The Preparation and Properties of Nitrile Rubber Filled with Different Kinds of Zinc Oxide

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Abstract. The vulcanizing properties, physical performances, and wear behaviors of nitrile rubber (NBR) filled with different kinds of Zinc Oxide (ZnO) were studied in this article. Based on samples preparation, this study provides the vulcanizing properties, physical performances and mechanical properties on NBR filled with different kinds of ZnO. This experimental results indicate that, compared with NBR filled with conventional ZnO, the tensile strength, tensile stress at 100%, and tensile stress at 300% of NBR filled with nano-ZnO are greater. The maximum torque of NBR filled with nano-ZnO is higher than that of NBR filled with conventional ZnO. The scorch time and optimum cure time of NBR filled with nano-ZnO are shortened. The NBR filled with nano-ZnO exhibits the more outstanding wear resistance.

Introduction

Nitrile rubber owns superior oil resistance in all-purpose rubber. It is used in oil resistant rubber slab, fuel tank, oil seal, and stator rubber of screw pump, and so on [1-2]. The same as other non self-reinforcing synthetic rubber, in order to improve the character of service, all kinds of ingredients are added into the nitrile rubber [3-4]. The ZnO is important compounding agent in rubber industry. It is used as vulcanizing activator in sulfur vulcanizing system. It not only activates the whole vulcanizing system but also improves the property of heat aging resistance [5]. Nano-ZnO and conventional ZnO own the same chemical composition, but nano-ZnO belongs to nanometer material, which exerts many fantastic characters, e.g. the surface effect, small dimension effect, quantum size effect and macroscopic quantum tunnel effect [6-7]. So, the NBR filled with nano-ZnO, its integrated performance is enhanced significantly. The vulcanizing properties, physical performances, and wear behaviors of NBR filled with different kinds of ZnO were studied in this article. It is the basic work for further research.

Experimental

The composition and mass fraction of NBR were listed as follow: N41 100, sulfuration agent 5, stearic 1, ZnO 5 (varieties), carbon black (N330) 60. anti-aging agent 1, and softener 2. Accelerating agents were DM, TMTD, and MgO. The mass fraction was 2.5, 0.25, and 0.15, respectively. The above chemical material of samples could be purchased in the market. The rubber samples were produced by the process of mixing and plate vulcanizing. NBR was vulcanized with the pressure of 10MPa and the temperature of 150℃ for tc90+5min.

The samples were mixed at room temperature using a two-roll mill. Vulcanizing properties were measured by the no rotor rheometer. The Shore Hardness of samples was measured by Shore durometer with the accuracy of 0.1 and else physical performances were obtained by tension tester. The tribological behavior of samples was measured at room temperature using a abrasive wear tester. During the test, the ring made by 40Cr steel was rotated on the rubber block under the load of 100N for 600s and its rotate speed was 200 $r \cdot \min^{-1}$. The weight of samples before and after wear test was measured using the electrical balance with the accuracy of 0.1mg. The steady frictional coefficient was collected when the wear condition was stable.

Results and discussion

The vulcanizing properties of NBR filled with different kinds of ZnO. The vulcanizing properties of NBR filled with different kinds of ZnO are shown in Table 1. Compared with the NBR filled with conventional ZnO, the maximum torque of NBR filled with nano-ZnO is enhanced by 19%, and the scorch time and optimum cure time is shortened by 13% and 23%, respectively. On account of surface effect of nano-particle, nano-ZnO owns excellent activity, which is the reason that the scorch time and optimum cure time are shortened.

Table 1 Vulcanizing properties of NBR filled with different kinds of ZnO

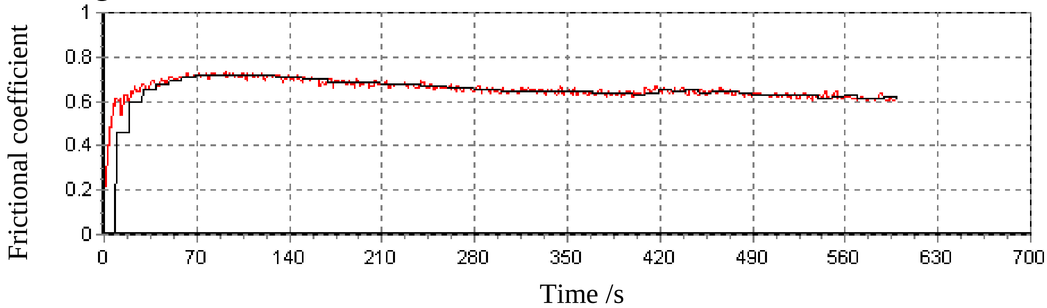
vulcanization parameters	NBR containing nano-ZnO	NBR containing conventional ZnO
MH[dN-m]	23.76	19.99
ML[dN-m]	1.41	2.47
tc10[min]	2:12	2:29
tc90[min]	5:05	6:16

