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Submission date: 07-Nov-2022 04:05PM (UTC+0700)
Submission ID: 1946975845
File name: 2.2._Proceedings_Terindex_WOS_-_Measurement....-22-23.pdf (328.57K)
Word count: 1090
Character count: 5645

Proceedings of Asia International Conference on Tribology 2018, pp. 315-316, September 2018

Measurement of film thickness of lubricant using ultraviolet induced fluorescence method

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Keywords: Fluorescence; ultraviolet light; water film thickness; tire

ABSTRACT – Fluorescence method is used to measure the lubricant film thickness between two surfaces of glass pieces. The fluorescence intensity was obtained though the irradiated UV ray on pyranine solution. As a result, the relationship between fluorescence intensity and film thickness was obtained. Newton's rings interference fringes created by plano-convex lens contacted flat glass plate. It was used to calibrate the gap.

1. INTRODUCTION

Recently, the tire labeling system in Japan is evaluated to apply tire's low fuel consumption and brake performance on the wet road surface. These performance on wet road surface is largely influenced by the thickness of water film between tread rubber tire and road surface. However, there are not many reports about the measurement method for this purpose. Therefore, Ultraviolet induced fluorescence method expected to be able to provide accurate measurement method between two surfaces.

2. METHODOLOGY

Figure 1 is the schematic of optical system used in this experiment. In this apparatus, plano-convex lens was attached on balanced arm and the top of lens was in contact with flat glass plate. In addition, the arm can be applied a constant load. Pyranine aqueous solution is fluoresced by irradiating ultraviolet ray. In this experiment, it was used as any water film. it was measured the fluorescence intensity of pyranine aqueous solution filled in the gap between two pieces. As a result, it was determined the relationship with each element.

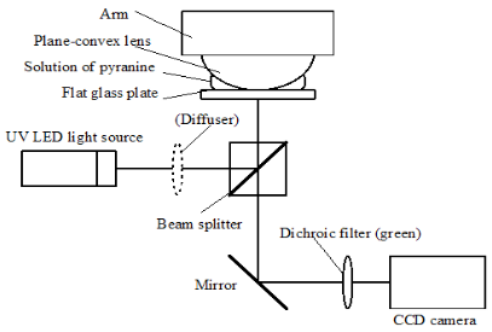

Figure 1 Schematic of optical system.

About experimental conditions, the curvature radius of plane-convex lens attached to the arm is 20.76 mm. The bore diameter of this lens is 20 mm. Flat glass plate is 25 mm square and 3 mm thick. Both specimens are made of BK7 (borosilicate glass) and shape accuracy is better than λ. In each experiment, the arm was applied a constant load. Temperature on this experiment was 23℃, in the dark.

3. RESULTS AND DISCUSSION

It was possible to change the gap between two surfaces to change the load to plano-convex lens attached the arm. Therefore, it was decided the relationship between water film thickness and fluorescence intensity of pyranine aqueous solution in this experiment.

It was determined the gap between plano-convex lens and flat glass plate applied elastic contact theory of Hertz. The contact circle radius a was obtained by the equation (1) (defined load to the arm w, radius of curvature R, Poisson's ratio ν, and Young's modulus E).

$$a = \left\{\frac{3}{4} wR\left(\frac{1-{\nu_1}^2}{E_1} + \frac{1-{\nu_2}^2}{E_2}\right)\right\}^{1/3} \quad (1)$$

In addition to this radius a, it was decided the gap between two pieces applied distance x from the center of contact circle in this experiment. Next, it was studied the relationship between the gap and fluorescence intensity. The gap h between plane-convex lens and flat glass plate was obtained by the Equation (2) (Figure 2).

$$h = \sqrt{R^2 - a^2} - \sqrt{R^2 - x^2} \quad (2)$$

Results are shown in Figure 3. It was understood that even when the load was changed, almost the same fluorescence intensity was exhibited at the same film thickness. Therefore, it was possible to measure water film thickness between two pieces by the relationship between the gap and the fluorescence intensity of lubricant film using the ultraviolet light induced fluorescence method with pyranine aqueous solution.

Table1 Numerical of theoretical contact circle radius.

