EAN 2014
52nd conference on experimental stress analysis

Experimental Analysis of Gear Loading in Planetary Transmission

BERKA Ondřej[1,a], LOPOT František[1,b] and DUB Martin[1,c]

[1]CTU in Prague, Faculty of Mechanical Engineering, Department of Designing and Machine Components, Technická 4, 166 07 Prague 6, Czech Republic

[a]ondrej.berka@fs.cvut.cz, [b]flopot@seznam.cz, [c]martin.dub@fs.cvut.cz

Keywords: Planetary transmission, strain gauge, stress state, gear meshing.

Abstract. This paper is focused on examination of teeth loading in rotating gears during standard operation and describes the applied approach and device developed. One of the closely examined items in planetary transmission testing is the gearing. The tooth load of each wheel in planetary transmission is monitored individually. In large devices, also the load across the width of the tooth is assessed by the $K_{h\beta}$ coefficient.

Introduction

For load monitoring on any gears, the strain gauge measurement is generally considered the method of choice. For measurements in stationary conditions, it is possible to use standard wired devices supplied by a number of manufacturers. However, in testing of rotating parts in planetary transmissions, a wireless autonomous measurement technology had to be developed. For instance, the Wi-Fi panels or similar technology can be used for signal transmission. The planet is the most complicated element of the transmission to be measured because it rotates around its own axis and at the same time also around the axis of the other gears. Moreover, access to the planet wheel may be difficult as it is often built-in in a closed cabinet. This also hampers Wi-Fi transmission and therefore a special device had to be developed as an autonomous recording unit. Its dimensions must be small so that it could be placed both inside or outside the gear, including the batteries and amplifiers.

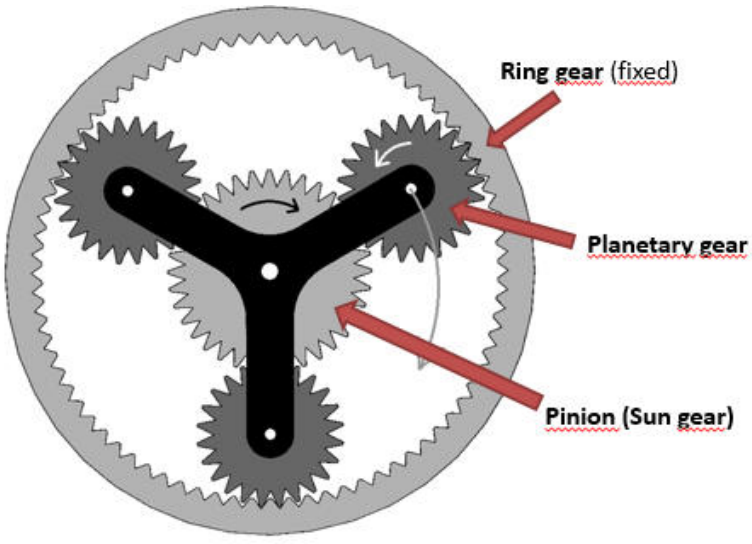

Fig. 1. Planetary transmission.

Other parameters to consider include for example limited space for the strain gauge placement, temperature conditions of both the tested component and its lubricant, and aggressiveness of the lubricating oil. Those factors are of utmost importance in the choice of necessary wiring, insulation and glue materials with regard to strain gauges protection. Also the electronics must be temperature-resistant in the range of expected temperatures. To fulfill of all this, a special recording apparatus was developed.

Because the measured gear boxes are ready made (standard production), there is no chance to modify their design and construction in any way for easier placement of the measuring components. After the testing, if successful, all components of the measurement system are removed and the gear box is delivered to the customer.

Strain Gauges Connection

Irrespective of kind of rotation there is recorded tensile load “A” (“B”) and than tensile load from spot “B” (“A”) due to the configuration of strain gauges to spot “A” and “B”. This is related to connection to w-bridge. Connection of strain gauges was made to ½ w-bridge (Fig. 2).

