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Final Report

on Deliverable

PPPT EUROFER 97 Material Handbook 2016

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| **Executive Summary** |
| MPH on EUROFER97 (grand deliverable) is ready after two years co-operative work of KIT and MTA EK. Organisational, content and editorial changes to the EUROFER97 MPH based on comments, and peer review are implemented. New data from the literature and enhanced analyses on some properties are also performed. This volume is a pilot volume for the DEMO structural materials MPH volumes, and the format can be used for other DEMO MPH-s. Revision recommended after 5 years, or when large number of new data will be collected. |

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| **Comments** (shortcomings, deviations, etc.) |
| *if any please shortly indicate here* |

*{Guidance on Report format given below, this is not mandatory and can be modified as required}*

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**Abbreviations**

|  |  |
| --- | --- |
| *DEMO* | *Demonstration Fusion Reactor* |
| *MPH* | *Material Properties Handbook* |
| *MTA EK* | *Energy Reserach Centre of the Hungarian Academy of Sciences* |
| KIT | *Kasrlsruhe Institute of Technology* |

# Short Introduction and Objectives of Work

MTA EK made application in 2013 for irradiation and PIE of DEMO materials. Modeling and understanding of flux effect, requires high and medium fluences irradiations too. MTA EK offered medium flux and fluence irradiations of different structural and other materials. The proposal were accepted, but the irradiation program delayed and changed, than MTA EK offered to participate in the WPMAT database and DEMO MPH elaboration. The institute have excellence in this filed too: elaborated the IAEA International Database on Reactor Vessel Materials and participated in the ITER MPH elaboration with the Titanium alloy section.

In 2014 MTA EK elaborated an format, content, and a sample file for the MPH. This file contained full size sample sheets of an structural material MPH chapter. Only one comment arrived from KIT, otherwise the format, and the content accepted. In 2015 the task was to elaborate a pilot chapter on EUROFER97. Decision have been made to use the existing database at KIT. The database access delayed since the safe delivery of it from KIT to MTA EK take time. When the database arrived MTA EK started the evaluation. Parallel with it KIT also made evaluation ( they document PPT Material Handbook....) had been upload to a personal section of IDM. MTA EK repeated all analyses made by KIT and extended it with own recommendations and analyses. Good co-operation started between the two institute and the first version of the pilot EUROFER MPH have been made until 31 December 2015. Unfortunately several decision have been made when the pilot version of the MPH have been ready. The file format have been changed for book format, and the points had to be deleted from the diagrams. If this decision would made when the format elaborated and the sample files provided some extra work, several late corrections would have been avoided.

In 2016 the task of MTA was : "Support from MTA to implement organisational, content and editorial changes to the EUROFER97 MPH based on comments and peer review of 2015 deliverable".

