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Improvement of Contact Fatigue Strength of Gear Teeth on Application of Cuprous Oxide

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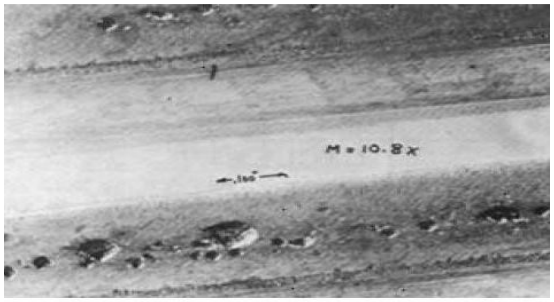
Abstract: **In this paper, it combined with the gear with the existence of cuprous oxide conversion coating and the gear tooth fatigue experiment of the system gear was conducted using a basic experiment and automatic shift of gear tooth fatigue of a simple substance gear pair. Consequently, it was proved that the gear which gave the cuprous oxide conversion coating had high pitting proof load capability by improvement in the initial familiarity nature of a gear pair, an improvement of lubricating oil holdout, and direct contact prevention of metal. Analysis of the pitting- proof fatigue characteristics of cuprous oxide conversion coating processing specification and the gear tooth wear characteristic etc. performed the engagement gear by one of the two or both in the experiment.**

Key Wards: **— Gear teeth, cuprous oxidetreatment, Tribology, Fatigue, pitting, wear.**

I. INTRODUCTION

In recent years, the power output of automobiles has risen to upgrade driving comfort. At the same time, the automatic transmission requires more gear range, less weight and size reduction to satisfy the fuel economy and environmental protection requirements. This trend has caused stress to the gear tooth dedendum and the tooth surface contact point to increase at the gear component which is the main structure of the power transmission, resulting in high risk of gear tooth damage due to dedendum pitting fatigue. Dramatic progress of the shot peening technology has made it possible to implement the appropriate counter measures to improve the dedendum fatigue life.



II. PRESENT METHOD

However, to improve the efficiency of AT power transmission, the oil with lower viscosity tends to be applied resulting in more severe Conditions for the pitting fatigue. Therefore, applying only conventional carburizing, quenching and tempering technologies were not enough, and the pitting durability has increasingly becomes the factor governing the gear life. Since the gears for automobiles are produced in very large quantities unlike those of other industrial machines, low Costs and stable effects are essential for life improvement measure.

III. PROPOSED METHOD

Therefore, the researchers focused on the improvement of pitting proof load capability by cuprous oxide. Cuprous oxide was put into practice as anti- rust processing in 1992. It is a kind of the chemical conversion treatment which forms crystalline coating on the surface by taking the advantage of the increase of surface pH while etching a metal material. Recently, the technology to control the crystal grain diameter and thickness of the coating has been improved allowing a large amount to be processed at once using the wet method. As a result, the lower cost has been realized and the method has also been applied to the precision part which was difficult in the past. This report describes the result of the durability test by power recirculation type test machine and AT unit. The effect to the pitting fatigue life by comparing the results with and without cuprous oxide is discussed.

IV. PROCESSING METHOD

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The steel grade is chromium steel (SCr420H). The small drive pinions of three specifications were used. The first was without coating as normal sheet, second one coated with normal paint and third one coated with cuprous oxide. Specification in which cuprous oxide were applied to the gears were used in the tests. The outline of power circulation type gear test machine which was used in the simple substance gear. In the experiment, the drive gear was operated at a speed of above 1,500 rpm and oil temperature of 120°C ±2°C. The gears are meshed and placed in ¾ liter of lubricating oil. To determine the pitting fatigue life of the test gears, the gear test machine was stopped at suitable intervals to allow observation of the development of pitting and measurement of the pitting area rate (i.e., the ratio of the pitting area to the effective contact area of the tooth surface). Lubrication oil and oil temperature are the same as the simple substance gear pair test. To lubricate the gears, the oil level was maintained at a few mm above the lower end of the final drive gear. The reduction gear revolution was set to 900 rpm, and we observed it for some days, after we observed the pitting formation on both gears by comparing weight of gears.

Also we observe the micro structure of both gears. In the initial stage of pitting, small pits (micro-flaking) are developed on the tooth surface in the mesh on set area near the dedendum. As the number of load cycles increased, the pitting expanded toward the tooth trace direction, and then it developed toward the tip, resulting in the flaking of small fragments there. One gear side without coating normal gear and driven gear side with cuprous oxide coating, after 10 days No tooth surface pitting are observed. The result of pitting progressing under the condition of the stress of the tooth surface contact point P_{max} = 2000 Mpa. The horizontal axis indicates the time in days, and the vertical axis shows the pitting area rate at each cycles. This shows that when both gears were with cuprous oxide coating and compared with without coated gear the pitting life was increased 5-10%.

The teeth of the gears are engaging under high load mesh with impact shock at the mesh onset due to the gear bending deformation. And the high tooth surface stress occurs near the dedendum of the drive pinion. In this area, relative sliding speed is high and local heat generation is also high. It is assumed the fatigue crack tends to start in this area. The temperature in an AT is above 80°C in the range of normal use. Also, the maximum flash temperature at the tooth surface contact point, which has been proposed by AGMA (American Gear Manufacturers Association), is approximately 90 - 120°C. Therefore, it is assumed that the temperature at the tooth surface of AT gears even under proper lubrication will rise as high as the ordinary tempering temperature (150 - 200°C). The softening due to tempering is thought to be an important factor which affects the pitting fatigue life; however the effects have not been clarified. The condition of the pitting damage on the test gears with and without cuprous oxide after AT unit test. The small pitting area observed on the gear pair of which only the reduction gear was cuprous oxide and shows the longest life, is below the pitch circle at the tooth surface center. The location of the pitting is different from those on the other two test gear pairs. It is assumed that the break-in effects have caused the difference. The dedendum wear amount of each specification gears measured after the test. The conditions of the tooth surface wear on each specification gears are almost the same.

