4 Fusion Technology Research and Development

Fusion technology tasks were carried out in seven fields:

- High temperature superconducting materials for fusion magnets. Measurements of the normal state properties of high temperature superconducting materials, evaluation of the consequences for fault conditions of the magnet (thermal conductivity, thermal expansion, normal state resistivity)
- In vacuum vessel dust measurement and removal techniques (Possible kind of measurements of dust produced during plasma transients)
- Calculation of the activation and the decay heat of the components – classification of the wastes
- Nuclear data: benchmark experiments to validate EFF/EAF data
- Preliminary mechanical analysis of a blanket manifold concept for ITER
- Direct costs of nuclear treaties, agreements and agencies
- Exploring lay understanding and reasoning about fusion technology and its applications in power generation

4.1 HTS materials for fusion magnets. Transitory states of the superconductor and its properties in the normal conducting state

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Andrzej Morawski, Daniel Gajda, Andrzej Jeżowski, and Tomasz Plackowski

Abstract

It was already decided that all superconducting winding of ITER will be made from Nb_3Sn and NbTi materials, both working at liquid helium temperature region. Both material have temperatures of superconducting transitions lower than 20K, so the thermal safety margin is not to high and all precautions should be made to avoid the quenching.
It was shown lately, that magnesium boride has very high potential to replace both above materials. It has much higher critical temperature (about 38K) and is much cheaper while its critical parameters are similar or even superior. Especially possibility to operate such superconductors at temperatures of about 20K would give opportunity to switch from helium to hydrogen as a coolant or even to apply lower cost closed-cycle refrigerators. What should be proved is availability of simple and reliable technology to produce long length of such conductors with high enough and steady parameters.
Our investigation at 2007 were just devoted to this subject.

Summary

Wires and tapes made of MgB_2 are prepared and studied in many laboratories in the world. It can be treated as widely accepted, that most promising technology is in-situ, in which magnesium or magnesium hydride powder is mixed with powdered boron, metallic tube is filled with this mixture and then pressing, drawing, swaging or rolling is applied to produce the wire or tape. After final forming heat treatment is applied, which transforms mixed powders into superconducting MgB_2.
Main difficulty in above route of producing the wire is the very high reactivity of dispersed magnesium. That is why as a material used as a sheath if iron. It enables plastic deformation of the material, but requires many interoperation heat treatments which converts some portions of boron into MgB_2, increase the dimensions of resulting grains and make it difficult to obtain the small diameter wires. It also should be mentioned that that the wire which can be used for magnet winding should be stabilized i.e. should posses the layer of metal with high electrical conductivity, which could conduct electrical current in the case of accident, when temperature of superconductor is locally higher than its critical value.

To accomplish our plans for year 2007 we decided to prepare and investigate MgB_2 wires and tapes using copper as a sheathing material and ex-situ MgB_2 as a barrier for magnesium diffusion. We have carried out systematic investigation of the influence of different impurities, usually present in commercially available chemicals necessary to obtain magnesium boride wire (magnesium, boron, copper, iron, silicon carbide, carbon), on technical parameters of obtained wires. Also morphology of material used was studied.

Our work, made in cooperation with the group of Dr. Andrzej Morawski from High Pressure Institute PAS in Warsaw was focusing on following subjects:

- Apart of ultrasonic purifying of commercial powders we used also method of ball milling and SHS (self-propagating high-temperature synthesis) to obtain the powders with really nanometer grain size.
- We have produced long length of magnesium boride wire (300m) to prove applicability of the technology accepted by us for preparation of the reasonably long wires and tapes.
- Although the critical parameters of our wires were lower than the record ones obtained in previous year (above 36 000 A/cm^2 at magnetic field of 12T and above 34 000 A/cm^2 for the field of 14T), but the latest results are very similar, and we understand much deeper

the technological processes influencing these parameters. We are sure these parameters will improved next year.

- We decided to concentrate our investigations on silicon carbide as the material increasing pinning at magnesium boride wires and tapes, although in cooperation with the Leibniz Institut fur Festkoerper und Werkstofforschung in Dresden we are continuing experiments with nano-diamond addition as the pinning centers in MgB_2.

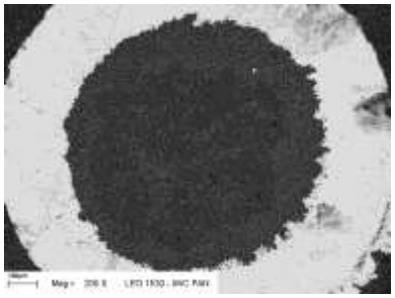

Figure 1 SEM of the copper sheathed wire wirh MgB_2 ex-situ barrier (outer part) and in-situ filling

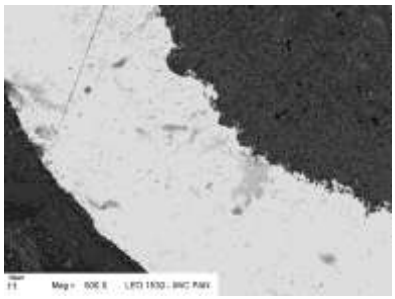

Figure 2 The detail of Fig1 showing the effectivness of ex-situ MgB_2 barrier for magnesium diffusion

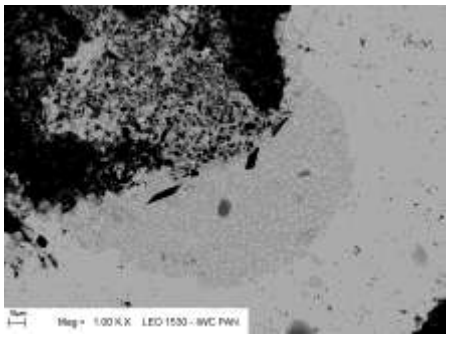

Figure 3 Example of the wire where diffusion barrier was broken. The instant diffusion of magnesium into copper and copper into ex-situ MgB_2 is clearly seen

On Figures 1-3 the effectivnes of the ex-situ MgB_2 barrier for magnesium diffusion is presented.