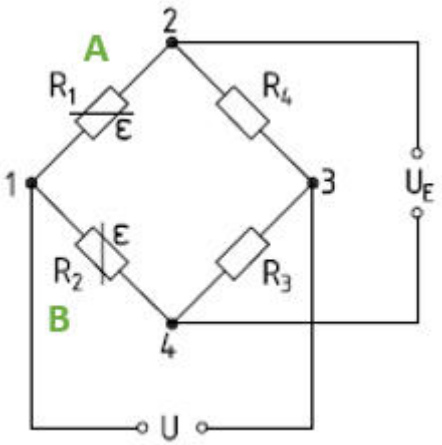

Fig. 2. Strain gauge connection.

At the moment of mesh of gearwheel with strain gauges „A“ is strain gauge in the spot “B” compensating the temperature difference and contrariwise. In this case of w-bridge connection is evaluating of the data more simple. Data from strain gauges “A” and “B” are subtracting “A” – “B”. The result of the data are presented at the Fig. 3. At the moment of “A” strain gauges measuring (pull) is change in resistance of the strain gauge "B" theoretically equal to zero and result data are “A” – 0 = “A”. At the moment of mesh of teeth with strain gauges “B” (pressure) is theoretical change of resistance now on strain gauges “A” equal to zero. Than the data measured by strain gauges “B” is 0 – “B” = -“B”. However pressure voltage is negative, that is why the final result coming from w-bridge is positive.

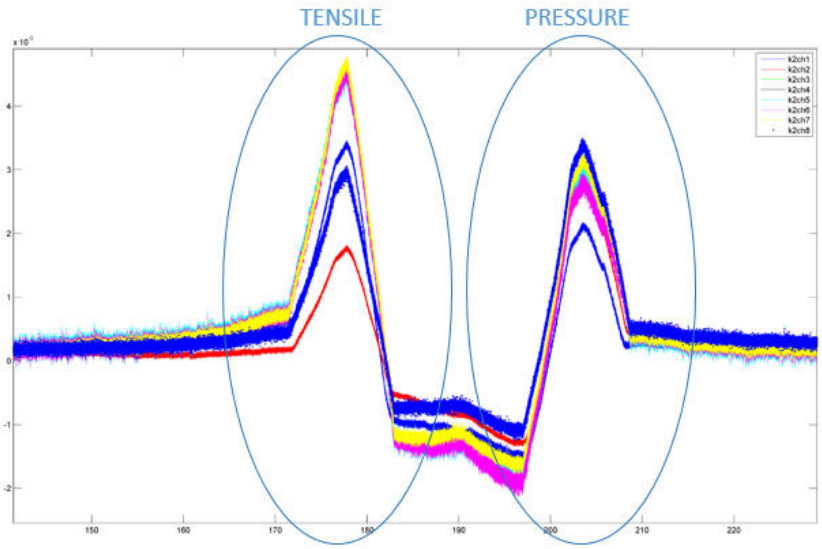

Fig. 3. The signal from strain gauges.

Strain Gauges Installation

The prepared strain gauges and measuring apparatus now must be installed on the single parts of transmission. Technology of sticking again depends on parameters, which are temperature and aggression of the lubricant. Location of strain gauges on tooth must satisfy the following conditions. Strain gauges should be in place, where is stress maximum of teeth. Strain gauges must not come into contact with other gears. Strain gauges must be in same height of teeth for following smoothness of gear loading. The apparatus is located to avoid the contact with another parts of transmission.

Fig. 4. Strain gauges on ring gear (with epoxide layer).

Clockwise planetary gear rotations. In this method of rotation the satellite comes into engagement with the first crown tooth. This tooth is measured by the strain gauges in the tooth gap “A”. Side of the tooth crown with these strain gauges is tensile loaded at the time of engagement. At the time before mesh of measured tooth is this side of this tooth also tensile loaded by deformation leverage of the ring. Tooth labeled “B” comes gradually into engagement with a line of strain gauges when rotating satellite. This spot is than loaded by pressure. Indeed at the time before mesh is this spot loaded by leverage of deformation of the ring similarly like the gap “A” (tensile load). It can be stated that teeth of the crown are before mesh tensile loaded and teeth in the time after mesh are loaded by pressure.

