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DEPENDENCE OF RUBBER FRICTION UPON ITS ELASTIC CHARACTERISTICS

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Rubber has large differences in elastic characteristics from the other solid materials such as metals. Firstly, the rubber exhibits considerably large elastic compliance. Second is highly non-linear elasticity in which the compliance decreases with increase in strain. The main objective in this research is to reveal the dependence of rubber friction upon these elastic characteristics of the rubber in detail. A super elastic FEM analysis is carried out with using an elastic property of practical rubber. From the calculated result, it is cleared that the rubber makes large real contacting area easier than the metals.

Keywords : Friction, Rubber, FEM, Contact ratio, Stress-strain curve, Elastic property

1. INTRODUCTION

It is well known that the friction coefficient of rubber is higher than the other materials. But the mechanism of the high friction coefficient has not been proven clearly yet. It is commonly believed that the large contacting area of rubber generates the high friction coefficient. In this paper, it is proposed that the high coefficient of friction results from the unique elastic property of rubber, the ratio of stress increase is enlarged as the strain is increased. This elastic property of rubber causes large real contacting area and high shearing stress at the contacting surface. Calculated results of FEM analysis show that the contacting area of rubber is extremely larger than that of the metal.

2. THE MODEL FOR FEM

FEM analysis is used to calculate the contacting area. The calculating model is shown in Fig.1. Surface roughness is simplified to triangular asperities. The side surfaces of the model are not restricted and the upper surface has a uniform displacement to the y direction but is restricted in the x direction. These boundary conditions are given in Table 1.

Two types of FEM analysis are carried out for the rubber and the metal. One is the super elastic analysis for the rubber. Stress-Strain relation of the rubber is measured experimentally, and is used in the FEM analysis with some material constants shown in Table1. On the other hand, the contacting area of the metal is calculated by an elastic-plastic FEM analysis. On this analysis, the ideal curve (two collinear approximation) is used. The ideal curve and the material constants are shown in Fig. 3 and Table 2.

3. RESULTS AND DISCUSSION

3.1 Comparison between experiments and calculation

Contacting area of the rubber is measured optically, where a rubber sheet with 90 degree wedges on the contacting surface is compressed by a glass plate. Contact ratio R_c is,

$$R_c = W_0 / W, \tag{1}$$

where W_0 is the width of the contacting area of wedge, and W is the width of the model shown in Fig.1.

The measured results and calculated result of the super elastic FEM analysis are compared in Fig.4. The contact ratio reaches 100% when the contacting pressure is about 5MPa on the analysis. The experimental results show the some feature as the calculated results.

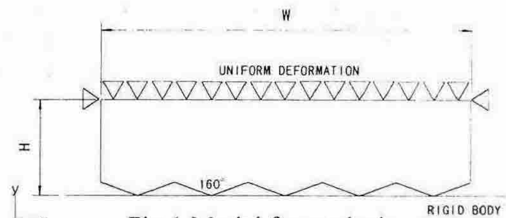


Fig.1 Model for analysis

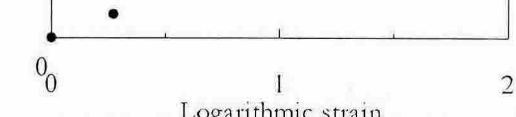


Fig.2 The Stress-Strain curve of rubber

Table 1 Constants for rubber

Coefficient of friction μ	1.0
Poisson ratio ν	0.499
Aspect ratio W : H	2:1 3:1

3.2 Analyses and comparison

An example of the calculated results for 160 degree wedge angle rubber is given in Fig. 5.

Non-dimensional stress S is introduced to compare the calculated results of the rubber and the metal. For the rubber

$$S = \sigma / \sigma_u \,. \tag{2}$$

where σ is stresses on the upper surface of the model, and σ_u is an ultimate stress of the rubber. For the metal,

$$S = \sigma / \sigma_y \,. \tag{3}$$

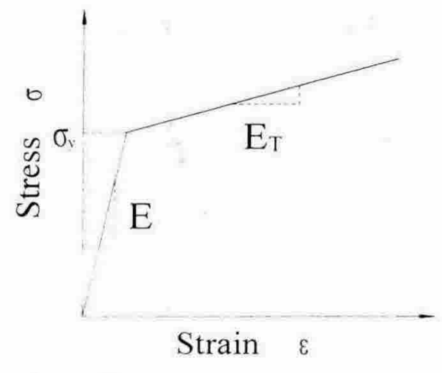
where σ is stresses on the upper surface of the model, and σ_y is a yield stress of the ideal metal.

