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Thermal Comparative Analysis Before and After Improvements to the Daihatsu Taft Hiline Transmission Experimentally

Nixon Randy

Department of Mechanical Engineering, University of North Sumatra, Indonesia

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ABSTRACT

The gearbox or transmission functions as a power transfer system which transfers and converts power from a rotating motor. In an ideal concept the mechanical energy generated by the transmission will be completely converted into mechanical energy, but in fact there is energy lost into heat energy even though the value is small by 5-10%. According to previous research using software to simulate work rather than transmission, it was found that the greatest heat energy is generated by friction between gears which will be transmitted through fluid flow (lubricant). The method used is by comparing the temperature of the vehicle's transmission before repair (overhaul) with the temperature of the vehicle's transmission after repair (overhaul) and change of lubrication. Temperature data retrieval at 2 different points of the gearbox was carried out using a type K thermocouple with a temperature range of -5oC to 1300oC accompanied by a hygrometer to measure the temperature and humidity of the environment during the testing process which acted as independent variables. Based on the experimental data taken before the repair was carried out, it was found that there were irregularities in the first experiment before the overhaul on the Neutral transmission (N) at speeds of 0, 600 and 1000 rpm, there was a significant increase in temperature at T1 (50-59- 62)oC and at T2 (44-49-58)oC. Furthermore, it was carried out seven times to obtain data variations and the allegations or hypotheses of damage that occurred in the transmission were made according to the results of graphical data analysis.

Corresponding Author:

Nixon Randy
Department of Mechanical Engineering
University of Northern Sumatra
Jln. Dr. T. Mansur No.9, Medan City, North Sumatra, 20222, Indonesia
Email: nixon@gmail.com

1. INTRODUCTION

In manufacturing and industry in this era, the gear component is a component that is commonly used to transmit power from one gear to another that is in contact with each other (Nurhidayatulloh, 2022). The mechanical advantage obtained in the use of gears is in accordance with the ratio (ratio) of one gear to another (Wicaksana, 2022). In the journal section of this thesis, we will discuss the thermal effect of the gearbox (Gemely, 2018) on the Daihatsu Hi-Line TAFT car where the transmission used is still manual. The test to be carried out aims to compare the thermals that occur in the gearbox that has (Septiyadi, 2013) symptoms of thermal damage that occur at the time after repair (overhaul) (Atmoko et al., 2018).

In some units, the engine has a power transfer system, namely a gearbox that functions to distribute engine power or power to one of the other engine parts, so that the unit (Kamarul, 2019) can move to produce a movement either rotation or shift. According to Carlos Valle (2014) the kinetic energy transmitted by the gearbox is not completely transferred in kinetic energy because there are energy losses that arise such as heat energy (Saleh & Bahariawan, 2018). Lubrication viscosity and temperature have a very strong bond and role in the process of energy loss in the form of heat (Prihandana et al., 2006). Temperature prediction on gearbox components is the basis which is divided into four basic elements, namely optimization (optimization) (Apriawan, 2006), analysis of possibilities or alternatives, heat reduction in the absence of lubricant, and possible (Malik & Basuki, 2021)can happen in the future (Marfai, 2019). Furthermore, according to Lionel Manin and Daniel Play (2013) to build a design methodology to predict heat properties (Faisal, 2015)that appears in the transmission by calculating all the mechanical components present in the transmission (Hizrie, 2022).

Overall discusses the relationship between the size or dimensions of each component so that the emergence of heat which is made into a matrix form for the computational process and the Newton Raphson method converges as an approach (Prastiyo, 2018). In measuring the temperature in the experiment using a type K thermocouple (Matthew Duff and Joseph Towey, 2010). There are advantages to using a thermocouple in terms of temperature range, robustness, fast response, and no self-heating (Pribadi, N.D.). In determining the thermocouple used, you must pay attention to the Seebeck coefficient because each type of thermocouple has a different temperature range (Alwinsyah, 2018). In designing the transmission, there are provisions and provisions in the calculations that must be followed according to Andrzej Maciejczyk (2010). Fundamental errors in the design of the transmission can result in damage and failure of transmission components during operation and even fatalities that affect the safety of operation (Fauzi, 2017). The resulting achievement is in the form of a formula in designing the transmission so that every component in the transmission can work optimally according to the motor as a driving tool (Nahdiy, 2018). In the experimental test of the gearbox, temperature data collection uses a thermocouple which has two points (Ismail et al., 2014)measurement with the help of a hygrometer to measure humidity which acts as an independent variable (Sandy, 2017). The data collection process is intended for analysis of damage to the gearbox with hypotheses or assumptions before carrying out repairs (overhaul) (Alvin, 2021). The results of the hypothesis and actual will show the accuracy of the thermal analysis method used.