The physical performances of NBR filled with different kinds of ZnO. The physical performances of NBR filled with different kinds of ZnO can be found in Table 2. Compared with the NBR containing conventional ZnO, the tensile strength of NBR containing nano-ZnO is enhanced by 9.6%. The tensile stress at 100% and tensile stress at 300% of NBR containing nano-ZnO is enhanced by 47% and 30%, respectively. The improvement of physical performances on NBR containing nano-ZnO could result from increase of crosslinking density. Because of nanometer effect of nano-ZnO, it results in the increase of crosslink junction per unit volume, namely the increase of crosslinking density. The Shore Hardness of NBR containing nano-ZnO and NBR containing conventional ZnO is 72 and 66, respectively.

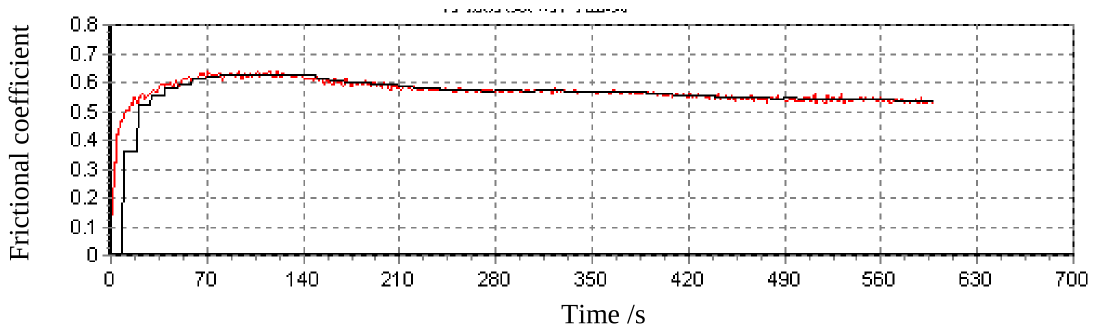
Table 2 Physical performances of NBR filled with different kinds of ZnO

physical performances	NBR containing nano-ZnO	NBR containing conventional ZnO
tensile strength[Mpa]	20.88227	19.06165
tensile stress at 100%[Mpa]	3.68202	2.49958
tensile stress at 300%[Mpa]	15.27015	11.77681
elongation at break [%]	399.52153	461.13006
shore A hardness	72	66

Tribological behavior of NBR filled with different kinds of ZnO. Fig.1 shows the curve of frictional coefficient with time on NBR containing different kinds of ZnO under dry sliding. It can be seen from Fig.1 that the frictional coefficient is basically steady with time. So, the wear mechanism should be single [8-9].



(a) NBR containing conventional ZnO



(b) NBR containing nano-ZnO

Fig.1 Curve of frictional coefficient with time on NBR containing different kinds of ZnO under dry sliding

Table 3 shows the stable value of frictional coefficient on both samples. It can be seen from Table 3 that the stable value of NBR containing nano-ZnO is less than that of NBR containing conventional ZnO. This phenomenon should be attributed to the higher hardness of NBR containing nano-ZnO, which results in decrease of real contact area between the steel pair and rubber block [10-13]. So, the force of friction between frictional pair would be reduced, and the frictional coefficient would be reduced, too.

Table 3 Stable value of frictional coefficient of NBR containing different kinds of ZnO under dry sliding

sample	**frictional coefficient**
NBR containing conventional ZnO	0.66
NBR containing nano-ZnO	0.57

It can be seen from Fig.2 that the wear loss is lesser on NBR containing nano-ZnO than that of NBR containing conventional ZnO. From the point of view of physical chemistry, if the crosslink density of rubber sample is small, then the wear loss of rubber sample will be high. This would be related to low density crosslinking can be easy to be broken by mechanical stress during friction process [14]. Because NBR containing nano-ZnO possesses higher crosslink density and the number of effective molecular chain bearing mechanical stress is more than that of NBR containing conventional ZnO. So, NBR containing nano-ZnO exhibits the more outstanding wear resistance.

