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Application of a New Specimen Geometry on Rapid Gas Decompression (RGD) Test

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Abstract
Elastomers used in gas transmission field such as seals, diaphragms, O-rings and sleeves are very important pieces which may be damaged in operating conditions. According to ISO 23936-2 standard, O-ring specimen is applied for RGD test but preparation of O-ring from final product is impossible in most cases. In this study, the RGD test implementing by using easily prepared Ring-type specimens from NBR vulcanizates were investigated. The new Ring-type specimen had similar dimentions to standard 312 O-ring. The RGD test was modified to 80 ^{0}C and 80 bar according to real operational conditions. Results showed that Ring-type specimens had higher RGD rating and cosequently more damages than O-ring ones. Furthermore, more conservative results were obtained for Ring-type samples. The Ring-type geometry was specified as an appropriate alternative specimen for RGD testing due to simple and easy preparation from final rubber product. The new Ring-type was applied successfully as test specimen in the RGD test for rubber sleeves in gas transmission fields.

Keywords: RGD, Specimen geometry, Ring-type, NBR, Elastomer product.

Introduction
Rubber seal products are flexible elastomers with variety of applications and widely used in oil and gas industry. Generally, in real conditions elastomer seals are exposed to various fluids such as crude oil, petroleum fractions, gas condensates, natural gas, CO_2 and H_2S. Also, the elastomer seal products are held at elevated temperatures (up to 120^{o}C) and high pressures (up to 1000 bar), simultaneously. Through working conditions, elastomeric components were saturated by gas molecules after a time period depend on pressure and temperature conditions. Whenever, rapid pressure fluctuations or releasing were happened, some structural failures might be imposed on rubber products which known as rapid gas decompression (RGD) or explosive decompression (ED) failures [1]. Depending on rubber compound, it leads to different damages such as bubbling, blistering, internal and external cracking or even rupturing. Few researchers challenged these damages in recent years. Embury [2] studied the high pressure gas testing of FKM and EPDM elastomer seals with practical design of RGD test under pressure 2000, 2200 and 2800 psi and and temperature of 100 ^{0}C. Embury found that by increasing the RGD test pressure, the failures such as cracks would be increased. Yamabe and Nishimura [3] investigated the influence of fillers on hydrogen gas diffusion and

blister fracture in EPDM and NBR O-rings under 10 MPa and 30 ^{0}C. They observed that vulcanizates with no fillers were more damaged. Yamabe et al. [4] also studied the hydrogen gas diffusion on EPDM O-rings with peroxide cure under pressure and temperature 10 to 70 MPa and 30 to 100 ^{0}C, respectively. Results showed that by increasing RGD test pressure and number of cycles, more bubbles, blisters and cracks to be observed. Young et al. [5] concluded that the swellable-type rubber such as NBR, HNBR and FKM is more RGD resistance materials at 80 ^{0}C and different rates of pressurization and depressurization. Routh [6] studied type of specimen geometry on RGD resistance of some elastomer seals. The conventional RGD test was designed and implemented for standard O-ring specimen. However, preparation of an O-ring from a final seal product such as sleeves is impossible. To evaluate performance of sleeves under RGD tests, alternative geometry type of specimen is required. In addition, the RGD test conditions must be modified to the actual conditions.

In this study, our attempts focused on implementing and comparative evaluation of RGD test using easily prepared Ring-type specimens from final product with similar dimensions to common O-ring standard specimens. Variuos smaples were prepared from vulcanized NBR compounds.

Experimental

Materials

Materials used in this study are nitrile rubber (KNB 35L, Kumho), Carbon black N330, stearic acid, Tetramethylthiuram disulfide (TMTD), n-cyclohexyl-2-benzothiazole-2 sulfenamide(CBS), powder sulfur, n-isopropyl-n'-phenyl-p-phenylenediamine(IPPD), dioctyl phthalate oil (DOP) and Nano Zinc Oxide (ZnO) purchased from Nano Kimia Danesh company (Iran) with average size 20-30 nm.

