BIOSCIENCE AND MATERIALS
CHEMISTRY AND MATERIALS

WP1 SAMPO Task 1.1
- Lifetime estimation

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Content

Background and aim

This task makes use of the results and analyses from the completed COMRADE project when suggesting useful and relevant acceptance criteria and safety margins. Results from laboratory aging tests and evaluations have been compared to materials obtained from Nuclear Powerplants (NPPs). Improvements to both test methods and aging environments are required to set acceptance criteria as well as safety margins. Some polymer components are extremely complicated or impossible to change in operating NPPs and thus their endurance during the whole lifetime of a plant is essential. To be able to make reliable lifetime estimations of components, information on material properties on both materials that have been in use at NPPs and artificially aged materials is extremely valuable. The question of residual lifetime assessment of polymer components in service is often raised. Without sufficient material data and service history of the materials, i.e. temperature, radiation dose, oxygen and moisture content in the atmosphere, this is almost impossible to predict. By studying materials from NPPs available from outages and decommissioned plants that have been in service for a long time, we have a unique opportunity to develop material lifetime prediction methods with correlation to materials from real service environment and long-term use.

The aim of this task is trying to identify critical components and to investigate the possibilities to obtain such components from plants under decommissioning or during maintenance, including material data. An obstacle with getting interesting components from decommissioning of NPPs, such as Ringhals R2 which were closed December 31, 2019 and Ringhals R1 which were closed December 31, 2020, is that it will not be possible to obtained in the materials for several years because the fuel will not be removed from the reactor immediately.

It has proven that it is difficult to get clearance of materials used in the NPPs and it is sometimes also difficult to achieve sufficient amounts of materials to perform relevant tests, therefore a full year project including workshops together with the NPPs is planned for this task to be able to discuss what components to choose. One group of materials mentioned in the running project are cables. Moreover, replaced materials from outages will be considered. In COMRADE many samples were too small and not in sufficient amount to be analysed. Therefore, artificially aged materials will be investigated in parallel. This work package will be run in collaboration with micro-calorimetry (MC) tests in order to calculate activation energies and verify the MC technology.

Project plan

The work package task will follow the plan below:

1) Identification of critical components in all plants

2) Possibility to extraction the components from plants

3) Estimating their residual and total lifetime.

4) If possible, order samples made from the same material from the supplier

For year two the plan was to continue with the workshops with NPPs. Based on these discussions' selection of interesting materials from closed NPPs and/or from outages should be made and find suitable reference materials. And a preliminary test plan for year 2-4 will be made.

Methods

The workshops that were held at Ringhals NPP and Forsmark NPP have been the main method to identify critical and interesting materials for further investigating. In a first stage focus was set on Ringhals because of their upcoming decommission of two reactors but during the decommissioning time it will be hard to get out materials because critical components will still be in used in the reactors for several years to come.

Discussion of materials of special interest for the project were also held at the SAMPO workshop at Fortum, Espoo in November 27-28th 2019.

For investigating residual lifetime of the chosen and obtained materials some testing has been initiated. This initial investigation of the materials has included testing of hardness, tensile strength, and elongation at break.

Results and discussion

Workshops with NPPs

Workshops have been held at Ringhals NPP (29 Oct, 2019), at the seminar days at Fortum, Espoo (27-28 Nov, 2019) and online with Forsmark NPP (21 Sept, 2020).

Summary of comments on interesting materials and other inputs from all workshops:

- Cables
    - New cables from Nexam at Ringhals
        - There is not much information about the material's long-term properties for cables outside the containment besides the supplier's certification, consisting of polyolefins.
        - Indenter measurements work poorly for these cables: alternative method?

    - PVC cables from the containment used for a long time may be interesting to check, however, most PVC cables are exchanged to other material.

- Valve membranes
    - replaced relatively often and it is interesting to investigate possibilities for possibile extension of maintenance intervals.
    - there are materials of the same type with several different exchange intervals to test on
    - May be more interesting than o-rings as it is more critical in case there is leakage.
    - Previous tests have been done with accelerated aging on natural rubber and EPDM membranes in shell valves from Ringhals this can be used for comparing used membranes. Tensile tests are also made on a membrane used for 12 years, which showed that it was a bit more "aged" than expected.
    - The reinforcement can be the weakest part of the membranes, this could be investigated more
        - What kind of reinforcement is sensitive?
        - Important to look at both ageing properties of the reinforcement material and adhesion between the rubber and reinforcement

- Test of LOCA or other accident simulation on replaced materials, as well as on accelerated aged material.

- Cable penetrations
    - Brattbergare is already under investigation

- Joint mass between concrete elements (e.g. between ceiling and wall)
    - Much of the material has been changed recently, and this has already been investigated.

