Volume : 2 | Issue : 8 | Aug 2013 • ISSN No 2277 - 8160

Research Paper | Engineering

Investigating the Condition of Gear Chips Being Dragged in A Single Stage Spur Gear Mesh

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ABSTRACT *In this paper various experiments were conducted on gear chips of different sizes by dragging them into spur gear mesh at different speeds. For performing these experiments a experimental setup was fabricated using a casing of Maruti 800 gear box. To account for the amount of deformation occurred on the surface of gear chip as well as on the gear tooth surface images of the gear chips before and after the engagement were taken with help of a Laser Scanning Microscope. It was focused that whether the gear chips broke up onto pieces or got deformed.*

KEYWORDS: Spur Gear, Laser Scanning Microscope, Gear Chips.

INTRODUCTION
In gear transmission systems operating at high speed and at high load there is some possibility that liberated debris might be entrapped into the gear mesh. Due to closely packed nature of mechanisms, chips that are released due to gear deformation or from the defected bearing can then introduced to other gear meshes with the system. It is desirable to know the consequences of these entrapped debris in the gear mesh. Main purpose was to determine the condition of the gear chip material after engagement with the meshing gear that either they get deformed or break into pieces and the effect on the gear surface by their motion.

LITERATURE SURVEY
W.D. Mark, C.P. Reagor, D.R. McPherson [1] proposed that for constant loading and speed conditions, the principal sources of vibration excitation arising from meshing gears, characterized by the "static transmission error" (STE) excitation, are geometric deviations of the working surfaces of the teeth from equi-spaced perfect involute surfaces, and tooth/gear body elastic deformations. Also Changes in these two sources caused by tooth-bending-fatigue damage on one or a few teeth are manifested primarily in the rotational-harmonic content of the STE of each individual damaged gear of the meshing pair, and are most effectively detected in the time domain. They specified the optimum number of gear rotations to be used in synchronous averaging along with how such synchronous averaging can be used to eliminate the effects of the mating gear in the case of "hunting tooth" gear pairs. Their precision measurements made on the teeth of a gear failed in a tooth-bending-fatigue test strongly suggest that whole-tooth plastic deformation—i.e. yielding, rather than changes in tooth stiffness caused by tooth-root cracks, is the principal source of detectable damage in the case of tooth bending fatigue. And such plastic deformations are geometric deviation STE contributions. Differences in gear materials, materials processing, and gear operating properties may significantly affect the amounts of such plastic deformations before tooth breakage and the operating duration between initial damage detection and tooth breakage, determining such dependencies they performed some tests. From the test results they found Precision measurements made on the non-working surface (coast sides) of gear teeth, of a gear tested and failed by tooth bending fatigue, have shown that plastic tooth deformations are almost surely the dominant source of gear-health monitoring changes in vibration responses in the case of tooth bending fatigue, and that changes in tooth stiffness caused by tooth-root cracks are likely to cause significantly smaller changes.

S.Eersbach and Z.Peng [2] had investigated the condition and faults of a spur gearbox using vibration and wear debris analysis techniques . The aim of their work is mainly to investigate the effectiveness of combining both vibration analysis and wear debris analysis in an integrated machine condition monitoring maintenance program. To this end a series of studies was conducted on a spur gear box test rig. They have conducted a test under normal condition to obtain basic condition of the test rig, then a no of different machine defect conditions were introduced under controlled operating condition at constant overload and cyclic loads. The data obtained from wear debris analysis is then compared with that of vibration analysis data in order to quantify the effectiveness of both the techniques in predicting diagnosing machine failures. The results have shown a evidence for decreasing wear rate as is typical for the running in to normal operating condition. The reduction in laminar particles, and the presence of limited quantity of fatigue particles found by wear debris analysis demonstrate good correlation with those of vibration analysis.

