Transactions of the Materials Research Society of Japan. Vol. 20

Tribological properties of woodceramics under ATF lubricated condition

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Tribological properties, such as friction coefficent and specific wear rate, of woodceramics and several other materials were tested under ATF (Automatic Transmission Fluid) lubricated conditions. Woodceramics show higher friction coefficient and higher wear resistance than several other friction materials usually which have been used for automobile clutches. These results suggest the higher possibility of woodceramics for the promising industrial application for a synchronizer ring or heavy-duty wet clutch devices.

1. INTRODUCTION

Woodceramics are new porous carbon materials obtained from wood or woody materials impregnated with phenol resin, and carbonized in a vacuum furnace at high temperature. Woodceramics have several superior characteristics from the engineering and ecological viewpoints; hard, strong, porous, low density, made from natural ressources, low environmental pollution, cheap to manufacture as C/C composite. Hokkirigawa et al. have been studying woodceramics by tribological approach [1, 2]. Woodceramics were found to have a stable friction coefficient ($\mu \fallingdotseq 0.15$) in air, water and base oil, and a low specific wear rate at low (5mm/s) and high (10.2m/s) sliding velocities. These results show the possibility of woodceramics for the wet friction materials in automobile clutches.

In this paper, we aim at opening the door for practical use through the evaluation in actual conditions simulating of the synchronizerring in manual transmission (MT) and the heavy-duty multiple wet clutch in automatic transmission (AT). For this purpose, tribological properties of woodceramics and several other friction materials were analyzed experimentally under ATF (Automatic Transmission Fluid) lubricated condition. Based on

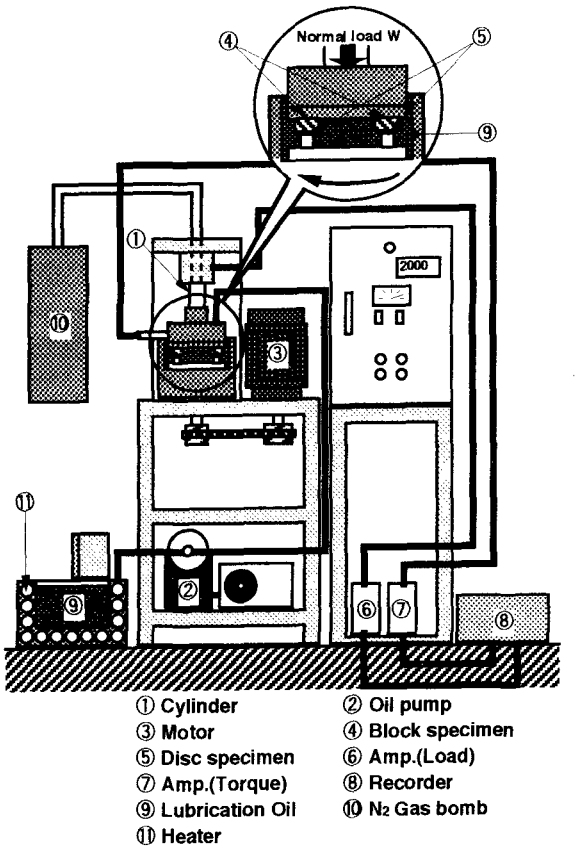
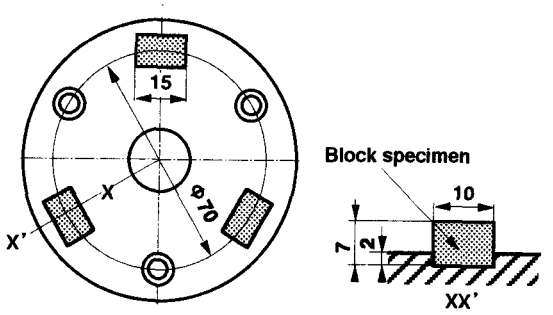
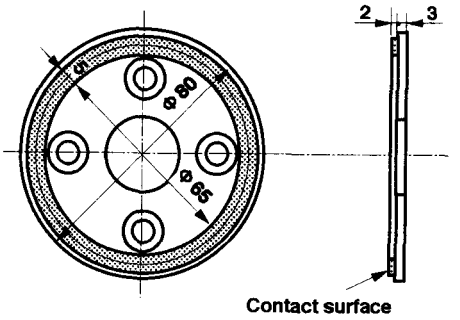


Figure 1. Schematic diagram of 3 blocks / disk type friction apparatus.



(a) Block specimen



(b) Disk specimen

Figure 2. Shape of block and disk specimens.

Table 1. Materials of block and disk specimens.