Conclusions

- We have developed the technology of preparing long length (up to 300m in 1.4 mm in diameter) of in-situ magnesium boride wires sheathed with copper (what gives them necessary thermal stabilisation) for which the barrier for magnesium diffusion was made from ex-situ magnesium boride. Although the critical parameters of the first obtained wire was not too high (because the quality of used magnesium and boron powders were low), they proved that the ex-situ MgB_2 barrier works perfectly, the technologically necessary inter-operation heat treatment may be done at much lower temperatures, and there is not any problem to reduce the diameter of such wire below 1 mm or prepare the tape from it, with the thickness of about 0.1 mm.
- We have proved, that ex-situ MgB_2 is perfect barrier for copper sheathed in-situ magnesium boride wires. We showed that the technological easiness and simplicity, and low cost of producing such wires even already now gives them advantage over NbTi wires while used at liquid helium temperatures, while for closed cycle refrigerators temperatures - its superiority can't be beaten.

Collaboration

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4.2 In vacuum vessel dust measurement and removal techniques: possible measurements of dust produced during plasma transients

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Paweł Gąsior

Abstract

In the Report there is included the study of measuring methods and instruments applied in a number of laboratories for dust diagnostics. In particular, it contained the following sections attributed to these issues: Background, Microbalance methods, Direct camera observation and scattering methods and methods developed in dusty plasma field. In the autonomous section: Application of pulsed laser light and optical spectrometry for removal and characterisation of deposited dust, the preliminary investigation performed in IPPLM in Warsaw has been described.
On the basis of the comparison of different diagnostics applied for characterisation of dust in thermonuclear devices it can be concluded that the methods using laser techniques for various measuring applications are very promising.

Summary

The review of possible measurements of dust produced during plasma transients has been prepared on the basis of documentation (mostly publications) related to different methods of characterisation of dust in tokamaks and in other physical domains – specially dusty plasma physics. We have included in this document results of our preliminary investigations of co-deposited dust removed from the TEXTOR tile with the use of laser ablation.

Generally, we have considered that most presently known diagnostic methods can be developed for application in the ITER conditions. Reported investigations of dust properties were performed on the following assumptions:

- the dust formation is significantly lower during normal pulses in comparison with plasma transients and plasma disruptions,
- the large range of dusts properties (size, elemental composition, shape, location) should be considered,
- the complexity of the measurement is due to the large range of dusts and to the properties of environment.

The two approaches were applied in discussed studies for characterisation of dust properties:

- measuring methods which interfere with the in-vessel conditions at the minimal level such as photonic methods based on the scattering (Rayleigh, Mie – extensive experience at DIIID) mechanisms to characterize dust (estimate grain size, distribution, chemical composition, production rate) present in the volume of the vessel; even direct camera observation of dust particles ablating at the edge of plasma may be useful (Alcator experience),
- measuring methods which can operate in harsh environmental conditions to measure the dust deposited on the walls, tests of microbalance methods (looking for sensors insensitive for high heat and neutron loads – one of candidates – Capacitive Diaphragm Microbalance, CDM), Electrostatic Surface Particle Detection (experience at NSTX) and investigation of potential application for special fiber-optics sensors. Data collected from these sensors may appear necessary for estimating vessel inventory to ensure operation in the safety limit conditions.

In the Report we describe our preliminary experiment on laser ablation removal of co-deposited dust controlled by an optical spectroscopy system. The results of this investigation show the efficiency of this method for on-line observation of co-deposit removal. Analysing the spectra recorded by the

spectrometer one can estimate the elemental content of ablated material and change of this content during subsequent laser shots; therefore, this method enables to estimate the depth distribution of different elements in the deposited layer of dust.

Simultaneously with optical measurements, the laser-ablated material was collected on the surface of glass and metallic substrates located at different distances from laser illuminated graphite tile. The collected dust was roughly characterised with the use of optical microscopy as well as SEM and NRA in collaborating laboratories (FZJ, Juelich, IPP ASCR in Prague and in Alfven Lab.). These works are to be continued.

Conclusions

On the basis of comparison of different diagnostics applied for characterisation of dust generated, transported and deposited in thermonuclear devices it can be concluded that the methods using laser techniques for different measuring applications are very promising. This conclusion is well supported by our tests of applying laser radiation for deposited dust removal and for ionisation or excitation of evaporated material combined with spectral analysis and characterisation of collected dust ablated by laser light.

