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Remote handling validation of the OPM-FDS connecting system for the IFMIF-DONES target assembly

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ABSTRACT

The qualification process of the materials for future DEMO fusion reactors plays a pivotal role towards its realization. In this light, the International Fusion Materials Irradiation Facility-DEMO Oriented Neutron Source (IFMIF-DONES) has achieved the final design stage and is currently under construction in Granada (Spain). IFMIF-DONES aims to reproduce the irradiation conditions foreseen on the first wall of DEMO by using deuteron-lithium stripping reactions induced by a D+ beam accelerated through a superconducting LINAC. These reactions occur in a Target Assembly (TA) within a closed cavity (Test Cell) housing the test modules. Due to the strong neutron activation, a Remote Handling System (RHS) is required to perform the maintenance operations in the Test Cell. Therefore, suitably custom-designed components necessary due to the conditions of IFMIF-DONES, must be validated from the RH point of view. In particular, the system responsible for connecting the TA with the accelerator beamline plays a key role. This system includes a compression element made of an extensible bellow actuated by a One-Point-Mechanism (OPM) and a circular chain acting as a Fast Detachment System (FDS), which secures the connection by applying the required tightening force on the sealing gasket. The main objective of this work is then to test and validate the OPM-FDS design with focus on the RH suitability. Therefore, to demonstrate the concept validity and qualify the system, the University of Granada made a prototype of the OPM-FDS connection in collaboration with ARQUIMEA® and delivered it to the ENEA Brasimone Center for experimental validation. The outcomes of the validation activity conducted in this work confirmed that the OPM-FDS design is suitable for Remote Handling and can perform several connections and disconnections. The rescue system, which detaches the FDS in case of failure, has also been tested successfully. The experimental campaign also showed some potential improvements in the design of the connecting system for further implementation.

1. Introduction

IFMIF-DONES (International Fusion Materials Irradiation Facility - DEMO—Oriented NEutron Source, from here on only "DONES") is an innovative accelerator facility aiming at producing a database of materials irradiated in conditions similar to the one expected on the first wall of the European DEMOnstration power plant (DEMO) [1,2]. DEMO, and more in general fusion reactors, are characterized by neutrons with energy up to 14 MeV, an energy value not achieved in already existing facilities. To achieve the required intensity of the neutron source, DONES uses a 125 mA deuteron (D+) beam, accelerated up to 40 MeV, using a linear accelerator (LINAC). The D+ beam then interacts, via Li(d, xn) stripping reactions, with a 25 mm liquid lithium target flowing at 15 m/s in the Target Assembly (TA) housed inside a solid shielded structure called Test Cell (TC) [3,4]. The neutron beam irradiates the specimens inside the High Flux Test Module (HFTM), producing extreme levels of radiation and material activation levels in the TC. Due to the neutronic activation of the TC structural materials and the components, the

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environment is too radioactive to allow for human intervention, leading to the need for Remote Handling (RH) maintenance.

Of all components in the TC, the TA is one of the most challenging from the point of view of RH maintenance [6] since it requires almost perfect alignment with the two beamlines, the inlet, and the outlet lithium channel. However, to ease the burden of the RH maintenance, the connections between the TA are designed to compensate for misalignments, such as the one with the beamlines and the outlet lithium channel. The connections of the TA are then achieved using metallic bellow, which is extended and secured with the reciprocal flange on DONES TC. One prototype of the connection between the TA and the beamlines has been designed and manufactured and is available for experimental testing at ENEA Brasimone. The connecting system has two main functions: 1) to establish and secure a vacuum-tight connection between the TA and the accelerator and 2) to detach the TA from the beamlines. To satisfy these two main functions, a custom-designed component called the OPM-FDS connecting system was developed as a joint effort between ENEA and the University of Granada. The system is composed of a Fast Disconnecting System (FDS), a metallic chain that clamps and links two flanges, securing the connection by applying the required tightening force to a metallic gasket, and a One-Point-Mechanism (OPM), which then drives the FDS flange to the fixed one on the beamlines. Since two beamlines are foreseen in the design of DONES TA, the system will require two OPM-FDS connection systems. A 3D view of DONES TA with the two OPM-FDS systems is shown in Fig. 1.