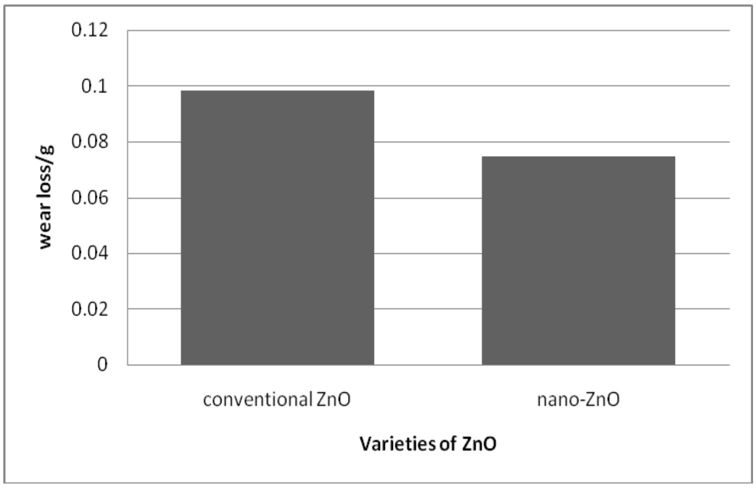


Fig.2 Variation of wear loss of NBR filled with different kinds of ZnO under dry sliding

Fig.3 shows the morphologies of worn surface of rubbers with the load of 100N under dry sliding. Obviously, apart from the plough, the worn surface shows the adhesion spot resulting from adhesion wear. The adhesion spots of NBR containing conventional ZnO are larger than that of NBR containing nano-ZnO, which showing that the adhesion wear resistance of NBR containing conventional ZnO is worse than that of NBR containing nano-ZnO.

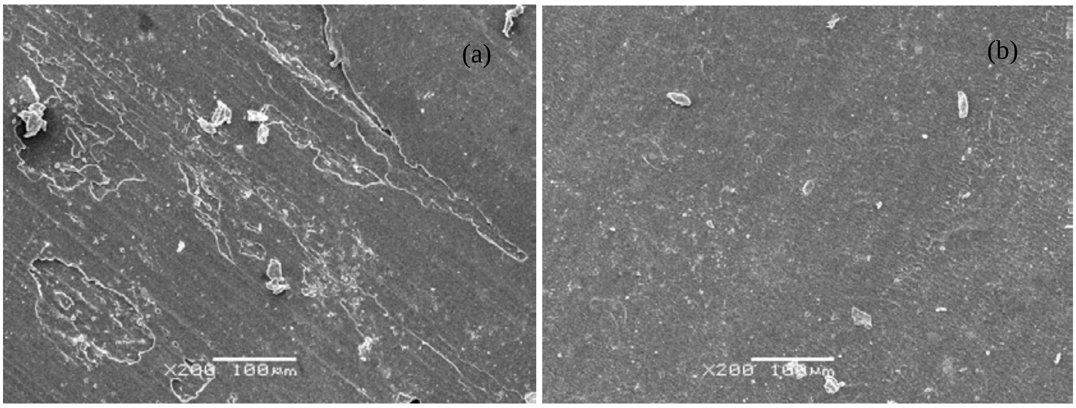


Fig.3 Morphologies of worn surface with the load of 100N under dry sliding
(a) NBR containing conventional ZnO (b) NBR containing nano-ZnO

Conclusions

(1) Compared with NBR containing conventional ZnO, the tensile strength of NBR containing nano-ZnO is enhanced by 9.6%. The tensile stress at 100% and 300% is enhanced by 47% and 30%, respectively. The NBR containing nano-Zno displays superior physical performances.

(2) The maximum torque of NBR filled with nano-ZnO is enhanced by 19%, and the scorch time and optimum cure time is shortened by 13% and 23%, respectively. These would be related to the activity of nano-ZnO.

(3) The frictional coefficient of both samples is basically steady with time. The wear mechanism should be single. The NBR containing nano-ZnO possesses less force of friction and frictional coefficient.

(4) The NBR containing nano-ZnO shows the more outstanding wear resistance, which is attributed to its higher crosslink density.

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