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Contribution IFJ PAN to the construction of the WENDELSTEIN 7-X stellarator (2008 – 2009)

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Praca wykonana w ramach projektu W7X/72/2007, *Realizacja przez IFJ PAN zadań badawczych i inżynieryjnych związanych z budową stellaratora Wendelstein 7X*

Streszczenie

Stellarator Weldenstein 7-X jest aktualnie budowany w Instytucie Maxa Plancka dla Fizyki Plazmy w miejscowości Greifswald w Niemczech. Porozumienie o współpracy między MPI Garching i IFJ PAN przy budowie W7-X zostało podpisane w 2007 r. W ramach porozumienia IFJ PAN zobowiązał się do wykonania następujących zadań:

1. Zainstalowanie systemu zasilania cewek nadprzewodzących we wszystkich modułach stellaratora.
2. Wzięcia udziału w zaprojektowaniu urządzeń koniecznych do manipulowania, transportu i montażu części zbiornika zewnętrznego stellaratora.
3. Wykonanie 30 sztuk polichromatorów używanych do diagnostyki plazmy.

Zadanie No 2 zostało zakończone w 2008 r. Zadania No 1 i 3 będą kontynuowane w latach 2010 - 2012 na podstawie aneksów przedłużających ważność porozumienia.

Abstract

The Wendelstein 7-X stellarator is now being assembled at the Max Planck Institute for Plasma Physic (IPP), Greifswald, Germany. The Agreement on Cooperation between the Max-Planck-Institut fur Plasmaphysik in Garching and the Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences in Krakow (IFJ PAN) was signed off in 2007. The intention of the agreement is to cover the whole period of the W7-X construction. According to the agreement IFJ PAN has taken over the following tasks:

1. to assembly of the bus bar system powering the superconducting coils of the stellarator;
2. to take part in design of equipment used during handling, transportation and assembly of outer vessels;
3. to manufacture 30 polichromators used for plasma diagnostics.

Task No 2 was completed in 2008 while tasks No 1 and 3 are to be continued.

1. Introduction

Task No 1

Max Planck Institute for Plasma Physics, Garching, Germany, is constructing the stellarator Wendelstein 7-X (W7-X) at the branch institute in Greifswald. The main aim of that device is to study behaviour of plasma in steady state conditions close to those necessary for a fusion reaction. A second very important goal of the project is to investigate whether the stellarator principle could be a desirable alternative to a tokamak on the path towards a future fusion reactor. One of the most important requirements for the reactor relevance is to demonstrate stability of the plasma confinement under steady state conditions.

The magnet system of the W7-X is capable of producing a magnetic field of up to 3 Tesla at the plasma axis for 1000 operational cycles. The system comprises 70 superconducting coils producing a magnetic field in the inner plasma vessel, arranged periodically around the machine axis into five identical modules. Each individual module includes 14 coils of 7 unique types (five non-planar and two planar) attached to a 72 degree sector of the central supporting ring. The bus bars are made of the NbTi superconductor (243 strands 0,58 mm OD twisted in 81 triplets) in an aluminium jacket of rounded square 16mm x 16mm (Fig.1). The bus bar is covered with multi-layer insulation, two layers of kapton foil and three layers of glass fabrics impregnated with epoxy resin. A free space inside the Al jacket (about 37%) serves as a liquid helium cooling circuit.

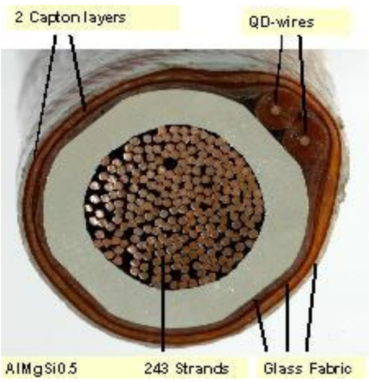

Fig.1 Cross section of the insulated bus bar with quench detection (QD) wires

The bus bars connect all coils of the same type in series and are fed by a current up to 18 kA from dedicated power supplies. The layout of the stellarator coils determines the complex 3D routing of the bus-bars (Fig. 2).

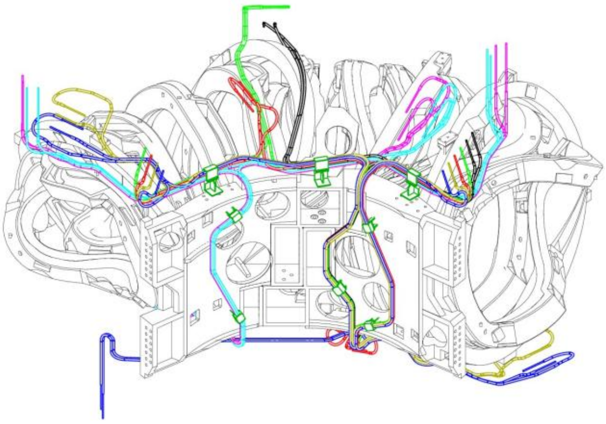

Fig.2 Example of bus bars routing on one W7-X module

The assembly of the whole stellarator W7-X is done one by one for individual modules, so all operations are repeated five times. The assembly of each module starts with the preparation of the main components: segments of plasma vessel, planar and non-planar coils and massive central supporting ring. All those components are then assembled into two so-called half-modules, which are point flip symmetrical to each other. The preparation of mounting two half modules is performed on twin mounting stands MST-1a and MST-1b in the assembly hall (Fig. 3).