Rui Man, Yushu Chen, Qingjie Cao [3] led their study focusing on the nonlinear dynamic and vibration characteristics of spur gear pair with local spalling defect to explore the spalling mechanism. They established the dynamic model of the gear pair with spalling defect and time-variant mesh stiffness to investigate the effect of spalling defect on mesh stiffness and dynamic response. They obtained the analytical solutions of the system, which is deduced into four different stages of the gear with the time-variant stiffness in a mesh period. Also the dynamic response with the evolvement of sapll are analyzed by using time history, phase contrail, Poincare section and spectrum analysis. They have employed statistical techniques for evaluating spalling characteristics and found it suitable to detect spalling defects under low velocity and small excitation. For obtaining a theoretical basis to spalling fault diagnosis of spur gearbox they have designed a gear box with spalling defect and carried out some experiments to determine the dynamic characteristics of the spalling vibration signals. The results obtained showed a good agreement qualitatively with the theoretical analysis, which provides a theoretical basis to spalling fault diagnosis of gearbox.

Robert F. Handschuh and Timothy L. Krantz [4] had investigated engaged metal wear debris into a gear mesh. Their idea was that in some space mechanisms the loading can be so high that there is a possibility that a gear chip might be liberated while in operation of that mechanism. Also due to closely packed nature of some space mechanisms and the fact that a space grease is used for lubrication chips that are released can be introduced to other gear meshes with in the mechanism. The main aim of their study was to determine the relationship of the chip size to the torque required to rotate the gear set through the mesh cycle. Another purpose was to determine the condition of the gear chip material after engagement with the meshing gear, primarily to determine if the chip would break in to pieces and to observe the motion of the chip as the engagement was complete. For this they have worked a number of experiments on a Glen Research Center spur gear fatigue test rig having two identical spur gears. From this experiment the chip size required to jam the mechanism can also be determined. The metal debris that was used for engagement into a pair of meshing gears are , shim stock , drill bit shanks and chips of gears liberated from a test gear . It was found that the peak torque required to rotate the gears with the object engaged was proportional to the size of the engaged object. In another way the engaging object of higher hardness required a significantly greater torque value relative to that of lower hardness comparatively. On the other hand the largest chip tested undergo sufficient deformation to the gear teeth to prevent smooth motions of the gear when the damaged tooth is engaged. During the experimentation no tooth fracture occurred. Finally they have concluded that the torque required to drive the gear chip through the gear mesh is system dependent.

Shengxiang Jia, Ian Howard [5] presented a 26 degree of freedom gear dynamic model of three shafts and two pairs of spur gears in mesh for comparison of localized tooth spalling and damage. They also gave details that how tooth spalling and cracks can be included in the model by using the combined torsional mesh stiffness of the gears. They also described the FEA models developed for calculation of the torsional stiffness and tooth load sharing ratio of the gears in mesh with the spalling and crack damage. Their result indicates that the amplitude and phase modulation of the coherent time synchronous vibration signal average can be effective in indicating the difference between localized tooth spalling and crack damage.

METHODOLOGY

The gear chip pieces used in the experiment were liberated from a spare gear pair. The gear chips were created by scoring a mark on the gear tooth using rotating cutting wheel and then striking the score line with a cold chisel. These created chips were irregular in shape and sizes, these chips were then made in required shape and size by machining process. Grease is used when gear chips were engaged as lubricant. Gear chips were introduced in the gear mesh and rotated for a fixed duration by a input supply that is a DC motor at different speeds in the presence of grease. It was observed that if the chip would break into pieces or get deformed.

Figure 1- Experimental Setup

TEST RESULTS

Figures below shows the images of the gear chips before and after engagement. The images show that there was only small deformation occurred on the chip surface but the chips does not go any severe breakage.

BEFORE TEST

Figure 2- Gear Chip(5 mm x 2 mm)

AFTER TEST

Figure 3- Gear Chip(5mm x 2mm)

BEFORE TEST

Figure 4- Gear Chip(4 mm x 2 mm)

AFTER TEST

Figure 5- Gear Chip(4 mm x 2 mm)

BEFORE TEST

Figure 6- Gear Chip(4 mm x 4 mm)

AFTER TEST

Figure 7- Gear Chip(4 mm x 4 mm)

CONCLUSION

From the experimental results obtained by dragging gear chips of different size it was found that there is no tooth breakage and not much deformation occurred to the gear surface, but the chips got plastically deformed after engagement. In future by changing the material of the debris and gear testing can be done, also single stage gear mesh can be converted to multi stage gear mesh and spur gear can be replaced by any other type of gear.

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