Development of Phenolic Resin for Idler Pulley

S. NAGAI

Due to a necessity to make automotive components more lightweight, resin idler pulleys are being used in a wider range of applications. It was found that in the case of resin idler pulleys which contact the back side of belts, wear increases significantly depending on the belt type used, and, as emerging countries have many regions with unpaved roads, there is a demand to improve the dust wear resistance of this type of resin idler pulley. By improving the phenolic resin and optimizing the amount of inorganic fillers, we have developed a material for idler pulleys which satisfies these requirements.

Key Words: *idler, pulley, wear, phenol, thermal shock resistance*

POWER TRAIN

1. Introduction

Vehicle manufacturers around the world are engaged in activities to improve fuel efficiency as a means of preventing global warming. One element of these efforts is making components more lightweight using resin. Due to this demand, action is being taken to make the idler pulleys used in engine rooms from resin also. Idler pulleys are used to adjust belt layout (**Fig. 1**), and come in two types, one which makes contact with the front of the belt, and the other which makes contact with the back of the belt. Resin type idler pulleys have a resin coating around the periphery, and the resin pulley portion is shaped differently depending on which side of the belt is contacted (**Fig. 2**).

In recent years the scope of resin type pulley application has broadened, and the demand to support high loads has emerged. As such, pulleys with large bearing dimensions are required, however conventional material is inappropriate due to large amount of internal stress being created and unsatisfactory thermal shock resistance.

Moreover, it was discovered that for pulleys which contact the back of the belt, the amount of wear increases significantly depending on the belt type used, and as there are many regions with unpaved roads in emerging countries, there is a demand to improve the dust wear resistance of this type of resin idler pulley.

This report introduces a phenolic resin that satisfies the abovementioned requirements.

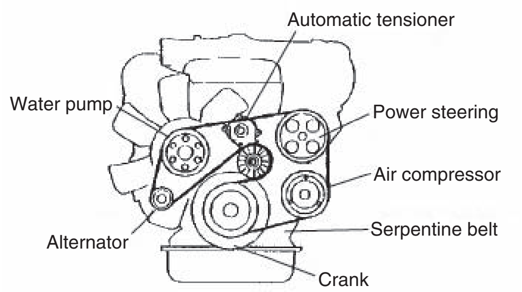

Fig. 1 Example of engine accessories layout

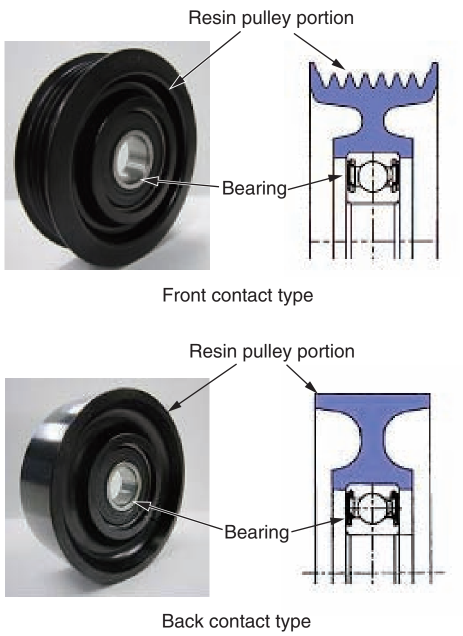

Fig. 2 Idler pulleys of phenolic resin

2. Current Challenges

2. 1 Thermal Shock Resistance

Pulleys with large bearing dimensions are required to support high loads. However, in the case of formed parts, such as resin pulleys, with resin coating around the bearing periphery, the contractile force of the resin pulley portion causes internal stress to occur, and bearings with large dimensions will lead to greater internal stress, resulting in unsatisfactory thermal shock resistance.

Heavy shrinkage and high elasticity are two factors contributing to high internal stress. Resin portions are subject to shrinkage at forming, thermal shrinkage depending on ambient temperature, and post-molding shrinkage at usage due to the heat history[1] (**Fig. 3**). To reduce internal stress these individual shrinkages need to be reduced. Also, high fatigue strength is required to secure thermal shock resistance.

2. 2 Improvement of Dust Wear Resistance

Depending on the type, some belts have rubber-covered backs while others do not. The back of the belt contains resin fibers called cores (**Fig. 4**) and, in the case of belts not covered in rubber, dust becomes lodged in these cores during use, which accelerates pulley wear (**Fig. 5**). Hardening the surface would be effective in suppressing this type of wear. The surface can be hardened by treating the resin pulley surface, however this is costly. To achieve sufficient hardness at low cost, a method of attaching a large amount of inorganic fillers is feasible, however impractical as the material welding viscosity would be high at forming, thus lowering productivity. Consequently, a low cost material, with only the surface which contacts the belt hardened, is required.

