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Backlash and Torsional Stiffness of a Gearbox

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Abstract: The paper occupies with the measurement of the torsional behaviour and backlash of the gearbox with large gear ratio. The incremental rotary sensors and torque sensor are used. The torsional stiffness during loading and total backlash of the gearbox results from this experimental measurement.

Keywords: Backlash; Torsional Stiffness; Gear; Measurement.

1 Introduction

Knowledge of the torsional features including the backlash of the gearbox is very important. It can influence the kinematics and dynamics of the whole drive chain of any mechanism during different operating load states and also during overloading states. The backlash of the gear train is also important when the reversing is considered and it can be more significant in case of gearboxes with higher gear ratios.

The purpose of this paper is to describe the measurement of the torsional features and backlash of the gearbox. The measurement was carried out on the gearbox with considerable total gear ratio $i_t \approx 7500$. The gearbox is consisted of three helical and three planetary gears [2]. During the measurement, two identical gearboxes were mounted together with their output shafts because this arrangement was used for previous running test of the gearbox and it is also suitable for the measurement. The measurement arrangement can be seen in Fig. 1.

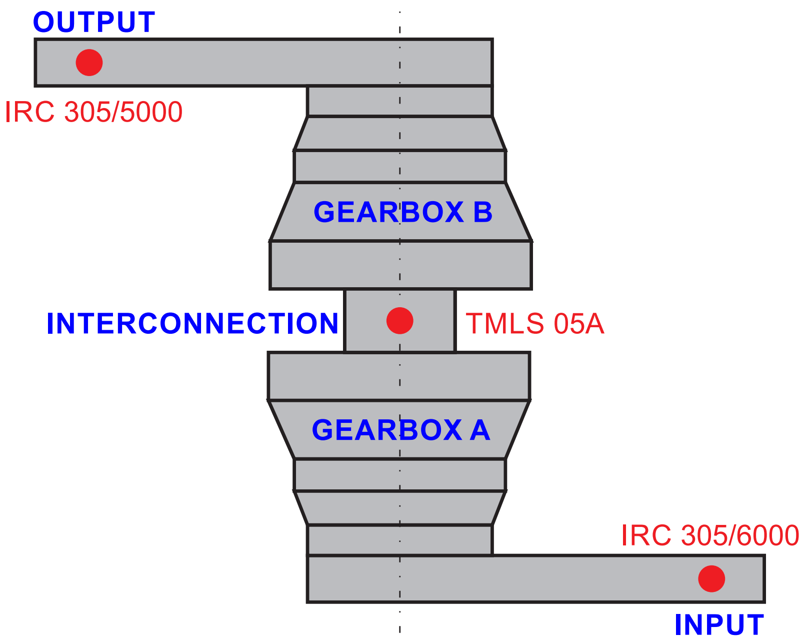

Fig. 1: The gearbox arrangement during measurement and sensors placement.

2 Measurement

The measurement had two main goals. The first one was to analyse the torsional behaviour of the gearbox, respectively measure the relationship between the loading torque and the twist of the gearbox. Furthermore the torsional stiffness of the system of gears and shafts can be then determined. The second goal of the measurement was to measure the backlash (flank clearance) of the gearbox [1], which is supposed to be considerable because of the large gear ratio.

2.1 Instrumentation

To determine the above mentioned quantities the rotation of the input and output shaft had to be measured. Two incremental rotary sensors (IRC 305/5000 and IRC 305/6000) was used for this purpose. Because of the arrangement of the gearboxes (interconnection of two identical gearboxes, Fig. 1) the third sensor (magnetic sensor of position TMLS 05A) was used in the location of output shafts interconnection to control the identity of both gearboxes.

The torque wrench with the digital output was used for the torque loading and simultaneously for the torque monitoring and capturing. The torque wrench was calibrated before own measurement to obtain the accurate results.

2.2 Torsional Stiffness

The measured data from the magnetic sensor of position TMLS 05A which was placed on the interconnection of both gearboxes proved the identity of both gearboxes. Thus the total number of rotations can be divided equally between two measured gearboxes. The output of the assembly (the input shaft of the gearbox B, Fig. 1) was fully fixed during the measurement of the torsional stiffness and the revolutions were counted by the incremental rotary sensor IRC 305/6000 mounted to the input shaft of the gearbox A.