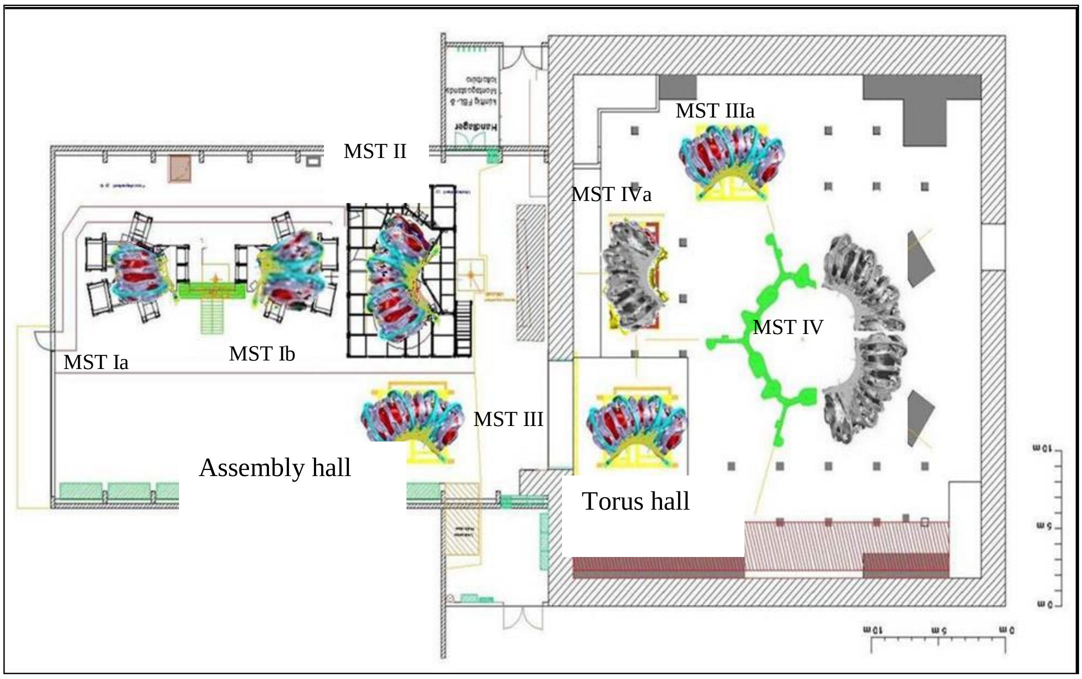

Fig.3 Arrangement of the assembly stands (MST) at IPP Greifswald

Then, both modules are connected together on mounting stand MST-II. On that stand the pre-assembly of bus bars takes place, which includes mounting and precision alignment of bus bar positioning supports (holders), installation of SA holders (Spulenabschluss, coil lead supports), installation of all 24 bus bars, installation and alignment of all the remaining bus bar holders, precise position marking of connection between bus bar ends and coils current leads (joints), and marking of clamp positions. Next, bus bars are de-installed from the module and transported to the preparation area where they are prepared for final installation and connection. Then, preparation and partial assembling of cryogenic piping and the so-called instrumentation (electrical cables to a number of different sensors) takes place. When the preparation of bus bars is finished, they are installed once again on the module (MST-IIIa, torus hall on Fig. 3) and cramped with the whole system of holders and clamps to compensate excessive forces acting on current conductors in the presence of magnetic fields.

After electrical connections of both the bus bars and coils are made, the whole module is assembled with the lower half of the outer vessel (MST IVa, Fig. 3) and transported to its final position on the stellarator ring. Electrical connections between modules and to the electrical and cryogenic supplies are done after that. Then the upper half of the outer shell is closed and a number of ports and different in-vessel components are installed.

Stellarator W7-X is very complex and its final reliability and performance is strongly dependent on the accuracy of the assembly process, so all operations are interlaced by numerous measurements with high precision laser instruments. Also, avoiding conflicts and collisions in such a complicated structure would be impossible without 3D computer modelling and keeping all necessary tolerances.

Fig.4 Two halves of the module at the assembly stand MST II

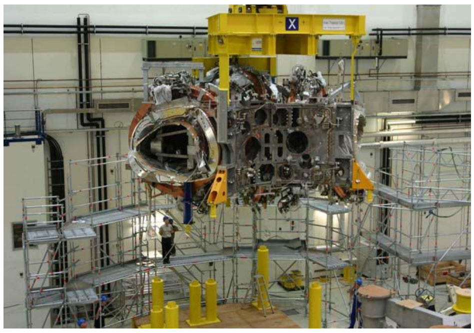

Fig.5 A magnet module moving from MST II to MST IIIa in the torus hall

Task No 2

Part of the preparation for the assembly process was the design of tools used during handling, transportation and assembly of the outer vessels. Structures called TMV (Transport-und-Montageversteifung) were designed for the purpose of using them when the lower/upper shells together with domes of modules 1, 2, 3, 4 or 5 have to be lifted with the help of a crane. The TMV structures for module 5, designed in 2007, were verified. In case of the remaining modules (1, 2, 3, 4) they were re-designed or modified, if necessary. The structure shown in Fig. 6 was designed for the lower shell of module 5.

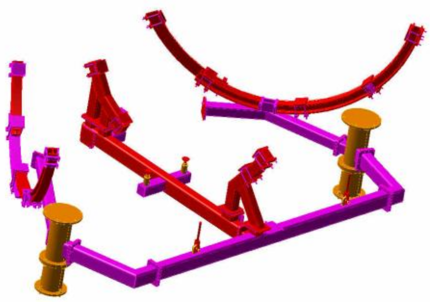

Fig.6 TMV structure for the lower shell of module 5

For each module, the deformation of the whole system (TMV and the shells together with the domes) has been checked by use of numerical calculations. An example of the numerical model and the results of the calculations [1], [2], [3] are shown in Fig.7. Deformation analysis included also transportation of the outer shells on a semi-trailer from Lubmin to Greifswald. Details of the deformation analysis are described in [4].

