

Measurement of Oil Film Pressure on Running Continuously Variable Transmission Pulley Part 1: Measurement Using Micro Data Logger System and Thin-Film Sensor

Kenji Matsumoto, Hideharu Koga, and Satoru Suzuki
Honda R&D Co., Ltd.

Yuji Mihara
Tokyo City University

ABSTRACT

In order to reduce friction and predict wear of the sliding part, it is important to determine the oil film thickness of particular area. A sensor or similar device must be attached to the sliding surface to detect the oil film thickness. However, a sensor could not be attached, due to the lack of space on contact surface, and moreover there was no method to secure the sensor on contact surface at that time. A several-micrometer-thin-film sensor was installed on a sliding surface to attempt measurement, but since the sensor was attached on a contact surface, wear occurred immediately and data was unable to be obtained.

To accomplish above issue, we developed a protective layer with excellent wear-resistance that successfully extended the measurement time by protecting the thin-film sensor. In order to measure pressure during driving, we provided a PVD (Physical Vapor Deposition) thin-film sensor of several micrometers on the drive transmission surface of a CVT (Continuously Variable Transmission) pulley. In addition, we were able to obtain data rapidly from parts during driving by independently developing an ultra-micro data logger (A/D conversion board + memory) and mounting it to mobile parts. In this paper, we describe the issues that must be solved in relation to the measurement method.

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INTRODUCTION

In designing automotive parts, the oil film thickness on sliding surfaces is a significant factor that defines the durability of the parts. However, there are still various issues in measuring the oil film thickness, which makes it difficult to measure the oil film thickness during driving condition.

There are several methods to determine the oil film thickness, including; measuring oil film pressure 1); measuring interference fringes in oil film 2) [1]; and using ultrasonic waves 3) [2] [3]. Due to the use of fused quartz, 2) and 3) are fragile and not preferable for the measurement within transmissions. For this reason, 1) is frequently used whereby the oil film pressure is measured by a pressure sensor. In CVT, driving force is transferred by the contact between pulleys and a metal belt, which generates a slight amount of slide at the point of contact. This nature of CVT requires the sensor to be made extremely thin to the extent that it does not give any gap on the sliding surface after the sensor is mounted.

Mihara and his fellow engineers successfully measured the oil film pressure by using a thin-film sensor that was mounted within the sliding bearing in the engine. [4] So the authors applied the same type of thin-film sensor in the sliding surface of a CVT and attempted measuring the oil film pressure. However, at the contact point between the pulleys and the metal belt where a slight amount of slide occurs, the thin-film sensor was scratched in a short period of time, and the data could not be obtained.

In order to obtain data from parts at driving condition, the data needs to be transferred externally without degradation. The methods generally used for this purpose are; the wired method [5] via linkage 1); a telemeter that uses electric wave to transmit data 2); and the data recorder method whereby data is stored in and retrieved later 3). A telemeter [6] is applicable when used with a high signal/noise (S/N) ratio sensor. However if a sensor is low in S/N ratio, including thin-film sensors, a

telemeter cannot be used as the sensor is influenced by radiation noise and/or conduction noise in the test environment.

For above reasons, we have chosen method 3) and used the data logger method after reducing its size.

When installing a micro data logger onto driving parts, there are several issues to be considered. First, as the micro data logger is exposed to environments in excess of 80°C in the transmission, the heat-resistance capability and temperature drift need to be controlled. Also, it has to be made sufficiently small, not only for it to be mounted, but also for it not to come off even after receiving centrifugal forces. Finally, as the sensor moves along with the driving part, it is difficult to understand at which position the data was obtained. There are some cases [7] where the clock and/or accelerometer in the data logger have been used. However, these are not suitable for such an environment where the temperature exceeds 80 °C or the maximum rate of acceleration is unclear.

In many cases the data collection turned out to be a failure only after the test was complete and the PC and the data logger were connected. This is because there has been no means to check if the data logger, which is installed inside the transmission, is properly collecting data during the measurement.