The objectives of this study are: (1) To be able to identify various symptoms that cause heat in the gearbox of the object under study, (2) To be able to determine the thermal comparison that occurs in good and failed gearbox components, (3) To identify lubricants that are suitable for the gearbox. gearbox of the object under study.

The benefits of this research are: (1) Academically, this research relates to the subjects of Engineering Dynamics, Vibration Engineering, FEM, Maintenance Engineering (Condition Monitoring & Assessment, Condition Based Maintenance), Physical Metal Science, Fatigue, so that this research is carried out can add insight and develop a mindset about the design of construction and maintenance of a component on the machine. (2) From a practical point of view, this research is expected to be applied to assist maintenance of the gearbox. (3) Can find out what factors affect the birth of the thermal effect on the gearbox.

2. RESEARCH METHOD

To observe the thermal changes that occur in the Daihatsu Hiline GTL gearbox, experimental testing was carried out on the gearbox with conditions before and after overhaul. In this research, the two rules will be reviewed so that the validation for the existing parameters (Herdianawati, 2013). To take the initial step of problem identification, the parameters of the object to be studied will be designed (Budiman et al., 2020).

2.1 Parameter Analysis Design (Design of Analysis)

In designing parameters, the main thing to do is to identify input and output parameters as well as design parameters that control the correlation between input and output parameters. The phenomena that occur in the gearbox are the occurrence of fracture of gears or other parts which can be caused by fatigue or fatigue, brittle ductile transition, compositional effects, grain size or heat treatment and alloying (Imanda, 2021). In engineering structures, especially steel with heat treatment cracks can come from welding defects, inclusions, surface damage and so on. For construction design it is necessary to know that defects do exist and can propagate at lower stresses than the microscopic stresses determined with the help of tensile tests (Fitria, n.d.). The fracture toughness of a material can change depending on the type of plastic-elastic field present at the face of the crack, whether there is a plane strain field or plane stress field. So for this reason, vibration testing is carried out on the gearbox to find out further phenomena in the gearbox. To get the failure and problems that occur in the gearbox that will be analyzed. In the end, the experimental data retrieval from the thermal test of the damaged gearbox will be compared with a normal gearbox. From these data, symptoms that arise from the differences in existing data will be identified (Supriyono, N.D.). For brevity, the design parameters are summarized in the Research Design Diagram in Figure 3.1 below.

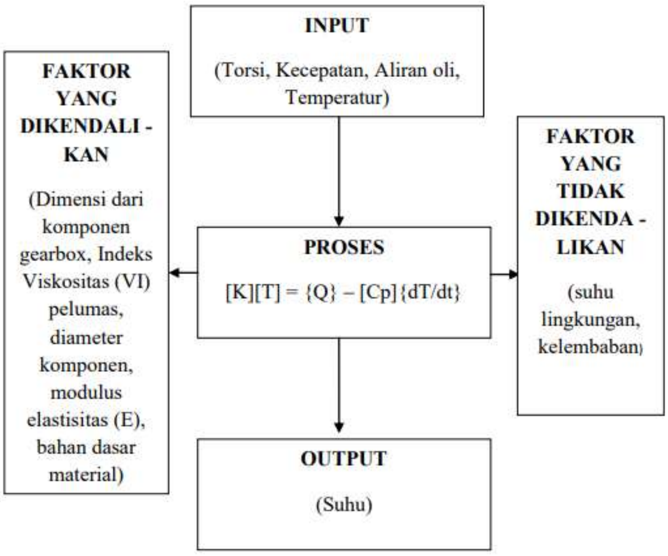

Figure 1. Research Design Diagram

3. RESULTS AND DISCUSSIONS

3.1. Thermal Experimental Results on Gearbox

From the experiments that have been carried out, it is found that the difference between the two temperatures at two different points as well as the humidity and temperature of the surrounding environment. The following is data from the experimental results before and after the overhaul. Based on the results of the thermal simulation by Surya, the reference temperature increase of the gearbox over time ideally forms a linear or straight line as shown in Figure 4.2