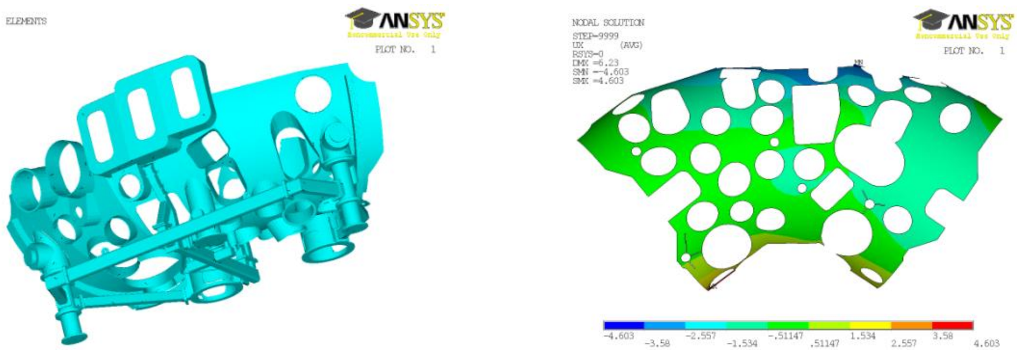

Fig.7 Example of numerical model (left) and results of deformation analysis (right)

Task No 3

IFJ PAN will deliver 30 polichromators used for plasma diagnostics to IPP Greifswald until June 30, 2011. The equipment will be manufactured on the basis of workshop drawings provided by the Diagnostics Group at IPP. Initially, three prototypes were made, which will be tested at IPP. Necessary modifications of the technical documentation will be done basing on test results. Then the remaining 27 devices will be manufactured at IFJ PAN.

2. Assembly of bus bar system powering superconducting coils

The bus bar system serves the electrical connections of the main superconducting coils within individual modules and between them. That package of operations was assigned in whole to the team of workers seconded from IFJ PAN within the framework of the cooperation agreement.

The bus bar system of each module comprises the bus bars themselves (24 superconducting cables for each module); two groups of supporting holders, primary one for positioning bus bars with respect to other components and a secondary one – additionally fastening the bus bars to rigid structures; SA holders supporting coil current leads; numerous clamps cramping bus bars to each other; so-called joints, i.e. low resistance connectors between coil current leads and bus bar ends. The whole system of holders and clamps serves to define the position of bus bars in the complex 3D structure of the W7-X machine and to compensate the excessive interaction of electro–magnetic forces. The assembly of the bus bar system on each module consists of the following steps:

2.1. Installation of bus bar holders on the central ring and coil headers;
2.2. Trial installation of 24 bus bars on the module including final shaping of bus bar ends to match coil current leads;
2.3. Completion of 48 bus bar ends in a preparation area;
2.4. Final installation of 24 bus bars on the module;
2.5. Assembly of 28 joints (mechanical and electrical connection of bus bar ends and coil current leads);

2.6. Electrical insulation of the assembled joints;
2.7. Assembly of Quench Detection system (QD) on all joints;
2.8. Painting and clamping of 28 joints.

2.1. Installation of bus bar holders on the central ring and coil headers

The holders (supports) are split into two main groups. The first one includes all supports mounted on the central ring and certain supports on the so-called coil-headers. This group as a whole serves to position the bus bars and is aligned with high accuracy with respect to the machine structure. All holders on the central ring usually represent bolted plates holding the bundle of bus bars (Fig. 8). Their positions are pre-defined by welded bolts and only limited adjustment of their base plates is possible during assembly. Supports mounted on the coil headers are usually used for holding one or two bus bars. They can be adjusted in wider range by means of the threaded connections and ball joints allowing their extension and/or tilting (Fig. 9). The second group of holders serves for final securing of the bus bars in positions already defined by type I holders.

After the preliminary mounting of both groups, an IPP survey team measures and adjusts their positions with 3D accuracy in the range of radial displacement of 1.5 mm by means of a laser tracker. What follows is tightening of all screws with a proper torque and then securing all screws, nuts and washers by means of tack-welding or blocking of the threaded spindle using epoxy resin.

There is also an additional type of SA (Spulenanschluss*)* holders. They are used to define positions of the ends of the coil current leads and to absorb interaction forces. The position of SA holders is determined by the IPP survey team to avoid collisions with other elements. They are constructed as sleeves glued to the leading bus bar and sliding inside clamps which are welded to the coil header structure.

Fig.8 Type I holders mounted on the central ring

Fig.9 Type II holder mounted on coil headers

2.2.Trial installation of 24 bus bars on the module including final shaping of bus bar ends to match coil current leads

The next step is the preliminary installation of all 24 bus bars on the module (Fig.10). The first objective of the pre-assembly is to mark positions of future joints, i.e. the connections between the bus bar ends and coil current leads. It requires also hand shaping of the bus bar ends which could not be performed during CNC process of the bus bar production due to position inaccuracy of the coil current leads (hand manufacturing).

The second goal is mounting and adjustment of all remaining holders which are located in the region of the coil-headers. Due to a very complicated routing of the bus-bars, as well as the accuracy of their fabrication, this is the only way to ensure proper matching of the supports and buses. At the same time, positions of special clamps used to cramp neighbouring bus bars are marked by IPP surveyors. There are double clamps to interconnect a pair of bus-bars and multi-clamps for interconnection of up to 10 bus bars. To decrease twisting of bus bar bundles fastened in clamps between supports, each clamp is firmly fixed only on one bus bar. Other bus bars can slide freely in the clamp (the same clearances as in the support holders). Thus high mechanical stresses during cool-down of the stellarator will be avoided.