Load, N	Theoretical contact circle radius, mm
9.9	0.153
20.0	0.194
29.9	0.222

In the above description, contact circle radius was decided from Hertz theory Equation (1) and determined the gap between plano-convex lens and flat glass plate by Equation (2). However, elastic deformation of lens and plate was occurred by applying the load. It affected the

outside of contact circle surface, so it might affect the equation that the gap between two surfaces was decided. Therefore, it decided to use the method of Newton rings because it was possible to measure the gap between two pieces by reading interference fringes of Newton rings observed by sodium lamp. From observation, it was analyzed the relationship between fluorescence intensity and its gap as water film thickness. As a result, it was possible to get the relationship between fluorescence intensity and water film thickness.

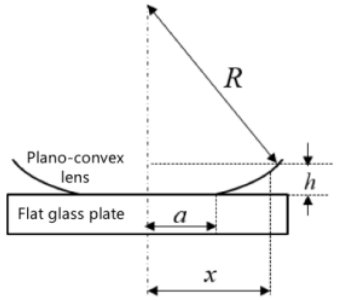

Figure 2 Clearance gap between plano-convex lens and flat glass plate.

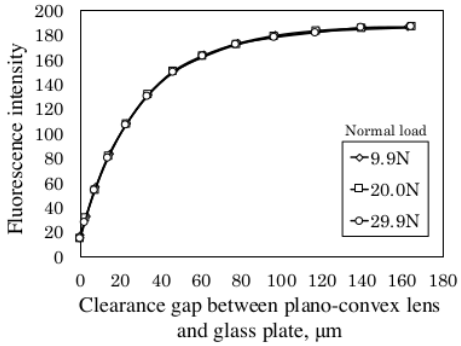

Figure 3 Relationship between fluorescence intensity and clearance gap.

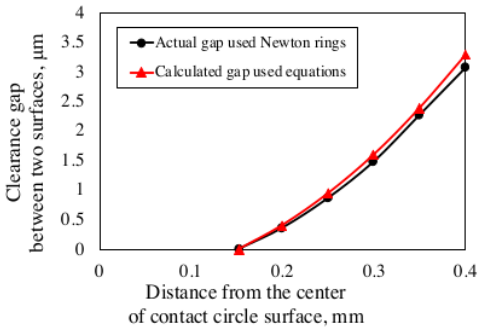

Figure 4 Relationship between distance from the center of elastic contact circle surface and clearance gap.

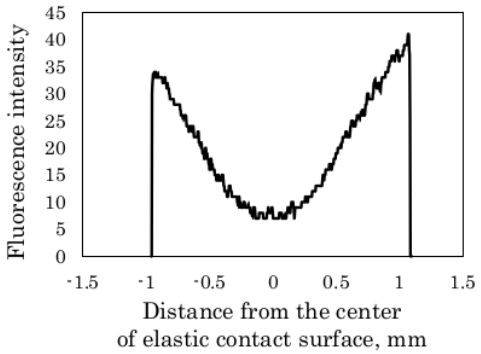

Figure 5 Relationship between fluorescence intensity and distance from the center of elastic contact surface.

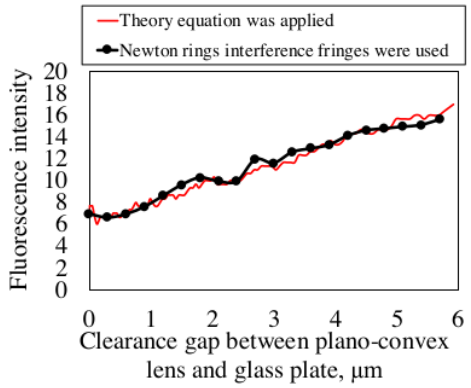

Figure 6 Relationship between fluorescence intensity and clearance gap.

4. CONCLUSIONS

It was possible to measure liquid film thickness between plano-convex lens and flat glass plate by ultraviolet induced fluorescence method with pyranine aqueous solution from the relationship between fluorescence intensity and its gap as water film thickness.

It was determined the relationship between fluorescence intensity of pyranine aqueous solution and water film thickness by Newton rings interference fringes method, created by two surfaces was applied to calibrate the gap.

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