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***Abstract* –** In this study, the influence of a variety of operating conditions on the power losses and efficiency of an automotive manual transmission was investigated experimentally. An experimental methodology was developed to measure power losses of a manual transmission under both loaded and unloaded conditions while all operation parameters were controlled tightly. A set of fixtures and instrumentation were designed and implemented to apply the experimental methodology to a five-speed, manual transmission from a front-wheel-drive passenger vehicle. Experimental parametric studies were performed to quantify the influence of operating conditions including load, oil viscosity and oil volume on load-dependent (mechanical) and load-independent (spin) power losses of the transmission. Analysis of the power loss data revealed that all three of these parameters influenced the components of the transmission power loss significantly, and specific conclusions were drawn in order to aid attempts to increase overall transmission efficiency. The experimental database formed as a result of this study is extensive so as to allow a complete validation of transmission power loss models.

***Keywords* –** *Manual transmission five speed gearbox, power losses, load dependent, load independent.*

I. INTRODUCTION

Control over power output, by means of the throttle pedal, simply regulates the rate at which the engine is doing work: at very high speeds, the power output will be correspondingly high but, as the torque output can at the same time be significantly less than at considerably lower speeds. In other words, maximum torque may be available over only a very limited speed range. Consequently, one needs to be able to regulate both the power output and the speed range of the engine relative to the range of speeds over which the vehicle is at any given time likely to be required to operate. Only in this way can the torque at the wheels be balanced against demands for either a steady speed uphill or downhill, or on the level, or for acceleration or deceleration. A gearbox is necessary, therefore, so that the driver can regulate torque by selecting the appropriate speed range or, in other words, the vehicle speed at which maximum torque is obtainable.

II. PROBLEM DEFINITION

Both emissions and fuel consumption of a vehicle are influenced largely by the efficiency of the power train of the vehicle. Power losses of a power train can be traced back to the inherent losses of the engine in generating the power and the losses that occur during transmission of power to the wheels through the drive train. The transmission can be identified as the major component of the drive train not only in terms of its contributions to the power losses, but also the potential it presents for improving overall power train efficiency. It is safe to categorize the power losses of a transmission into two groups. The first group includes all losses associated with the transmission of torque. These load-dependent (or mechanical) losses are all induced by friction at contacting interfaces of the transmission. Gear meshes and the rolling element bearings provide multiple contacts, contributing significantly to the mechanical losses of the transmission [1]. The other group of power losses is associated mostly with the interactions between the surrounding medium (oil, air or a mixture of the two) with the rotating components such as gears and bearings [2, 3]. These spin power losses are independent of load transmitted and are dictated mostly by factors such as effective oil levels, rotational speeds, transmission temperature and the geometry of the transmission housing. This study aims at quantifying experimentally (i) the individual contributions of spin and mechanical losses and (ii) the influence of several operating parameters on the total power losses and overall efficiency of a manual transmission.

A. SPECIFIC OBJECTIVES OF THIS STUDY ARE AS FOLLOWS:

- Develop an experimental methodology to measure power losses of a manual transmission under loaded and unloaded operating conditions.
- Design and implement a set of fixtures and instrumentation to apply the experimental methodology to a specific five-speed manual transmission.
- Demonstrate the accuracy and the repeatability of the measurements.
- Perform experimental parametric studies to quantify the influence of operating conditions, including load, oil viscosity and oil volume on mechanical (load dependent) and spin (load independent) power losses.
- Identify the key parameters influencing the components of the transmission power loss in order to arrive at guidelines on how to increase overall transmission efficiency.

