TECHNOLOGY FOR BUSINESS

Condition Monitoring, Thermal and Radiation Degradation of Polymers Inside NPP Containments - COMRADE

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Introduction

Different polymer based materials are widely used in various applications in nuclear power plants and inside containments, e.g. cable jacketing/insulators, sealants, paint coatings, lubricants and greases. Elevated temperature, ionizing radiation and moisture are considered to be the most important ageing stressors for polymers. In addition to these ageing stressors, properties of polymer blend has an effect to the ageing behavior. In COMRADE project polymer ageing studies are conducted in three different work packages which concentrate on development of condition monitoring methods and related acceptance criteria, mapping and acquisition of components in real ageing environments and study the polymer ageing mechanisms both by the means of computational and experimental methods.

WP1 - Development of condition monitoring methods for polymeric components

Peroxide cured EPDM o-rings and test sheets were aged in sequence using heat (90, 120, 140°C) and radiation (29 Gy/h). Total time of heat 6 months and total dose 14-18 kGy. During the ageing five evaluations were done.

By studying the change in material properties little difference between irradiation and non irradiation can be seen. Furthermore the DSC OITe shows a similar change for both 120 °C and 140°C for evaluation 5 even though compression set shows a large difference still.

The first goal of the WP was to correlate a function, in this case tightness, to a material property. The tightness failed for the first time for the o-ring running in 140 °C (both irradiated and not irradiated) at evaluation 3 and later on at evaluation 4. This is after 5 months of heat and 4 weeks of irradiation. The material properties can be seen in the below table.

Property	End of life	Initial value
Compression set	105%	4,9%
Hardness	80	72,3
Elongation at break	50%	182%
Tensile strength	7,5 MPa	12,8 MPa
DSC – OITe	235,9°C	265°C

Figure 1. Test set up for leakage detection conducted after each evaluation point.

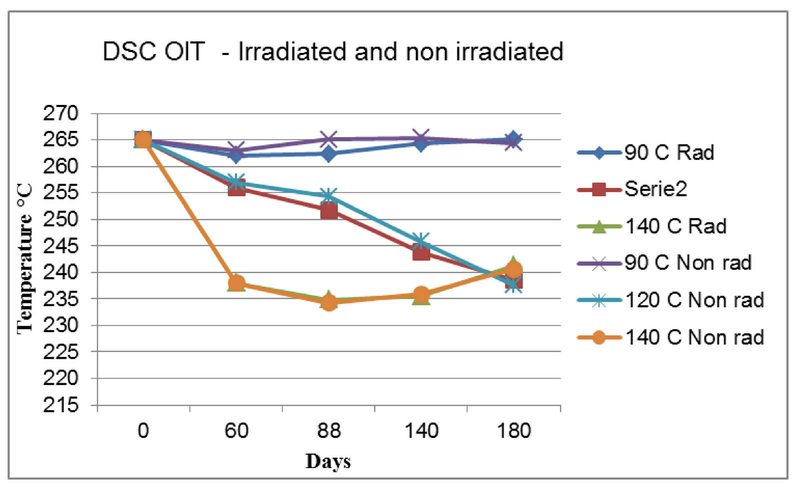
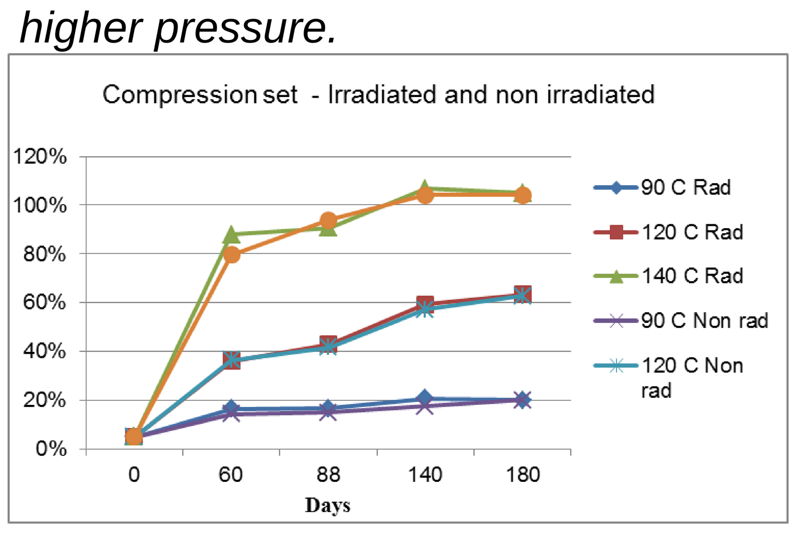


Figure 2. Test blocks used for the functional test. The tightness was tested at 110 bar with a holding time of 60 seconds.

