Transactions of the Materials Research Society of Japan 25 [2] 535-538 (2000)

Improvement of Tribological Characteristics of Polyacetal Resin by Reactive Organic Compound

Takashi Nakamaru Namiko Kaneko and Mataichi Kasahara*
Oiles Corporation
Fax: 81-0466-46-4722, email: nakamaru@oiles.co.jp n.kaneko@oiles.co.jp
*Menshin Engineering Corporation
Fax: 81-03-3578-6063, email: kasahara@oiles.co.jp

Interpenetrating Polymer Network (IPN) is a technique in the polymer blend to combine two kinds of polymer materials like a mesh linked mutually. In this study, it was investigated to form IPN of polyacetal resin (POM) and silicone resin, and sliding characteristics of the IPN product were evaluated. Tensile strength and moldability of the IPN product improved in comparison to those of polymer material filled with silicone oil. And, its wear characteristics were superior to those of any polymer material containing either silicone oil, mineral oil or silicone rubber.
Key words: Polyacetal resin, Interpenetrating Polymer Network(IPN), Silicon oil, Triazine Thiol

1. INTRODUCTION

Improvement on wear characteristics of resin materials have been conducted conventionally by adding solid lubricants such as graphite, molybdenum disulfide, PTFE, and so forth, and also by adding a lubricant oil such as mineral oil, and so forth. Recently, polymer alloy made by compounding resins in micro-level has been examined. IPN has been widely investigated as a method of forming a polymer alloy. [1]-[3] In our investigation, POM was used as base resin and a network of Silicone oil containing Epoxy group (S-EP) and Triazine Thiol (TST) was formed to evaluate their sliding characteristics. The reaction of S-EP and TST is shown in Fig. 1. Both metal and POM were used as mating part to evaluate sliding characteristics.

2. EXPERIMENTAL

2.1 Specimen

After mixing a base resin POM with S-EP and TST in Henschel mixer, pellets were produced by a twin-screw extruder. And then, specimen were produced by an injection molding machine. In these specimen, an IPN was formed by adding 4-20 mass % of S-EP and TST to POM, and then TST was added so as to make epoxy and thiol groups equal amount. In addition, following materials were produced. A POM filled with 2 and 4 mass % of S-EP only, a POM filled with 8mass% of spherical and 2μm mean diameter methyl silicone rubber only, and a POM filled with 4mass% mineral oil only. Composition of each specimen is shown in Table 1.

2.2 Thermal analysis

Differential Scanning Calorimetry (DSC) of the S-EP, the TST and their mixture, was measured. Their Thermogravimetric Analysis (TG) was also performed.

2.3 Moldability and tensile strength of the material

In order to evaluate moldability of the material, a metering time was measured with the injection molding machine. The metering time was the time to fill the space of the screw of the injection molding machine with resin. And, tensile strength of the materials was measured by Instron testing machine.

2.4 Friction and wear test

Friction and wear tests were conducted with thrust type tester. Length, width and thickness of the specimen were 30 mm, 30 mm and 3 mm, respectively. The mating part of 20 mm inner diameter, 25.6 mm outer diameter and 15 mm height was used. For the mating part, carbon steel for machine structural use JIS S45C (Ra 0.1) and POM were used. Testing conditions of the specimen and the mating part were shown in Fig. 2. Sliding test conditions were, when using S45C as the mating part, 10 m/min in sliding velocity, 0.49 MPa in load and 5 hr in testing time, and when using POM, 5 m/min, 0.49 MPa and 5 hr, respectively.

2.5 Scanning Electron Microscopic (SEM) Observation

Morphology of the specimen was observed by SEM. S-EP filled materials, IPN product and methyl-silicone rubber filled materials were used as specimen.

3. RESULTS AND DISCUSSION

A DSC curve of S-EP and TST mixture is shown in Fig. 3. It was found that an exothermal peak by reaction heat appeared at about 150°C to show reaction between two materials. TG curves of TST, S-EP and reaction products between TST and S-EP are shown in Fig. 4.

TST began to decompose at about 200°C. And, S-EP began to decompose at about 350 °C. The decomposition temperature of the reaction product between TST and S-EP shifted to a higher temperature than that of only S-EP.

Metering time in injection molding machine of each specimen is shown in Fig. 5. The metering time of the material filled with S-EP and TST was slightly longer than that of POM, but even the material filled with 20 mass % was sufficiently moldable. The materials filled with 8 mass % S-EP, slipped on screw of the injection molding machine to make its metering time much longer. And, the material filled with 4 mass% showed bleeding out on its molded surface. And, the silicone rubber filled material showed metering time similar to that of POM and was easy to mold.

In Fig. 6, tensile strength of the IPN product and the S-EP filled material is shown.

The tensile strength of the IPN product was higher than that of the S-EP filled material. However, 8 mass % S-EP filled material could not be molded to test pieces for tensile strength test.

