T}{J} = \frac{F_s}{r}$$

By using relation between driver and driven gear

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \tag{4}$$

Where N1 & D1 = speed and diameter of shaft of the motor on driver gear.
Where N2 & D2 = speed and diameter of shaft of the motor on driven gear.
Torque transmitted by shaft,

$$T = \frac{P X 60}{2\pi n N_2} \tag{5}$$

$$\sigma_t = \frac{F}{A} \tag{6}$$

4.2.2 Design of Upper Motor

Let the torque on one side of the arm = Ta, Nm
We require 60 rpm motor.
Total Torque, T = 2 x Ta

$$P = \frac{2\pi nT}{60} \tag{7}$$

4.2.3 Design of Gear Pair

Material of the gears used is plastic. A non metallic gear will carry almost as much load as a good cast iron or

M.S steel gear, even though the strength is much lower, because of the low modulus of elasticity. This low modulus permits nonmetallic gear to absorb the effect of tooth errors so that dynamic load is not created. It also has the advantage of operating well in the marginal lubrication. As the material for the pinion and gear is same, pinion is weaker than the gear. So design is based on the pinion. We design the plastic gears for the wear failure. We can neglect the bending failure.

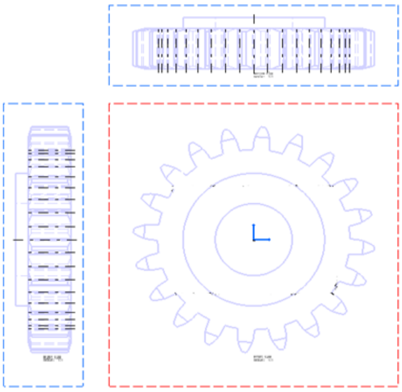

Fig.3 Spur Gear

Beam Strength

$$F_b = \sigma_b . b . m . Y_p \quad (8)$$

Wear strength

$$F_w = d_p . b . Q . K \quad (9)$$

$$Q = \frac{Z_g}{Z_g + Z_p} \quad (10)$$

$$K = 0.16 \text{ X} \left(\frac{B.H.N}{100} \right)^2 \quad (11)$$

$$V = \frac{\Pi \text{ x } d_p \text{ x } N_p}{60 \text{ x } 1000} \quad (12)$$

$$F_t = \frac{P}{V} \quad (13)$$

$$F_{eff} = \frac{K_a . K_m . F_t}{K_v} \quad (14)$$

$$F_b = F.O.S. \text{ x } F_{eff} \quad (15)$$

4.2.4 Design of springs

These are the two springs installed.
Spring required to with stand the pull of 20 kgf (max) = axial thrust.

To find the diameter of spring wire,
Torque = T = w x D/2

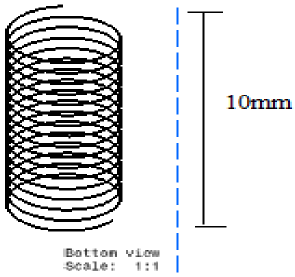

Fig.4 Spring

To find the number of turns

$$\delta = \frac{8 \text{ W } D^3 \text{ n}}{(d^4 \text{ G})} \quad (16)$$

4.2.5 Design of Bearing

The ball bearing is selected for radial load of 15 kg. During 90% of time the shaft rotates at 1000 rpm. We have to determine the value of dynamic load rating for 5000hrs of operation with not more than 10% of failure.

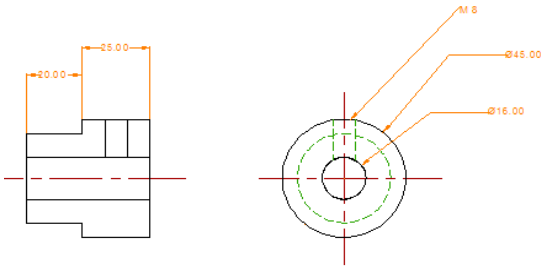

Fig.5 Bearing

Basic dynamic load rating = C

$$C = \left(\frac{L1W13 + L2W23}{106} \right)^{1/3} \quad (17)$$

Fig. 6 Bearing Mounter

5. Results

All dimensions in mm.
Deflection measurement using amplitude

1. $\delta = 1/n \log(X_0/X_n)$
   $=1/6 \log(50/30)$
   $=0.03697$

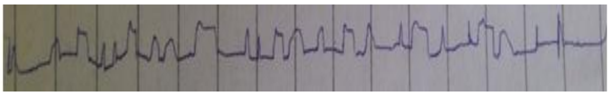

Fig. 7 Deflection measurement for 6 oscillations & X6.

2. $\delta = 1/6 \log(5/2)$
   $=0.06632$

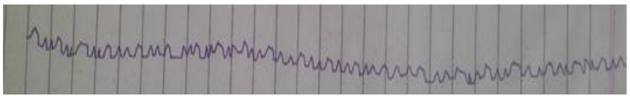

Fig. 8 Deflection measurement for 6 oscillations & X3

Conclusions

Gear Roll Test Rig is designed and developed for the functional testing of spur gears.

The test rig is manufactured which gives very high accuracy. Gears with different types of defects were tested on the test rig to ensure the accuracy of it. This test rig is an important tool to the gear manufacturer to test the gears for their functional performance. The test rig can be used further to analyses noise and vibrations.

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