Collaboration

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4.3 Calculation of the activation and the decay heat of the components – classification of the wastes

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Abstract

An estimation and characterisation of the life-time induced activity in fusion reactor is the base of classification of the used materials in view of radiotoxicity. The respective quantitative characteristics are: Clearance Index, (CI) deciding of the clearance of materials, the Contact Dose (CD) and heat of its radioactive decay i.e. the Heating Rate (HR). The present study has laid in evaluation of the above characteristics of DEMO waste, searching, among others their time behaviour and significance of particular nuclides. These calculations of induced activity in the DEMO system brought about valuable results, e.g. indicating sometimes the dominant contribution of very rare reactions or nuclides within about 100 years of decay. Apart from this some interesting questions left opened, (e.g. validity of homogenised model of DEMO) as lying beyond the scope of this work, deserve future studies.

Summary

In view of the problems with social acceptance, limited burial facilities in the EU and foreseen scarcity of materials an optimum management of those used in fusion installations has to be developed. Importance of this issue is due to the fact that high material inventory and consumption will strongly influence the economy of fusion power. Solution of this problem requires first a reliable estimation and characterisation of the life-time induced activity in fusion reactor that will allow, first of all, for the classification of the used materials from the point of view of their radiotoxicity. The radioactive inventory arises in the process of the activation of materials exposed to the D-T neutrons from plasma.

The classification of materials follows the evaluation of the induced activity that allows for assigning to the following pertinent characteristics namely: Clearance Index, (CI) which, if proves less than unity enables the material in question to receive desired clearance, the Contact Dose (CD) that determines difficulties of material's handling and heat of its radioactive decay that imposes necessary cooling expressed by the Heating Rate (HR).

The induced activity, obviously, strictly depends also on the operation of the reactor, determined in turn, first of all by availability of the i.e. random failures on one hand and planned interruptions – on the other. Thus, a schedule of breaks in reactor operation has been assumed: once per year but of pertinent length and the time horizon 40 years long reflecting the gradually increasing availability (10%, 33%, 50% and 85%) in successive decades.

The above mentioned parameters of DEMO waste: CI, CD and HR have been evaluated in hundreds cells of the DEMO model and their time evolution within time intervals $0 \div 100$ or sometimes $0 \div 1000$ years. For illustration of the performed calculations just the distribution of HR in the Vacuum Vessel has been selected.

The assumed time structure of DEMO operation is reflected in the decay heat of VV vs. time. On the basis of the observed decay by two orders of magnitude within one year and negligible influence of the availability of DEMO one can deduce that the heating is determined by short lived nuclides. Apart from the above the striking differences in the decay heat depending on poloidal angle suggest that activity of deeper layers (as seen from the plasma) seems sensitive to the source positioning. Much stronger effect one should expect while having taken the neglected here streaming into consideration.

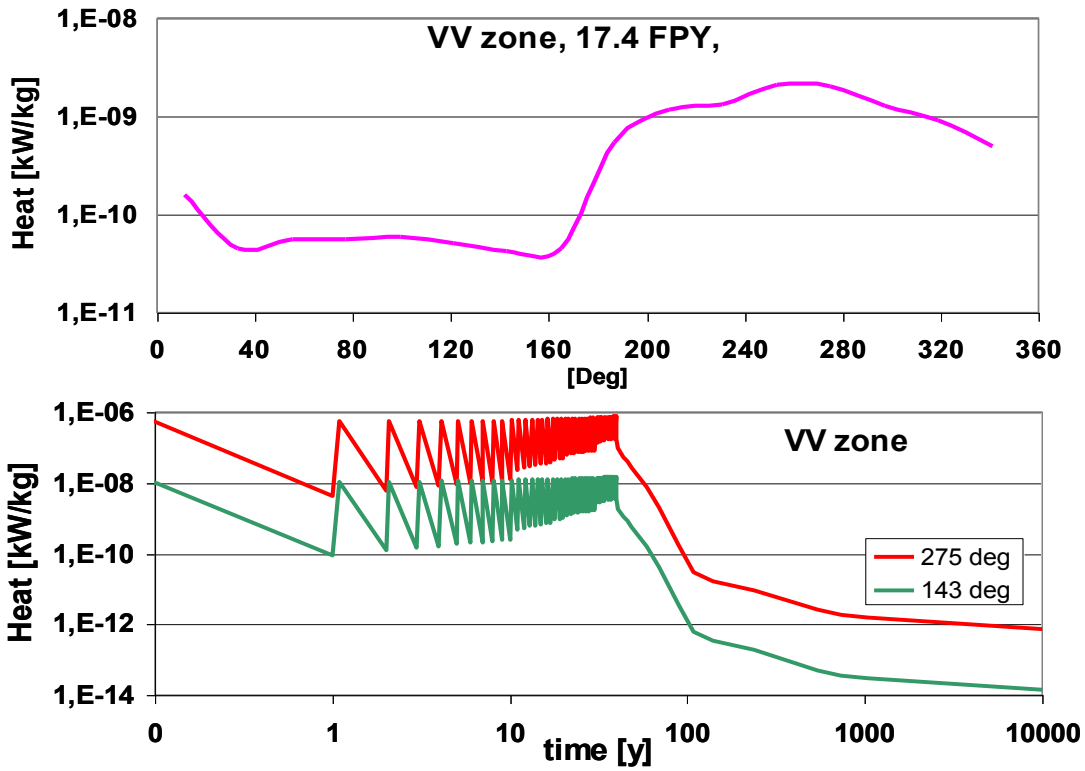

Figure VV decay heat distributions vs. poloidal angle (top) and vs time (bottom).