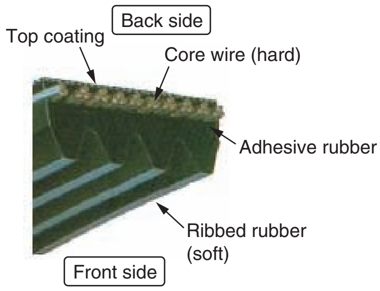

Fig. 4 Belt structure

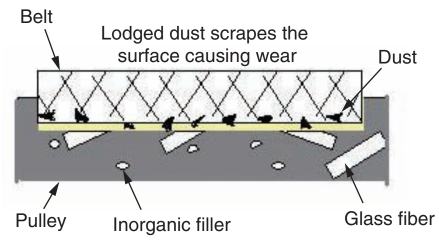

Fig. 5 Wear acceleration mechanism of belt back

3. Countermeasures

3. 1 Internal Stress Reduction

3. 1. 1 Adjustment of Inorganic Filler

Forming shrinkage and thermal shrinkage of the resin portion can be reduced by lowering the linear expansion coefficient. Contractile force requires the elasticity ratio to be lowered as well as the shrinkage. However, linear expansion coefficient and elasticity ratio reduction mutually conflict one another. The former will decrease if the amount of inorganic filler is increased, while in contrast, the latter will decrease if the amount of inorganic filler is decreased. In order to satisfy both of these conflicting properties, we have used glass fibers together with inorganic filler, adjusting the filler amount, so that both the linear expansion coefficient and elasticity ratio could be reduced without compromising strength (**Fig. 6**).

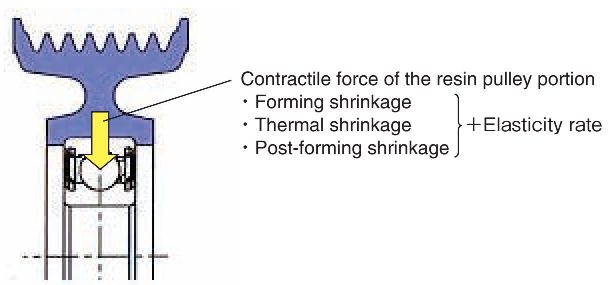

Fig. 3 Internal stress

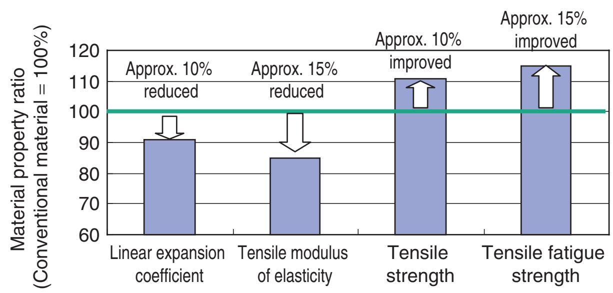

Fig. 6 Properties of developed material

POWER TRAIN

3. 1. 2 Adjusting Hardening Agent Amount

One of the factors causing post-forming shrinkage of resin portions is the degree of curing reaction at the time of injection molding. Due to this, the amount of curing agent was adjusted to the extent possible without compromising formability, using a Curelastometer (cure meter) to measure the cure rate as an indication of curing reaction. This resulted in being able to reduce the amount of post-forming shrinkage to approximately one-third of conventional material (**Fig. 7**).

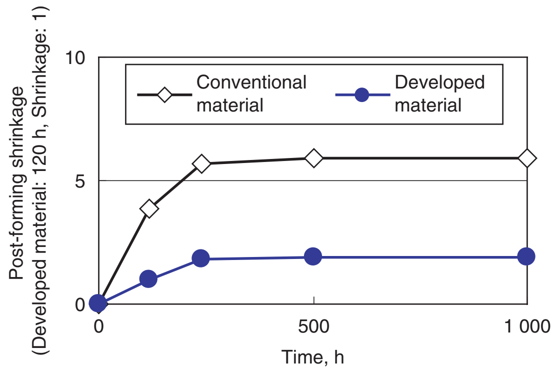

Fig. 7 Post-shrinkage when placed in a 120℃ environment

3. 2 Method for Improving Dust Wear Resistance for Back Contact Type

As a mechanism to suppress the wear caused by dust lodged in the back of the belt, a method was devised whereby the dust which infiltrated the engine room during operation would adhere to the resin pulley surface, and only the surface which made contact with the belt is hardened (**Fig. 8**). To improve adherence of the dust to the desired surface, a study was conducted to modify phenolic resin both chemically and physically. Chemically-wise, the modifier must have a polar molecular configuration for high dust adherence efficiency. Physically-wise, the glass transition temperature of the modifier must be less than the surface temperature of the resin pulley at the time of use. Of the modifiers that satisfy these conditions, the one which showed the best results in a basic adherence experiment was applied.

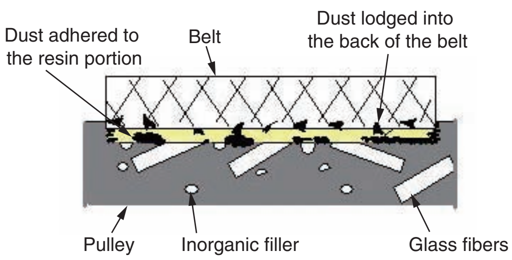

Fig. 8 Wear suppression mechanism

4. Benefits

4. 1 Thermal Shock Test

A thermal shock test was carried out using a pulley fabricated from the developed material of a size suitable for a large bearing. No cracks or other damage occurred after 2 000 cycles, proving that the material satisfied the requirements for idler pulleys (**Fig. 9**).