Fig.10 Trial installation of the bus bars on module 4

2.3.Completion of 48 bus bar ends in the preparation area

For each of the five W7-X modules, a set of 24 superconducting bus bars is produced in the Forschungszentrum Julich. The bus bars arrive to IPP Greifswald formed to required shapes and insulated over nearly the entire length (Fig. 10 left.). Both ends are free of insulation to allow their shaping (bending) during a fine alignment to the coil current leads (see point 2.2). Only after this operation are the bus bars taken to the preparation area where they will be completed. This phase consists of several operations:

- cutting off of the excess length of the bus bar,
- removing of the aluminium jacket to expose superconducting strands,
- welding of special steel/aluminium adapters (T&C),
- leak testing of the welds,
- cramping and tinning of individual strand triplets,
- completing of the electrical insulation and painting with a conductive lack,
- high voltage testing (Paschen test) of the completed insulation,
- gluing of aluminium sleeves at marked positions,
- covering with thermal insulation.

Some of the above operations are shown in Fig. 11, 12, 13.

Fig.11 One end of a bus bar prepared for vacuum test after welding of T&C piece (left), two additional QD wires bonded to the Al jacket (right)

Fig.12 Electrical insulation of bus bar ends at various steps

Fig.13 A bus bar end during Paschen test (left), Al sleeves glued (centre), bus bars covered with thermal insulation (right)

2.4. Final installation of 24 bus bars on the module

That job comprises of the installation of bus bars themselves on the module, final adjustment of joint positions, bus bar and coil terminal holders, final tightening and securing of holders, installation of all clamps (additional cramping points), gluing those which have to be adjusted *in situ*.

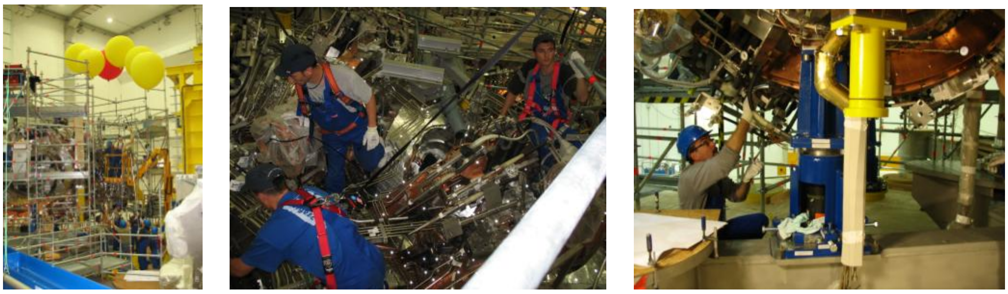

Fig.14 Final installation of the bus bars on module 1: transportation of the bus bars to module 1 (left), fastening of the bus bars in holders on top and bottom of the module (centre and right)

2.5. Assembly of joints (mechanical and electrical connection of bus bar ends and coil current leads)

The so-called joints are electrical connections of main superconducting current circuits. They should have extremely low resistance (less than 5 nano-Ohm). This requires a combination of high precision mechanical assembly of the joint body and T&C adapters and very good electrical connection. Each triplet from the bus bar end has to be soldered with one triplet of the coil current lead along a distance of roughly 30 cm. Configuration of triplets to be connected and the sequence of their soldering are determined in detail due to very small dimension tolerances of mechanical components of the joints (bi-metallic clamp and stainless steel cap). Despite the fact that the whole process was prepared very carefully, there were many problems at the beginning. As a consequence modifications of the assembly process were invented, approved and applied, e.g. [5]. Additional trainings of personnel were also needed. After finishing the electrical connection the bundle of soldered triplets are mechanically cramped with the bi-metallic clamp. Then the joint is closed with the cap welded to the body. Finally, the joints are leak-tested. The joint assembly work package consists of:

1. Pre-assembly of each joint including position alignment of components and measurement of their relative position.
2. Visual inspection of a welder supervisor.
3. Scanning position of joints and corresponding bus bars/coil terminals if required.
4. Welding T&C pieces to joint body.
5. Soldering together superconducting wires of both the coil current lead and bus bar end.
6. Mechanical clamping of soldered wires.
7. Tack welding of clamp screws.
8. Assembly of the joint cap.
9. Welding of the joint cap.

Points 2, 3, 4, 7 and 9 are done by other groups than the bus bar system assembly team; however, the work has to be coordinated by IFJ PAN management team.

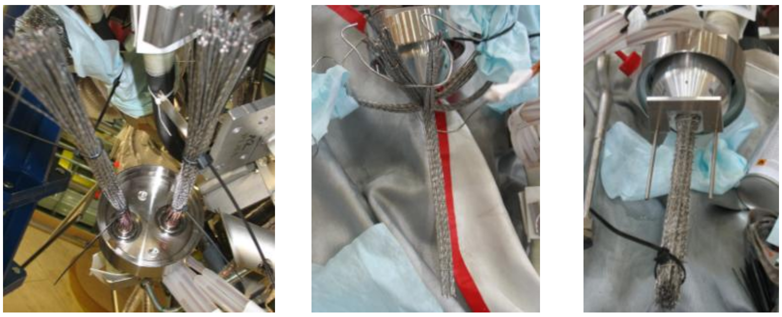

Fig.15 Various phases of joint assembly: T&C adapters welded to joint body (left), first layer of triplets soldered (centre), all 9 layers soldered (right)

Fig.16 Various phases of joint assembly; transition region shaped with special tools (left), superconducting triplets squeezed with bi-metallic clamp (centre), welded joint ready for insulation (right)

2.6. Electrical insulation of the assembled joints

Electrical insulation of the joints is made in the process of wet lamination at room temperature. The insulation consists of kapton foil, glass fiber composite pieces and several layers of glass fibre tape and epoxy resin. The process has to be performed in four steps to ensure required quality of the insulation. After each step laminated layers have to be cured for a minimum of 12 hours. Tightness of the insulation is tested in a vacuum (Paschen test).