Figure 3. Compression set data for the tested EPDM o-rings. First leak at > 100% compression set. Tightened at higher pressure.



WP2 - Barsebäck pre-study on aged polymers

To verify the model in WP1 and provide materials aged at real conditions for WP3 ageing studies, the possibility to extract polymer materials from the closed down NPP Barsebäck were investigated. The material acquisition from Barsebäck was considered to be challenging so the scope was expanded to cover the NPPs still in use e.g. outtakes or containments that has been/will be closed down. From the candidate materials given by the NPPs, suitable materials will be collected and tested by the methods used for WP1 and WP3. During the acquisition process, it is emphasized that the materials are similar to the model materials and they can be fluently obtained from the NPP site.

WP3 - Polymer ageing mechanisms and effects inside NPP containments

Polymer ageing occurs at different size and time scales. Currently a multi-scale material model that takes account all size and time scales does not exist. The current ageing models are semi-empirical and have limited applicability. The synergistic effects of radiation and heat were experimentally studied with EPDM and CSM. As a result it was noted that increasing temperature can either hinder or accelerate degradation, depending on the polymer type. From oxidation profile measurements it was noted that ToF SIMS seems to be a promising method to obtaining from the three techniques tested (FTIR and DSC being others). ToF SIMS was sensitive to detect oxygen content on the sample surfaces and also sensitive towards surface roughness so careful sample preparation is required. For dose rate effect evaluation, three different semi-empirical models were identified which could be applied for this purpose.

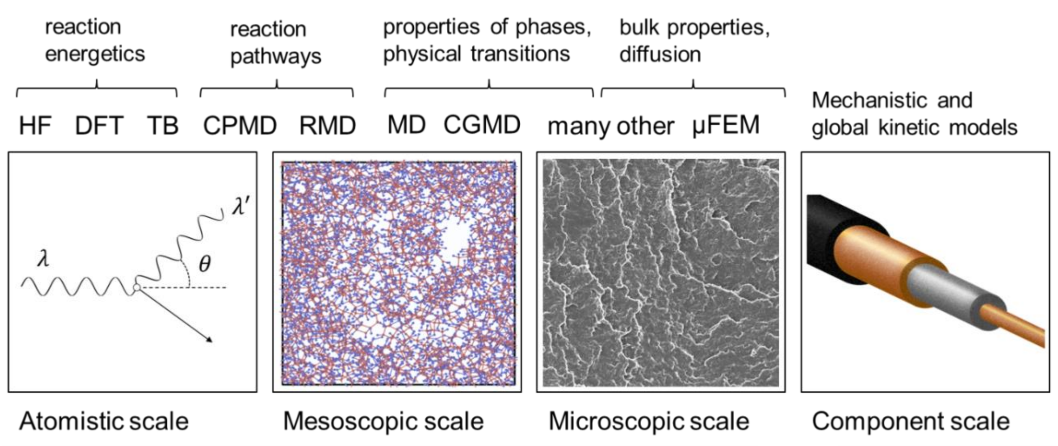


Figure 4. Scales and processes of thermal and radiation ageing coupled with numerical modelling methods.