THIN-FILM SENSOR

In designing an optimum sensor profile for the measurement on the CVT pulley, we chose a Cu-Mn-Ni alloy system - an alloy with the same component as the strain gauge. It consists 4-layers structure where, on top of the lining, an insulation layer, sensor layer, and another insulation layer are being formed. Figure 1 shows the thin-film sensor structure. For the protection film, a newly developed diamond-like carbon (DLC) has been used for protecting the sensor film from being damaged by the contact.

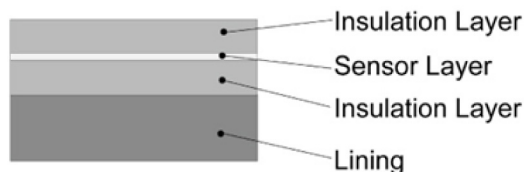


Figure 1. Thin-film sensor in cross section

The pressure sensitivity of the Cu-Mn-Ni alloy is from 18 - 22 [$\mu\epsilon$ /MPa].

In modeling, we considered that the contact between the pulley and metal belt to be linear that actually move during the measurement. Based on this concept, we chose linear-profile, not circular, for the sensor formed on the surface of the pulley.

The sensitivity of the linear-profile sensor used in this study were set to; $F_n=0.6$, the strain sensitivity where the strain is applied only to lateral direction; and $F_a=-1.2 \sim -1.4$, the strain sensitivity where the strain is applied only to longitudinal direction of the sensor.

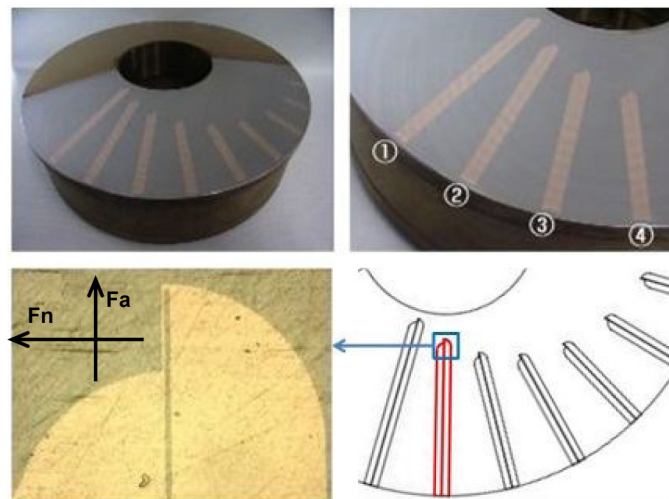


Figure 2. Thin-film sensors on CVT pulley

Figure 2 shows the physical appearance of the thin-film sensor formed onto the pulley, along with the magnified photo of the sensing areas.

For the DLC, the protection film, a vapor phase epitaxy (VPE) was actively used as a means to form certain level of convex and concave on its surface. To prevent peel between the sensor layer and the insulator layer, convex and concave were also formed on the insulation surface, to improve the peel strength in the area. [8]

Aforementioned techniques have improved the anti-wear performance of the protection film for the thin-film sensor. Figure 3 shows the scanning electron microscope (SEM) image of the protection film for the thin-film sensor.

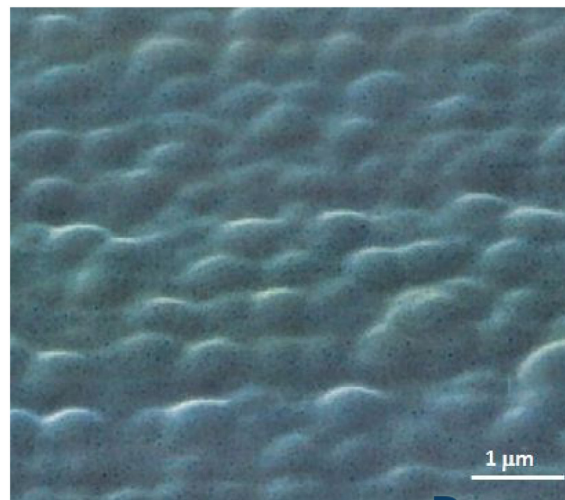


Figure 3. DLC (SEM image) protection film for the thin-film sensor