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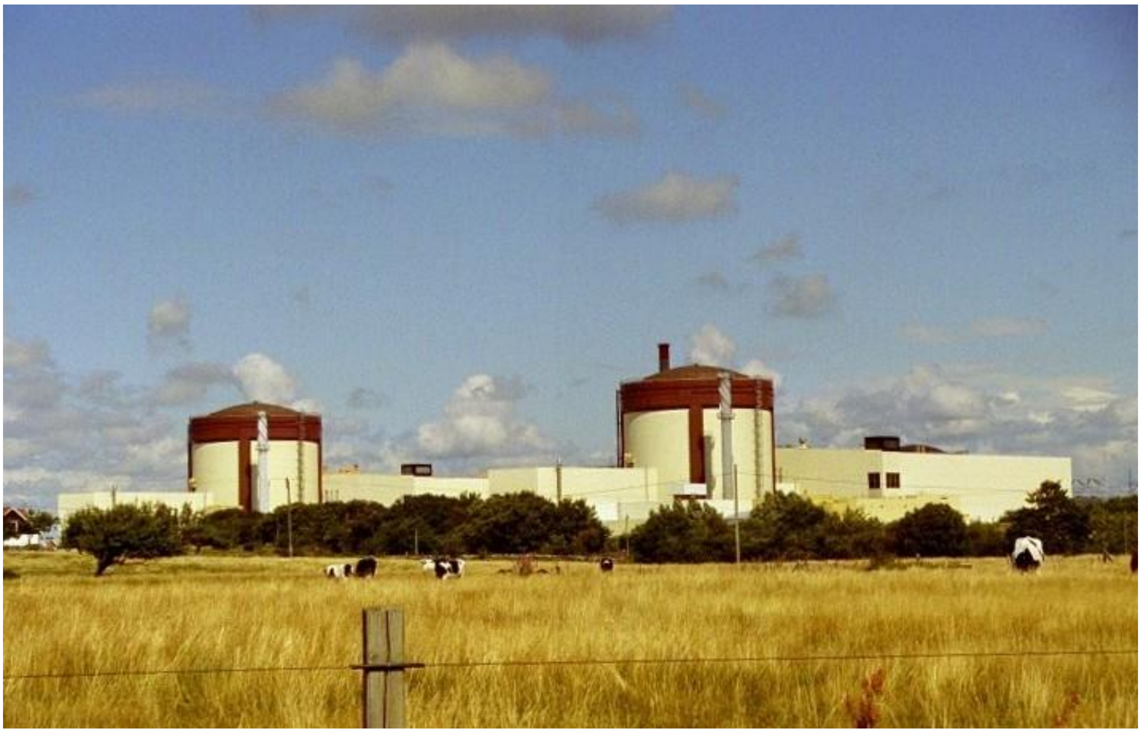

WP1 SAMPO Task 1.3 - Setting up safety margins for O-rings

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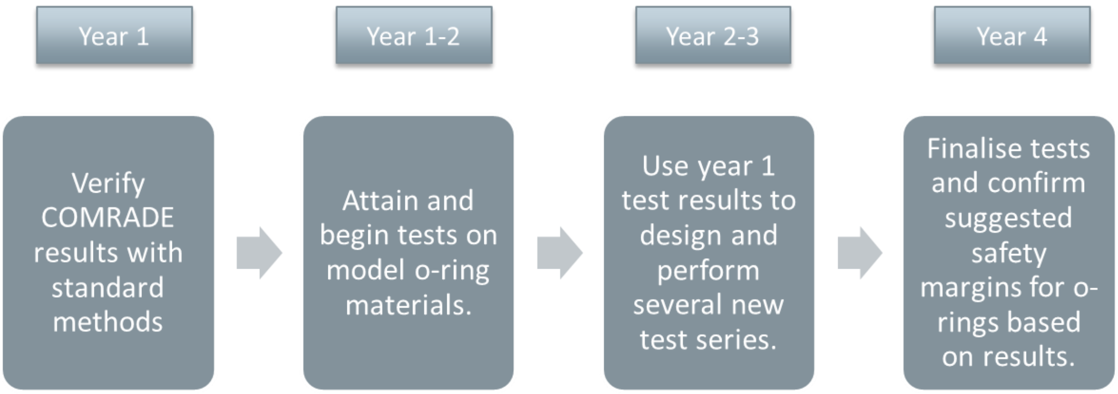
Background and aim

This task primarily aims to attain usage lifetimes for rubber O-rings which are present in critical functional capacities in Nuclear Powerplants (NPPs). The previous project COMRADE was performed under non standardized methodologies, thus SAMPO year 1 (2019) aims to verify the results of COMRADE with standard methods.

Rubber O-rings can be found in some critical components such as pumps and pipe connections. If these pipes were to fail, a so-called 'loss of coolant accident' (LOCA) could occur. This could obviously be disastrous to the Powerplant and surroundings.