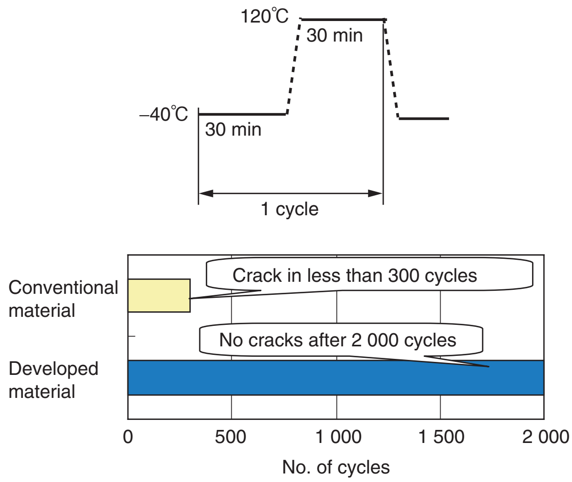

Fig. 9 Result of thermal shock test

4. 2 Dust Wear Experiment

A back contact type pulley was fabricated from the developed material then subjected to a rotation experiment in a dust-sprayed tank. The dusts in **Table 1**, belt layout of **Fig. 10**, and sample shape of **Fig. 11** were used in this experiment and afterwards the belt transfer section was evaluated and compared with a pulley made from conventional material.

The dust wear resistance of the developed material was approximately 30% better than that of the conventional material (**Fig. 12**). **Figure 13** shows that following the test, dust particles smaller than glass fiber had adhered to the transfer section of the belt, proving that the modifications made had been effective.

Table 1 Dusts used for test

	Type	Median diameter range
JIS 1 type	Silica sand	185～200 μm
JIS 8 type	Kanto loam	6.6～8.6 μm

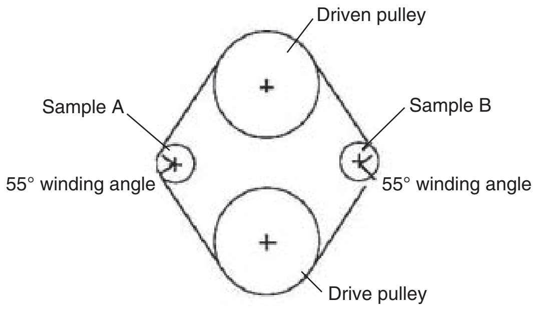

Fig. 10 Belt layout used for dust wear test

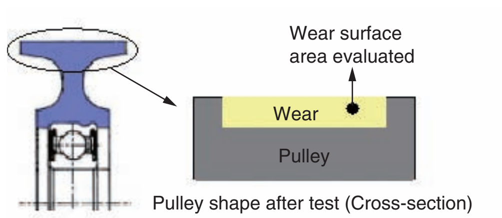

Fig. 11 Sample shape

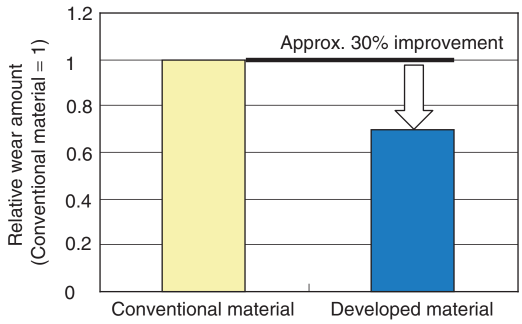

Fig. 12 Result of dust wear test

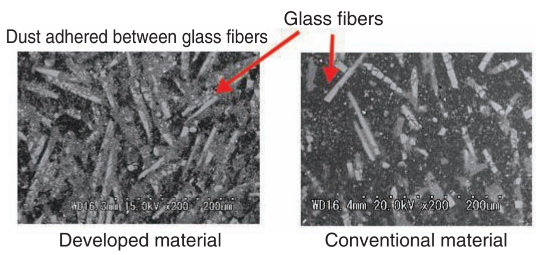

Fig. 13 Pulley surface after dust wear test

5. Conclusion

In response to the demand to broaden application of lightweight components made from resin, a material was developed that could be used for pulleys with large bearing dimensions capable of supporting high loads. Also, based on new knowledge of wear suppression mechanisms, dust wear resistance of the back contact type was improved by 30% compared with conventional material. Resinification is necessary to make components lightweight and resin will undoubtedly be used in an increasingly wider range of applications in the future. JTEKT will continue efforts to develop material meeting the requirements of resinification.

Reference

1) H. Arai, K. Mori: Development of High-performance Phenolic Resin Idrer Pulley, Koyo Engineering Journal, No. 164 (2003) 35.

POWER TRAIN

S. NAGAI*

* *Material Engineering R&D Dept., Research & Development Center, Research & Development Headquarters*