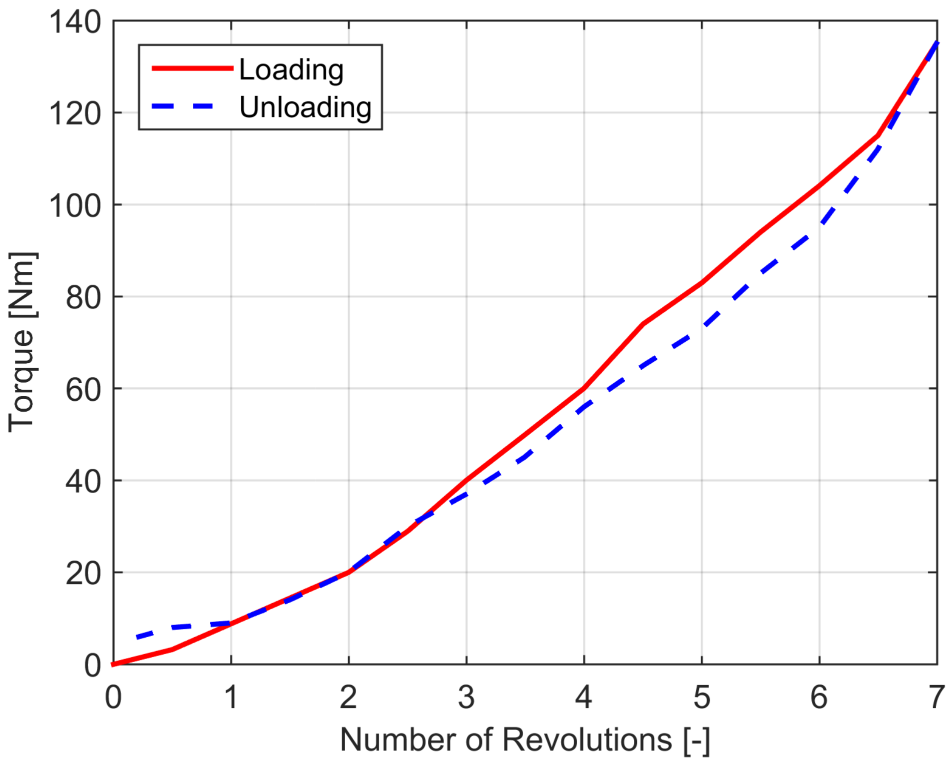

Fig. 2: Torsional behaviour of the gearbox during loading and unloading.

The revolutions-torque dependence is shown in Fig. 2. The gearbox torsional behaviour was measured during loading and unloading to obtain the complete information. Both curves are in good agreement which indicate very low hysteresis of the gearbox. The maximum reached torsional pre-loading of the gearboxes was

135 Nm. The torsional pre-loading was reached manually by means of the torque wrench. Using those data the torsional stiffness of the gearbox can be determined. The torsional stiffness behaviour during loading is described in Fig. 3. It is obvious that the torsional stiffness of the gearbox is not remaining constant during loading.

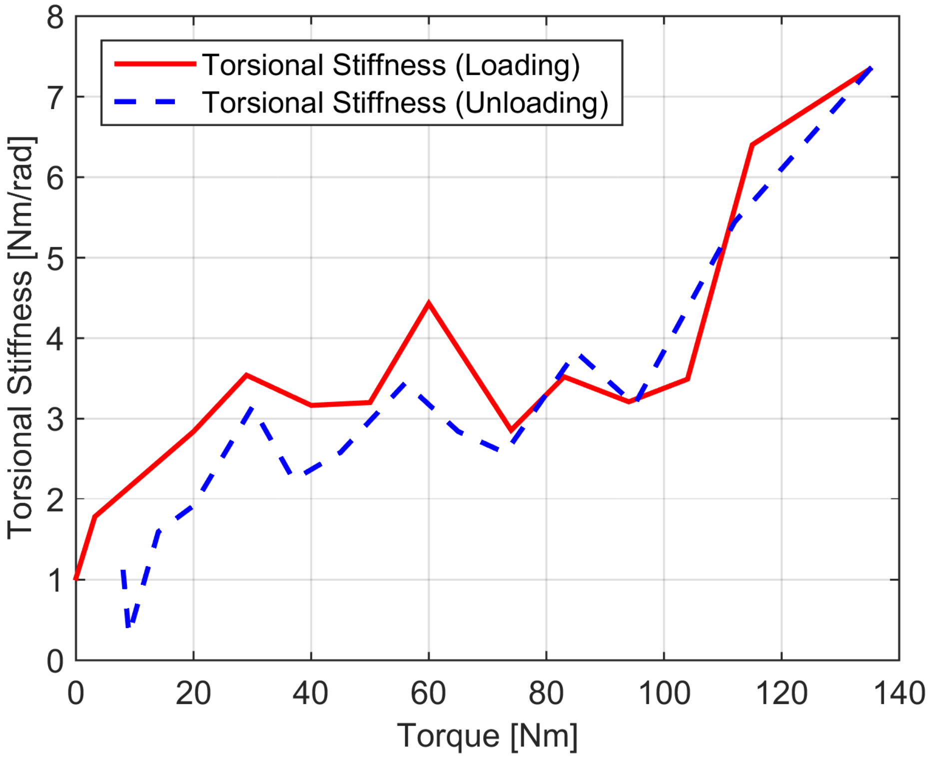

Fig. 3: The torsional stiffness behaviour during the loading and unlouading of the gearbox.

