MEASURMENT OF TRANSMISSION ERROR IN SPUR GEARS

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ABSTRACT: The power transmission by the gears is mostly used in the industries, automobile gearbox, robotics office automation, etc. and this is possible mostly by the gearing. Gearing is one of the most critical components in mechanical power transmission systems. Transmission error is to be one of the main contributors to noise and vibration in gear set. This paper aim is to know about the gear "Transmission error". A transmission error is considered to be an important excitation mechanism for gear noise and vibration. The definition of a transmission error is "the difference between the actual position of the output gear and the position it would occupy if the gear drive were perfectly conjugate". The gear transmission error that widely occurs in the actual gear system which arise because of irregular shape tool geometry imperfect mounting misalignment of two gears and so on. The influence of transmission error cannot be determined by investigating the gears only.

I.   INTRODUCTION

Gears are used for the transmission of Power/Torque from one shaft to another and are important machine elements. The transmission of torque/power should be uniform and accurate to avoid any noise, vibration, wear etc. Any deviation from accuracy in design or manufacturing, results in various defects leading to the transmission error. The Transmission Error (TE) is defined as the difference between the effective and the ideal position of the output shaft with reference to the input shaft in a gear set. The ideal position represents a condition of perfect gear box, without any type of errors and deformations. TE can be expressed either by an angular displacement or, more conveniently, as a linear displacement measured along a line of action at the base circle [1].

Gearing transmissions have a long history dating back since the time of the first engineering systems. Their practical usage in the present day modern engineering system is enormous. In accordance with a contemporary development of mechanical engineering techniques ever growing requirements and working specifications. Along with modern high speed manufacturing industry development, gear are widely used in many applications ranging from automotive transmission to robot and aerospace engines. Different kinds of metallic gears are currently being manufactured for various industrial purposes.

Transmission error occurs when a traditional non-modified gear drive is operated under assembly errors. Transmission error is the rotation delay between driving and driven gear caused by the disturbances of inevitable random noise factors such as elastic deformation, manufacturing error, alignment error in assembly.

1.1 Transmission Error actually arises due to:

a. Tooth geometry errors: Profile error, pitch error and runout errors from manufacturing process.

b. Elastic deformation: Local contact deformation at each meshing tooth pair and deflections of teeth in gear bodies due to the transmitted load through and transverse to the gear rotational axis.

c. Imperfect mounting: Geometric errors in alignment, which may be introduced by static and dynamic elastic deflections in the supporting bearings and shafts.

d. Lubricating film thickness etc.

The gear mesh stiffness is a time varying parameter that reflects gear mesh conditions as the number of teeth in contact varies, and as the line of contact of the engaged gear teeth varies [2, 3].

1.2 Methods of measurements of Transmission Error:

There are so many methods to measure the transmission error some are as

1. Pulse Timing method : That method are very old method and based and associated with optical encoder measurement of transmission error consists in using through shaft encoders to avoid couplings .The principle of this method pulse timing technique is integrated data acquisition ,The collection and storing

of data with the time interval between the rising edges of the encoder signals .

2. Angular sampling method: This method is based on the angular displacement on eithr the pinion or gear shaft or as displacement along the gear line of action. In the following,only transmission error as an angular error on the pinion shaft is used.