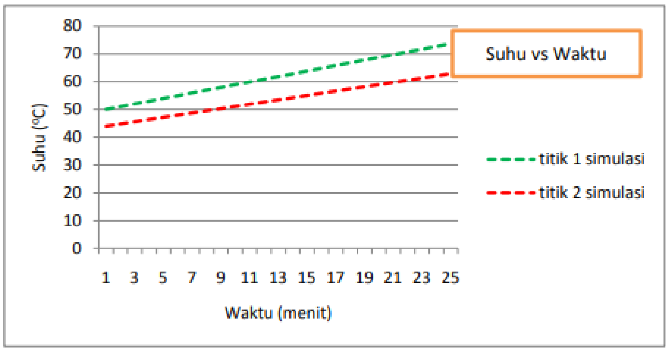

Figure 2. Desired Experimental Graph Reference (Source: Surya, 2016)

Simulation shows that in the center (point 1) of the casing wall, there is a higher temperature increase compared to the left side of the casing (point 2). This happens because the sides of the casing are not trapped with the heat flow completely unlike the middle which is flanked by two heat streams.

3.1.1. Results Of Experimental Data Before Repair (Overhaul)

Results of experimental data before repair (overhaul) From the experiments carried out, the data obtained in Table 4.2 -Table 4.8 (attachment) and converted into graphic form for
Simplify the process of data analysis in Figure 4.3 - Figure 4.9 In the first experimental data Figure 4.3 found irregularities in the Neutral transmission (N) at speeds of 0 , 600 and 1000rpm there was a significant increase in temperature at T1 (50-59- 62)oC and at T2 (44 - 49- 58) oC. Furthermore, on the transmission shift from N to 1 there was a decrease in temperature at T1 (66 - 64) oC and at T2 (61 -56) oC and continued when the transmission shift from 1 to 2 there was a significant temperature decrease at T1 (67 - 64) oC and T2 (61 - 54) oC. Not only in the previous transmission shift, but also accompanied by a decrease in the temperature of the transmission shift from 4 to 5 at T1 (73 -70) oC and T2 (68 - 65)oC.

In the third experiment, Figure 4.5, there was a high temperature increase during Neutral transmission at 600 rpm at T1 (37 -41) oC accompanied by a decrease in temperature when switching N to 1 transmission with T1 (52-48) oC conditions. Furthermore, the transmission shift from 1 to 2 there is a decrease in the temperature of T1 (56-52) oC.

The fourth experimental data Figure 4.6 shows irregularities in the N transmission (600 rpm and 1000 rpm) with a significant increase in temperature at T1 (61 - 68) oC and at T2 (60 - 66) oC and a decrease in temperature in the transmission shift from N to 1 where T1 (75 - 72) oC

In the 5th experimental data, Figure 4.7, at the second point with a Neutral transmission condition of 600 rpm it increased rapidly (47 -55) oC and when the transmission was in position 4 (1000 rpm - 2000 rpm) T1 and T2 were constant at a temperature of 68 oC.

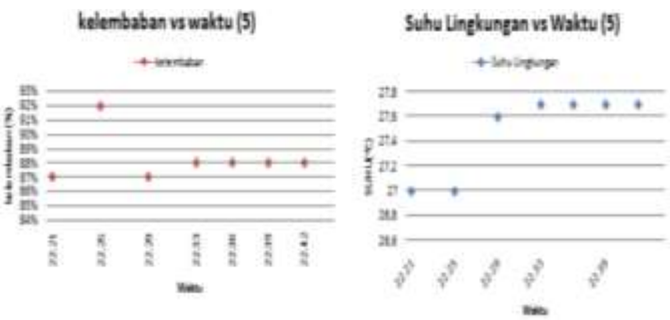

Figure 3. Experimental Graphics Before 5th Overhaul

In the sixth experimental data in Figure 4.8, the transmission in the Neutral position and the displacement to transmission 1 experienced a fluctuating temperature at T2 (38 - 42 - 36) oC and also at transmission 1 (1500 rpm - 2000 rpm) experienced a high temperature increase at T1 (41 - 45) oC . The trend of fluctuating temperature in the transmission shift from neutral position to transmission 1 has started to occur so that it becomes a suspicion of damage.