The primary objective of this work is to study the performance of the designed OPM-FDS connecting systems, assessing the design suitability for operation and RH maintenance. The study involves a thorough experimental campaign thanks to the availability of a full-scale prototype realized by ARQUIMEA. The activities are performed at the Divertor Refurbishment Platform (DRP) lab of ENEA Brasimone, a flexible RH facility vastly used in validation activities for the International Thermonuclear Experimental Reactor (ITER) divertor maintenance and, more recently, in both IFMIF-EVEDA and IFMIF-DONES [7–10]. This paper is structured as follows: Section 2 provides an overview of the OPM-FDS design; Section 3 describes the results of the validation activities, focusing first on the OPM and then on the FDS. Finally, Section 4 presents the main conclusion of the work alongside future perspectives.

2. The OPM-FDS connecting system

The beam duct connection system, also known as the "OPM-FDS connecting system", is a one-of-a-kind component specifically designed for RH compatibility and operation in DONES. The system includes two main subsystems: the OPM and the FDS. The OPM consists of a bevel gearbox connected to two worm gears via flexible shafts. The mechanism extends and compresses the bellow (acting as a movable flange) to connect or disconnect the TA from the beamlines. Once the bellow is fully extended, the connection between the TA and the Accelerator System (AS) is secured by a circular FDS, which compresses a spring-energized metal seal to provide the vacuum tight connection required. This type of FDS is made of a metallic chain divided into four segments (FDS segments) as shown in Fig. 2. To close and open the chain, the FDS is driven by two threaded rods (FDS rods in Fig. 2). When tightening the FDS, the chain squeezes two flanges of the connection, compressing a spring-energized metallic gasket which ensures the tightness of the connection. The FDS concept was developed and validated for operation with lithium by ENEA during the IFMIF-EVEDA (IFMIF - Engineering Validation and Engineering Design Activities) [5,7]. Fig. 2 shows a 3D CAD view of FDS, along with safety features to ensure the FDS opening and the TA detachment, even if the standard opening system of the FDS fails. The safety components ensure the detachment of the FDS (Fig. 2 shows the position). The components are the safety pins and the detachment bolts. The pins are designed so that once "pulled" with the robotic arm, they separate the chain into the four segments. Then, if the four segments are stuck on the flange, the detachment bolts are engaged, separating the segment from the flange.

In the OPM system, the flexible shafts transmits an equal torque from the OPM to the gearboxes, which are positioned on both sides of the system. These gearboxes then operate a metal rod to extend or compress the bellow. Once the bellow is fully extended, the FDS is engaged by tightening the FDS rods, one on each side and one at a time, to ensure the connection and compress the spring-energized metal gasket. Thanks to the design, it is possible to tighten the FDS only with these two rods. The procedure to release the FDS is similar: the FDS bolts are loosened, and the bellow is compressed using the OPM. The only RH tool needed to operate the OPM-FDS connecting system is a Bolting Tool (BT). Fig. 3a show a view of the OPM in the connecting system highlighted in orange. The different components that make the OPM-FDS system are then reported in Fig. 3b.

The process of the extension and compression of the OPM-FDS system is instead reported in Fig. 4, using the prototype of the OPM-FDS system available at the DRP lab. In particular, Fig. 4a shows the fully extended bellow when the FDS is engaging the fixed flange and is ready to be tightened, Fig. 4b instead shows the fully compressed bellow where the FDS is detached from the fixed flange, representing the beamline, leaving enough clearance to lift the TA. When the FDS is at the end of travel with the bellow fully extended, the gasket housed on the moving flange (not directly in the FDS chain) contacts with the fixed flange in the beamlines. Then thanks to the oblique shape of the two flanges and of the internal part of the chain, when the FDS is tightened the force is also transmitted horizontally squeezing the two flanges and the gasket.

Fig. 4 also highlights the OPM (in light blue) and the FDS (in orange) subsystems. The realized prototype is stored in a support frame, providing the rigidity necessary for handling the system. The OPM-FDS system is also equipped with a KF-40 flange for fluid connections to enable leak testing to assess the quality of the sealed connection. The connection system should be vacuum tight by design to avoid any penetration of external atmosphere in the accelerator line. However, it is possible to have leaks from the FDS if the metallic gasket is not properly compressed. Furthermore, leak testing on the welds allows to assess the quality of the manufacturing.