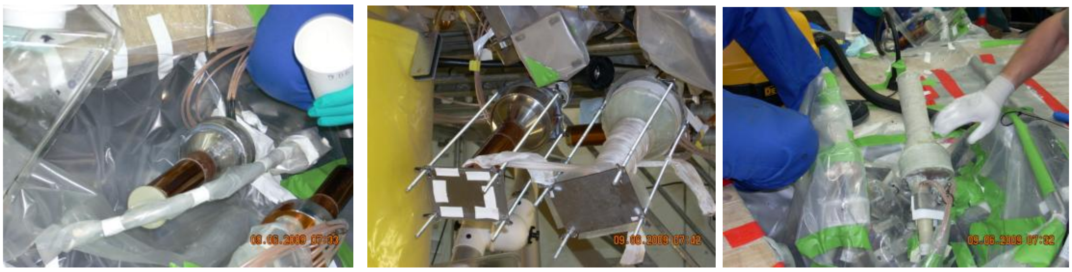

Fig 17. Various phases of joint insulation (mainly wet lamination of glass fibre tapes)

2.7. Assembly of Quench Detection system (QD)

Assembly of QD system can be launched when the joints are assembled and electrically insulated. First, continuity of QD wires and quality of their insulation have to be verified.

It turned out that the original design of quench detection (QD) wire exits from bus bar ends and coil current leads does not protect the QD wires against damages of their Kapton® insulation during assembly process. The wire insulation is especially exposed to damages during assembly and insulation of the joints. In case of module 5, insulation of seven QD wires was seriously damaged and had to be repaired. That fact triggered elaboration of a method protecting QD wires during the whole process of W7-X assembly.

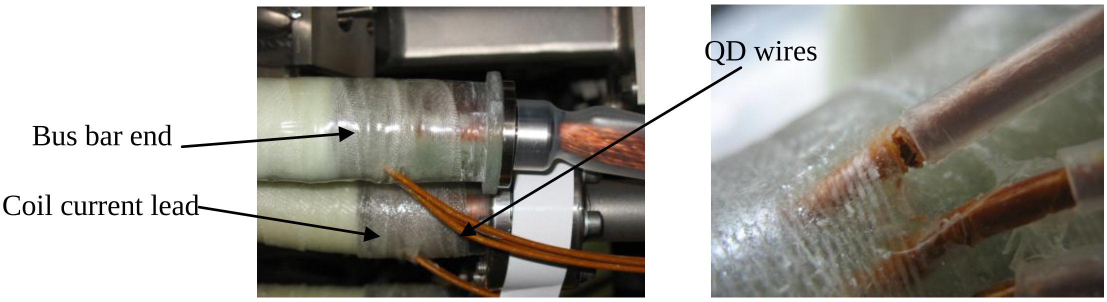

Fig.18 Original design of QD wires exits (left), example of insulation damage (right)

IFJ PAN team proposed a protection method that could be adapted accordingly to the stages of module assembly. The method was discussed and finally approved. The protection method of QD wires is described in the working instruction [7]. Our team was also involved in elaboration of repair procedures of damaged QD wires [6], [8].

After continuity and insulation of QD wires are verified the wires can be electrically connected. There are three different schemes of the QD wire connections in the whole stellarator. Each connection has to be very well insulated in so called QD boxes. The assembly process of the QD system includes also electrical measurements performed at intermediate stages. The measurements are required by quality assurance procedures.

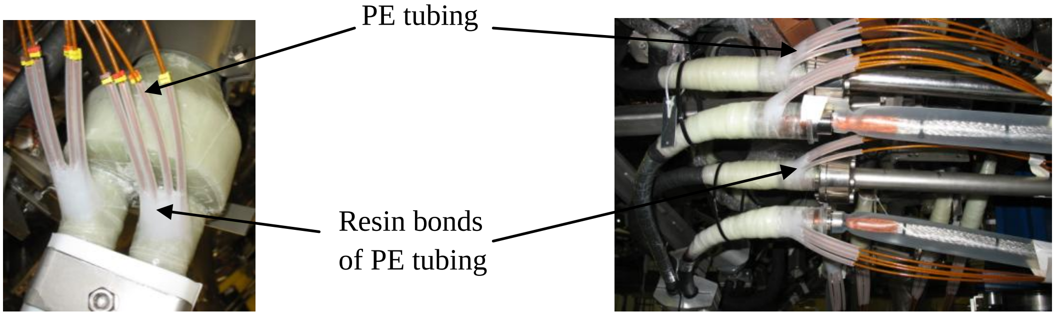

Fig.19 QD wires protected: on insulated joint of module 5 (left), on bus bar ends and coil current leads before their connection, module 1 (right)

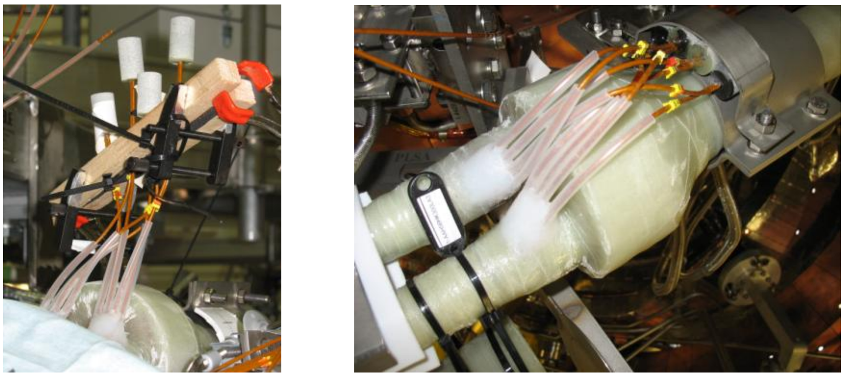

Fig.20 Casting of four QD boxes on one joint (left); ready QD boxes mounted on the joint clamp (right)