III. DESCRIPTION OF TEST SET-UP

A special-purpose test set-up was developed in this study to allow a direct measurement of the power loss of an example automotive manual transmission under varying load, oil viscosity and oil volume conditions at each gear range. An image of the test set-up is shown in Figure 2.1, and a schematic of the layout with each component labeled is provided in Figure 2.2. In this arrangement, the manual transmission was held by a massive bracket that provides an interface that is identical to that of the intended internal combustion engine in a vehicle. A set of bolts were used to hold the transmission rigidly in its place on the holding bracket in such a way that all the axes of the transmission are horizontal. At the input side, a 5 hp 3-phase AC induction motor was used to drive the transmission at any desired load conditions within the limits of the drive unit. The output shaft of transmission is connected to propeller shaft by universal coupling. A propeller shaft is connected to rope break dynamometer with the support of bearing housing. The bearing housing is help to reduce vibration when applied variable load on rope break dynamometer .The different load applied at rope break dynamometer is adjusted by spring load. The attachment of spring weight bracket shown in figure 2.1. The input power is measured with the help of voltmeter and ammeter at different load, oil volume and oil viscosity. The tachometer measures input and output speed of transmission. The 3-phase AC motor was capable of reaching input speeds up to 2880 rpm in all gear ratios. The rope break dynamometer measure output torque values up to 20 Nm.

Fig. 2.1 : Experimental Test Set Up

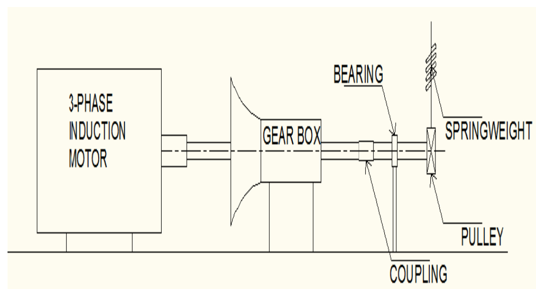

Fig. 2.2 : Schematic Diagram of Test Set Up

IV. TEST PROCEDURE

Before any particular test was initiated, a certain volume of oil was measured and poured into the transmission, which was emptied completely after the previous test. When a test was performed to measure transmission power losses under loaded conditions, the entire set-up shown in Figures 2.1 and 2.2 was used with both input and output power to the transmission. With the help of voltmeter, ammeter reading and power factor calculate input power (P_{in}) at every stage of gear.

$$P_{in} = \sqrt{3} \times V \times I \times \cos\phi \quad \text{watt}$$

Where , P_{in} = Input power

V = voltage

I = current

Measure input speed with help of tachometer and calculate input torque by following equation

$$T_{in} = (60 \times P_{in}) / 2 \times \pi \times N \quad \text{N-m}$$

Where , P_{in} = Input power

N = rpm

For measure spin power loss minor load one kg on rope break dynamometer by adjusting spring balance.

$$T_{out} = 9.81 \times W \times R \quad \text{N-m}$$

Where R= $\frac{D+d}{2}$ m

W = $S_1 - S_2$ Kg

Where , T_{out} = output torque

W = load on pulley

R = Radius of pulley

$$P_s = (2 \times \pi \times T_{out} \times N_{out}) / 60 \quad \text{watt}$$

Where , P_s = Spin power loss

N_{out}= rpm at output shaft

By considering load more then one unit calculate total power loss(P_t) and output torque (T_{out})by using above equation.

The total transmission power loss under loaded condition is determined simply as

$P_t = P_{in} - P_{out}$

Where, P_t = Total power loss

P_{in} = input power

Mechanical power loss

$$P_m = P_t - P_s$$

Now, Mechanical efficiency

$$\eta_m = 1 - (P_m / P_{in})$$

The overall transmission efficiency is determined as

$$\eta_t = 1 - (P_t / P_{in})$$

V. TEST RESULT

A. Influence of input load

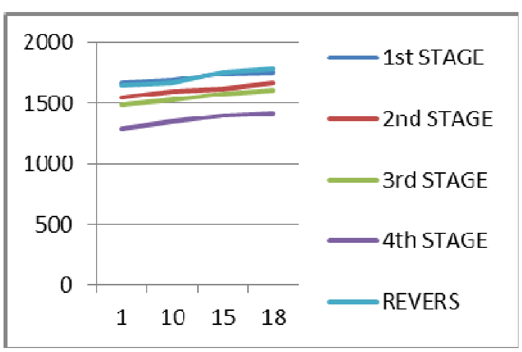

Fig. 3.1: P_t Vs LOAD(W)