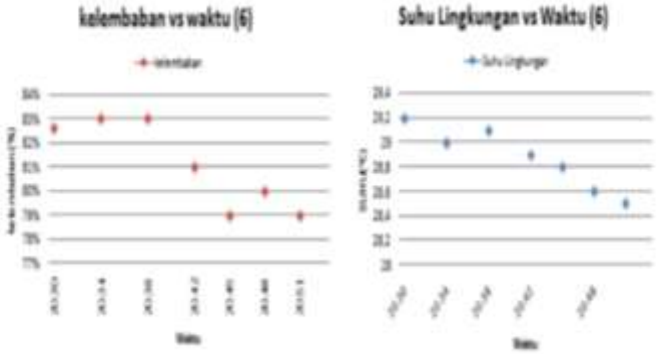

Figure 4. Experimental Graphics Before the 6th Overhaul

In the seventh experimental data, Figure 4.9, at the second point there is a fluctuating change in T2 (65 - 63 - 65) oC with the transmission shift condition from 1 to 2.

Figure 5. Experimental Graphics Before 7th Overhaul

3.1.2. Experimental Data Results After Overhaul

From the experiment after making improvements, the data obtained in Table 4.9 - Table 4.15 (attachment) and converted into graphic form to facilitate the data analysis process in Figure 4.10 - Figure 4.16. In the first experiment after the repair, there was a decrease in the final temperature of the test by 9oC and the increase in temperature seen in Figure 4.10 tends to be normal because there was no fluctuating temperature and a significant increase or decrease in temperature.

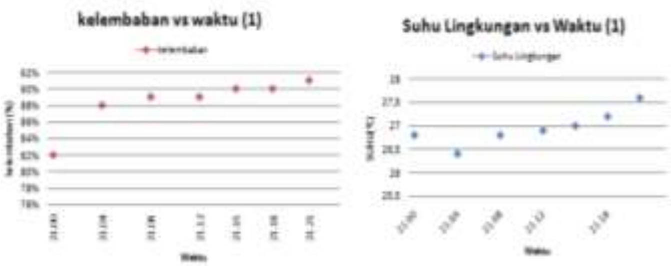

Figure 6. Experimental Graphics After 1st Overhaul

After the first experiment, the next test was carried out with an interval of about 30 minutes to reduce the temperature of the research object due to the previous test. The initial and final temperatures of the test tend to be the same as the previous test and the increase in temperature seen in Figure 4.11 tends to be good.

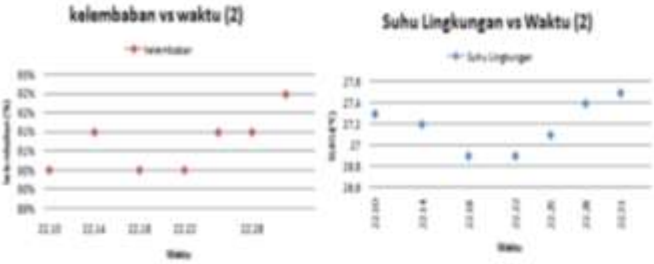

Figure 7. Experimental Graphics After 2nd Overhaul

After the second experiment, the next test was carried out with an interval of about 24 hours to obtain data on the second day of testing. The initial and final temperatures of the test tend to be the same as the previous test and the increase in temperature seen in Figure 4.12 tends to be linear.

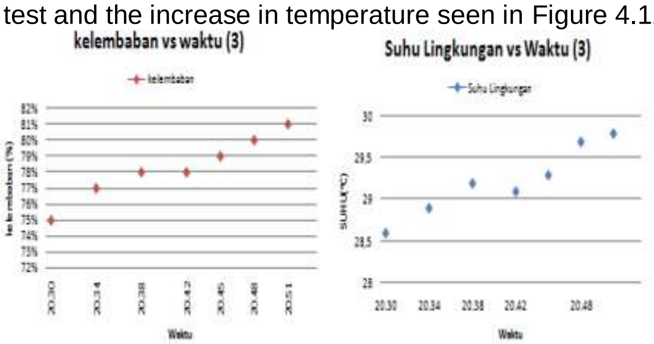

Figure 8. Experimental Graphics After 3rd Overhaul

After the third experiment, the next test was carried out with an interval of about 30 minutes to reduce the temperature of the research object due to the previous test. The initial and final temperatures of the test tend to be the same as the previous test and the increase in temperature seen in Figure 4.13 tends to be linear.