3. The OPM-FDS validation campaign

The validation activities for the OPM-FDS system have been agreed between University of Granada (UGR) and ENEA to assess the design suitability to operation and RH maintenance also in long-term scenarios. The experimental campaign is divided into two main sets of activities: the validation of the OPM and the validation of the FDS, all performed at the DRP lab of ENEA Brasimone in a joint effort between ENEA, Politecnico di Milano and the University of Basilicata. The general framework of the OPM-FDS validation campaign is that in order to have a positive outcome, the analyzed prototype must satisfy three main requirements: having the design suitable for operation, being suitable to

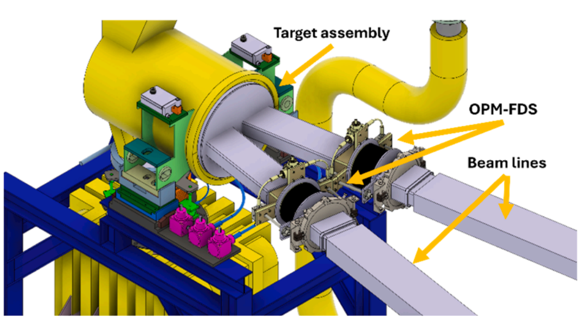


Fig. 1. DONES TA 3D model with the OPM-FDS connecting systems.

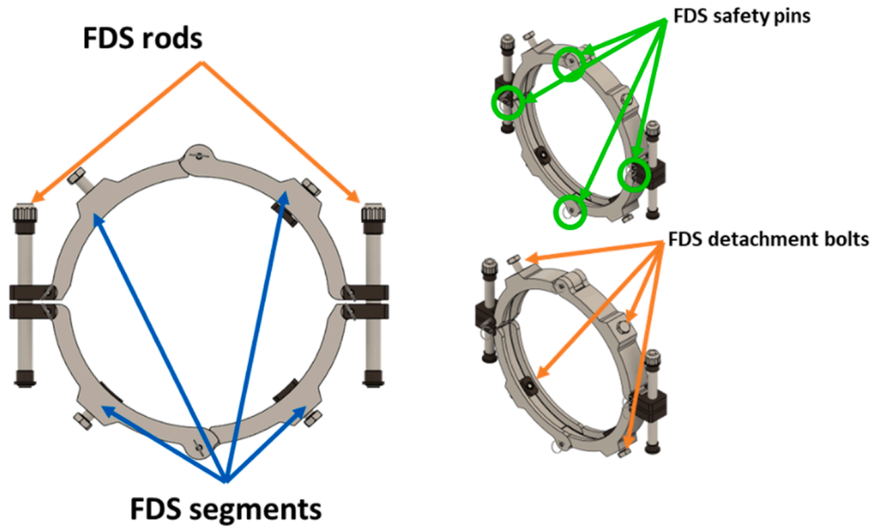


Fig. 2. 3D views of the compression system specifying the subsystems.