Conclusions

The evaluations of induced activity in the DEMO system brought about interesting results. Sometimes the contribution of very rare reactions or nuclides proved dominant already within about 100 years. Since the CI is a measure of material activity (that is independent of associated energy) the behaviour of decay heating is not necessarily identical with the one of CI. As a result one can observe rather different trajectories vs. time of the above parameters. The heating within the 40 years interval increases less and after these 40 years drops deeper (ca. 4 orders of magnitude) than the Clearance Index.

Also on the basis of a previous study [5] one should repeat that the neutron transport and the respective phenomena as, for instance, the neutron induced reactions in the zones placed deeper (as seen from the D-T sources) are not correctly represented in homogenised models of the reactor. The lack of streaming effects leads underestimation of the induced activity in the zones in question. A detailed description of the reactor structure seems necessary.

The mentioned in the introductory chapters of the present study material recycling (in view of expected reduction in consumption of materials, thus also a cost reduction of fusion) is described as one of key factors in the strategy for the fusion. However, the final concept of material management and respective proceedings would require first a thorough economical analysis. Such studies have to take into consideration the very basic trade-off: higher consumption of fresh materials and such the respective storage after use vs. lesser consumption of fresh materials and then easier storage of the used ones, but at much more difficult and costly dealing with (fabrication: melting, rolling, machining etc.) radioactive materials. This question as lying beyond the scope of the present study was not further discussed here, but certainly requires attention and should be undertaken in future investigations.

Collaboration

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Association EURATOM – FZK, Karlsruhe, Germany

References

[1] D. Maisonnier et al., A Conceptual Study of Commercial Fusion Power Plants, EFDA-RP-RE-5.0, 2005

[2] R. Pampin, V. Massaut, N. P. Taylor, *Revision of the inventory and recycling scenario of active material in near term PPCS models*, Nucl. Fusion, 47 (2007) 469-476

[3] R. Pampin, W. Pohorecki, M. H. O'Brien, DEMO: Neutronics and active material assessment, DEMO Meeting, EFDA, Garching, Nov. 2007

[4] W. Pohorecki, S. Taczanowski, M. Kopeć, Results of material activation calculations of DEMO plant; DEMO Meeting, EFDA, Karlsruhe, Nov. 2007

[5] S. Taczanowski, W. Pohorecki, M. Kopeć, *Activation of the divertor region as a function of different designs and configurations*; Fusion Engineering and Design, vol.82 (2007) pp. 2089-2094

4.4 Nuclear Data: Benchmark Experiments to Validate EFF/EAF data Measurements of the tritium production with the use of Thermo-Luminescence Detectors (TLD) in the neutronics HCLL TBM mock-up

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Abstract

Neutronic codes and nuclear data need to be validated in order to assure reliable results when applied in design calculations. Validation of Test Blanket Modules (TBM) design calculations is achieved through integral benchmark experiments where mock-ups are irradiated with 14 MeV neutrons and nuclear responses of interest are measured and compared to calculations, which closely simulate the experimental set-up. Very important one is the tritium production rate (TPR) crucial for the thermonuclear reactor proper functioning. Here the use of the Thermo-Luminescence Detectors (TLD) for T proposed and preliminary tested.

Summary

In the frame of the EFDA Work Programme the field of Nuclear Data and Neutronics is embedded as a part of the the neutronic aspects in the design, safety and future operation of the ITER, IFMIF and DEMO including the neutronics tasks for TBM. For the purpose of the further development and upgrade of the European Fusion File (EFF) and the European Activation File (EAF) dedicated neutronics benchmarks experiments are planned. One of them is helium-cooled lithium-lead (HCLL) TBM mock-up serving for design and performance analysis of the DEMO Test Blanket Modules to be inserted in ITER for testing purposes

The objective of the present work is to measure the Tritium production using Thermo-Luminescence Detectors (TLD) in the neutronics HCLL TBM mock-up. The mock-up will be irradiated at FNG 14 MeV neutron source for sufficient long time in order to obtain a measurement of the Tritium production in LiF pellets with the desired experimental uncertainty. Expected total 14 MeV neutron output should reach $10^{15} – 10^{16}$ value during several days of irradiation.

In the 2007 the preparative works were performed:

1) The project of the design of the the implementation of Thermo-Luminescence Detectors in the experimental set up was proposed, discussed and accepted.
2) The way of the conversion of the LiF into liquid form without loss of the generated ^{3}H was assessed and fixed,
3) The method of ^{3}H measurements in the TLD pellets applying LSC technique – was successfully tested and introductory measurements were performed as well
4) For the sake of the preliminary calibration 3 sets of 30 TLD's have been exposed for 3 different irradiation times in MARIA nuclear reactor in Swierk near Warsaw with neutron flux – 2.5×10^{13} /5.5×10^{11} (thermal/fast) [n/cm^{2}s]
5) the preliminary post irradiation TLD light output measurements measurements were performed. It was concluded that during one simple readout there is no significant loss of the T from TLD pellet.