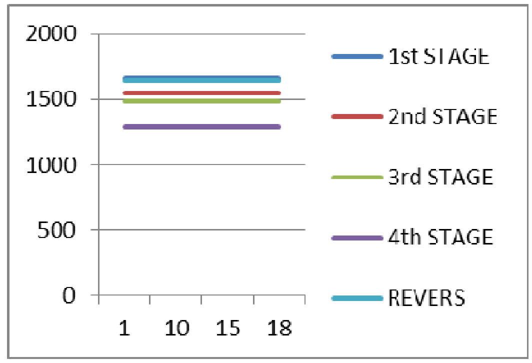

Fig. 3.2: P_S Vs LOAD(W)

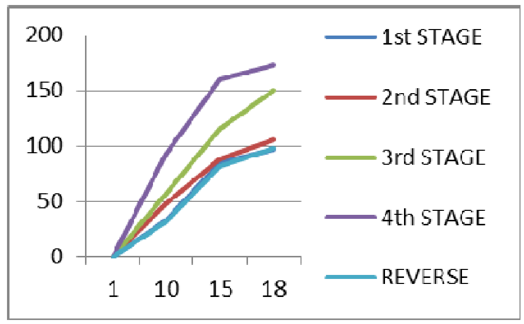

Fig. 3.3: Pm Vs LOAD(W)

From fig:-3.1 the value of P_t is increase with increase of Load and decrease with increase of gear stage.

From fig:-3.2 the value of P_s is constant through each Stage so it is independent to load .this thing is happen due to oil churning and oil shearing in journal bearings and synchronizer cones, windage losses and seal losses.

From fig:-3.3 mechanical power loss (P_m) is increase with load. P_m depend on the friction at matting teeth and rolling bearing.

B. Influence of oil level

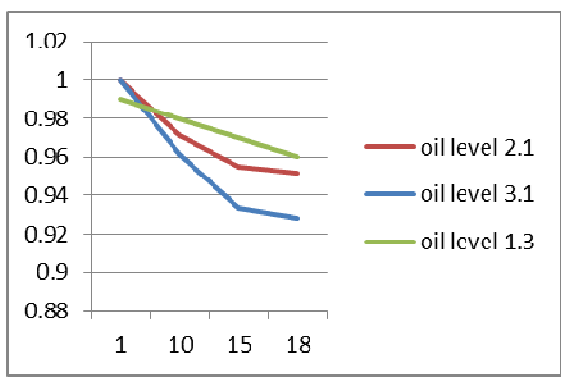

Fig. 3.4: η_mVs LOAD(W)

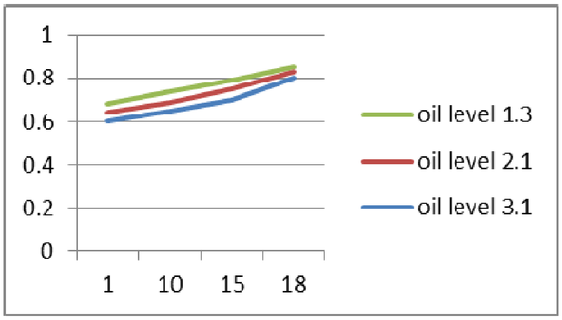

Fig. 3.5 : η_tVs LOAD(W)

From figure :-3.4 the mechanical efficiency decrease with increase in oil level. Due to increase of mechanical power loss.

From figure :-3.5 conclude that the transmission efficiency increase with decrease oil level and increase in load.

A. Influence of oil viscosity

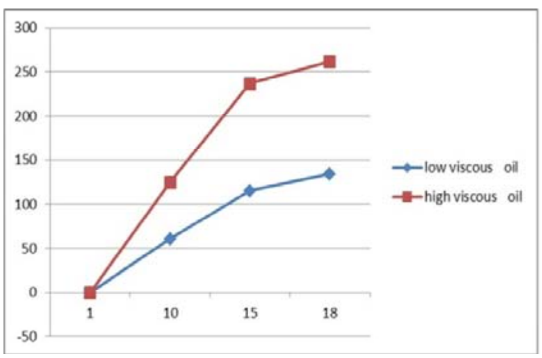

Fig. 3.6 : η_m Vs LOAD (W)

From figure 3.6 mechanical efficiency higher for low viscous oil compare to high viscous oil due to less oil churning losses.