(a) Block specimen

Specimens	Density ρ, g/cm^3	Maximum roughness Rmax, μm
MDF+Phenol	0.91	2.0
Woodceramics (MDF-400)	0.68	1.0
Woodceramics (MDF-600)	0.78	4.0
Woodceramics (MDF-800)	0.79	5.0
Woodceramics (MDF-800+Phenol)	0.94	4.0
Paper type friction material1	–	6.0
Paper type friction material2	–	5.0
High-resistance paper type friction material	0.60	4.5
Longer-strand synthetic fiber type friction material	0.80	8.0
Special brass (MBA-5)	8.40	1.2
Carbon based friction material	1.50	2.4

(b) Disk specimen

Specimens	Density ρ, g/cm^3	Maximum roughness Rmax, μm	Vickers hardness Hvkgf/mm^2
SCM-435	7.85	5.0	500～550

Table 2. Experimental condition.

Normal load W, N	684～812
Apparent contact pressure P, MPa	3.04～3.61
Sliding velocity v, m/s	0.73～7.48
Sliding distance L, m	8.8×10^2～9.4×10^4
Lubrication condition	Oil lubricated(A TF(M3))
Temperature of supplying oil T, ℃	80
Flow rate of oil q, cc/min	100

the experimental results, possibility of application of woodceramics for the wet friction materials in automobile clutches was discussed.

2. EXPERIMENTAL PROCEDURE

Sliding friction and wear tests were carried out by using three blocks / disk type friction apparatus as shown in Fig.1. Temperature-controlled oil was supplied to frictional interface by a pump. Normal load was applied by air-cynlinder. Test materials for block and disk specimens were machined to the shape as shown in Fig.2. Materials of block and disk specimens are shown in Table 1. Three kinds of woodceramics (MDF-400, MDF-600 and MDF-800) carbonized at 400, 600 and 800°C respectively, and several other materials were used as the block specimens. Disk specimens were made of steel (SCM-435) and finished by #2000 abrasive paper. Sliding tests were carried out in automatic transmission fluid (ATF) at 80°C and at the different sliding velocities (0.73-7.48m/s) as shown in Table 2. The apparent contact pressure was 3.04-3.61MPa which was about three times higher than the current wet clutch condition.

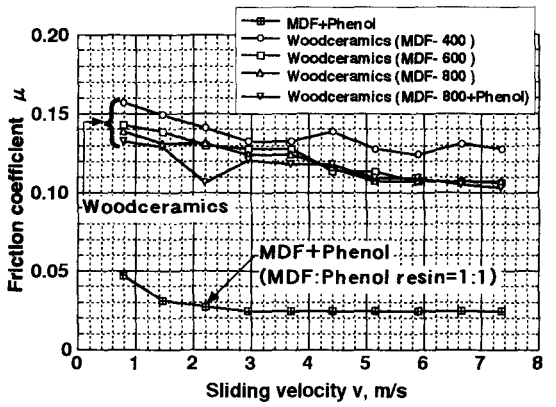


Figure 3. The relationship between sliding velocity and friction coefficient for "woodceramics" and "MDF impregnated with phenol resin".

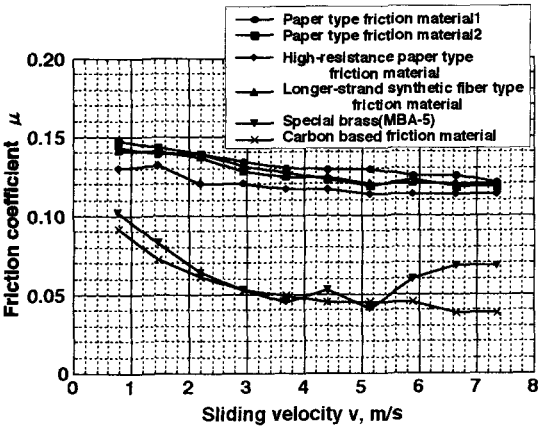


Figure 4. The relationship between sliding velocity and friction coefficient for several other materials.

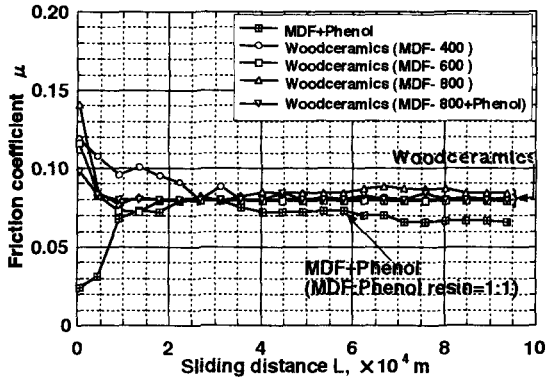


Figure 5. The relationship between sliding distance and friction coefficient for "woodceramics" and "MDF impregnated with phenol resin".