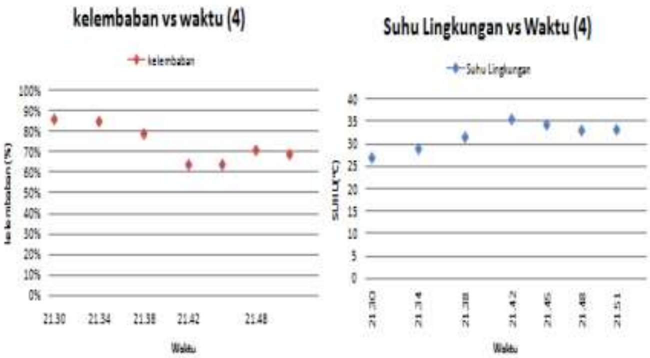

Figure 9. Experimental Graphics After 4th Overhaul

After the fourth experiment, the next test was carried out the next day with the aim of reviewing the results obtained on the previous day. The initial and final temperatures of the test tend to be the same as those of the previous test and the increase in temperature seen in Figure 4.14 almost forms a linear line.

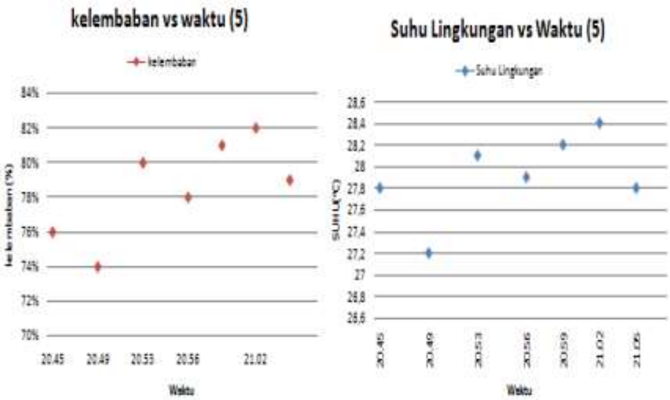

Figure 10. Experimental Graphics After 5th Overhaul

After the fifth experiment, the next test was carried out with an interval of about 30 minutes to reduce the temperature of the research object due to the previous test. The initial and final temperatures of the test tend to be the same as the previous test and the increase in temperature seen in Figure 4.15 tends to be good.

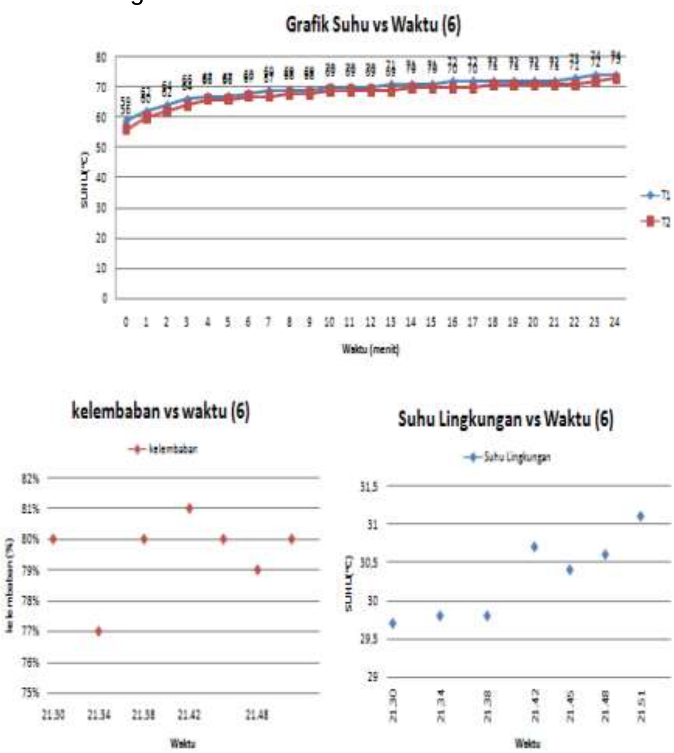

Figure 11. Experimental Graphics After 6th Overhaul

The previous experiment was carried out at night with almost the same humidity and ambient temperature. The experiment shown in Figure 4.16 was carried out during the day to obtain variations in data with different humidity and environmental temperatures. The initial and final temperatures of the test tend to be the same as the previous test and the increase in temperature seen in Figure 4.16 tends to be linear.

