Development Of A Power Re-Circulating Gear Test Rig

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ABSTRACT

In order to evaluate the performance of gears, a power re-circulating test rig has been designed and developed. The test rig consists of one pair of test spur gears and one pair of helical loading gears. The variation in gear loading is achieved by axial loading of the helical gear using a pneumatic actuator. The no load-starting feature in the test rig reduces the size of the motor.

The test rig is equipped with multimode condition monitoring unit and computer data acquisition system. Continuous multimode monitoring, online data analysis and post data analysis make the system more versatile in accurately predicting the failure. The features of the test rig and advantages are discussed in detail in this paper.

INTRODUCTION

Gears have been in use for hundreds of years and their usage will undoubtedly continue for a few more decades in all kinds of machinery owing to their advantage over other methods of power transmission. The gear performance depends on a number of parameters such as material, design, manufacturing, operation and environment. The interaction between these parameters makes it difficult to evolve mathematical models that can predict gear life accurately [1-7]. Hence, laboratory testing has become mandatory for evaluation of performance of the gears.

The mechanical power re-circulating gear test rig also called four square gear test rig is the most preferred test rig because of the low power requirement just to overcome the frictional losses and windage losses in running condition [8-9]. The test rig can run at high efficiency most of the time. However, in these test rigs, the loading is done in static condition and they require high starting torque. The power re-circulating gear test rig with loading in dynamic condition [10] can be started in no load condition and it requires a smaller drive motor than the conventional test rigs. This rig also offers a versatile loading environment where the actual working conditions can be simulated in laboratory testing.

POWER RECIRCULATING GEAR TEST RIG

The power re-circulating gear test rigs are used where the power rating of the gear system is high. The four square gear test rig consists of two sets of gears placed back to back with their high-speed shafts connected together. Hence there is mechanical power re-circulation. One gear system is called the slave that is to be tested; the other gear system is called the master. In most of the test rigs the torque is applied in the static condition. When statically loaded system is started, metal to metal contact existing between the teeth of pinion and gear at the beginning will give rise to high adhesive wear owing to the absence of hydrodynamic lubrication. There is also a likelihood of premature failure due to adhesive wear. High initial torque will require higher size motor for starting, even though in running condition the torque required is less. Hence the motor efficiency will be lower.

GEAR TEST RIG WITH LOADING UNDER DYNAMIC CONDITION

The in house developed improved version of power re-circulating gear test rig has the facility of loading the test gear under dynamic conditions [4]. The test rig consists of two identical gearboxes with the high and low speed shafts connected together. The torque is applied by twisting one shaft relative to the other dynamically. In the test rig developed by NASA Glenn Research Center for studying pitting fatigue life, torque is applied through loading vanes. Oil pressure is supplied for the loading vanes and proper sealing is provided by shaft seals. Schematic diagram of the test rig is shown in Fig. 1. This type of test rig developed in the Machine Design Section, IIT Madras faced with leakage and difficulty in maintaining steady load. The test rig developed in the laboratory recently is shown in Fig.2. In this rig, torque is applied using helical gear loading arrangement. The

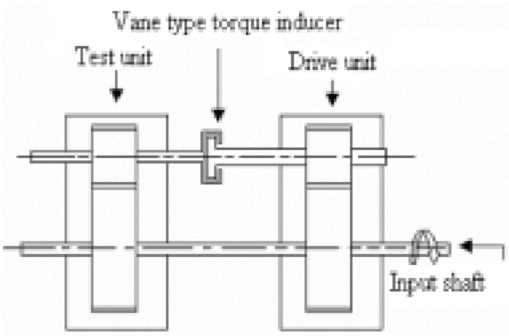

Fig. 1: Hydraulic type torque inducer.