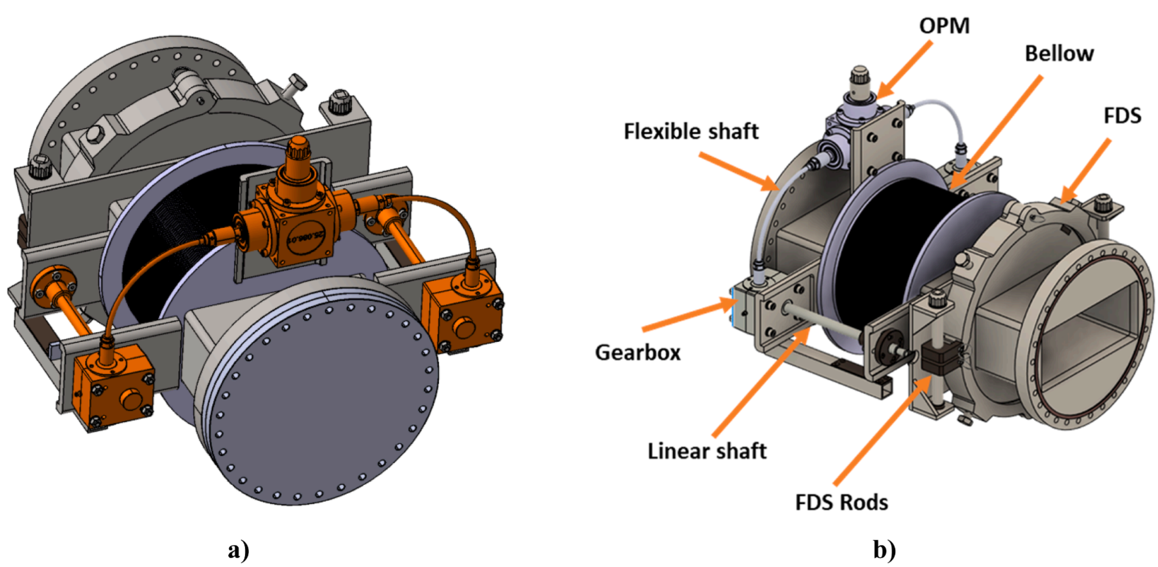


Fig. 3. a) 3D view of the OPM system (in orange), b) 3D view of the OPM-FDS connecting system identifying the different subcomponents.

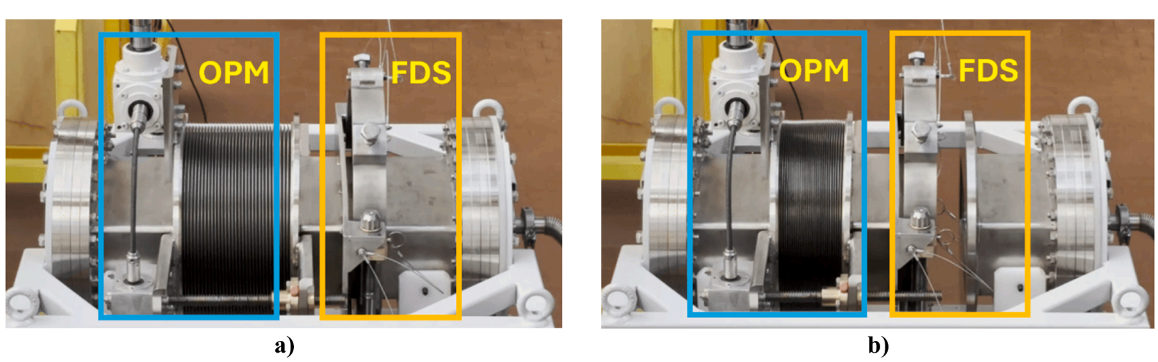


Fig. 4. view of the different stages of the OPM-FDS system, a) fully extended bellow, b) compressed bellow.

RH, and functioning correctly. In the proposed framework, the validations start with a visive control (inspection) of the manufactured prototype to then assess the reachability and visibility of the RH interface on both the OPM and the FDS. This qualitative assessment is required as a preliminary step in the validation to assess any potential issues to the campaign. The visive control is more related to assessing if the prototype is realized according to the 3D model. The reachability and visibility of the RH interfaces is instead more related to a qualitative assessment of the easiness to perform the RH procedure. In the case of the OPM-FDS system the procedure requires only to release the FDS and compress the bellow, or to extend the bellow and secure the FDS. Indeed, the connecting system prototype has the RH interfaces all placed in positions with enough room to accommodate the bolting tool and the robotic arm. Furthermore, the view of the interfaces is not obstructed by the system itself where the interfaces (the bolts heads) are all placed in easy to spot locations. However, some of the safety pins are harder to reach and to see having the beamline channel obstructing the path. This preliminary qualitative assessment achieved positive results: the interfaces are indeed easily reachable and visible so that the robotic arm can always handle the RH interfaces since during the tests no issues were observed in coupling the robotic system with the interfaces on the OPM-FDS system. However, the visive inspection highlighted a manufacturing mistake in placement of one of the mechanical stops in the system. Then, the activity will shift to the two subsystems. First, the validation campaign of the OPM involves the following objectives, referred to the three requirements of the validation:

- Qualitative assessment of the correct operation of the OPM system during the extension and compression cycles of the bellow;
- Qualitative verification of the functioning of the different componensts of the OPM system, like the gearboxes, the flexible, and the linear shafts;
- Qualitative assessment of the feasibility of RH operations and tools required;
- Quantitative assessment of the engagement of the flanges, assessing if the OPM drives the FDS in the same position within 2.5 mm of tolerance when completely extended.

Instead, the set of activities performed on the FDS includes the following operations:

- Quantitative assessment of the torque required by the FDS to achieve the required leak rate;
- Qualitative assessment of the feasibility of RH operations and tools required;
- Quantitative assessment that the leak rate of the OPM-FDS system is less than 10^{-11} $Pa{\cdot}m^3/s$;
- Qualitative assessment of the correct functioning of emergency-related components (safety pins and detachment bolts).

