The Portion Effect of LNBR on the Tribological and Characteristic Properties of Nitrile-butadiene Rubber

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Abstract. Frictional behaviors of nitrile rubber of screw pump stators with liquid nitrile rubber (LNBR) as a plasticizer with different mass portions(5,10,15,20) are investigated by the MPV-600 wear tester, and their physical properties and curing characteristics are studied. The morphologies of worn surface are measured by the scanning electron microscope. The results show that the tc90 time of the rubber is shortened due to LNBR modified stator nitrile rubber, and its processing performance is improved, hence energy is saved. The 100% modulus, tensile strength, elongation at break of stator nitrile rubber increases with the increasing amount of LNBR, while the tensile strength and hardness show the opposite trend, and LNBR is reactive plasticizer. It has a relatively excellent overall performance when the mass portion of LNBR is 15.

Introduction

The applications of progressing cavity pump are applied in a wide range of oil extracting as a new type of artificial lift equipment due to its outstanding properties of cost saving, convenient adjustment, less area occupation[1]. However, the working conditions of corrosiveness of stator rubber, internal swelling, under pressure and shear force leading to the material damage limits the working life of the oil extracting system [2-3]. Therefore, in order to facilitate the development of NBR rubber, more attentions are focused on enhancing its properties [4]. Palaty and Joseph were studied the improvement of the curing property of the NBR at a low working temperature [5]. A dynamic vulcanization of PP/NBR thermoplastic elastomer blend was conducted by selecting grade of Polypropylene (PP) modified with dimethylol-phenolic resin and melt-mixed with NBR for several weight ratios [6]. As also studied [7-8] that the plasticizing system can reduce the van der Waals force between rubber molecular chains, and facilitate the mixing refining of powder in order to reach a better vulcanization, physical, and elasticity properties. Hence, the plasticizing is becoming an indispensable process for the rubber preparation. But, still very few studies on liquid NBR (LNBR) for plasticizing the NBR rubber materials have been investigated from author's knowledge.

In this work, we hence mainly force on the studies of physical, vulcanizing, and tribology properties of the LNBR plasticized NBR rubber. 5, 10, 15 20 of mass fraction of the plasticizer (LNBR) of the NBR rubber are classified and prepared. The curing time, tensile strength and fracture strength of serials of mass fractions of the NBR matrices are conducted. Frictional experiments under the normal loading of 100N are also taken.

1. Experimental

1.1 Materials and in Gredients

The mass fracture of the materials are listed in Table 1. The mass fractures for the preparation of the NBR rubber are designed to be 5, 10, 15, 20.

Table 1. The mass fractures of the materials for the preparation of the NBR rubber

Materials	Mass fracture
Pure NBR	100
LNBR	5, 10, 15, 20
Curing agent	1.5
Stearic Acid	1
Oxide Zinc	5
Furnace black	80
Accelerator	2.5
TMTD	0.25
Antioxidant	1

1.2 Rubber Preparation

The distance between the rollers of the mixing mill is first set to be between 0.5 to 1mm. The temperature of the mixing is controlled in a range of 20 to 40°C. The NBR matrices are filled and mixed 2 or 3 minutes by a means of triangular packet. The ZnO and stearic acid are then mixed into the mill machine from 3 to 5 minutes. The antioxidant (4010NA) and high abrasion carbon black are then mixed into the machine respectively. The means of triangular packet are used to make it even. In addition, the DM and TMTD are applied to be packaged for 6 to 8 times. 24 hours are required to be placed for the compounds. Finally, the rheometer are used to check the t_{10} and t_{90} . The cuing can then be obtained at the temperature of 160°C and the pressure of 10Mpa by the GT-M2000-A machine.

1.3 Wear experiment

The machine of MPV-600 with ASTM B 611-85(2005) is used to investigate the tribological properties of the NBR rubber which is shown in Figure 1. The schematic diagram of experimental apparatus is shown as Fig.1. The friction ring is chosen to be 45[#] steel in a size of 178mm×12mm. The size of the samples are in a size of 6mm×25mm×40mm. The friction tests are conducted with a rotating speed of 120r/min and 100N for the normal loading in a time of 600s. The friction coefficients are recorded during the experiments. Then, SEM is applied to observe the worn surface morphology of the samples.

