

Transmission Output Chain Spin Loss Study

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ABSTRACT

Transmission spin loss has significant influence on the vehicle fuel economy. Transmission output chain may contribute up to 10~15% of the total spin loss. However, the chain spin loss information is not well documented. An experimental study was carried out with several transmission output chains and simulated transmission environment in a testing box. The studies build the bases for the chain spin loss modeling and depicted the influences of the speed, the sprocket sizes, the oil levels, the viscosity, the temperatures and the baffle. The kriging method was employed for the parameter sensitivity study. A closed form of empirical model was developed. Good correlation was achieved.

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INTRODUCTION

As emission requirements become more stringent, fuel economy becomes increasingly important. The transmission plays an important part in improving vehicle fuel economy. The transmission efficiency and the spin loss has great impact on the fuel economy prediction. Many people tried different ways to estimate transmission efficiency [1]-[4]. A lot of research has been done for the transmission components [5][6]. However, the studies on the transmission output chain churning have rarely been reported. The preliminary studies show this churning loss may have 10~15% contribution to the total transmission spin loss.

In normal transmission design, a chain may be used to transfer the power from one shaft to the output shaft. The driven chain sprocket is partially immersed inside the sump oil. When the chain passes through the oil, it creates the churning losses. It is really difficult to calculate the drag force analytically using fluid dynamics with an accepted accuracy for the real world applications. Part of the reason is that it is hard to consider the flow separations. This causes wakes which build the low pressure area and result in high drag losses. Current technology still relies on the experiments [9]. A complex CFD analysis may help to find the solution, but it involves high computational time and efforts [1]. The accuracy of the modeling is still not clear. In this paper, an experiment study was carried out with the testing fixture in Southwest Research Institute (SwRI). Based on the testing data, the relationship of the drag coefficient and the Reynolds number were derived for the chain. A closed form equation of chain spinloss was developed.

TESTING SETUP

The chain and sprocket assembly was installed inside an aluminum chamber shown in [Figure 1](#). The sprockets were mounted to shafts which extend outside of the box for support and alignment. The back baffle and scoop snub was installed against the chamber back wall. The front side of the baffle was attached using brackets to simulate the real transmission environment. In addition, a cylindrical enclosure was fabricated to represent the final drive housing and prevent oil from spilling onto the chain. A ruler was mounted to the chamber to determine the fill level relative to the lower driven shaft centerline. The dynamic oil levels during the tests were measured through an ACT fluid level sensor. Fluid density changes due to oil aeration were measured through use of a Micro Motion density meter installed in line with an external oil circulation pump. Careful attention was paid to maintain clearances that represent the actual transmission environment.

The chain assembly was driven by a 15KW, 6000rpm motor mounted outside of the chamber. A high accuracy 20Nm Futek torque meter was used to measure the torque required to drive the chain assembly. A magnetic pickup was used for speed measurement. Four oil lubricated bearings were used to provide alignment and assembly load support. Each bearing has a K type thermocouple tapped for temperature monitoring and recording. A picture of the test stand is shown in [Figure 1](#).

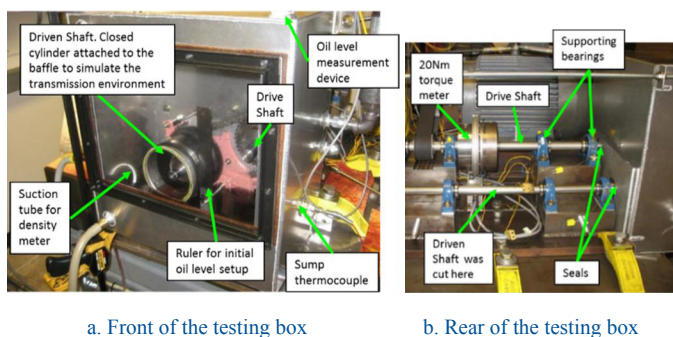


Figure 1. Testing Setup and Measurement

During the testing, the following parameters were measured and recorded at a minimum of 20Hz:

Drive Sprocket Input Speed	Accuracy +/- 1rpm
Drive Sprocket Input Torque	Accuracy +/- 0.05Nm
Oil Temperature	Accuracy +/- 1DegC
Oil Level	Accuracy +/- 2mm
Drive Sprocket Input Speed	Control +/- 2rpm
Oil Temperature	Control +/- 2DegC

In order to maximize the accuracy of the chain spin loss measurement it was necessary to account for the spin losses associated with the test stand support bearings and oil seals. The supporting bearing temperatures were recorded throughout all the testing. We normalized the measured torque loss with a certain factor to make it dimensionless. The losses of the supporting bearings (and housing seal) as a function of speed and temperature are shown in Figure 2. A linear trend line was applied to the data at each speed to equate spin loss as a function of each individual bearing temperature. The bearing spinloss under the corresponding bearing temperatures was subtracted from the raw torque measurement to achieve the chain assembly-only losses.