3.1. OPM validation

The OPM validation focused on studying the outcome of repeated extension and compression cycles on the system to achieve correct engagement of the fixed flange and to enable the operations of the FDS. The repeated cycles also allowed for assessing for any damages during operations, evaluating the necessary torque to drive the bellow, and extrapolating potential further improvements to the design. Out of approximately 50 cycles, the OPM completed almost all, with one failing due to yielding of the flexible shafts. The OPM gearbox system is designed with a 5:1 gear reduction where five turns of the bevel gearbox nut are equivalent to one of the worm gearboxes on each side, which is correctly achieved by the prototype as built, always driving both sides concurrently without noticeable unbalance. The most important parameter for validation is the ability of the system to extend the bellow without exceeding the corrective effect of the "lips" present in the FDS mobile flange. These lips interfere with grooves on the fixed flange to realign the FDS flange (and to counteract the cantilever effect), thus achieving correct coupling. A 3D CAD view of the lips and grooves is shown in Fig. 5 and highlighted in red. The grooves and lips have a theoretical maximum misalignment compensation of 2.5 mm. The system was indeed always able to correctly engage the fixed flange, correcting the misalignments during the validation activities.

Repeated tests were also conducted to assess if the bellow equally extends when engaging the fixed flange on the beamlines. These measurements were done by taking a "cross" on the FDS while looking at the TA as a reference system and defining four different positions as left, right, top, and bottom, as exemplified in Fig. 6, which also shows the labelling of the different FDS chain segments.

The results of the measurements are shown in Table 1 and reported in mm. The important quantity of interest is that the maximum spread between the measured points is below 2.5 mm, which is the maximum misalignment that the system can compensate. The values were registered when the bellow was fully extended, and the FDS engaged the fixed flange. The table shows that, in general, the bottom part extends more than the top one due to the need to compensate for the deformation of the bellow due to the weight of the FDS. Indeed, the bellow behaves as a cantilever since it is supported on the OPM side and free on the FDS side. The FDS weight then induces a bending moment on the bellow which then deforms. However, the system is designed to counteract this effect so that the "drop" of the FDS flange was always compensated. Indeed, it was observed during the bellow extension that the first part of the mobile flange that interferes with the fixed one is the "top", leading to a further extension of the "bottom" part of the bellow to compensate. The measured maximum spread achieved is 1 mm for the top side, 0.8 mm on the bottom side, 1.6 mm on the left side, and 0.7 mm on the right side. Indeed, these values are below the 2.5 mm requirement showing satisfactory performance of the OPM system.

During the validation of the OPM, issues were encountered regarding the positioning of the end of travel on the left and right sides of the system (labeled 1–2 and 3–4), as shown in Fig. 7 reporting also the relative position of the mechanical stop (with accuracy of 0.05 mm).

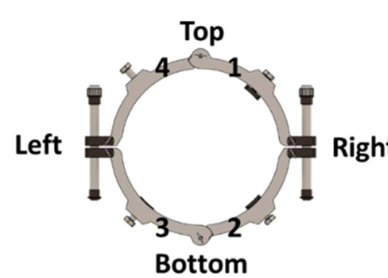


Fig. 6. Labelling of the different sides of the FDS.

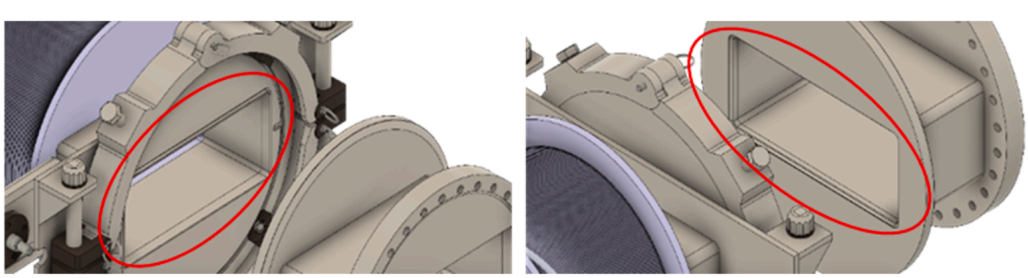


Fig. 5. 3D view of the mobile and fixed flanges of the FDS showing the alignment lips and grooves.

Table 1
Extended bellow position on vertical (top – bottom) and horizontal axis (left – right), all measures have an uncertainty of 0.05 mm.