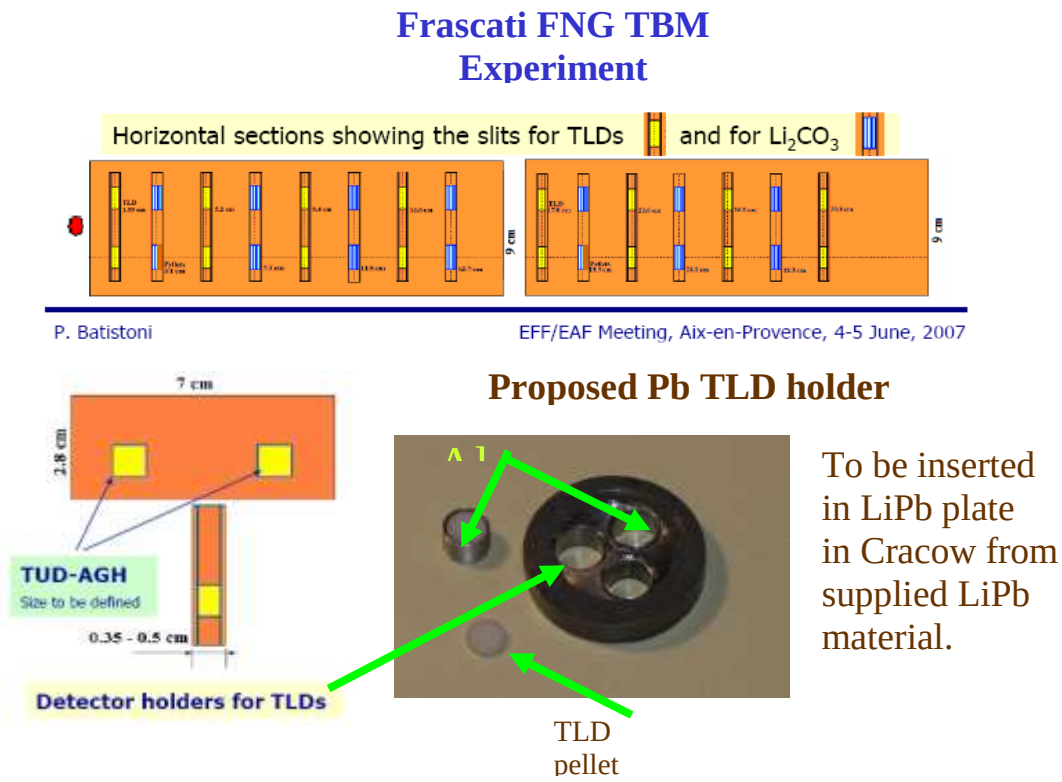

Figure 1 Samples in the the HCLL mock-up

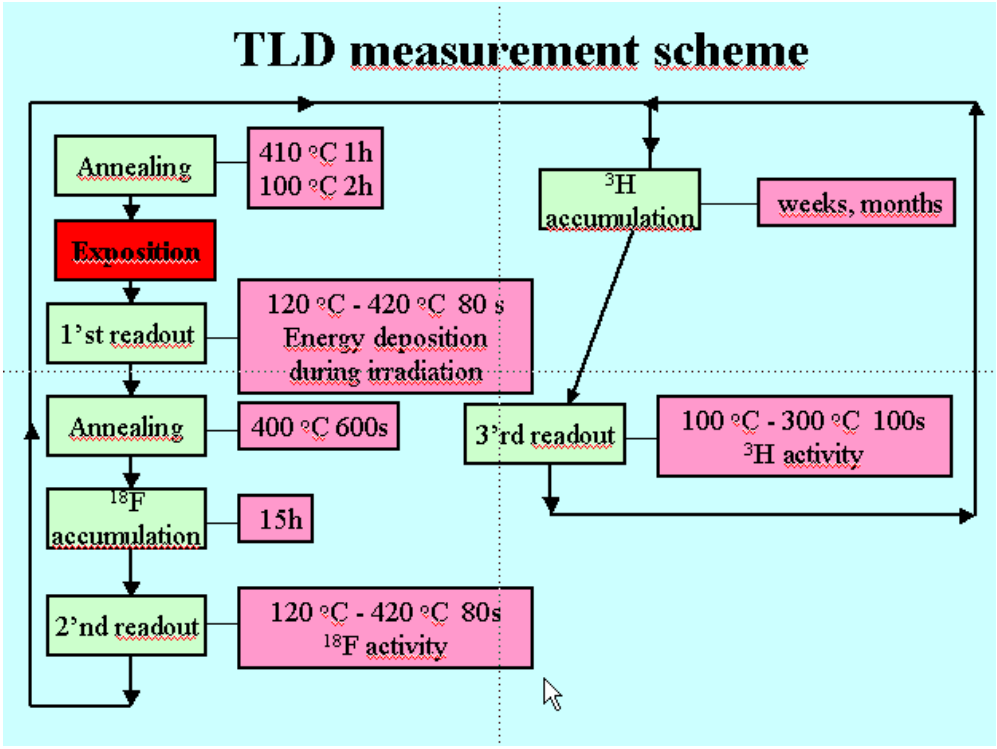

Figure 2 Tritium measurement procedure scheme (fast neutron field)

Conclusions

During the design and preparation of TBM - HCLL neutronics experiment ^{3}H measurement method with the use of Thermo-Luminescence Detectors was proposed and implemented in the TBM mock-up construction plan. The absolute calibration method of the TLD response against intrinsic tritium

activity with the use of the Liquid Scintillation method was proposed and preliminary tested. For the sake of the preliminary calibration 3 sets of 30 TLD's have been exposed for 3 different irradiation times in MARIA nuclear reactor in Swierk near Warsaw. It is concluded from the first TLD measurements results that during one simple readout there is no significant loss of the T from TLD pellet. The calibration procedure is still investigated and depending upon the obtained results could be repeated in less intensive neutron flux.