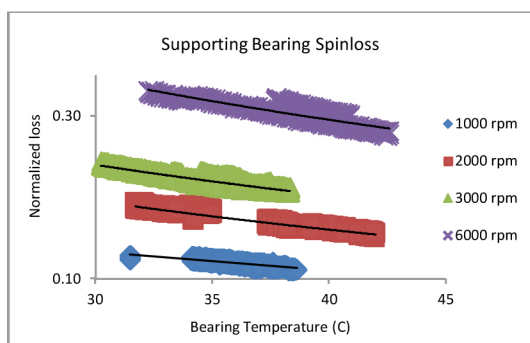


Figure 2. Supporting Bearing and the housing seal spinloss

Three sets of hardware with two different chain width and sprocket radii are employed for the testing. In this paper the radius R1 is smaller than radius R2 and the width w1 is narrower than width w2. The chain loss is collected at the drive sprocket spinning speed of 1000rpm, 2000rpm, 3000rpm and 6000rpm respectively. The oil levels are set to 27mm, 38mm and 59mm respectively, measured from

the bottom of the driven sprocket. The testing is run at 40C and 90C to capture the viscosity influences. Five different oils are used in the testing. Their viscosities are shown in Figure 3. To study the influences of the scoop-snob and baffle, several tests without baffle and scoop-snob are conducted. The simplified notations are used and listed in the Table 1. 50 data points were collected at 20Hz for each test condition. The average of the 50 points will be defined as the results under that testing condition.

Table 1. The testing notations for Baffle and Scoop-Snob

Notation	Baffle	Scoop-Snob
BS	Y	Y
NBNS	N	N
BNS	Y	N

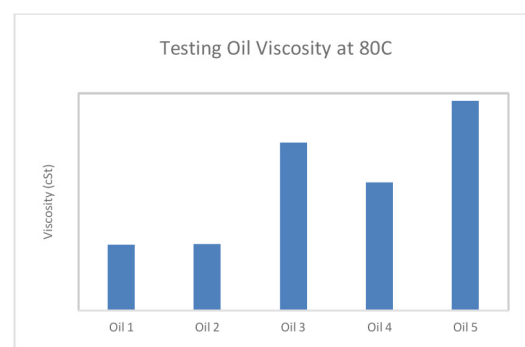


Figure 3. The viscosity of the testing oil at 80C

The testing error was investigated. The overall torque loss error ranges are within +/-0.1Nm. This is larger than the original designed +/- 0.05Nm. The larger error range occurred at the cases of the 3000rpm and 6000rpm. When the sprocket is spinning around 3000rpm, the chain tension side vibrates up and down wildly. The centrifugal force is fighting with the tension force, trying to find a balance. This instability seems more evident with a certain combination of width and sprocket diameters. When the speed goes up to 6000rpm, the centrifugal force over-controls the tension force and it forms a bulge shape on the tension side of the chain. However, the high speed leads to high churning of the oil which is flying around the chain system. This causes the variation of the losses. Under the no baffle and no scoop cases, the influence of the churning and chain vibration is more severe, especially for the oils with higher viscosities. In most transmissions, baffle and the scoop-snob are used. The baffle controls the oil level and limits churning. The oil flows into the chain area through a hole which smooths out some oil churning surrounding the chain system. The scoop-snob helps to maintain the stability of the chain and reduces the chain waving at the high speed.

TESTING RESULTS AND DISCUSSIONS

The chain spin loss are plotted with respect to the different parameters. Figure 4 shows that the chain loss increases as the speed increase. The higher the oil level, the bigger the speed influence is. In

Figure 5, it shows the spin loss increases as the radius increases. The increasing rate depends on the oil sharing properties and the oil height. The higher the oil level, the more sensitive the loss is to the radius. This sensitivity, depending on the oils, gradually decreases as the oil level reaches a certain height (Figure 6). In Figure 7, it shows that the chain loss and the oil height has an approximate linear relationship. For the chain with smaller sprocket, the loss is less sensitive to the oil height at the lower oil level. In Figure 8, the chain loss increases as the chain width increases. The increasing rates are very similar at different oil levels except at the low oil level. When the oil level is low, the chain takes most of the oil away and mixes with the air. The loss is less sensitive to the chain width. In Figure 9, the influence of the viscosity is shown. The chart shows the testing results with different kinds of oils at temperatures of 40C and 80C with baffle and scoop-snub. The trend of the loss with respect to the viscosities is well described by the linear relationship.