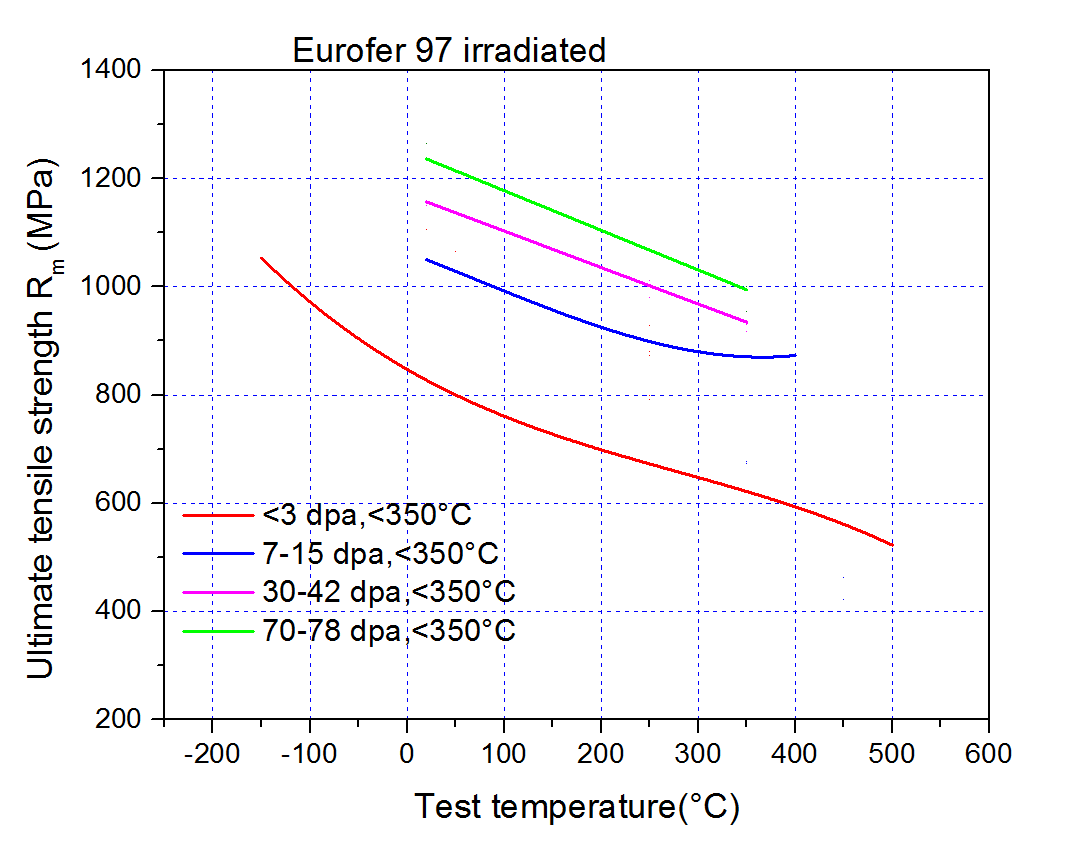
# Description of Work

Several changes have been performed on the pilot version of the MPH.

The changes can be divided into two groups: editorial changes and changes enhancement or extensions of the content.

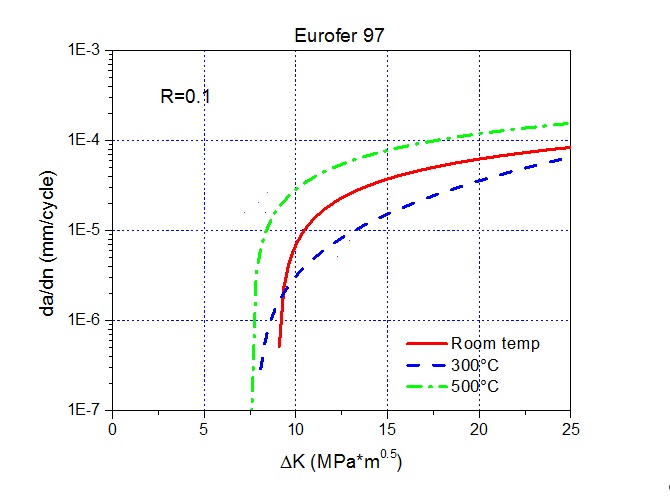
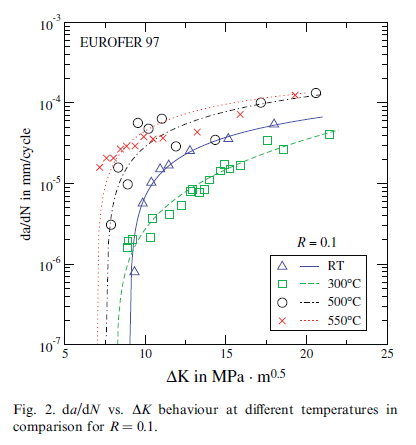
The content have been extended some new property. The KIT structural material database mostly includes the mechanical properties, and the physical properties have been collected from the literature, or from reports. Several property have been re-analysed since the extension of collected knowledge. The analyses of the data is relatively easy in the case of standard as-received material. The main steps are as it follows: data collection, evaluation (whether is it acceptable high level data or outliner. Is outliner can be important or is it erroneous? After the data selection a function (generally an polynomial have to be fit on the data to get the average trend curve. The proper selection of the polynomial level is important: if it is too high the use of it difficult, if the level is not high enough the fit may causes deviations form the real values. Also the decimals of the fitting constants have to be carefully selected. Too many decimals are not user friendly, too few causes errors in the calculated values. Sensitivity analyses used to find the best compromise. The final step was to elaborate the diagrams and tables of the property.

Working with aged EUROFER the is more difficult. There are several parameters to consider: irradiation fluence, spectra, flux, temperature, testing temperature. The designers minimum requirement to know every material property in the function of operating temperature and fluence. The available number of combinations are too large to measure all, and long term irradiations are very expensive and time consuming. Since the irradiations performed in different reactors (different spectra, different flux, different irradiation temperature) the scatter of the data are large. The only way of the evaluation is to make groups from the available data and provide the average curves. Several grouping may be made from the available limited number of data. To select the best grouping many attempt and considerations, knowledge of the ageing mechanism is required. After proper grouping the procedure of analyses for every group is the same as in the case of as received material. (See figure 1).



***Figure1****. Irradiated Eurofer data filtered into groups according to the fluence values.*

In case of literature data the first step is evaluate the reliability and usefulness. Many paper, conference presentation (and sometimes research report too!) doesn't identify properly the tested material or the ageing conditions. Such data are not, or only after comparison with other data can be used for prepare a design trend curve. Some data are correctly published, but not useful for preparing trend curve for designers.