After irradiation in TBM setup, the same calibration method will be checked.

Collaboration

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4.5 Preliminary analysis of a blanket manifold concept for ITER

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Abstract

The aim of this work was to perform the 3-D finite element stress analysis of the manifold concept proposal (pipe option). The analysis assessed the stresses in the two longest pipes and their supports for different considered loads and boundary conditions.
The finite element analysis was performed for the longest inboard and outboard pipes according to the technical specification presented in the document 07-1621AnnexA.doc and later correspondence. The 3D FE models of the pipes have been built using the CATIA databases. Different cases of supports distribution, including seizing, were considered. The presented study was performed to supply the information about displacements and stresses for further discussion enabling to define the final design.

Summary

The ITER Blanket-shield system is the innermost part of the reactor directly exposed to the plasma. Its basic function is to provide the main thermal and nuclear shielding to the vacuum vessel and external reactor components.

The EFDA CSU Garching in the frame of the on-going ITER design review has elaborated a new manifold concept. Single pipes of 48/54 mm inner/outer diameters supplying the water to each module have replaced the original welded structure. These pipes are routed at the same location as the present manifold design, minimizing therefore the design changes of the present ITER vessel and in-vessel systems. Thermal mechanical analyses need therefore to be performed to substantiate this proposal.

The 3D finite element models were built using ANSYS program. The geometry was imported from the received CATIA files.

According to the technical specification the following cases of loads have been selected in the preliminary analysis:

- TH – thermal load corresponding to the heating of the pipe in relation to the support (ΔT=50K, from 100°C to 150°C). In this case also the additional constraint in the middle of the pipe was considered
- EM – electromagnetic load applied in the form of uniformly distributed force along the pipe (q=11kN/m for the inboard pipe, 5kN/m for the outboard pipe), acting in direction perpendicular to the VV shell - outward. The final analyses were performed assuming the EM forces acting towards the plasma
- PR - pressure acting on the internal surface of the pipe p=4.4MPa,
- V0 – inaccurate assembling (displacements 1mm in all directions and the displacement vector [1, 1, 1] applied at the bottom end of the pipe),
- ALL - all components of loads without inaccurate assembling (p=4.4 MPa, ΔT=50K, q),
- ALL+VO - all components of loads with inaccurate assembling (p=4.4 MPa, ΔT=50K, q), V0=[1,1,1]).

The performed analyses were linear.

Using the CATIA database and additional information the realistic parametric model study of the support was performed. The aim of the analysis was to investigate details of the pipe – support interaction and to estimate the stresses within the support. The change of the parameters describing the geometry of the structure (diameters of the support holes, thickness of the support body, thickness of the bronze sleeves) can provide information helpful for the improvement of the support structure.

The importance of different load components based on the final results can be summarized as follows:

Pressure: The maximum von Mises equivalent stress caused by the pressure was always less than 64 MPa. The small increase in relation to the previous results is caused by restraining the pipe in the top chimney.

EM loads: In all analysed cases the stresses are less than 100 MPa. For this type of load, additional constrains applied in Cases 2 and 3 did not affect significantly the stress magnitudes.

Thermal stresses: The great stress concentration (350-370MPa) was obtained in the top chimney for all three cases. It is caused by the additional constraints in this part of the pipe (supports G to J). The highest equivalent stress value was obtained in the elbow near the support J. This local effect may be eliminated by removing the axial constraint at the end of the pipe or/and some of the supports G-J.

Assembly stresses: Results for inaccurate assembling (applied displacement at the bottom of the pipe) are nearly the same for all three cases. The highest equivalent stress (about 400MPa) corresponds to applied radial displacement oat the end of the pipe V0 = [1mm, 0, 0] close to the new radial constraint B. If the assembly inaccuracy at the end of the pipe is the valid assumption this support (B) should be released.

The results of support analyses allowed to formulate the following design considerations:

- The stresses within the pipe are lower for the thicker support. From this point of view the 'flexible support' is disadvantageous.
- The impact of the thickness of the bronze sleeve on the stress concentration doesn't influence much the stresses. The increased sleeve thickness reduces slightly the maximum equivalent stresses.
- The gap between the sleeve and the support should be minimized. The larger gap increases the contact stresses. Additionally the gaps and assembly inaccuracy lead to the geometrical nonlinearity for the static loads and may be a reason of vibrations difficult for numerical simulation.