Project plan

The project plan can be best summarised as followed:



As yet, year one was successful in accomplishing planned tasks, to verify COMRADE results (see results and discussion) and tests are set up already on model 'bad' materials (in order to verify in greater detail our test methods on a material that will actually fail testing – so far COMRADE materials did not fail, so it will be useful to know a potential (but unlikely) fault lies in the test methods, rather than the test materials. This report concludes that the next stages of method development and testing of materials can now begin, primarily with the design of a new water test rig (to simulate sealing – or lack of – at pressure) and compression set-tests of newly attained 'bad' materials and other materials deemed to be of interest. NB: the test rig designs are almost complete, the workshop at Fortum [1] provided much valuable input.

Experimental

Materials

Ethylene Propylene Diene Monomer (EPDM) and Nitrile rubber sheets with a grade code of LR 9444 and NM27/70, respectively, were supplied by James Walker Ltd. These two materials were used in COMRADE project.

Compression set

Compression set test was performed on standard test specimen of cylindrical shape with a diameter 13 ± 0.1 mm and a thickness 5,6 ± 0.2 mmm according to ISO 815-1. The standard test specimens were cut from the rubber sheets with a standard cutting mould. Three test specimens were placed between the plates of one compression device with the spacers with a height of 1.4 mm. The bolts were tightened so that the percentage of the compression was 25% of the original thickness. In total, three assembled compression devices were papered for EPDM and nitrile sample, respectively.

Two of the assembled compression devices were placed in ventilated oven where the rubber samples were aged in air at 80 °C and 120 °C for the nitrile rubber and EPDM sample, respectively. In order to measure the compression set of rubber samples exposed to water, one of the assembled compression devices was immersed in water in a 2L sealed autoclaves. The autoclave was then placed in oven.

One of the compression devices aged in air was taken out from the oven after 21, 111 and 180 days of ageing, and the test specimens were removed immediately and cooled in a condition room (23 °C and 50% RH) for 30 min. The thickness was then measured by an electronic digital calliper with 0.01 mm accuracy. After the thickness measurement, the specimens were mounted in the compression devices and then placed in the oven. In order to determine the effect of the disturbance occurred during the multiple tests on the final compression set, another assembled compression device aged in air was only taken out from the oven after 180 days of ageing, the longest ageing time, without disturbance.

The compression set was calculated as:

$$\frac{h_0-h_1}{h_0-h_s} \times 100\% \tag{1}$$

where h_0, h_1 and h_s is the initial thickness of test specimen, the thickness of the test specimen after recovery, and height of the spacer, respectively.

Results and discussion

As shown in Figure 1, even though being aged at a lower temperature in air, nitrile rubber samples showed a greater and faster increase in compression set with increasing ageing time than EPDM rubber. After half year exposure to air, the compression set reached 84% and 61% for the nitrile rubber and EPDM samples, respectively. The obtained values of the compression set agreed well with the results obtained in COMRADE project, in which the compression set was ca. 60% for EPDM O-rings after half-year exposure to air at 120 °C and was ca. 85% for the nitrile rubber exposed to air for half year at 80 °C [2]. One probable reason for the greater compression set for nitrile rubber sample than EPDM sample is plasticizer migration from nitrile rubber into the air during the test. Thermogravimetric analysis showed that the nitrile rubber samples contain a certain amount of small molecule additives (plasticizers), indicated by initial loss starting at approximately 180 °C in the mass loss curve, but EPDM does not consist of any plasticizers [2]. As a result, apart from oxidation, nitrile rubber sample also underwent plasticizer loss during the ageing in the air at elevated temperature, leading to a greater increase in compression set.

Figure 2 compares the compression set of the samples aged for half year with or without disturbance during the measurement. There is only a very small difference between these two results, indicating that the disturbance can hardly influence the compression set result.

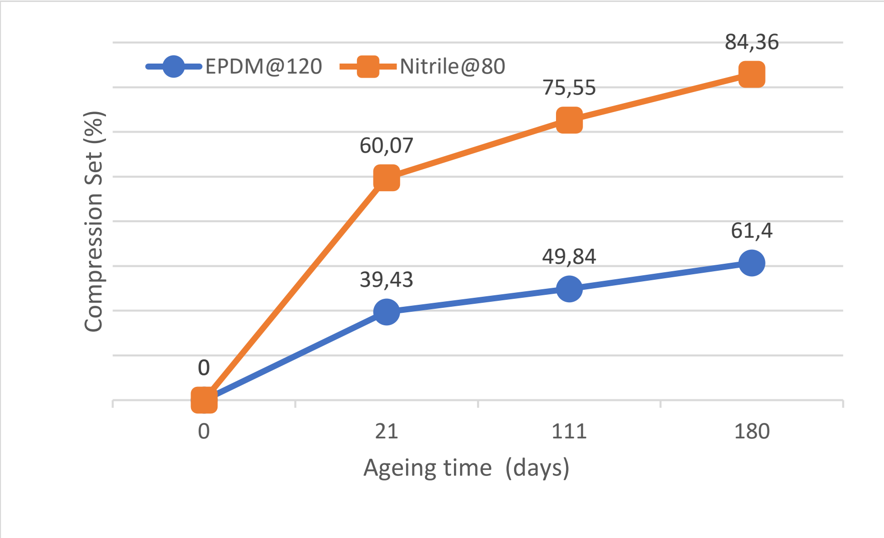


Figure 1. Compression set for the EPDM aged in air at 120 °C and nitrile rubbers samples aged in air at 80 °C.