Observations of the tooth surface pitch circle area on the cuprous oxide gears before and after operating with load in the simple substance gear pair test. The thickness of cuprous oxide coating is approximately 10 – 15 µm. Since the coating has a monoclinic crystal structure, the lubricating oil is maintained well and it can be assumed that this prevents the oil film from being cut out. The tooth surface is blackish brown in color with a non-glossy appearance. The grinding marks are coated and the surface morphology is smooth. Therefore, direct metal contact is prevented and even smoother sliding surface can be created. This presumably has the effect of reducing friction and can prevent the generation of friction heat compared with non- coated test gears. The coating is produced as etching the steel surface, and the remained etching bit will prevent the lubricating oil film from being cut out even after the coating surface is machined out. Therefore, it is thought that the cuprous oxide has the function to prevent the damage from pitting fatigue.

V. RESULT

Comparison of tooth surface roughness shows the results of the gear surface roughness measured along the tooth profile after the AT unit test for comparison of with and without cuprous oxide. According to the roughness measurement results, the roughness sum for the gear pair with only one gear processed is smaller when compared to the gear pair with both gears processed. (Difference is 1.34

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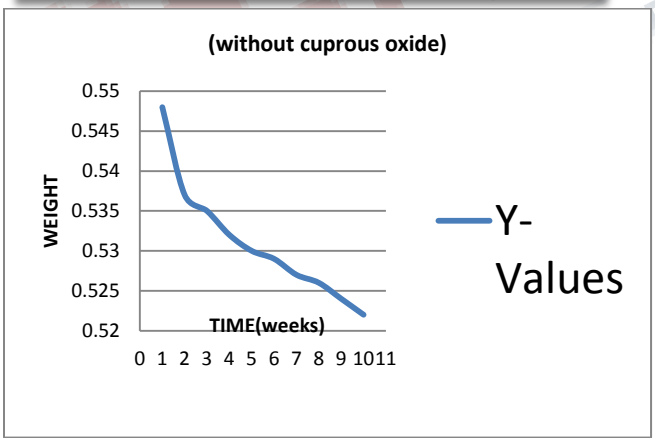
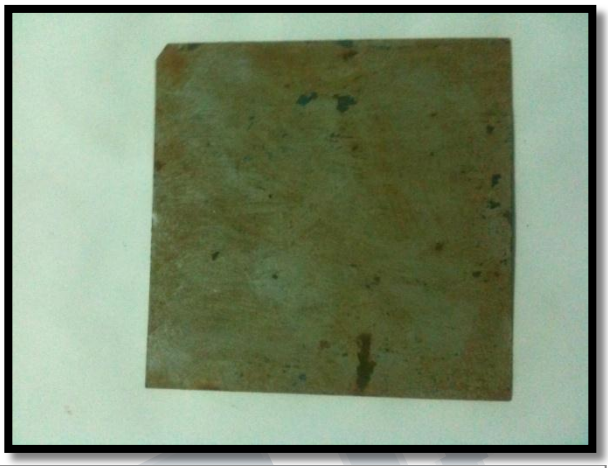
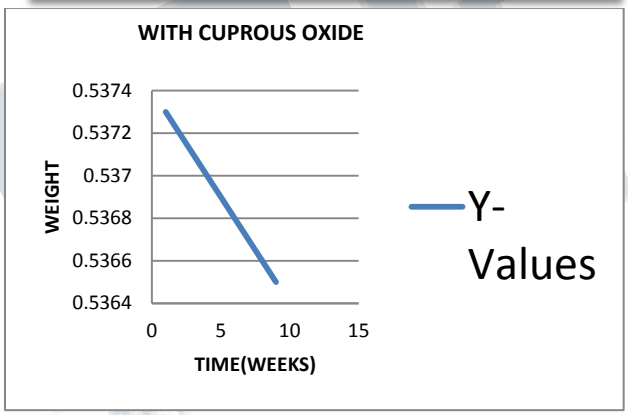
µm.) The reason is assumed to be the coating of both gears which scratches each other, resulting in more wear when compared to the gear pair with only one cuprous oxide gear. Therefore, it is assumed the pitting fatigue life for the gear pair with only one gear cuprous oxide was the best specification.

At the tip and dedendum surfaces having a large sliding speed and contact pressure. It is inferred that softening resulting from the temperature rise which occurs when gear pairs mesh, must be taken into account. when we observed this weight reduction takes place more having without coating compared with coating with cuprous oxide, also pitting fatigue life also increases coating with cuprous oxide compared with without coating by cuprous oxide 5-10%.







VI. CONCLUSION

The followings are the conclusion based on the study comparing the pitting fatigue strength of the carburized/quenched or quenched gears with and without cuprous oxide. The gear with cuprous oxide has initial break-in effects and improves its pitting durability as the coating covers the grinding marks of tooth finishing. The gear with cuprous oxide coating shows bigger oil reservoir depth which affects the tooth surface lubrication, and better lubricating oil holdout which prevents the oil film from being cut out. The coating remains as etching bit and has lubricating oil holdout even after the coating surface is machined out. Among the several test specifications in this study, the gear pair with only one gear cuprous oxide was observed as the best specification for the pitting fatigue life. It is assumed that gears with cuprous oxide lowers friction due to smoothing of the asperities of the mating gear surface and keeps the tooth surface shape.

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