2.8. Painting and clamping of 28 joints

The last step of assembly of the bus bar system is covering the joints and the QD system with conductive black paint and fastening them to the coil structures. Special clamps are used to fasten both the joints and QD boxes. The joints are glued inside the clamps by means of epoxy resin filled with chopped glass fibers. The clamps ensure correct positions of the joints with respect to other components of the stellarator.

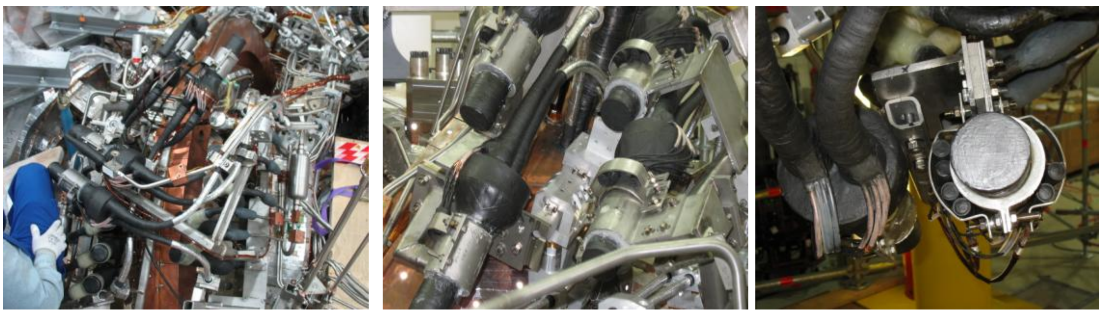

Fig.21 Joints equipped with QD system, painted with black conductive lack and clamped to coil structures

3. Responsible Officers (RO)

The processes of production and assembly of all components of the W7-X stellarator are strictly controlled in terms of quality. Every single working step is documented by responsible workers and/or managers using the so-called QAAP (Quality Assurance and Assembly Plan). Some sensitive steps are flagged as “stop points”, which require responsible officers to sign and stamp their permission to proceed. At those points, the responsible member of the Quality Management team must also sign his acceptance. In case of revealed nonconformities, a “Red Card” is open which means that corrections/repairs are discussed and decided. After successful repair, the “Red Card” is closed but remains attached to the appropriate QAAP for future reference.

All assembly operations are described in detail in the Working Instructions. For a particularly sensitive operation, a worker must undergo a qualification procedure which tests his ability to understand and perform the task. The result of the qualification procedure is registered and confirmed by the responsible officers.

One of the important tasks in the bus bar assembly package was to verify all procedures, quality assurance documents and tools. As a result, a substantial reduction in quality deviation and number of open red cards was observed.

The Bus Bar Assembly (BBA) team consisted of 10 - 20 technicians from IFJ PAN and IPP Greifswald headed by 2 Responsible Officers from IFJ PAN, on average. The RO were responsible for:

- Work organization of the BBA team within the schedule of W7-X Construction Project;
- Coordination of work with Welding division, Vacuum group and Electrical Test group also involved in assembly of the bus bar system;
- Instruction and training of supervised technicians;
- Supervision and quality assurance of work performed by the technicians;
- Completion of work documentation.

In addition, they were also involved in:

- Preparation of work instructions;
- Solution of technical problems encountered during assembly process;
- Modification of work procedures and instruction according to new solutions.

Work of the IFJ PAN Responsible Officer resulted in (among others):

1. Instruction and training of technicians:
    - Completion of bus bar ends – 38 persons
    - Assembly of joints – 25 persons
    - Electrical insulation of joints – 16 persons
    - Assembly of QD system – 10 persons
2. Solution of technical problems encountered:
    - Damages of superconducting strand during removal of Al jacket – invented, designed and used new tools which eliminated the problem;
    - Difficulties in joint assembly – application of new solutions and tooling reduced number of joints affected by factor 4;
    - Damages of QD wires during the bus bar assembly process – invented method of the wire protection practically eliminated the problem;
    - Reparation of damaged QD wires – contribution to validation process speeded up reaching the final method.

3. Modification of work procedures and instructions:
    - Bus bar dismantling;
    - Insulation of bus bar ends;
    - Assembly of joints;
    - Electrical insulation of joints;
    - Assembly of QD system (protection and reparation of QD wires, assembly of QD boxes).

4. Design of equipment used during handling, transportation and assembly of outer vessels

Lower shells of modules 1, 2, 3, 4

A structure called TMV has been designed for the purpose of using it when the lower shell together with the domes of modules 1, 2, 3, 4 or 5 has to be lifted with the help of a crane. The structure shown in Fig. 6 was designed for module 5 and can be used without any change for modules 1 and 2. For modules 3 and 4 the TMV structure has to be slightly redesigned. For each module, the deformation of the whole system (TMV and the lower shell together with the domes) has been checked by use of numerical calculations. Results of this analysis are shown in [1].

Upper shells of modules 1, 2, 3, 4

A structure called the new TMV frame has been designed for the purpose of using it when the upper shell of modules 1, 2, 3, 4 or 5 has to be lifted and rotated upside down with the help of a crane. The structure shown in Fig.22 was first designed for module 5 and results of calculations are presented in [11].