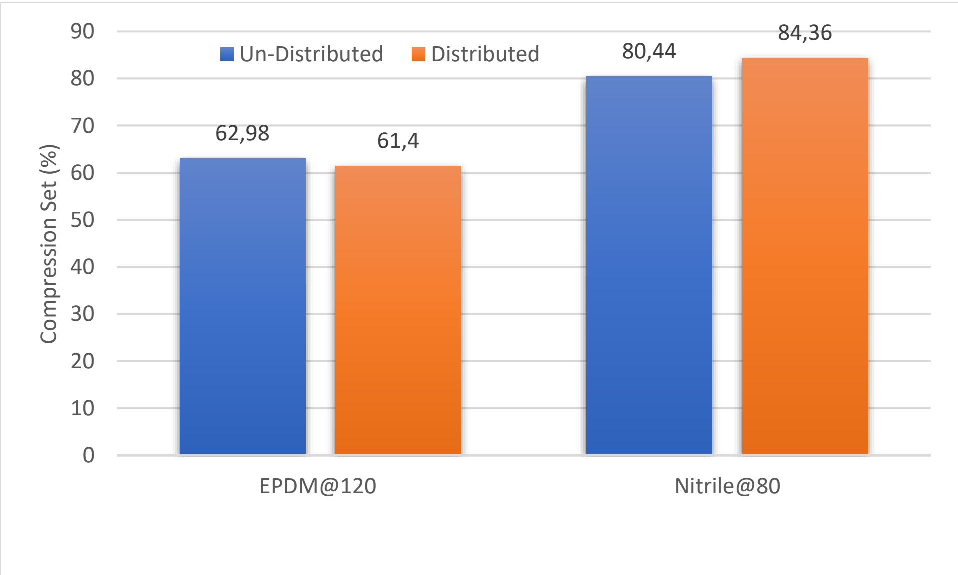


Figure 2. Compression set for the EPDM and nitrile rubber samples aged in the air with or without disturbance during the test. EPDM and nitrile rubber samples were aged for half year at 120 and 80 °C, respectively.

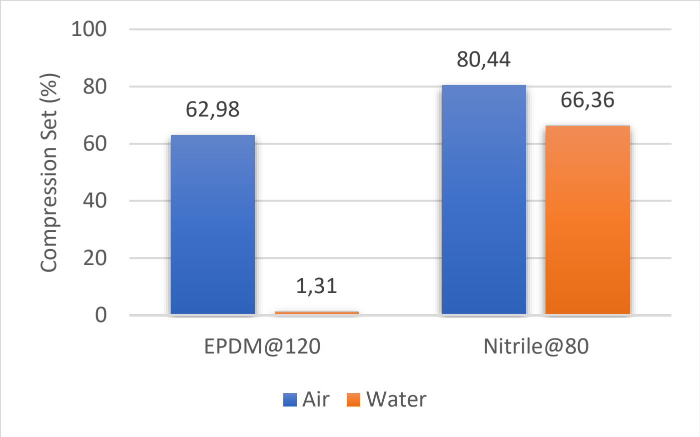


Figure 3. Comparison of the compression set of rubbers aged in air and water. EPDM and nitrile rubber samples were aged for half year at 120 and 80 °C, respectively.

The compression set of rubbers aged in the water and air was also compared. Figure 3 shows that the compression set of EPDM samples was only ca. 1% after half-year ageing in the water at 120 °C, which was much smaller compared to that (63%) of the sample aged in air. The compression set value reached 66% for nitrile rubber sample age in the water, which was smaller than that (80%) of the sample aged in air. This finding suggests that water is a much less harsh medium for the application of rubber, especially for EPDM, compared to air. What needs to be pointed out is that the autoclaves, used to age the samples in the water, is a closed environment where the oxygen supply is limited. Hence, the oxidation of the rubbers exposed to water was suppressed by the limited amount of oxygen in the autoclaves. However, the nitrile rubber still underwent the plasticizer loss during the exposure to water, leading to an increase in the compression set.

Conclusions

1. The compression set results performed under a standard method confirmed the COMRADE results performed under non standardized method.
2. Compared to nitrile rubber, EPDM samples showed much better durability in the applications in air and in water.
3. The effect of the disturbance occurred during the multiple tests on the final compression set was very small.
4. The access to oxygen needs to be considered in future before the compression set test on samples immersed in water.

References

[1] Conference Polymers in nuclear applications 2019, November 27-28, Fortum head office, Keilalahdentie 2-4 (CD-building), Espoo, Finland.

[2] Sipilä K, Vaari Jukka, Jansson A, Bondeson A. 2019. Condition monitoring, thermal and radiation degradation of polymers inside NPP containments (COMRADE). As part of SAFIR2018 - The Finnish Research Programme on Nuclear Power Plant Safety 2015-2018, Final Report.