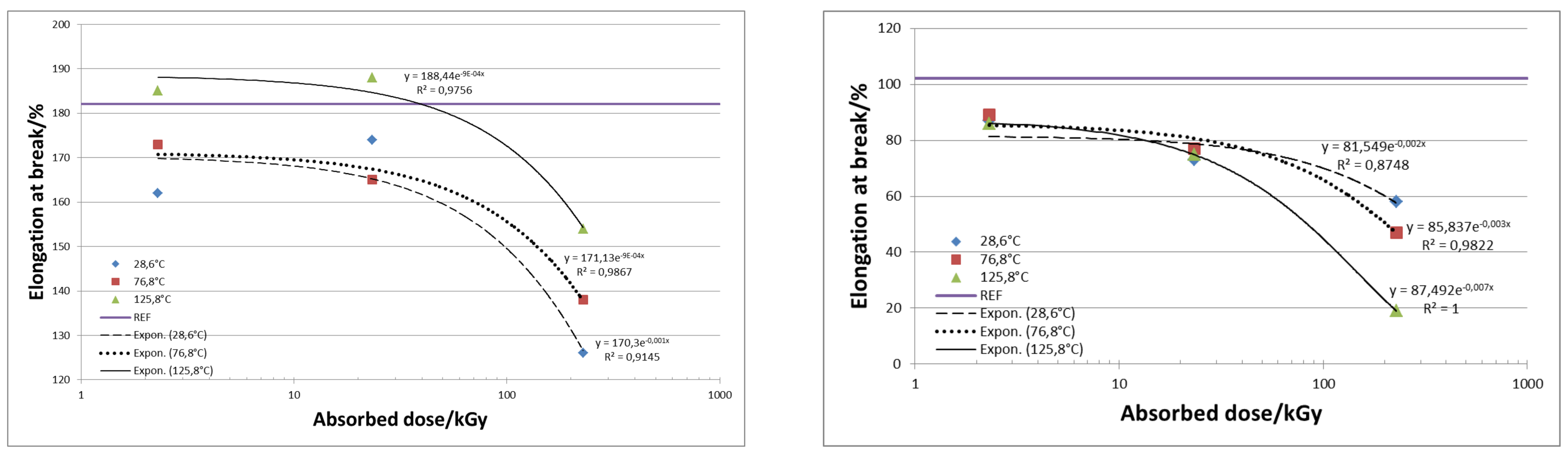
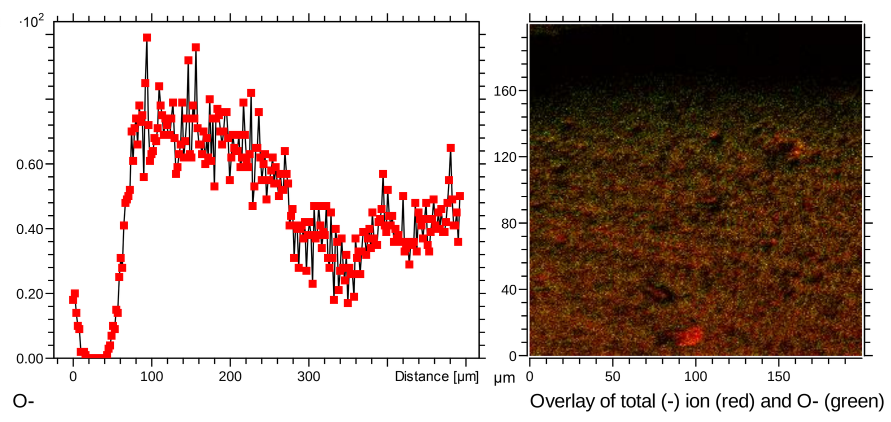


Figure 5. The effect gamma radiation to material degradation on EPDM (left) and CSM (right) as function of temperature. Increase of temperature up to ca. 125°C seemed to hinder degradation on EPDM but not on CSM.

Figure 6. On left, measured oxidation profile with thickness ca. 240 μm. On right, two dimension quantitative oxidation graph obtained with sample irradiated and exposed to thermal ageing with even cross section surface. Surface is on top and oxygen illustrated as green.



Conclusions

The relevant issues related to ageing of polymer components inside NPP containments are studied in COMRADE project. After a first year of study, promising results has been obtained related to o-ring condition monitoring method and setting up relevant acceptance criterion, acquisition of materials that have experienced ageing in real service environments, applicable computational methods on polymer ageing, polymer behavior under DBA, oxidation profile measurements and methods applicable to predict the severity of dose rate effect.

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