- Seal between joists
    - Both TVO and Forsmark have some test coupons of joist seal which were installed on at the same time as the actual sea for test purpose. The TVO material is a reinforced EPDM and the Forsmark material is chloroprene.

- Dome seals in highly radiated environment (Forsmark) made in Shieldseal 663 from James Walker
    - These seals are changed every year
    - Probably not possible to get clearance to take out the material from the NPP
    - Shieldseal 663 is similar to the EPDM designated LR9444 provided by James Walker for the COMRADE project

Selected materials for testing

EPDM o-rings were selected as a special point for interest, as these materials are easy to obtain and may be compared to the tested materials for verifying results in COMRADE WP1 and SAMPO WP1 T3. They are common in the NPPs and are regularly replaced. But due to small sample size a lot of o-rings needs to be collected to get a statistically good data set. This requires further discussions with NPP maintenance department before outtakes to help us collect the material.

Neoprene membranes from Ringhals NPP: Ringhals has collected membranes from earlier revisions and the collection contains several membranes of similar type and of similar conditions and time in use.
- Outtake was made in September 2018
- They have been in the plant for 8 years (which is maintenance interval)
- There is membranes of three dimensions 40, 19 and 17.5 cm in diameter
- All neoprene membranes come from two systems: (liquid waste processing system (WP)) and (Sampling System (SS)). The sampling system is a giant system consisting of many different parts. Neoprene membranes come from pneumatically operated valves, which means that the membrane is at the top of the valve and does not come into contact with process water. Thus, it does not experience the temperature of the water medium. The temperature to which they are exposed is the ambient and air that pushes the membrane that triggers the opening or closing of the valve.

Reinforced EPDM seal between structure joists from TVO
- Installed in 2005, planned lifetime until 2025
- Exposure temperature 45 °C, during power operation in nitrogen atmosphere, after outage it has been stored in air
- Installed in L-shape
- Should withstand LOCA, the LOCA profile would be some time at 2,4 bar and 95°C followed by some time at 3,7 bar and 170°C

Test program

EPDM o-rings

What type of testing we will perform on the o-rings is depending on how much and what information about the material we will get. Examples of test methods: Tensile test, stress relaxation, TGA, DSC OIT – will be continued in year 3 and 4

Neoprene membranes

Tensile test; tensile strength and elongation at break – was done in year 2
Hardness – was done in year 3
Stress relaxation – year 3
High temperature test – year 3

EPDM joist seal

Artificial aging in 45 days – was done in year 2
Tensile test; tensile strength and elongation at break – was done in year 2
Micro calometry – was done in year 2 (see report for task 2.2)
Hardness – was done in year 2
Stress relaxation – year 3
LOCA test – year 3

Results from testing

Test methods

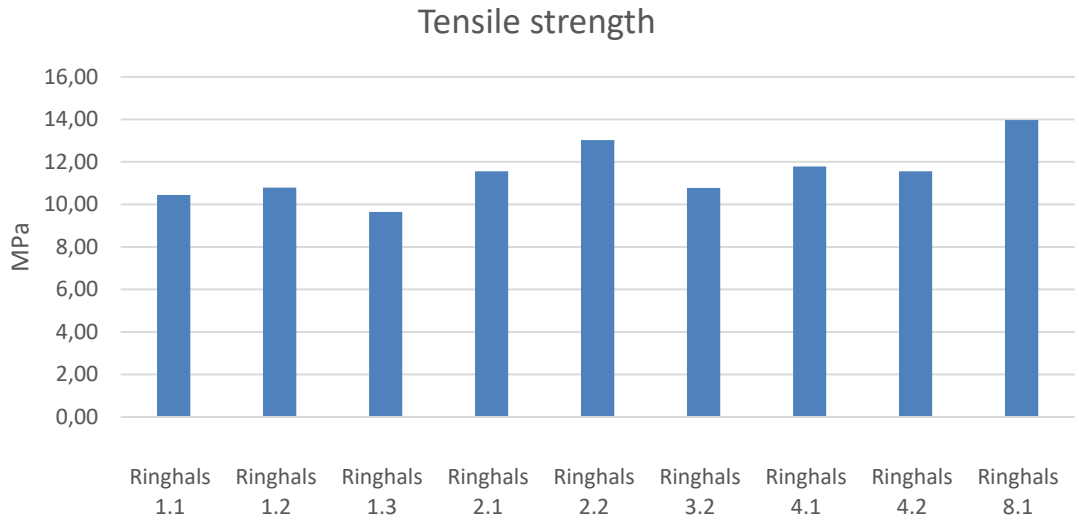
The membranes and the joist seal were reinforced so the rubber material was cut off and punched into dumbbells.