VI. CONCLUSION

The analysis of the power loss data revealed that all three operating parameters nominal torque transmitted, oil viscosity and oil volume influence the power losses from the transmission significantly.

Specifically:

- P_s significantly increases with increases in speed and volume of oil. The increase in P_s with speed is exponential. Likewise, increased oil volume causes increased oil churning activity that results in elevated P_s values. While the range of speed is not negotiable, reducing the oil volume within the transmission to a minimum amount that still meets the durability requirements can be identified as a way of increasing transmission efficiency.
- Influence of speed on P_s is more pronounced at higher gear stages since the transfer and output gear sets rotate at higher speeds.
- P_s increases with reduced oil temperature. The spin losses at cold-start (room temperature) conditions are significantly larger than those at typical steady-state operating temperatures. This is mainly due to the increase in oil churning losses with increased viscosity at lower operating temperature ranges.
- As expected, T_{in} primarily influences the P_m portion of P_t as increased amounts of nominal load transmitted correspond to increases in P_m . Losses in the form of P_m represent a larger percentage of P_t at lower gear ranges, while they become secondary at higher speed and higher gear ranges of operation. This suggests that the efforts to improve the transmission efficiency at high speed and lower load conditions (as in highway driving conditions) must focus on reduction of spin power losses rather than friction-induced mechanical losses.

VII. RECOMMENDATIONS FOR FUTURE WORK

The experimental database generated in this study exhibited clear trends in terms of the influence of various operating parameters on transmission power losses. While these trends can be described heuristically, it is not possible to pinpoint the underlying mechanisms leading to such trends. In order to bring a complete understanding to the measured power loss behavior of manual transmission efficiency, this experimental work must be complemented by a theoretical study.

While this experimental study provided a thorough examination of the parameters studied, several expansions to the database are warranted. Among them, the nominal torque T_{in} range should be increased. The torque range that was used in this study was limited by the capabilities of the dynamometer facility used in this study. Likewise, the range of oil volume can also be expanded beyond the range used in production to obtain a more complete picture of this trend.

REFERENCES

[1] Seetharaman, S., Kahraman, A., Bednarek, G. and Rosander, P., 2008, “A Model to Predict Mechanical Power Losses of Manual Transmissions,” Automobiltechnische Zeitschrift, April 2008, Issue 4, pp. 346-357.

[2] Seetharaman, S., Kahraman, A., 2008, “Load Independent Spin Power Losses of a Spur Gear

Pair: Model Formulation," (in review) Journal of Tribology.

[3] Seetharaman, S., Kahraman, A., Moorhead, M. D., and Petri-Johnson, T. T., 2008, "Load Independent Spin Power Losses of a Spur Gear Pair: Experiments and Model Validation," (in review) Journal of Tribology.

[4] Martin, K. F., 1978, "A Review of Friction Predictions in Gear Teeth," Wear, 49, pp. 201-238.

[5] Yada, T., 1997, "Review of Gear Efficiency Equation and Force Treatment," JSME Int. J., Ser. C, 40, pp. 1-8.

[6] Li, Y., and Seireg, A. A., "Predicting the Coefficient of Friction in Sliding-Rolling Contacts," Tribology Conference, K18.

[7] Heingartner, P, and Mba, D., 2003, "Determining Power Losses in the Helical Gear Mesh," Gear Technology, September/October 2005, pp. 32-37.

[8] Changenet, C., Oviedo-Marlot, X., and Velex, P., 2006, "Power Loss Predictions in Geared Transmissions Using Thermal Networks-Applications to a Six-Speed Manual Gearbox," Transactions of the ASME, Vol. 128, pp. 618-625.

[9] Handschuh, R. F., Kilmain, C. J., 2003, "Efficiency of High-Speed Helical Gear Trains," 59th Annual Forum and Technology Display sponsored by the American Helicopter Society, Phoenix, AZ.

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