Then, for modules 1, 2, 3 and 4 the TMV structure has been slightly redesigned. This means that positions of some connecting beams have been changed. For each module, the deformation of the whole system (TMV and the upper shell together with the domes) has been checked by use of numerical calculations. Results of this analysis are shown in [3]. Examples of analysed cases when the system is rotated up-side down are presented in Fig.23.

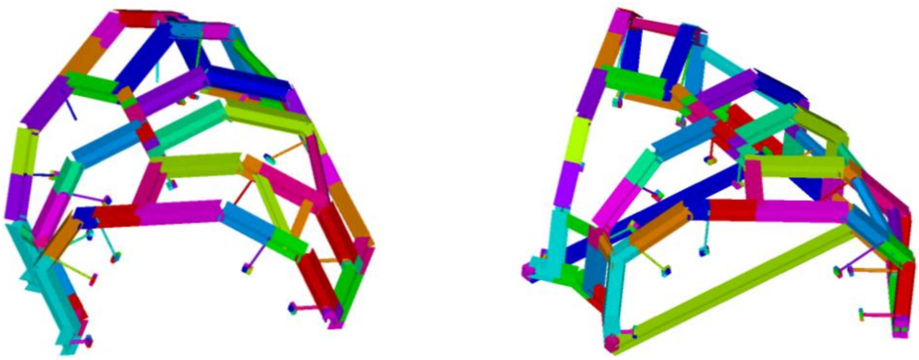

Fig.22 TMV structure for the upper shell of module 5

Modules 1, 2, 3, 4, 5 during transportation

A platform which has been designed and utilized as a component of testing stands is planned to be used for transport of the outer vessel shells from Lubmin to IPP in Greifswald. They will be transported by a semi-trailer and the aim of using the platform is to minimize deformations of the modules. The whole system (the module with the TMV connected to the platform) will be supported at three points on the semi-trailer. Such a method of supporting will prevent the transmission of any deformation of the semi-trailer to the system. The deformation of the semi-trailer will cause only a rigid body movement of the system.

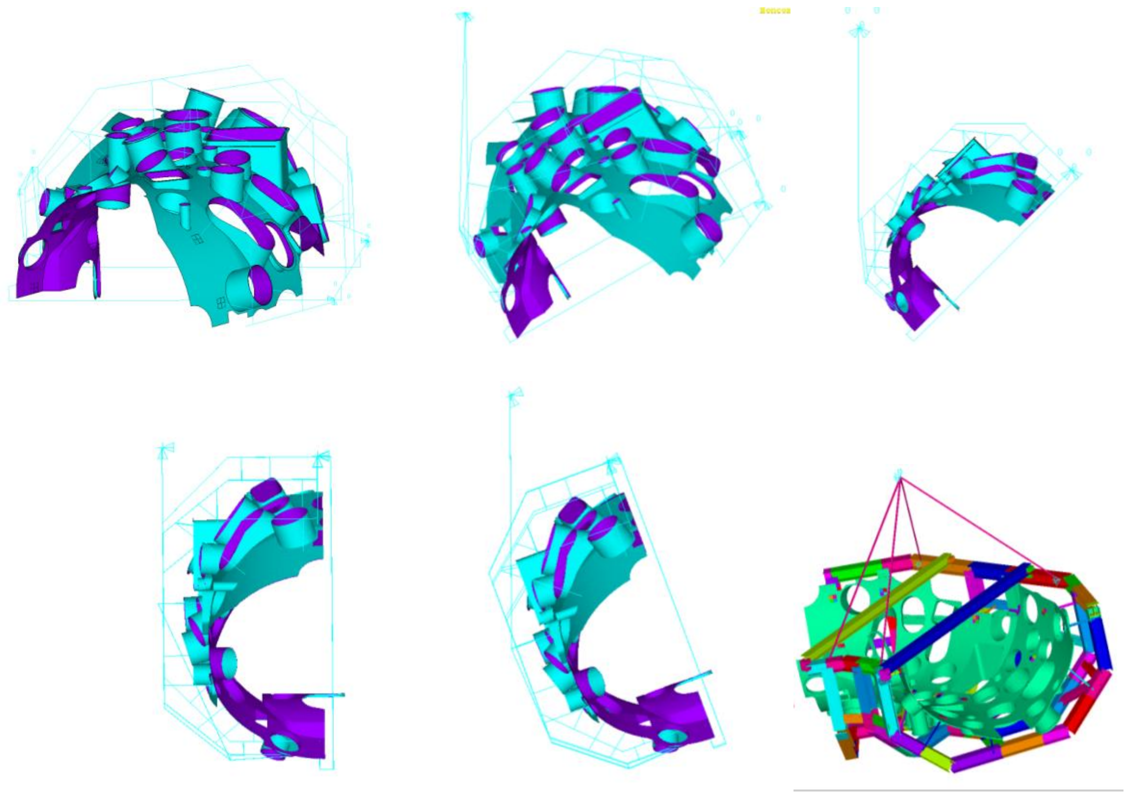

Fig.23 TMV structure with the upper shell of module 1 verified at various stages of handling

The deformation of the system caused by the gravity load has been checked by use of numerical calculations. Detailed results of this analysis are presented in [4]. Examples of the results are shown in Fig. 24.