II. LITERATURE REVIEW

Many researchers have worked and are working on the effects of gear failure modes on the gear mesh stiffness, transmission error etc. M. Beghini et al [1] has proposed a simple method to reduce the transmission error for a given spur gear set, at the nominal torque, only by means of the profile modification parameters. Fakher Chaari et al [2]. presented the analytical modeling of tooth cracks and quantification of the gear mesh stiffness reduction due to the tooth crack. The validation of analytical formulation is done with the finite element model. S Du et al [3] introduced a modified transmission error model for analysing the effects on the transmission error of variation of tooth body stiffness with load application point. Olle Lundvall and Anders Klarbring [4] investigated the development of transmission error in a wear process in a gear system and demonstrated that the transmission error can be found from the infinitesimal displacement field superposed on the rigid body configuration. Markus Scherer [5] worked on vibration monitoring of gears using dynamic models to indicate, predict, and diagnose healthy and unhealthy gear systems. He investigated the influence of tip relief on contact forces followed by evaluation of common gear failure mechanisms. Somani S K [6] predicted the transmission error behavior using interference volume concept for spur gears having pitch error using solid modeling technique. Various spur gears pairs have been modeled for the determination of transmission error. He considered different parameters such as module, number of teeth and pressure angles. Evgeny Podzharov et al [7]. They used a simple method which consists of increasing the number of teeth on mating gears and simultaneously introducing negative profile shift in order to provide the same center distance to design spur gears with a contact ratio nearly 2.0. Sorin Pater et al [8] described the composite effect of any deviation of the gear teeth from perfectly formed involutes surfaces of static transmission error. Flavia Chira [9] analysed the influence of the pressure angles on the transmission error of the symmetric gear. W D Marka et al [10] derived a closed-form formulae allowing approximate computation of the static-transmission-error vibratory excitation caused by whole tooth plastic deformations on a single tooth, or on a few neighboring teeth. Cameron P Reagor [11] in his work described a method called Fourier Null Matching Technique for computing the optimal gear and tooth design for the minimization of transmission error fluctuations and the maintenance of constant transmitted gear mesh loading. H Zachary et al [12] developed a test rig for parallel-axis gearing that can measure static transmission error and shaft deflections to take a look at transmission error, shuttling and friction force excitations. Raul Tharmakulasingam [13] investigated the effect of tooth profile modifications on the transmission error of gear pairs. A spur gear pair was modelled using finite elements, and the gear mesh was simulated and analysed under static conditions. He also investigated the main differences between the static and dynamic transmission error generated during the meshing of a spur gear pair model.

III. PROBLEM DEFINITION

1. Gearboxes are the most widely used mechanical components in industrial equipments such as automotives, helicopters, and ships. Detecting the gear defects while the machine is still on operation can help to avoid abnormal event progression and to reduce productivity loss.

2. The faulty gear is usually the major source of severe vibrations and may result in the abnormal operation and failure of the system. These may lead to transmission error. Therefore, various method are used for the measurement of TE. This project work deals with the fabrication and measurement of TE.

The main objective of this work is to fabricate the experimental setup for the measurement of TE and to perform correct test on the set-up to obtain meaningful result from the observations.

IV. FABRICATION OF EXPERIMENTAL SET-UP

4.1 Experimental Test Rig

In the work, the single stage gear box has been fabricated for the experimental work. The input shaft of gearbox is connected to 0.5 HP, 1500 rpm electric motor through Oldham's coupling. A dimmer is used to vary the speed of electric motor and speed of motor or input shaft is measured with the help of tachometer. Medium carbon steel spur gears were used in the tests, to drive a

dynamometer. The driver gear is having 25 teeth, mounted on driver shaft coupled with a single phase 50 Hz DC motor (power rating 0.5 HP). The driver shaft is supported on two ball bearings. The gear on the driven shaft is having 75 teeth and also supported between two ball bearings. Other end of the driven shaft has provisions to apply load.

4.2 Components used in Experimental Setup

1. Gear- A gear or cogwheel is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part to transmit torque

2. Spur gear- A gearwheel with teeth projecting parallel to the wheel's axis. The material of spur gear is forge steel and under process of heat treatment no of teeth 75.

3. Pinion- A pinion is a round gear used in several applications: usually the smaller gear in a gear drive train. The material of spur gear is forge steel and under process of heat treatment no of teeth 25.

4. Shaft- A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The material of the shaft is Mild steel

5. Bearing- A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The Type of bearing is seal bearing .

6. 2 nos Digital Tachometer alongwith sensors - An instrument which measures the working speed of an engine (especially in a road vehicle), typically in revolutions per minute.

7. Motor-An electric motor of 1.5 HP is an electrical machine that converts electrical energy into mechanical energy.

8. Accelerometer- an instrument for measuring the acceleration of a moving or vibrating body.

9. Coupling- Spider type direct coupling

10. Brakes and Pulley

11. V- Belt along with round handle for providing manual break.
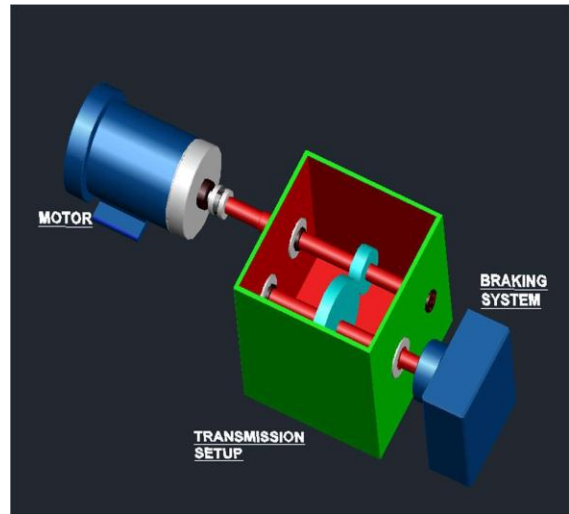
4.3 Proposed Model

