Friction of 316L Stainless Steel on Soft-tissue-like Poly (vinyl alcohol) Hydrogel in Physiological Liquid

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1. Introduction

In order to develop medical devices contacting soft or hard tissue, it is essential to understand the friction behavior of materials in physiological condition. We investigate the friction behavior of medical 316L stainless steel on soft-tissue-like poly (vinyl alcohol) hydrogel (PVA-H) on this purpose. We found that the adsorption of hydrogel polymer onto stainless steel is important for friction. Particularly in lower velocity region, the maximum friction coefficient is observed at certain velocity due to the adsorption and desorption of polymer chains on stainless steel. This phenomenon is called “elastic friction”. In this study, we investigated the effect of plasma proteins on tribology of medical stainless steel in elastic friction. We also measured the adsorption of plasma proteins onto stainless steel and attempted to investigate the relationship between proteins and elastic friction.

2. Materials and Method

Friction coefficient of 316L on PVA-H was measured by using a ball-on-disc rotational tribometer at ambient temperature. 316L was processed into a ball with a diameter of 10 mm. We employed four liquids as lubricant: (i) distilled water, (ii) PBS solution containing human serum (protein concentration = 6.4 g/dL, pH = 7.4), (iii) PBS solution containing human serum albumin (HSA) (concentration = 3.0 g/dL) and (iv) PBS solution containing human serum γ-globulin (IgG) (concentration = 1.0 g/dL). A volume of 3 ml of liquid was deposited on the surface of the PVA-H disc before friction. Linear sliding velocity (V) varied from 0.5 mm/s to 600 mm/s under normal load (F_N) of 1.0 N. The friction test was carried out at 23ºC for 10 min in each condition.

A PVA-H disc with 88 mm in diameter and 12 mm in height was prepared for friction test, following a procedure already described [1]. The elasticity of this hydrogel was estimated at 289kPa, and the contact pressure on the ball specimen was 70.4 kPa. The solvent of hydrogel was only distilled water.

Ball specimen was polished to have a surface roughness (Ra)less than 0.4 µm. The surface free energy (γ_{SV}) of the specimen was obtained by using Owens-Wendt method. The amount of adsorbed proteins (protein concentration was the same as lubricant for friction test) on 316L and PVA-H was measured by Bradford test.

3. Results and Discussion

In water lubrication, 316L shows elastic friction in lower velocity region. By adding serum or blood proteins, the friction coefficient of 316L was reduced. HSA seems to have a more important role to reduce the friction coefficient compared with IgG.

Bradford tests have shown that the amount of adsorbed proteins on 316L is much more than on PVA-H (Table 1). This indicates that proteins adsorbed on 316L play an important role in reducing friction force. IgGis more adsorbed than HSA on 316L. HSA, however, could reduce the friction force more in elastic friction regime than IgG. Figure 1 shows the Stribeck curve of 316L in presence of four liquids. The friction coefficient in HSA lubrication is close to that in serum lubrication in the condition of this study. The results indicate that HSA adsorbed on material has an important role to reduce the friction force in elastic friction regime by inhibiting the adsorption of polymer onthe metallic counter face.

Table 1 Adsorption of proteins on 316L and PVA-H.

	HSA [µg/mm^2]	IgG [µg/mm^2]
316L	63.0 ± 5.7	130.6 ± 2.2
PVA-H	1.9 ± 0.4	3.9 ± 0.1

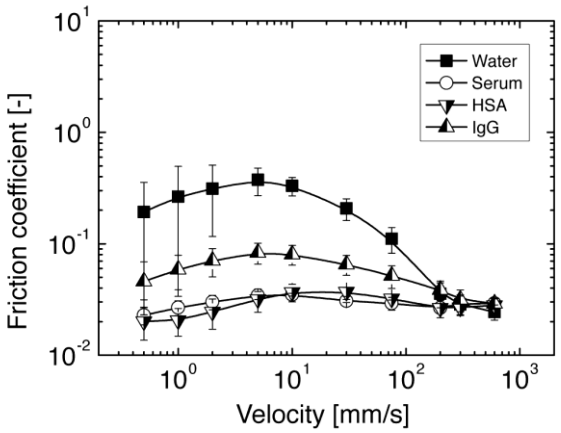

Figure 1 Friction coefficient of 316L on PVA-H against sliding velocity in four kinds of liquids.

4. References

[1] Kosukegawa, H., et al., J Fluid Sci Tech, 3, 4, 2008, 533-543.