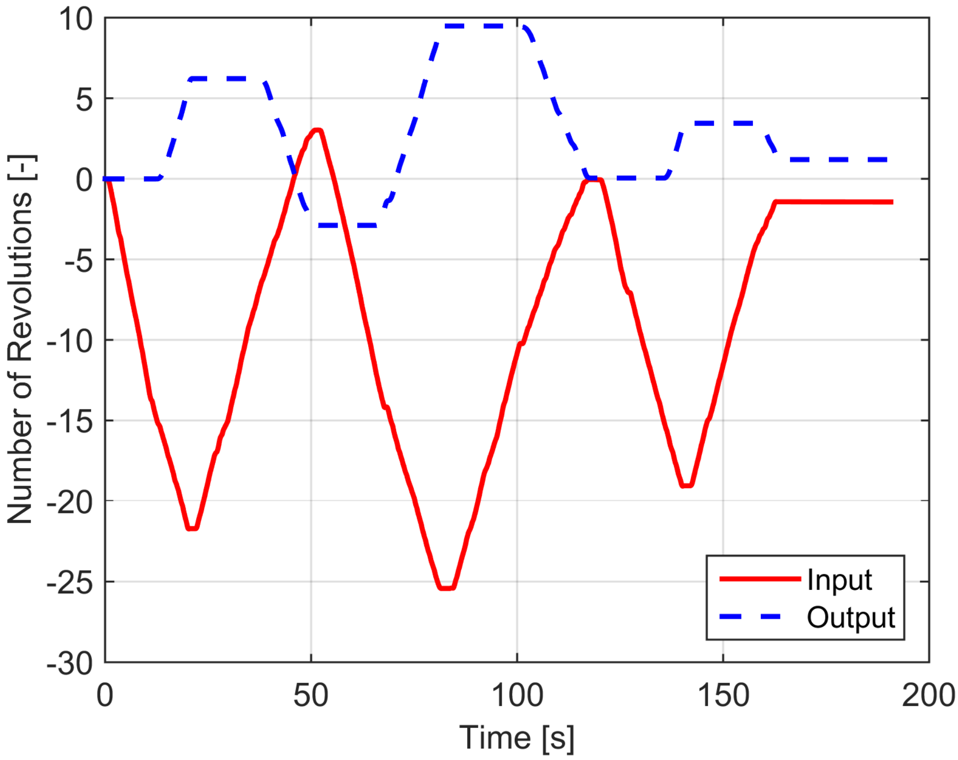

Fig. 4: The process of backlash measurement (Controlled rotation is designated by the red line.).

2.3 Backlash

The aim of this measurement was also to investigate the total backlash b_t of the gearbox. The backlash measurement was carried out with the same assumption as in the previous case, namely that both gearboxes are identical. The output shaft (the input shaft of the gearbox B) could freely rotate and the number of its revolutions was counted by the second incremental rotary sensor IRC 305/5000. The flank clearances of both gearboxes were took up before each measurement by means of reversing. The number of revolutions of the input shaft of the gearbox A was recorded since the output shaft started to rotate. This procedure was carried out several times in both directions of rotation and it is demonstrated in Fig. 4. The total backlash of the gearbox b_t expressed in the number of revolutions of the input shaft was finally determined using measured data as

$$b_t = 7,665 \pm 0,089 \text{ rev.} \tag{1}$$

3 Results and Conclusion

The torsional behaviour characterized by the torsional stiffness of the gearbox was investigated. It is obvious that the torsional stiffness of measured gearbox is not constant during loading. Therefore the gearbox does not behave as a linear spring. The torsional stiffness is increasing as expected. The gearbox was loaded by the relatively low value of the torque (135 Nm) because of manually loading. For better description of the torsional stiffness it is necessary to load the gearbox by considerably higher value of the torque. It was not unfortunately enabled by the measurement conditions .

Furthermore, the total backlash of the gearbox was determined from measured data in both directions of rotation. The gearbox is characterized by the relatively large backlash which is considerable influenced by the total gear ratio.

Acknowledgement

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