Compounding formulation and vulcanization

Table 1 shows presented compounding formulations of NBR vulcanizates. Row materials were mixed with two roll mill located in research laboratory of polymer testing (RPT lab.) of Ferdowsi university of Mashhad. Curing process was done by hydraulic compression press (SantamCo, Iran) at 160 ^{0}C for 5 minutes under 150 bar pressure. All compounds are including 1 phr sulfur, 1phr stearic acid and 1 phr IPPD.

Table 1. Compounding formulations of presented NBR samples (phr)

Ingredient	Test number							
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
KNB 35L	100	100	100	100	100	100	100	100
N330	60	60	60	50	60	50	60	50
TMTD	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CBS	2.5	2.5	2.5	2.5	2	2	2	2
DOP	5	5	5	5	10	10	10	10
Nano ZnO	3	2	5	3	5	5	3	3

Sample preparation and modified RGD testing conditions

According to ISO 23936-2 standard [7], O-ring samples prepared with a nominal CSD of 5.33 mm and Ring-type samples prepared with same diameters and thickness as shown in Figure 1.

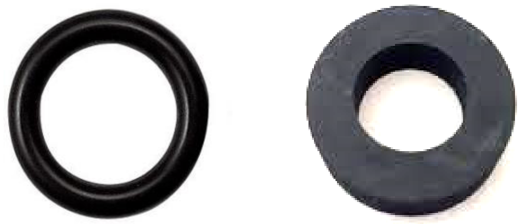


Figure 1. Two specimen geometry as O-ring and Ring-type of rubber samples used in modified RGD test

The RGD test procedure is similar to ISO 23936-2 standard and the conditions are modified as following: The gas mixture including 90 mol% of N_2 and 10 mol% of CO_2. The test period was 7 days and 8 cycles, decompression rate: 25-30 bar/min and temperature and pressure about 80 ^{0}C and 80 bar, respectively.

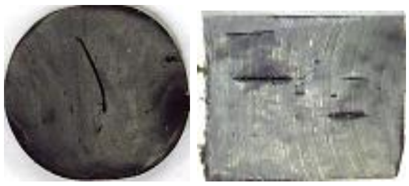
Results and discussion

Results of the modified RGD test are listed as rating grades in Table 2 and corresponding images are shown in Figure 2, respectively. All the prepared samples passed the RGD test. Rating of vulcanized NBR samples for both Ring-type and O-ring specimens were obtained in accordance to ISO 23936-2 standard procedure.

Table 2. the RGD rating of NBR vulcanizates

	sample	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Rating	O-ring	1	0	1	1	1	1	1	1
	Ring-type	2	1	2	2	1	2	1	1

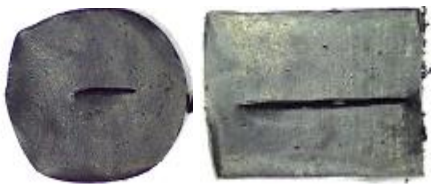
Clearly, the RGD rating of the Ring-type samples are higher than O-ring ones. As presented in Figure 2, Ring-type samples were shown more cracks, because of larger exposure surface to gas ambient of RGD test. Consequently, the gas diffusion in NBR elastomer structures was increased and more damages happened in Ring-type samples.



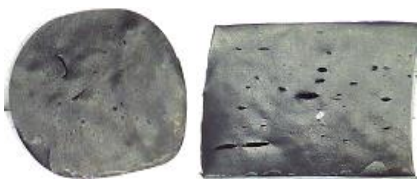
S_1

S_2

S_3



S_4



S_5

S_6

Figure 2.Observed damages of NBR vulcanized samples as O-ring and Ring-type specimens under the modified RGD test.

Conclusions

In this work, the damages of Ring-type and O-ring specimens with the same dimensions caused by a modified RGD test were investigated and compared. The results indicated that under same conditions, the damages were more for Ring-type specimens in comparison to O-ring ones. The rating of O-ring specimens was 0 or 1 while it was even increased to 2 for Ring-type samples. It considered that more gas exposure surface of Ring-type can lead to more gas diffusion and more damages. Therefore, the Ring-type geometry can be simply prepared and applied as test specimen in the presented modified RGD test to evaluate performance of rubber seal products specially as sleeves in gas transmission field.

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