Test n°	Top (mm)	Bottom (mm)	Left (mm)	Right (mm)
1	182.3	184.6	180.2	179.3
2	182.4	184.5	180.1	179.1
3	182.5	184.6	180.1	179.2
4	182.0	184.2	181.3	179.3
5	183.0	184.6	181.0	179.8
6	182.6	184.3	181.7	179.8
7	182.0	184.2	181.0	179.1
8	182.6	184.6	180.3	179.4
9	182.4	184.1	180.3	179.8
10	182.4	184.9	180.1	179.5

Currently in the prototype the mismatch between sides is of 5 mm as observed in the figure, where the difference is assessed in positioning from the “pillar” to the moving flange when completely extended and from the end of travel to the flange housing the gearboxes.

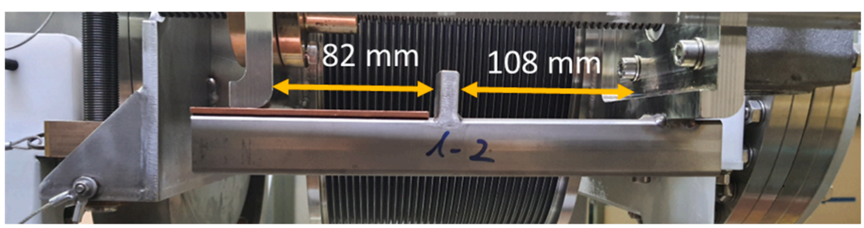
These structures must stop the bellow compression by interfering with the moving flange and stopping the motion. However, the incorrect placement leads to uneven arrival at the end of travel of the OPM-FDS that, when combined with erroneous handling of the automated bolting tool, led to yielding and permanent damage to one of the flexible shafts, as shown in Fig. 8. Despite the critical damage, it was still possible to complete the bellow extension and compression by using the OPM (even after repeated trials).

The uneven placement of the end of travel is attributed to manufacturing and assembling issues rather than design flaws, as there is a difference of 5 mm between the left and the right side, while the total length is the same. However, there is potential to improve the system functioning and prevent damage that, when irradiated, could be catastrophic. Therefore, two potential solutions were identified. The first involves the introduction of a clutch system where the linear shafts are attached to the FDS moving flange so that when it reaches the end of travel, during both the extension and the compression, the clutch detaches the flange from the fillet of the linear shaft. The other solution instead requires the substitution of the flexible shafts with universal joints and solid shafts, as exemplified in Fig. 9. This solution would also potentially avoid issues with the potential embrittlement of the flexible shafts. These solutions are still in the conceptual phase and will be integrated and analyzed in future prototypes.

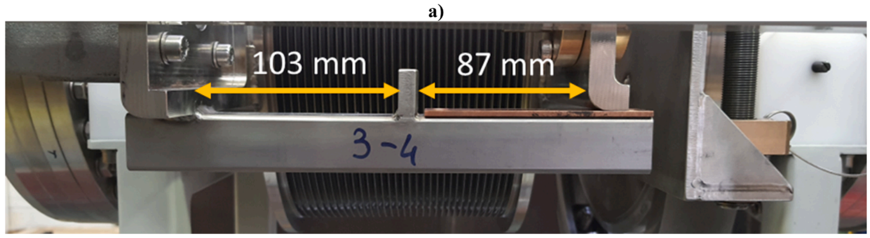
One issue that will be addressed in further tests with the OPM will involve the assessment of the system performances when lithium is present, which could cause the two flanges (the FDS and the one on the beamlines) to stick. Sticking on the flanges is indeed expected, and it would be necessary to assess if the OPM with the flexible shafts can detach the FDS flange without damage due to over-torque, or if alternatives are needed. One of these alternatives lies in using a detachment bolt on the FDS flange which, when acted, separates it from the beamlines. However, even using rigid shafts and universal joints could be enough if the over-torque necessary does not damage the bevel and the worm gearboxes.

3.2. FDS validation

The validation of the FDS is the second part of the validation of the entire OPM-FDS connecting system. In this part, the most important



a)



b)

Fig. 7. Different end of travel placement on the OPM-FDS connecting system, a) left side and b) right side.

Fig. 8. Different views of the yielded OPM-FDS flexible shaft.