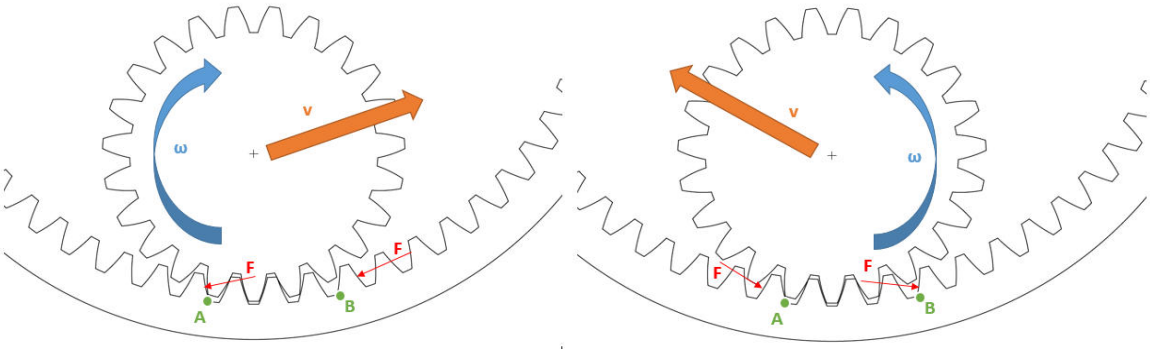

Fig. 5. Planetary gear rotations – clockwise and counterclockwise.

Counterclockwise planetary gear rotations. In this kind of rotation satellite comes first into mesh with the tooth crown which is measured by strain gauges in the gap "B". Side of the tooth is at the time of the mesh tensile loaded with this strain gauges. At the time before mesh of gearwheel is this side also tensile loaded due to deformation leverage of the ring. While rotating the satellite there is gradually coming mesh of the tooth crown with set of strain gauges marked "A". Differently from spot "B" this spot is loaded by pressure. It can be stated that teeth of the crown are before mesh tensile loaded and teeth in the time after mesh are loaded by pressure.

Conclusions

There are a lot of possibilities, how getting data present. For example, we calculate coefficient $K_{h\beta}$. In another case, we represent data to 3D diagram (Fig. 6). 3D diagram is made for comparing with ring gear and it describes measured loading along length teeth. For verification the measurement it is compared with a gear-testing using colour. Tooth are painted by colour along their whole length. Colour is wipe off after contact with another tooth. Positioning of loading along length of teeth is evaluated by this test.

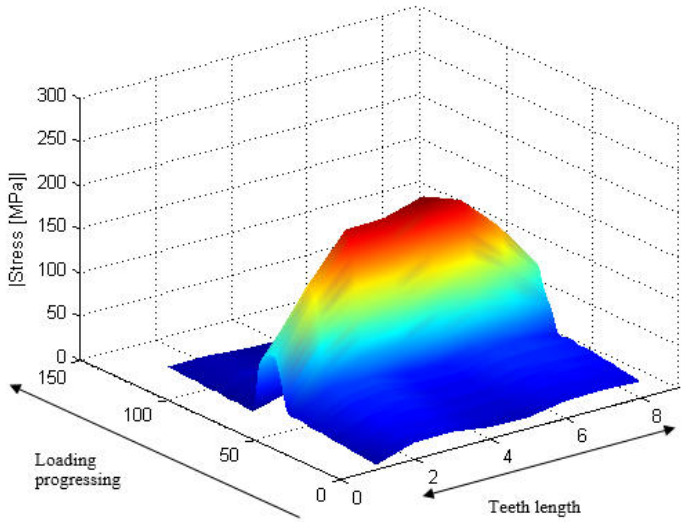

Fig. 6. Loading processing along teeth length.

References

[1] Č. Šalamoun, M. Suchý, J. Svoboda, Mechanické a hydraulické převody, ČVUT v Praze, Praha, 1984.