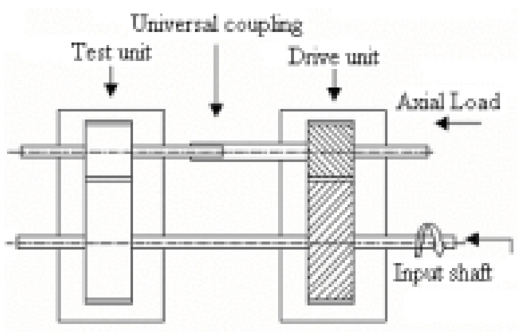

Fig. 2: Helical gear type torque inducers.

helical gear is axially loaded using a pneumatic actuator. The axial load induces both radial and tangential load in the helical gear pair. This test rig is used in the study of the surface fatigue life of case carburized and other surface treated gears. The gears are tested for 10 million cycles without any type of surface fatigue failures. The test rig can also be used for studying the performance indigenously developed lubricants and new surface treatments to the gear materials. The test rig is divided into sub-units based on individual function carried out by them as test unit; drive unit, lubrication unit and the instrumentation unit.

Test unit

The gear test rig consists of a test gearbox and a slave gearbox, which is, connected through high and low speed shafts. The gearboxes with the drive unit are mounted on a rigid concrete bed. Schematic drawing of assembled test rig is given in Fig. 3 and Fig. 4.

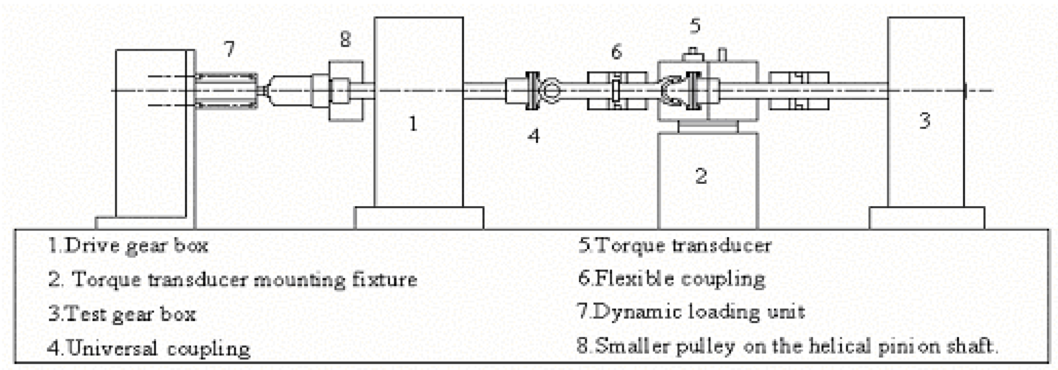

Fig. 3: Front view of the assembled gear test rig

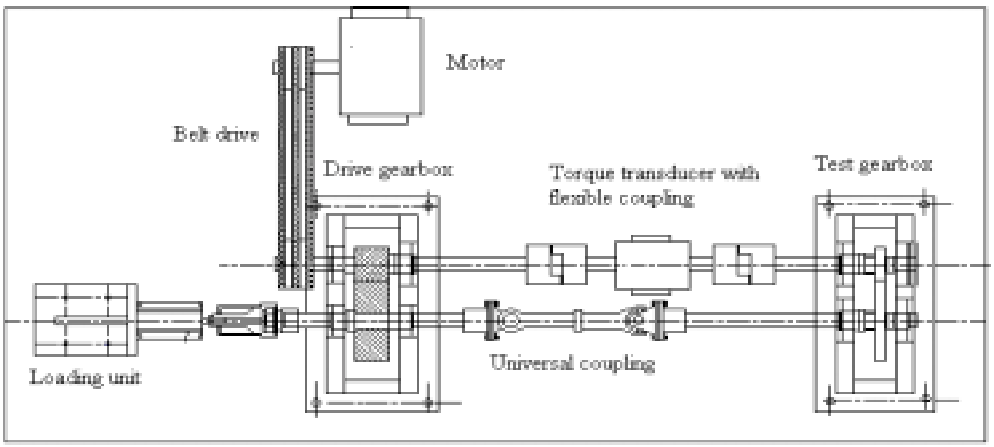

Fig. 4: Top view of the assembled gear test rig

The spur gear shaft and the helical gear shaft are connected through universal coupling. A non-contact torque transducer is connected between the spur pinion and spur gear shafts to measure the torque and speed of the pinion side of the gear test rig. The specification of the test unit section is given in Table 1.