The calculated results are shown in Fig.6, where the contact ratios are compared in the case ratios of height and width are 2:1 and 3:1. It shows that the contact ratio of the rubber can reach 100% when S is less than 0.04. But the contact ratio of the metal is about 35% even when S is 1.

It can be clearly understood that the rubber extends the contact area much easier than the metal against their strength. The rubber slides with so large real contact area on the flat surface, and supports a large friction force with its high strength.

3.3 Discussion

The high friction property of the rubber cannot be explained by only the fact that the rubber exhibits a large real contacting area. Sufficient strength of the rubber is necessary at the real contacting area. As shown in Fig.2. The rubber has high degree of strength at the high strain, despite of the low strength at the low strain. It can be summarized that the elastic property of the rubber, which shows convex profile toward downward in the stress-strain relationship, will give a singular characteristic of the rubber.



Two collinear approximation

Table 2 Constants for metal

Coefficient of friction μ	0.5
Poisson ratio ν	0.3
Aspect ratio W : H	2:1 3:1
Yielding stress σ_y [MPa]	240
Young's modulus E [GPa]	206
Tangential modulus E_T [GPa]	0.5

4 CONCLUSION

Contacting area of the rubber is calculated by a super elastic FEM analysis, and compared with calculated result of the metal. Ratio of real contact area to apparent area of the rubber increases more easily than the metal. The high coefficient of friction of the rubber results from its elastic property, which shows convex profile toward downward in the stress-strain relationship.

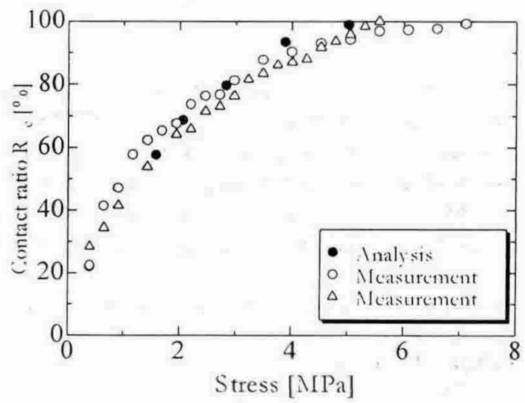


Fig.4 Comparison between experiment and calculating

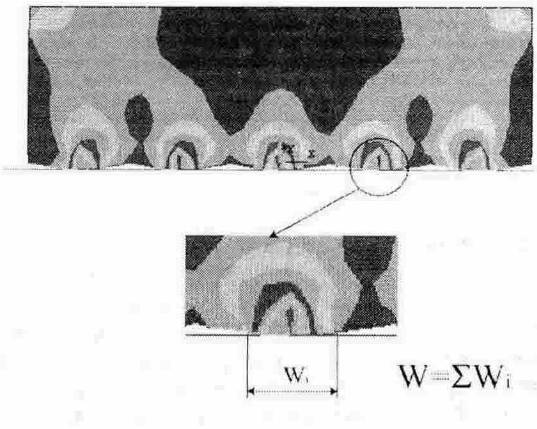


Fig.5 Result of analysis

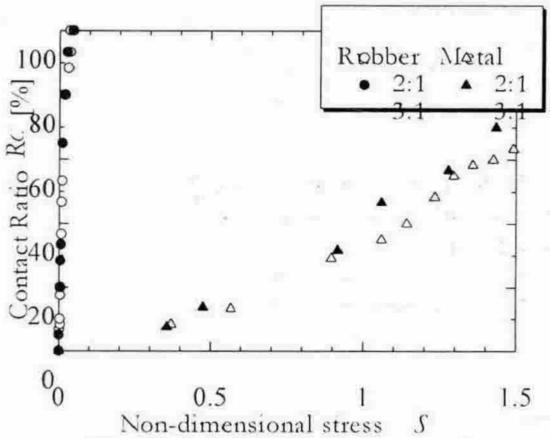


Fig.6 Relationship between Rc and S