Fig. 1 Schematic diagram of experimental apparatus

2. Test result

2.1 Vulcanizing properties

The vulcanizing properties of the NBR rubber are investigated and shown in Table 2. From Table 2, it is indicated that the lowest point of 3:12 of the t_{c90} of the NBR is observed when the mass portions of LNBR is 15. The values of t_{c10} show little influence by introduction of different mass portions of the LNBR. The greatest value of 25.64 of the M_H is also observed at the mass portions of LNBR of 15. It can be understood that the main chains of the polymer matrices tend to break when incorporation of

LNBR. The reactions between polymer matrices and vulcanization accelerator are more likely occurred leading to less time of vulcanizing. However, the values of M_H and tc_{90} tend to reach the lowest and greatest point of 23.87 and 4:18 respectively when the mass portions of LNBR are at 20. It is because of that the ineffective reactions are occurred between the free radical of the polymer matrices and vulcanization accelerator based on the excess introductions of LNBR leading to side reactions, shorten chains, branching, et al.

Table 2. The vulcanizing properites of the NBR rubber

	A ₁	A ₂	A ₃	A ₄
mass portions of LNBR	5	10	15	20
$M_H/dN\cdot m$	24.23	24.77	25.64	23.87
$M_L/dN\cdot m$	2.53	2.44	1.95	2.16
tc_{10}/min	1: 32	1: 38	1: 30	1: 47
tc_{90}/min	3: 52	3: 46	3: 12	4: 18

2.2 Frictional properties

Figure 2 shows the variation in frictional coefficient and wear rate of NBR with different mass portions under the condition of crude oil. It can be seen from Figure 2, with the increasing of the mass portion of liquid nitrile rubber (LNBR), frictional coefficient and wear rate decreases firstly, and then increases. It has a minimal wear rate of 0.3 and a minimal frictional coefficient of 0.32 when the mass portion of LNBR is 15.

Fig. 2 Variation in frictional coefficient and wear rate of NBR with different mass portions under the condition of crude oil

2.3 Mechanical Properties

Figure 3 shows the variation in 100% modulus and fracture strength of NBR with different mass portions under the condition of crude oil. It can be seen from Figure 3, with the increasing of the mass portion of liquid nitrile rubber (LNBR), the 100% modulus and fracture strength of NBR shows an increasing trend. It is noteworthy that it has a maximum 100% modulus of 6.2 and fracture strength of 20 when the mass portion of LNBR is 15. This may be due to the full proportion of between the HAF and fillers.

Fig. 3 Variation in 100% modulus and fracture strength of NBR with different mass portions under the condition of crude oil

Figure 4 shows the variation in tensile strength and fracture elongation of NBR with different mass portions under the condition of crude oil. With the increasing of the mass portion of liquid nitrile rubber (LNBR), the fracture elongation of NBR shows an increasing trend. It can also be clearly seen from Figure 4 that the tensile strength showed the opposite trend. Fig.5 shows the stereoscopic morphologies of worn surface of NBR, where 5(a), 5(b), 5(c) and 5(d) represent the mass portion 5, 10, 15 and 20 respectively. It can be clearly seen from Figure 5(c) that the wear scar is slight, which indicated it has a relatively excellent overall performance when the mass portion of LNBR is 15. The decrease of tensile strength was mainly due to the plasticizer effect that the processing performance of masterbatch further improves by means of infiltration powder medicament. The solubility of carbon black, sulfur and stearic acid is reduced by the macromolecular. Therefore, the tensile strength is decreased.

Fig. 4 Variation in tensile strength and fracture elongation of NBR with different mass portions under the condition of crude oil

Fig.5 Stereoscopic morphologies of worn surface of NBR

3 Conclusion

- (1) The tc90 time of the rubber is shortened due to LNBR modified stator nitrile rubber, and its processing performance is improved, hence efficiency is improved and energy is saved.
- (2) The 100% modulus, tensile strength, elongation at break of stator nitrile rubber increases with the increasing amount of LNBR, while the tensile strength and hardness show the opposite trend, and LNBR is reactive plasticizer.
- (3) It has a relatively excellent overall performance, such as low wear rate, good heat resistance and hardness decreased slowly, etc. when the mass portion of LNBR is 15.

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