Table 1: Specification of the test unit

Description	Value	Description	Value
Center Distance	94.5mm	No of teeth on helical pinion	18
Shaft diameter	27mm	No of teeth on helical gear	45
Gear ratio	2.5	No of teeth on spur pinion	18
Pressure angle	20^0	No of teeth on spur gear	45
Circular pitch	9.42mm	Pitch circle diameter of spur pinion	54mm
Maximum Pitch line velocity	4.5m/sec	Pitch circle diameter of spur gear	135mm
Module	3mm	Tooth thickness on pitch circle	4.7mm
Helix angle	15^0	Face width of spur gear	10mm
Concrete bed Dimensions	1520mm x 620mm x 680mm	Face width of helical gear	50mm

Drive unit

The drive gearbox, which contains one pair of helical gear, serves as the drive side. The drive power is from a variable speed D C motor to the helical pinion through three-groove pulley and belt drive. Driver side specification is given in Table 2. The smaller pulley is connected on the drive shaft and the larger pulley is connected on the motor shaft so that a speed increase of 1.25 times is obtained. The pinion side shaft will be rotating at maximum of 1800 rpm and the gear side shaft will be rotating at 720 rpm. The test specimen is taken in the form of spur pinion. Different combination of spur pinions and spur gears can be evaluated for their performance to find compatible combination under simulated conditions. Even the lubricating oil performance can be tested.

Table 2: Specification of the drive side

Description	Value	Description	Value
Motor Power	5 hp	Pitch circle diameter of larger pulley	100 mm
Motor Speed	1440 rpm	Pitch circle diameter of smaller pulley	80 mm

Loading unit

The basic principle of loading is twisting one shaft relative to its mating shaft and locking it in position. In this power re-circulating test rig, this is accomplished even in the running condition. The test rig can be started at no load. A pneumatic actuator via a load cell loads the helical gear in the drive gearbox axially. This will induce proportional radial and tangential loads in the mating gears. The axial load is measured using the in house developed strain gauge based load cell. The torque so generated is transmitted through the test gears back to the drive gears. The load can be varied in the running condition by adjusting the air pressure in the pneumatic line. The axial movement of the helical gear permitted by the NU type support roller bearings is taken care of by the universal coupling provided between the spur gear and helical gear shafts. Loading data is given in Table 3.

Table 3: Loading data

Description	Value	Description	Value
Maximum axial load (N)	2000	Maximum Tangential force (N)	7500
Maximum hertz contact stress at the Pitch line (MPa)	2600	Pneumatic actuator diameter, stroke length (mm)	80,50

Lubrication unit

The test rig is provided with forced lubrication system. Two separate lubrication lines are provided for the helical gear in the drive gearbox and spur gear in the test gearbox. A third lubrication line is provided for the deep groove ball bearings on the test side and roller bearings on the drive side. Each lubrication line is provided with independent flow meters by which the flow rate can be adjusted. The lubrication set up includes a 50μm suction filter, a filter breather, low-level oil indicator and magnetic particle separator on the suction side. An online filter of 10μm is provided between the pump and the pressure relief valve. The test gears are lubricated with a single oil jet directed to the mesh location. The maximum flow rate of oil is 3 lpm. Gear testing can be done for various flow rates and their effect on the surface fatigue life can be studied. A schematic diagram of the lubrication set up is given in Fig. 5.

The lubrication aspects in gear testing and the effect of various lubricants on the life of the gears can be studied. The study of the EHD lubrication on the fatigue life of gears can be carried out in this test rig. The lubricant temperature at the bearing side and the gear meshing side is monitored constantly by non-contact infrared temperature sensors.