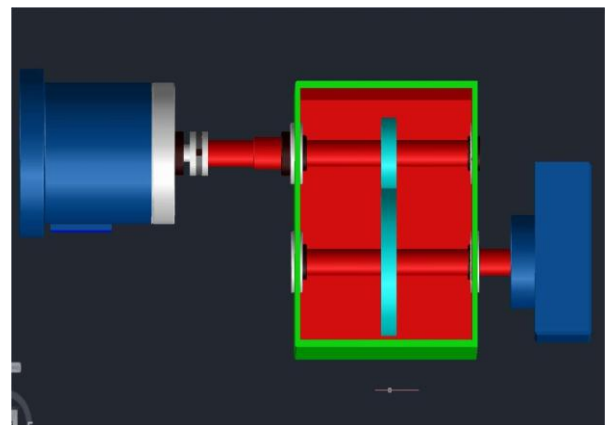*Figure -4.1 (Proposed Model – I) 3D View*

Figure-4.2 (Proposed Model – II) Top View

4.4 Design & Component Setup

A gearbox dynamics simulator type setup have been fabricated with incorporation of AC motors along with accelerator , pinion gear, Spur gear which under testing mounted with bearings ., an manual brake load, and two sensors for measuring the RPM one at input shaft coupling and another at output shaft pulley along with digital RPM meter at dash board. (which are indicated in Figure below).
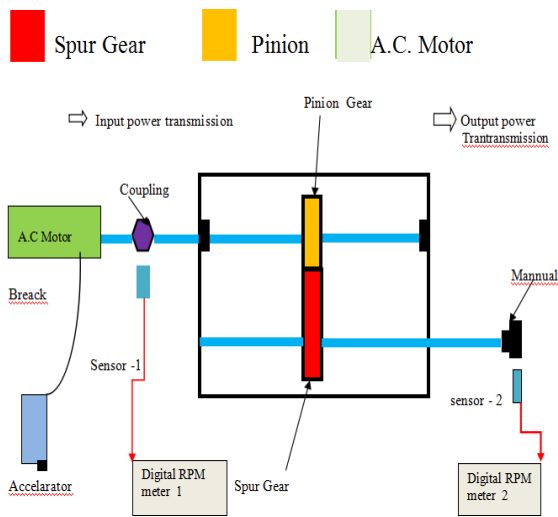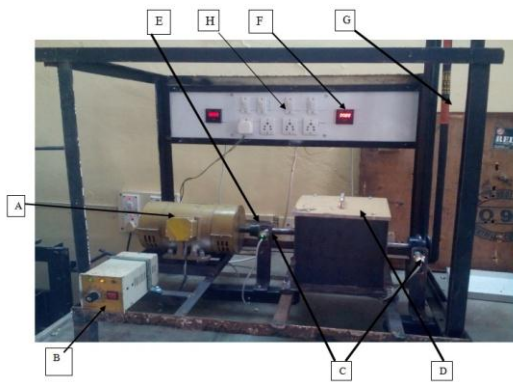
Figure – 4.3 Schematic drawing for fabrication

Figure – 4.4 Front view of fabricated Experimental setup

Details of Notations

  A- AC Motor

  B-Accelerator

  C-Sensors

  D-Gear Box

  E-Coupling

  F-Digital RPM meters

  G-V-Belt

  H-Electrical Dash board

Simple Spur Gear Pair

Figure – 4.5 Top view of fabricated Experimental setup

V.   MEASUREMENTS OF TRANSMISSION ERROR

The method for analysis of transmission error the following steps have been taken Based on above study, references and researches it is the conclusion that for designing & fabrication of "Experimental setup for measuring of Transmission errors of spur Gear'' the design is required to work with the spur gear.