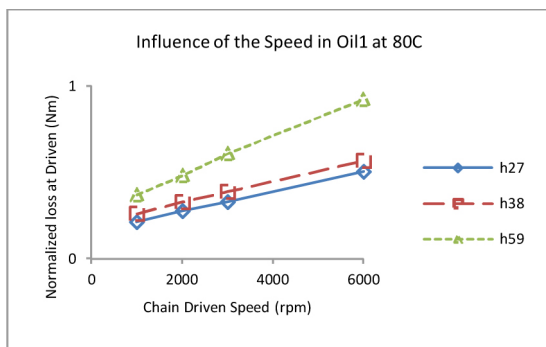


Figure 4. The chain loss respect to the speed

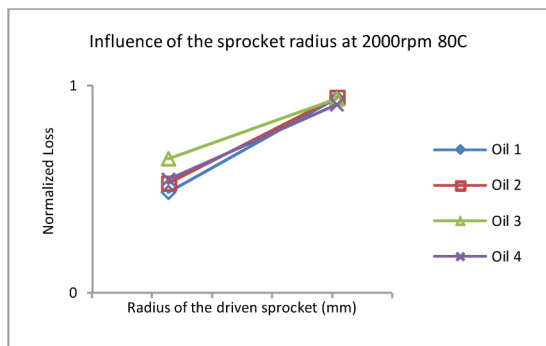


Figure 5. The influences of the driven sprocket radii at the oil height of 59mm

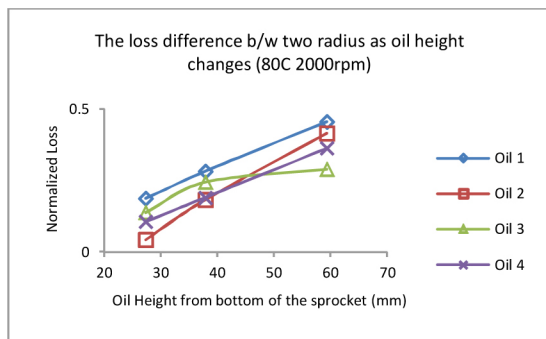


Figure 6. The influences of the driven sprocket radii and the oil height

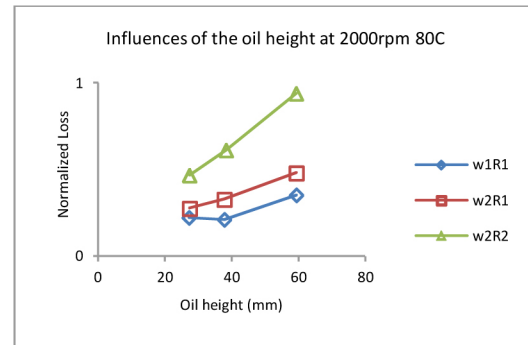


Figure 7. The influences of the oil height in oil1

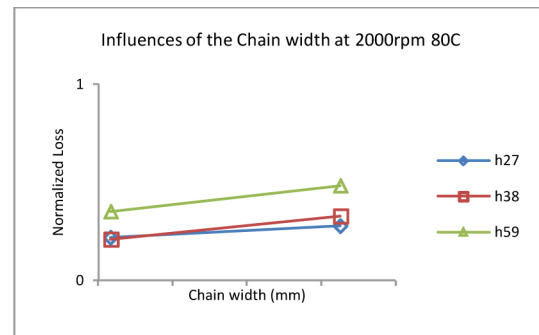


Figure 8. The influences of the chain width in oil1

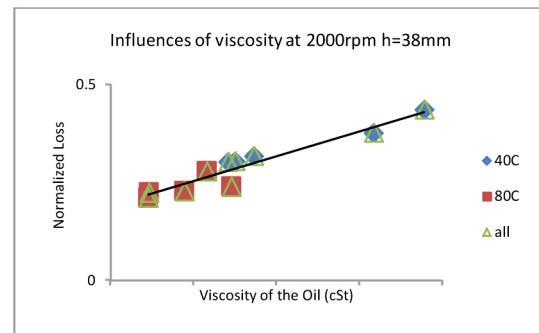


Figure 9. The influences of the viscosity

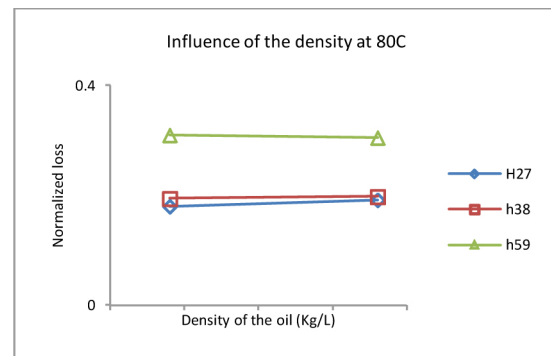


Figure 10. The influences of the density in oil1