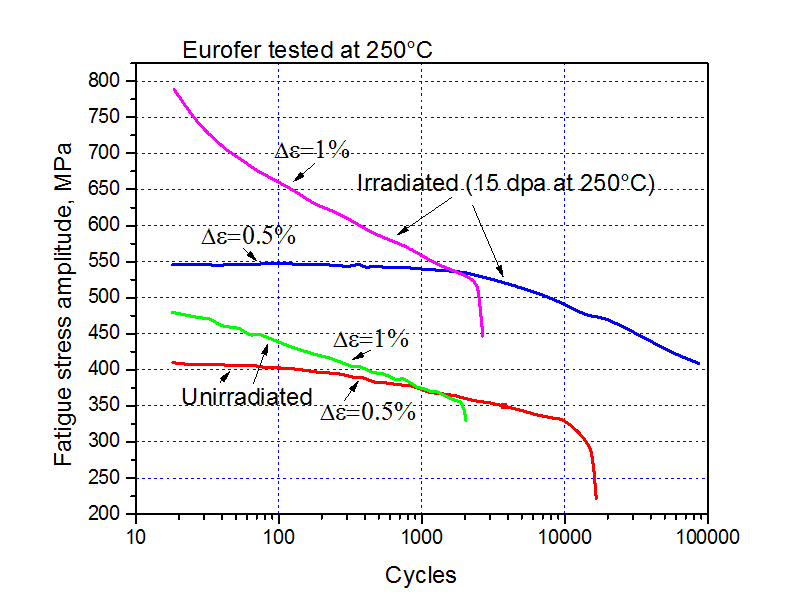
***Figure 2****. The original published picture on fatigue crack growht (left) and the figure in the MPH (right). The difference is the points measured at 550°C deleted, since the explanation of the strange behavor is too difficult, and may mislead the user without metallographic knowledge*.

The EUROFER MPH elaborated mostly in 2015 in co-operation between KIT and MTA EK. Analyses made by one institute had been repeated by the other one. Differences between the solutions or calculations discussed and solved. This is a basic step of quality insurance. Many times the way of analyses have been discussed personally, or by e-mail exchange, by VC.

In 2016 the planned task was to finalise the document, mainly editing according to the advices of the designers. Finally much more work performed, again in close co-operation between KIT and MTA EK. The short description of the tasks fulfilled at 2016:

Design allowances have been included into the EUROFER MPH. The inclusion of the design allowances were not planned in the original format (they are not material properties, since they can be calculated from the material properties according to the relevant design code. The ITER MPH isn't contained design allowances. The advantage to include design allowances is extra information for the designers, the disadvantages, that the different codes may use different design allowances and it can mislead the designers in future). The inclusions of them required to take into separate paragraphs of them, to separate from the measured material properties, since the use of them is different.

Several material property analyses reviewed, and three new property included. As an example see figure 3.



***Figure 3****. Comparison of low-cycle fatigue toughness of as received and irradiated Eurofer. (simplified diagram based on literature)*

Typical editorial changes was to renumber of the figures. The inconvenience of the book format is that any corrections or extensions change the list of content, reference list, and the number of the figures and tables. The advantage of the book format is easier to use than the sheet format. The difficulties since the book format partially have been solved by using chapter numbers before the figure and table numbers. The another suggestion was to organise the property sheets (in book now called chapters) in order of meanings (mechanical properties, physical properties etc.) . It also took efforts, 75 pages of the book had to be re-ordered.

It was requested, that only the trend curves can be published, the measured data points shouldn't be in the figures. More than 70 figures had to be changed.

The present version of the EUROFER MPH contains 25 files and trend curves or data for the following 22 mechanical and physical properties:

1. [General information on EUROFER97](#_Toc465180893)
2. [Chemical composition](#_Toc465180894)
3. [Density](#_Toc465180895)
4. [Yield strength](#_Toc465180896)
5. [Tensile strength](#_Toc465180897)
6. [Elongation](#_Toc465180898)
7. [Reduction of area](#_Toc465180899)
8. [Young’s modulus](#_Toc465180900)
9. [Poisson’s ratio](#_Toc465180901)
10. [CHARPY impact energy](#_Toc465180902)
11. [Fracture toughness](#_Toc465180903)
12. [Fatigue-crack-growth rate](#_Toc465180904)
13. [Fatigue](#_Toc465180905)
14. [Creep](#_Toc465180906)
15. [Linear thermal expansion](#_Toc465180909)
16. [Thermal conductivity](#_Toc465180910)
17. [Thermal diffusivity](#_Toc465180911)
18. [Specific heat](#_Toc465180912)
19. [Electrical resistivity](#_Toc465180914)
20. [Magnetic saturation](#_Toc465180915)
21. [Remnant magnetization](#_Toc465180916)
22. Coercive field

Empty chapters prepared also for [Swelling](#_Toc465180907), [Ratchetting](#_Toc465180908), and [Melting temperature](#_Toc465180913), due to the lack of data.

# Conclusion

The EUROFER MPH is ready after two years good co-operation of KIT and MTA EK. It have been elaborated on the base of structural materials database (supplied by KIT) and using the open literature.

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1. One *Deliverable Report* shall be submitted for each deliverable e.g. Study Report, Commissioning Report, Final Assessment Report, Technical Acceptance Report, Procurement Report, etc. [↑](#footnote-ref-1)