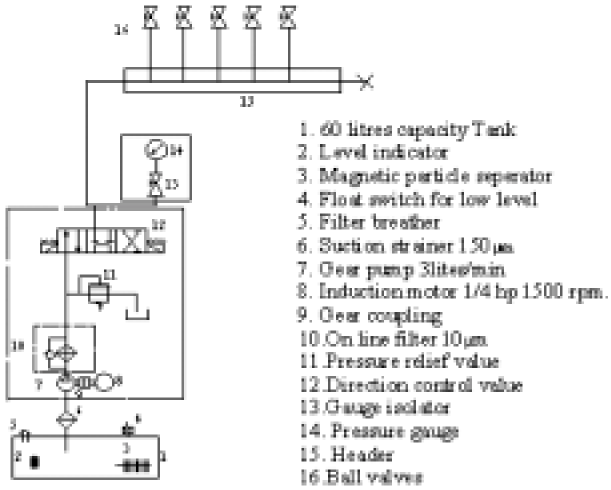

Fig. 5: Lubrication circuit

Instrumentation unit.

The on line instrumentation unit consists of accelerometers for vibration pickup, infrared temperature sensors, B&K sound meter, load cell with measuring amplifier, torque sensor with display unit, pressure regulator for the pneumatic actuator, 16 channel A/D data acquisition card with 100kHz sampling rate and a dedicated computer system. The in-house developed data acquisition software can directly store data in excel sheet, specimen wise, with date and time according to the sampling rate specified. The time taken for failure can be correctly recorded.

The torque sensor is of non-contact type based on rotating transformer principle. A schematic diagram of the torque transducer is given in Fig.6. It gives both torque and speed measurements.

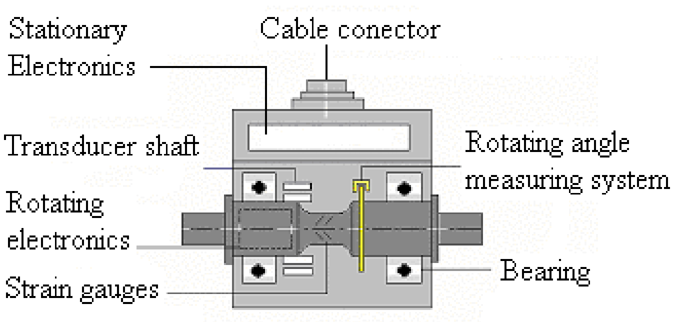

Fig. 6:Torque transducer

The axial load measured by the strain gauge based load cell is supplied to the HBM measuring amplifier, which is calibrated to display the load directly.

The B&K integrated sound level meter measures the RMS and peak values of the sound level. The desired band width i.e., broadband, 1/3 octave or 1/1 octave can be set for the RMS detector and broadband for the peak detector. The condenser microphone is kept near the gear mesh zone and the sound level from the gear meshing is continuously monitored.

Two vibration sensors are fixed on the gearbox near to the bearing on the drive and the test gearboxes. The gear meshing and the bearing frequencies can be isolated. The sound and vibration data can be used for FFT analysis and wavelet analysis using Mat Lab and other analysis software.

The infrared temperature sensors continuously monitor the temperature at the gear-meshing zone. The sound level, vibration effects, temperature, oil analysis, and pressure measurements offer a multi mode strategy in effectively predicting the performance of the gears.

PRACTICAL SIGNIFICANCE

This power re-circulating gear test rig with loading in dynamic condition offers a very convenient and economically viable means of creating the actual working condition for the gears to be tested. Many indigenously developed surface treatment processes, new materials for gears can be evaluated for their performance under accelerated conditions at low cost. The gear performance can be monitored continuously and the data can be stored and analyzed. Safe working regime for working of the gears can be established. Currently studies are done on the effect of residual austenite content on pitting behaviour of through hardened, case carburized-and-quenched steel gears. High contact ratio gears are also being tested for their performance.

CONCLUSION

The power re-circulating gear test rigs with dynamic loading offers a very versatile means of simulating the actual working condition of the gears. The data obtained from the multimode data acquisition system are more reliable in predicting the life of the gears and in establishing the safe working regime for the gear materials. With smaller size drive unit, this system will be more energy efficient.

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