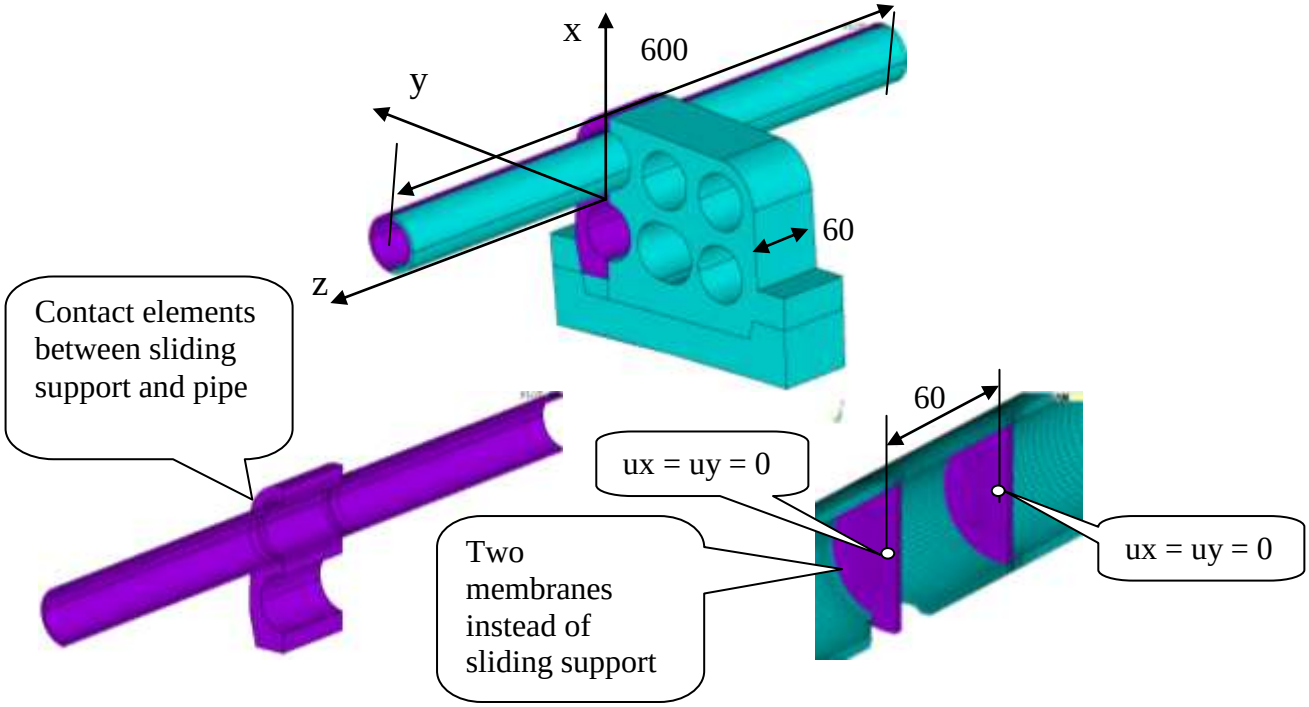

Figure 1 Two models of sliding support

Conclusions

The analyses performed including the additional cases, allow to state that the ne concept of the blanket manifold system seems to be advantageous from the stress analysis point of view. The stress concentration presented for the last three cases are local and may be reduced by eliminating or removing some of the constraints to the level below 150MPa.

The final optimization of the supports distribution should be preceded by precise information concerning the loads components and their combinations. For example, the assumption concerning the assembly tolerances (displacement of ± 1 mm for the bottom end of the pipes in all directions) probably may be released. Also the parametric stress analysis of the presented concept of the support shows that the design can fulfil the strength criteria.

Collaboration

EFDA CSU - Garching

4.6 Direct costs of nuclear treaties, agreements and agencies

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Abstract

The direct costs of international nuclear treaties, agreements and agencies (e.g. surveillance, materials accounting, safe-guarding, etc.) are currently borne by fission alone and come on top of the regulatory process. In the future it can be expected that they will have to be shared between fusion and fission. These costs are currently not included in the energy models of EFDA. In order to take them into account that it is necessary to perform some additional investigation, namely:
- to carry out a literature review and report on the current situation,
- to provide information on the order of magnitude of the above mentioned cost contributions, and
- to assess possible cost to be born by fusion according to a few scenarios of fusion development that will be provided by EFDA.
The main achievements of the project are the following:
→ Establishing general rules of estimation of discussed costs;
→ Reviewing existing nuclear treaties agreements and agencies;
→ Identification of information sources.

Summary

The direct costs of international nuclear treaties, agreements and agencies (e.g. surveillance, materials accounting, safe-guarding, etc.) are currently borne by fission alone and come on top of the regulatory process. In the future it can be expected that they will have to be shared between fusion and fission. In order to include these costs in the energy model of EFDA it is necessary:
- to carry out a literature review and report on the current situation,
- to provide information on the order of magnitude of the above mentioned cost contributions, and
- to assess possible cost to be born by fusion according to a few scenarios of fusion development that will be provided by EFDA.
In particular the following problems have been addressed:
- Establishing general rules of estimation of discussed costs;
- Reviewing existing nuclear treaties agreements and agencies;
- Identification of information sources.

The detailed report (M. Borysiewicz, I. Garanty, A. Kozubal, S. Potempski, Direct Costs of Nuclear Treaties, Agreements and Agencies in the Nuclear Nonproliferation Field, Centre of Excellence MANHAZ, Institute of Atomic Energy, Swierk- Otwock, October 2007 (143 pp)) has been prepared to deal with the following issues:

- *Inventory of International Nonproliferation Organizations & Regimes*: International treaties; Treaties, conventions & agreements related to the IAEA´s work; Treaties, conventions & agreements under IAEA auspices; Safety & Security; Science & Technology; Safeguards & Verification; Organization & Cooperative Agreements.
- *The safeguards system of the International Atomic Energy Agency including*: Legal Basis of Agency Safeguards; Evolution of the Safeguards System 1991 – 2005; Measures to Strengthen the Safeguards System, 1991-2005.
- *Problems of safeguards system implementation*.
- *Safeguards current status*.
- *Financing IAEA verifications of the NPT*.
- *Cost of implementation of nonproliferation regime in states including*: U.S. Financial Support to Meet Safeguards Obligations of IAEA; US FY 2006 Budget request for Defense Nuclear Nonproliferation; Case of Poland.