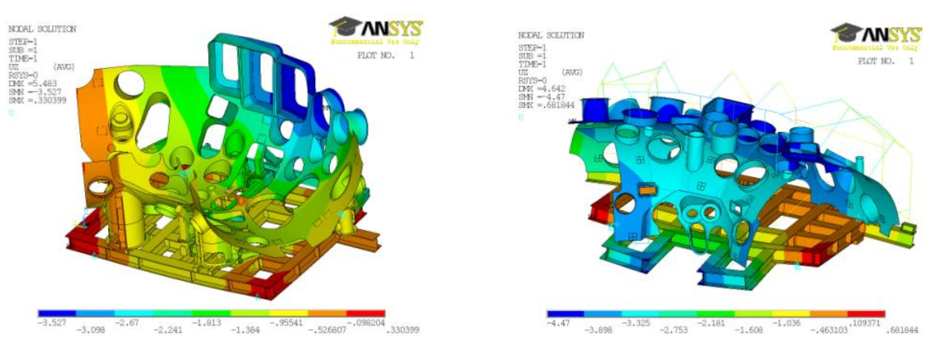

Fig.24 Vertical displacements of the system with the lower (left) and upper (right) shells supported at four points

5. Manufacturing of the polichromators to be used for plasma diagnostics

Technical discussions on tolerances and material equivalents started in July 2009. Technical documentation and manufacturing drawings were completed by the end of September. Three sets of mechanical components and two boxes were ready and pre-assembled in 2009. All parts were shipped to IPP Greifswald in January 2010 and then assembled and tested. The outcome from the tests is as follows:

- all components were made according to the agreed documentation;
- the box made of POM does not meet requirements, thus IFJ PAN will deliver 29 boxes made of glass fiber/epoxy resin composite;
- tests performed at IPP Greifswald showed some detail modifications of mechanics are necessary; IPP Greifswald will provide detail workshop drawings of components concerned;
- while waiting for the modified drawings, IFJ PAN starts to purchase raw materials for next 27 sets.

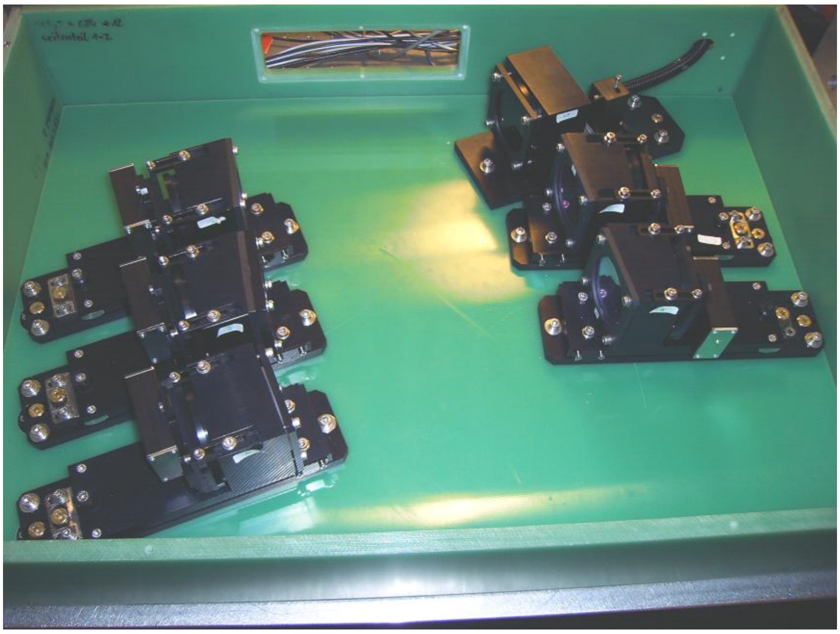

Fig. 25 One set of mechanical components assembled inside the box made of glass fiber/epoxy resin composite at IPP Greifswald, March 2010

6. Conclusions

The following tasks were performed in 2008-2009 within the range of collaboration between Max-Planck-Institute IPP in Garching and IFJ PAN in Krakow:

Task No 1

1. Completion of the bus bar system on module 5
   - Installation of bus bar holders on the central ring and coil headers
   - Trial installation of 24 bus bars on the module
   - Completion of 48 bus bar ends in a preparation area
   - Final installation of 24 bus bars on the module
   - Assembly of 28 joints (mechanical and electrical connection of bus bar ends and coil current leads)
   - Electrical insulation of the assembled joints
   - Assembly of Quench Detection system (QD) on all joints
   - Painting and clamping of 28 joints
2. Advancing of the bus bar system assembly on module 1
   - Installation of bus bar holders on the central ring and coil headers
   - Trial installation of 24 bus bars on the module
   - Completion of 48 bus bar ends in a preparation area
   - Final installation of the bus bars on the module
   - Assembly of 28 joints
3. Advancing of the bus bar system assembly on module 4
   - Installation of bus bar holders on the central ring and coil headers
   - Trial installation of 24 bus bars on the module
   - Completion of 48 bus bar ends in a preparation area

Completion of the assembly work package on the remaining modules will be continued in 2010–2012.

Task No 2

Structures called TMV (Transport-und-Montageversteifung) were designed for the purpose of using them while the outer vessel is handled, transported and assembled. During those operations the lower/upper shells of the outer vessel have to be lifted with the help of a crane. The TMV structures designed for module 5 were verified. In case of the remaining modules (1, 2, 3, 4) they were re-designed or modified, if necessary. For each module, deformations of the whole system (TMV and the shells together with the domes) were checked by use of numerical calculations. The TMV structures for module 5 were fabricated in 2008 and used in assembly process in 2009. That task was completed in 2008.

Task No 3

In 2009, technical documentation was discussed and completed. It includes manufacturing drawings. Three prototypes of the polichromators were manufactured at IFJ PAN and shipped to IPP Greifswald. The prototypes passed successfully tests at IPP during the first quarter of 2010. Detailed remarks and modifications will be included in the production process of the remaining 27 sets.

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