Coefficient of friction and wear of each specimen against the mating part of S45C is shown in Fig. 7. Wear of the IPN product was lowest. And, coefficient of friction became low and stable, as the volume of the silicone oil increased. The 4mass% S-EP filled material showed a lower coefficient of friction but slightly larger wear than those of the IPN product. The reason was guessed that the S-EP material generated on its surface bleeding out of silicone oil, which was apt to be removed out of sliding surface to increase its wear.

Coefficient of frictions and wear of each specimen against the mating part of POM is shown in Fig. 8. The S-EP filled material showed an extreme increase of wear at 2 mass % filling. However, at 4 mass % filling, both specimen and mating part scarcely showed any wear and also showed low coefficient of frictions. In the IPN product, both wear and coefficient of friction decreased as its filling mass increased. The mineral oil filled material showed much wear and also high coefficient of friction. The silicone oil filled material caused melting of the specimen, which made its test difficult to continue. Against the mating part of POM, the S-EP filled material showed a superior tribological characteristics.

In general, it is thought that in a mutual sliding of plastics they have low thermal conductivities, increased temperatures of their sliding surfaces, and cause their melting and adhesion to increase the wear.

Effect of the S-EP is thought to protect mutual adhesion of resin at sliding surface, and to reduce its coefficient of friction and control its wear.

In Fig.9-11, SEM micrograph of the S-EP material, the IPN product and the silicone rubber filled material are shown. The IPN product shows its imperfect formation of IPN in its SEM micrograph and seems to be similar to that of the S-EP filled material. A reason to form no IPN is thought to be inferior mutual solubility between POM and silicone oil.

4. CONCLUSIONS

1) Although we tried to form the IPN product by using POM, S-EP and TST, the perfect IPN product was not obtained. The reason is thought to be inferior mutual solubility of POM and silicone oil.

2) The IPN product we tried shows characteristics of both silicone rubber and S-EP filled materials in its moldability and sliding characteristics.

3) The IPN product we tried was found to have a superior tribological characteristics against S45C and POM mating part.

5. REFERENCES

[1] Cosby,J.M. and Hufchins,M.K., SPI 40th RP/cpm. ANTEC, Section 11-C (1995)

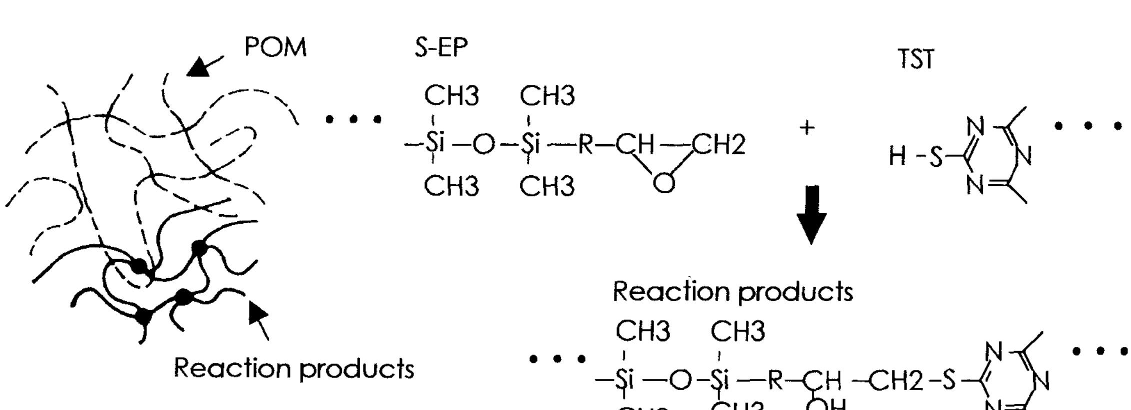
[2] M. Egami, Proceedings of the International Tribology Conterence Yokohama(1995)

[3] J. E. Theberge, Mchin. Design., 56, Sept. 6, 14 (1989)

[4] S. AKIYAMA, T. INOUE, T. NISHI, The Polymer Blend

Table 1 Composition of test specimens (mass%)

Specimen	S-EP2	S-EP4	IPN4	IPN8	IPN16	IPN20	M4	R8
POM	98	96	95.85	91.7	83.4	79.25	96	92
S-EP	2	4	4	8	16	20	-	-
TST	-	-	0.15	0.3	0.6	0.75	-	-
Mineral oil	-	-	-	-	-	-	4	-
Silicone rubber	-	-	-	-	-	-	-	8



Schematic Image of Molecular structure [4]