- *Expanding the nonproliferation regime on a different financial basis*.
- *IAEA Safeguards expenditures and resources*.
- *EURATOM, including*: Operation of the EURATOM safeguards office; EURATOM safeguards resources (budget, staff resources and safeguards equipment).
- *FUSION energy, including externalities and proliferation implications of thermonuclear-fusion energy systems*: Risk assessment of fusion research; Technical points related to thermonuclear weapons and their proliferation; Nuclear Weapons Proliferation Issues of Thermonuclear-Fusion Energy Systems; Common proliferation implications of all fusion energy systems; Neutron abundance: Fusion-fission hybrids and plutonium breeders; Tritium abundance: Boosted-fission and pure-fusion nuclear weapons; Dedicated nuclear weapons materials production facilities; Latent thermonuclear proliferation; Induced nuclear proliferation; Specific proliferation implications of inertial confinement fusion (ICF): Nuclear weapon-effects research, Driving force of spin-off technologies, Declassification and latent proliferation.

Conclusions

The prepared report can stand as a basis for including the direct costs of international nuclear treaties, agreements and agencies into the energy model of EFDA. Some general rules of estimation of these costs with the review of existing obligations is contained in the report.

Collaboration

Continuous acquiring and exchange of information on costs of verifications of nuclear nonproliferation in international context was performed.

References

[1] The Safeguards System of the International Atomic Energy Agency
[2] IAEA Safeguards, Staying Ahead of the Game, IAEA, July 2007
[3] Report from the Commission to the European Parliament and the Council, Brussels, 26.07.2001 COM(2001) 436 final
[4] Report: Andre Gsponer and Jean-Pierre Hurni, ITER: The International Thermonuclear Experimental Reactor and theNuclear Weapons Proliferation Implications of Thermonuclear-Fusion Energy Systems, ISRI-04-01.17, April 1, 2007
[5] James Martin Center for Nonproliferation Studies. - http://www.miis.edu/rcenters-cns.html

4.7 Communication quality and lay understanding of fusion technology: a quasi-experimental study of message formulation effects on attitude change

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Abstract

The objective of the project is to elaborate and implement a group-based research methodology investigating the influence of learning process on lay understanding and reasoning about fusion technology. In particular, the research in course target is to examine whether and to what extent certain defined features of scientific information on fusion received affect lay attitudes toward fusion technology (such as its understanding, acceptance, desirability and its risk and benefit perception). The methodology proposed follows the experimental research design with apposite modifications, according to the nature of research subject and hypotheses being tested. The methodology will be for the first time implemented in a field research in Poland and it has potential to be easily replicated in various European contexts.

Summary

Works carried out during 2007 (reported in 1st and 2nd Interim Reports to EFDA) consisted in elaboration of research methodology including: definition of experimental treatment and experimental scenario, construction of research instruments (measuring attitudes toward fusion technology and other variables under investigation), preparation of the pilot study testing research methodology.

1. **Experimental treatment** is information material about fusion technology (created in close collaboration with a physicist belonging to the Polish fusion community and then peer-reviewed), prepared in 5 *experimental* versions (of about 800-1000 words) and one *control* version (of about 40 words). Experimental versions of informative material differ under 3 clear cut aspects, which role for shaping lay reasoning about fusion will be tested.

2. **Research procedure**: Students attending first class of sociology and pedagogy of the Warsaw Agriculture University (SGGW), assigned on the basis of combined random and matching procedure to experimental and control groups, will answer the pre-test questionnaire, subsequently will be taken through the experimental treatment (one of 6 versions of informative material) and then will answer to the post-test questionnaires. The research will be carried out during scheduled university classes a fixed day.

After post-test questionnaires compilation, group discussions will be held in three separate groups corresponding to three versions of experimental treatment. These discussions, conducted according to pre-defined interview guide and registered, will provide deeper, qualitative insight in students' way of reasoning about fusion and their response to the learning process they were taken through.

The data gathered from the questionnaire enquiry will be processed and analysed with use of statistical methods. The data gathered from group discussions will be elaborated qualitatively.

3. **Research instruments**: questionnaires of pre-test and post-test, interview guide for group discussions.

Questionnaires contain:

a) indicators measuring fusion technology understanding (elaborated by a physicist)
b) indicators of other dependent variables such as fusion technology acceptability and its risks and benefit perception, trust in information received, and others), and indicators of alternative (to experimental treatment) independent variables and/or modifying variables, according to research hypotheses.

Interview guide for focus groups is under preparation, taking into account conclusions from the pilot study carried out in March.

Conclusions

The pilot study carried out by SGGW researchers confirmed feasibility and adequacy of research methodology proposed by scientific coordinator and provided precise indications concerning research time-table and research procedure and instruments refinement.

Work in course: sampling, research instruments refinement (including graphical form of questionnaires, elaboration of group interview guide), logistic and organisational aspects of research in the SGGW premises.