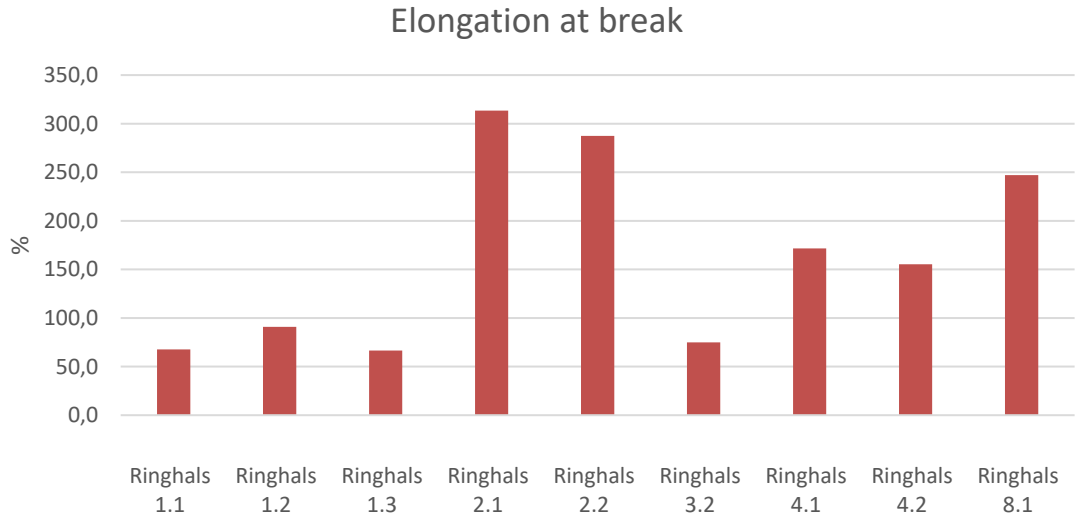
Tensile testing was made according to ISO 37 with type 2 dumbbell on a Zwick Z1 tensile tester at a rate of 500mm/min and with a clip-on extensometer.

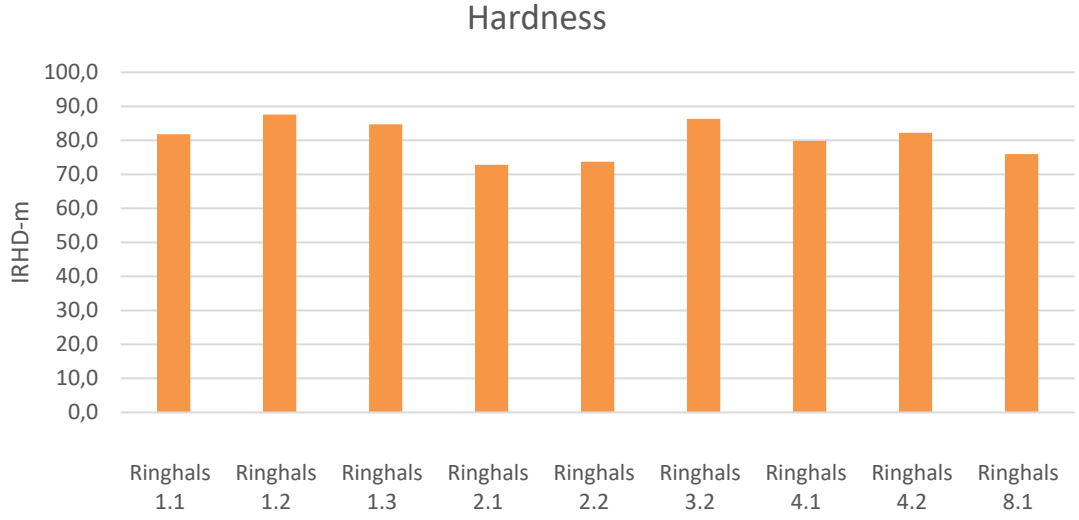
The hardness was measured according to ISO 48-2 on a Bareiss Digitest Hardness Tester equipped with an IRHD-m measuring device.