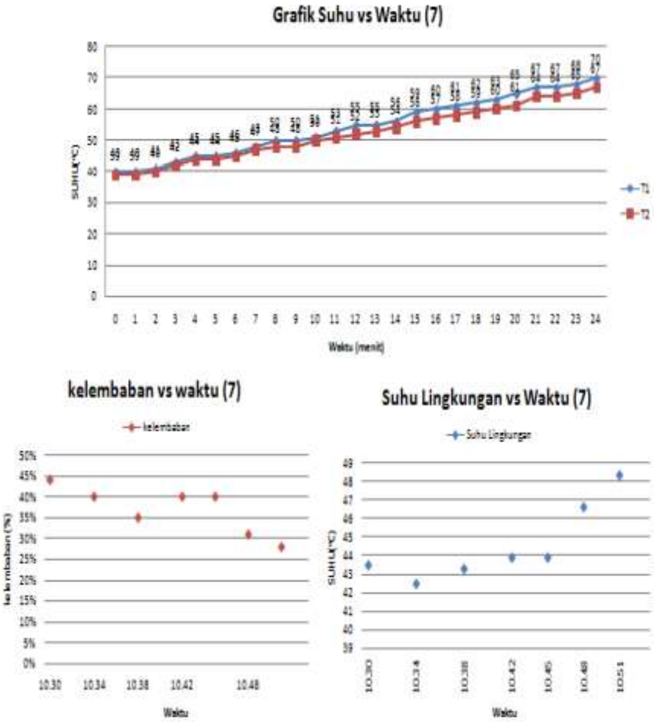

Figure 12. Experimental Graphics After 7th Overhaul

3.2. Actual Damage (Failure)

The cause of the decrease in temperature from 4th gear (gear) to 5th gear (gear) and constant temperature in experimental data 5 before overhaul is the bearing with code 62012RSCM which is at the end of the main shaft which is also the main driver of the 4th gear. You can see in Figure 4.17 the shape of the bearing with the code 62012RSCM. Damage to the roller bearings in Figure 4.17 to Figure 4.21 was caused by excessive friction in the transmission with an indication that there was no change in the transmission lubricant in accordance with the reference period of use. In Figure 4.22, it is shown that the former object of the transmission oil was damaged, where in terms of color it is clear that the use of lubricant has exceeded the reference period.

Figure 1. Transmission Oil Before Overhaul

From the results of the transmission oil analysis, it is known that material deposits form which cause the bearing to be damaged. The cause of damage to the oil is caused by silicon, iron and aluminum materials. For the selection of transmission lubricants can be seen in Table 4.16 there are several types of lubricants with different specifications which will affect the results in terms of usage.

Table 1. Characteristics of Pertamina Transmission Lubricants
(Source: PT. Pertamina Lubricants)

Characteristic	RORED EP A 90	RORED EP A 140	RORED EP A 80W-90
No. SAE Viscosity Grade	90	140	80W-90
Specific density, 15 °C	0.8985	0.9043	0.8986
Viscosity Kinematic, at 40 °C, cSt	182.10	429.6	146.60
at 100 °C, cSt	16.85	28.74	14.68
Viscosity Index	97	94	99
Colour ASTM	L1.5	L1.5	L2.5
Flash Point, (COC) °C	236	238	205
Pour Point, °C	-18	-9	-18

Viscosity is inversely proportional to the increase in the temperature of the lubricant, so to obtain maximum results it is necessary to use a transmission lubricant with a high viscosity according to the Pertamina RORED EP A 90 lubricant which has the highest kinematic viscosity among others.

4. CONCLUSION

Based on the experimental results shown in the previous chapter, conclusions can be drawn from the results of this experiment, namely: (1) The heat generation in the Taft Hiline gearbox is caused by damage (failure) to the bearing with code 62012RSCM which is directly related to the input shaft and transmission lubricant that has been exceeding the age limit. (2) The highest temperature occurred in the experiment before the overhaul reached 88oC while the experimental data after the overhaul was 74oC. The increase in temperature of a good gearbox tends to be linear with the duration of use until it reaches the optimum temperature of gearbox performance around 3oC from the temperature before the rpm increase or transmission change occurs. (3). The lubricant that is suitable for use is Pertamina RORED EP A 90 because it has a viscosity index of 97 where the higher the viscosity, the lower the temperature of the gearbox.

After the experiment has been carried out, the suggestions that the author can give are: (1) In the test, it is better if the gearbox is separated from other engine components that can provide heat so that it affects the precision of data collection. (2) Change of lubricant must be carried out periodically according to the recommendation so as to maintain the life of the components contained in the gearbox (3) To get more accurate results and identify problems with rapid heat generation, a thermograph can be used.

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