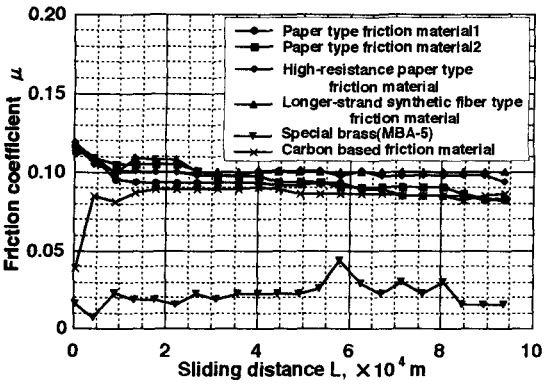


Figure 6. The relationship between sliding distance and friction coefficient for several other materials.

3. RESULTS

3.1 Friction properties

Figure 3 shows the relationship between sliding velocity and friction coefficient for "woodceramics" and "MDF impregnated with phenol resin". Figure 4 shows the relationship between sliding velocity and friction coefficient for several other materials. It can be seen that friction coefficient of woodceramics decreases slightly as the sliding velocity inreases and becomes constant (μ=0.13) for velocities of more than about 5m/s. Friction coefficient of MDF-400 is 0.13 - 0.16 which is higher than that of the other woodceramics (MDF-600 and MDF-800). On the other hand, friction coefficient of MDF impregnated with phenol resin, which is raw material of woodceramics, is lower than that of woodceramics.

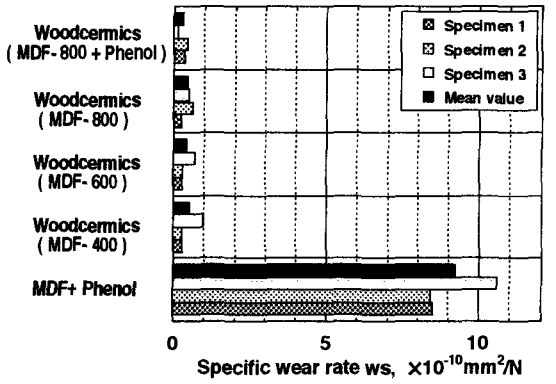


Figure 7. Comparison of specific wear rate of several woodceramics.

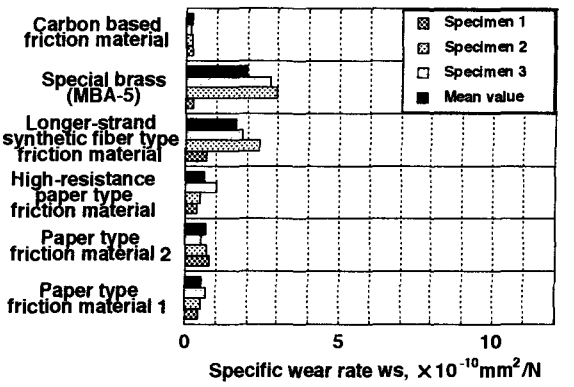


Figure 8. Comparison of specific wear rate of several other materials.

Figure 5 shows the relationship between sliding distance and friction coefficient for "woodceramics" and "MDF impregnated with phenol resin". Figure 6 shows the relationship between sliding distance and friction coefficient for several other materials. It can be seen that friction coefficient of woodceramics is almost constant (μ=0.09) for sliding distance more than about 10^4 m.

3.2 Wear properties

Figures 7 and 8 show the specific wear rates of woodceramics and other materials. It is clear that the specific wear rate of all woodceramics is about 4×10^{-11} mm^2/N, which is lower than the other clutch materials. On the other hand, the specific wear rate of MDF impregnated with phenole resin, which is raw material of woodceramics, is about 9×10^{-10} mm^2/N which is higher than other materials.

4. DISCUSSION

The friction coefficient of current materials for the wet clutch is 0.05-0.15. Paper type materials have higher friction coefficient (μ=0.11-0.15), but their durability is not good in heavy-duty conditions. On the other hand, brass, carbon and sintered materials have the good durability but lower friction coefficient (μ=0.05-0.09). To get both high friction and high heat-resistance at the same time is the ultimate target of the development of wet clutch materials. Woodceramics are more heat-resistant because of its carbon composite's nature in contrast with paper materials. In this paper, woodceramics are found to have almost same value of friction coefficient as paper materials at the heavy-duty condition, that is, higher contact pressure, higher temperature and longer sliding distance. It is also found that woodceramics have higher wear resistance than other friction materials. These results suggest the higher possibility of woodceramics for the promising industrial application, for example, for a synchronizer ring or heavy-duty wet clutch devices.

5. CONCLUSIONS

(1) Woodceramics show high friction coefficient (μ = 0.13-0.16) enough for the wet clutch material in the heavy-duty sliding condition.

(2)Woodceramics show the low specific wear rate (ws=4×10^{-11}mm^2/N) in the heavy-duty sliding condition.

(3)Woodceramics have higher possibility for the practical use for new-type heavy-duty clutch devices.

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2. K. Hokkirigawa, T. Okabe and K. Saito, J. Porous Materials, 2, 3(1996)237.