Testing of membranes from Ringhals

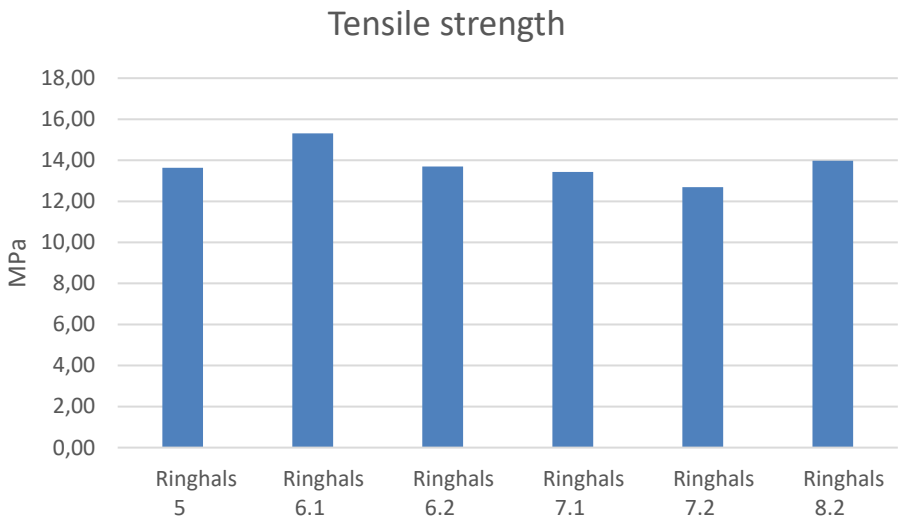
Membranes d = 17.5 cm

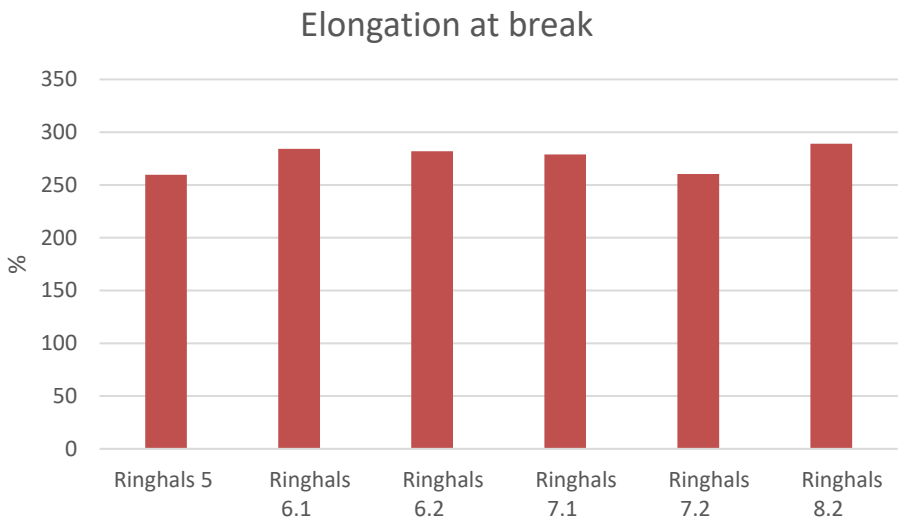


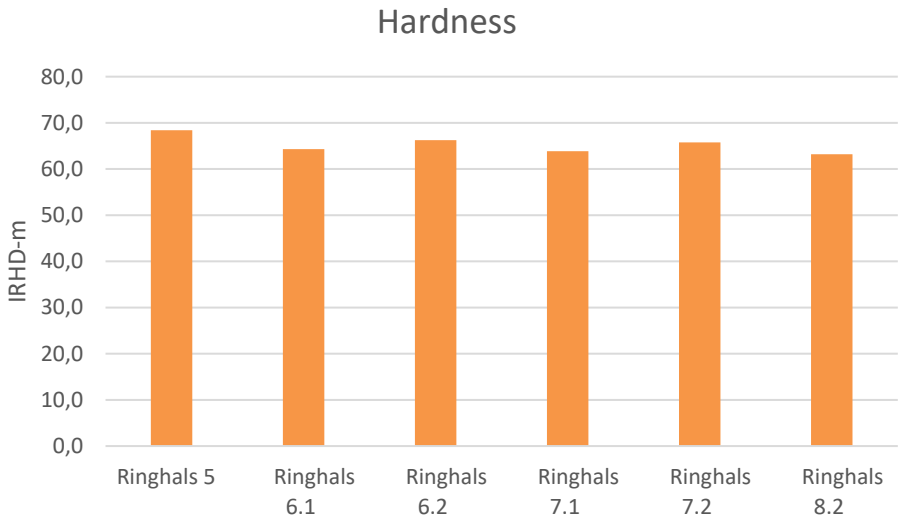




Membranes d = 19 cm







Testing of joist seal from TVO

The material was heat aged in 120 °C for 45 days.

	Tensile strength (MPa)	Elongation at break (%)	Hardness (IRHD-m)
naturally aged	6,92	294,5	72,4
naturally+heat aged	7,01	283,1	78,3

Conclusions

- Materials were chosen on suggestions from workshops
- An initial test plan was made
- Testing of two materials
    - Membranes
        - For the 17.5 cm membrane there were some difference in the test results between the samples, you can see that the membranes with the same first digit is more alike each other, they were placed in the same bag and thus taken from the same environment
        - For the 19 cm membrane the result was more similar between the samples
    - TVO seal
        - Not much difference after ageing
        - The aging was made in air which is tougher for the material than the nitrogen atmosphere it is used in the plant

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