Fig.1 Reaction of S-EP and TST

Fig.1 Reaction of S-EP and TST

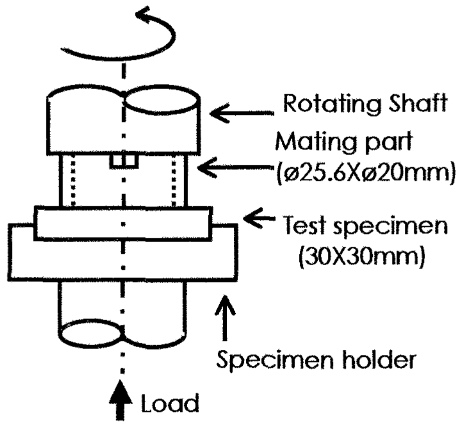


Fig.2 Arrangement of the test specimen and mating part

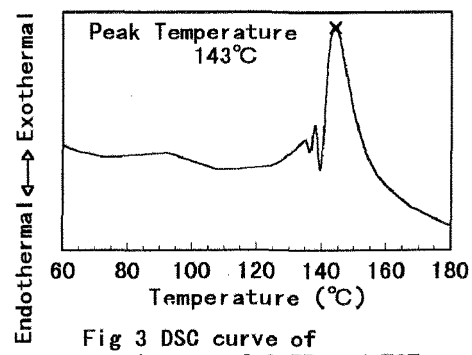


Fig 3 DSC curve of mixture of S-EP and TST

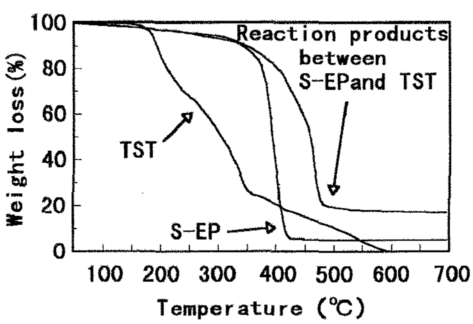


Fig. 4 TG curve of S-EP, TST and their reaction products

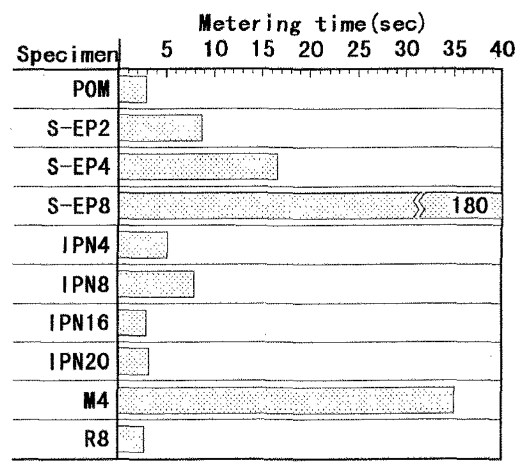


Fig. 5 Evaluateion of moldability for specimens

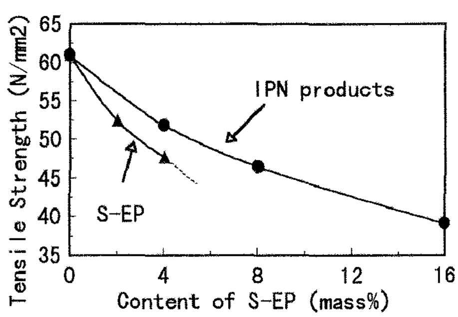


Fig. 6 Tensile strength of IPN products and S-EP filled materials

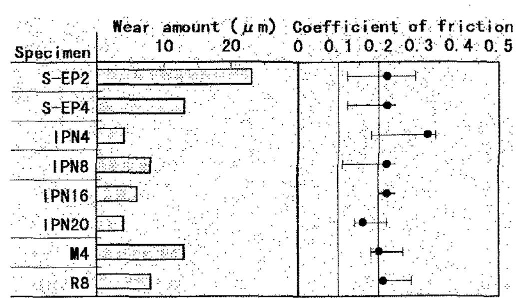


Fig. 7 Coefficient of Friction and Wear amount against S45C

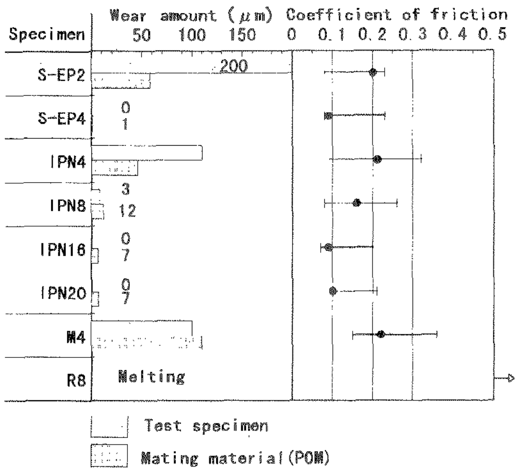


Fig. 8 Coefficient of Friction and Wear amount against POM

Fig.9 SEM micrograph of S-EP4

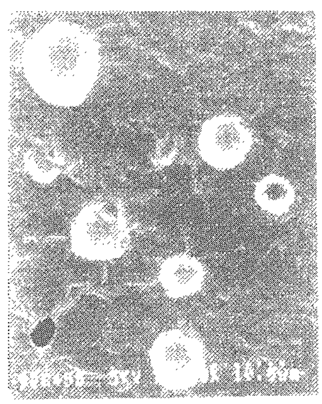


Fig.10 SEM micrograph of IPN8

Fig.11 SEM micrograph of R8

(Received December 16, 1999; accepted February 7, 2000)