First we take the vibration of prices gear with no error .Vibration of that gear without faults are plotted in graph will be taken as reference .Vibration in gears with defects and measured errors . Analysis of vibration in both the gears & comparing the vibration .The analysis of vibration will be detecting the transmission error in gear box.

After taking readings at various stages of running of A.C. motor through accelerator and RPM reading at both end or say readings of RPM at input driver and reading at output driven with the help of digital RPM meter ,and making some calculations for Transmission Error that is the difference between input and output data.

As per the readings table ,It shows that the RPM readings witch taken from non magnetic sensors setup at a particular position of rotational position and both sensor measure the Transmission error and it clearly shows that problem of gear meshing problem or showing of damaged or cracks teeth . The experimental error of readings are may be taken as ± 5RPM .

To reduce and minimization of Transmission error, The use of an automated profile generation tool along with the automated profile modification tool greatly helped in the increased efficiency of this research and slightly change to be made in geometry of gear profile . The two factor witch

responsible for optimization made in modification in the tip or root relief to find the optimized spur gear tooth profile that provided the lowest TE for gear and pinion respectively.

Table:1 Reading Table

Sr.No.	Step Time (Min.)	Precise gear		Defective Gear		Transmission Error (in rpm)
		Input (RPM)	Output (RPM)	Input (RPM)	Output (RPM)	
		Pinion	Spur Gear	Pinion	Spur Gear	
1	Mini.	20.48	6.43	23.48	5.05	2.78
2	Mini.	20.40	8.20	19.61	8.20	-1.66
3	Mini.	17.00	4.48	15.50	0.00	5.17
4	Mini.	23.48	7.59	25.41	7.59	0.88
5	1	60.34	20.18	60.97	18.99	1.33
6		60.16	20.01	60.51	18.98	1.19
7		59.35	20.07	62.08	19.65	1.04
8		61.20	21.01	63.02	19.81	1.20
9	2	119.67	39.87	120.56	38.74	1.45
10		120.20	39.75	119.50	38.85	0.98
11		118.90	40.29	121.50	37.90	2.60
12		119.70	40.05	120.50	39.74	0.43
13	3	180.95	60.12	184.33	60.05	1.39
14		179.40	59.64	183.40	60.17	0.96
15		180.80	59.87	183.60	61.20	0.00
16		182.40	60.93	182.40	59.23	1.57
17	4	241.15	80.68	244.30	79.37	2.06
18		239.50	80.14	242.20	61.14	19.59
19		240.20	80.20	244.90	81.55	0.08
20		243.30	81.00	242.20	60.20	20.53
21	5	302.96	101.29	302.60	97.68	3.19
22		299.40	100.40	300.50	99.50	0.67
23		301.20	100.60	303.30	80.80	20.30
24		306.80	102.70	304.10	76.06	25.31
25	6	360.40	120.02	362.14	118.36	2.30
26		358.70	118.91	359.80	117.10	2.83
27		359.60	119.80	361.90	118.80	1.83
28		361.10	120.50	362.80	119.56	1.37

VI. CONCLUSION

The contribution of this work shows here can be concluded as follows the aim of the work is highlight the factors to generate the transmission errors in gears and its adverse effect on the gearing. There are various points consider to cause of transmission error is generate in gearing. First problem is very common that improper mountings of gears for collecting information of entire effect and action of gearing , the manufacturing error during operation such as milling of gears, hobbing of gears etc., The tooth mesh stiffness and load variation on the gears. These are problems to spared noise and vibrations during operating condition of gears. According to some review of literature the fabrication of experimental setup up to some extant of level to achieve the perfect result of transmission error. In this paper to review some literary, various papers to overcome the transmission error and its effect. Apart from that the static transmission error overcome by the proper mountings of gears for proper meshing and the dynamic transmission error overcome by the modeling of the gears.

VII. SCOPE FOR FUTURE WORK

An area of opportunity for future work would be to monitor a gearbox from break in to failure without external influences. Recording regularly spaced data samples using the current data collection procedure from start up to eventual failure would further identify useful characteristic features obtainable from the Transmission Error trace. Over time, a library of fault conditions and incipient failure indicators could be keeping in mind.

Another opportunity for future work would be to re-examine the steel gears used at the beginning of this study. Using the updated data acquisition method and modifying filter values would results in increased clarity of the TE traces.

Ultimately, these inexpensive non-contact fixed position sensors were used to accurately detect and measure Transmission Error, providing a means to quantify and qualify gearbox health.

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