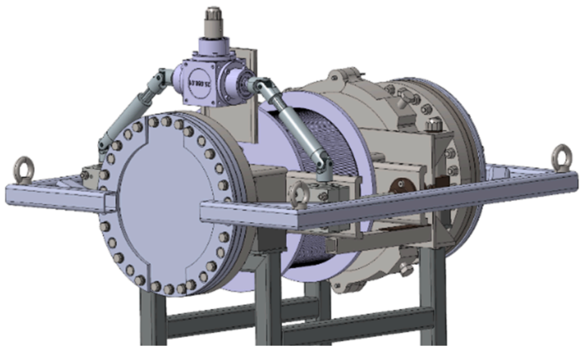


Fig. 9. 3D CAD view of the OPM-FDS system prototype with solid shafts and universal joints.

topic is to verify if the FDS can provide the leak-tight connection between the TA and the beamlines and if it is possible to do repeated closing and opening cycles both manually and with a robotic system. This validation part will also cover the different safety-related components of the FDS, such as the detachment bolts and the detachment pins. In this validation, the leak tests were performed using helium as trace gas and a Pfeiffer ASM-340 as leak detector. A picture of the test set-up in the DRP lab is shown in Fig. 10: in the experimental activities, the leak test is successful if the measured leak rate is less than 10^{-11} $Pa{\cdot}m^3$ $/s$, as required by DONES guidelines.

Two main types of gaskets were tested in the validation activities: one made with AISI 304 with a compressibility of 200 N/mm and one made with INCONEL 718 with a compressibility of 100 N/mm. The AISI 304 behaves reasonably good up to at least 5500 h when used in presence of lithium vapors thanks to results from testing performed in ENEA where an AISI 304 gasket was tested while in contact with liquid lithium [5]. However, currently it is not known how the INCONEL gasket behaves in lithium environments. Further tests are currently ongoing in the DONES project to validate different gaskets material behavior in lithium environment. However, the INCONEL 718 one has a drastically lower compressibility, meaning that it can ensure a more effective seal at lower tightening torque values. In the test campaign, incremental values of tightening torque were used on both gaskets until the required level of leak rate was reached. The maximum torque applied to the FDS in the tests was limited to 270 Nm since higher values could cause permanent damage to the system. The results of the leak tests, which assess the suitability of the FDS to operation in DONES, with the two different gaskets are then reported in Table 2.

In the table, it can be observed that using the AISI 304 gasket the FDS system is not able to achieve the desired leak rate of 10^{-11} $Pa{\cdot}m^3$ $/s$; instead when using the INCONEL 718 metallic gasket the system achieves a leak rate below the desired level only at 80 Nm of applied torque to the FDS. However, one issue is that the load relation of the FDS is not currently known (an information which must be supplied by the manufacturer). This relation must be known to determine the relationship between the torque applied to the FDS and the force transmitted to the gasket. Furthermore, the INCONEL 718 gasket also needs to be validated for compatibility with lithium vapors, which could be present during the operation of DONES, since the AISI 304 failed to achieve satisfactory leak rate and would first require improvements in the compressibility. Therefore, in general, the FDS system performed well when handled, although operation with the robotic arm was not performed. Indeed, the system lacks torque reaction support, so that when tightening the FDS the reacting torque gets dampened to the robotic arm, which would lead to permanent damage. The bolting cycle is also cumbersome, requiring sequential steps, which prolongs the maintenance process. Nonetheless, the FDS design will be considered suitable to RH with the introduction of torque reaction supports, as the interfaces are easy to see, reach, and operate.

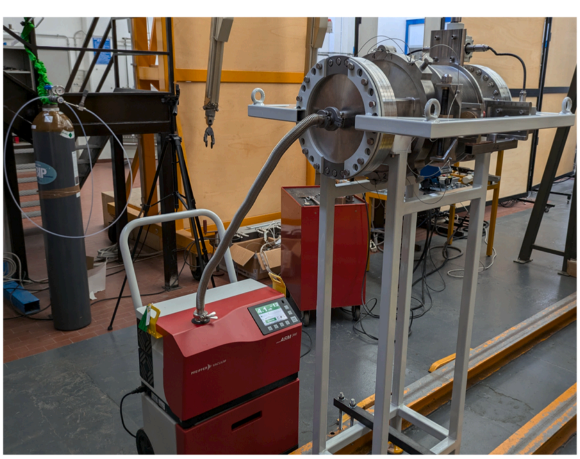
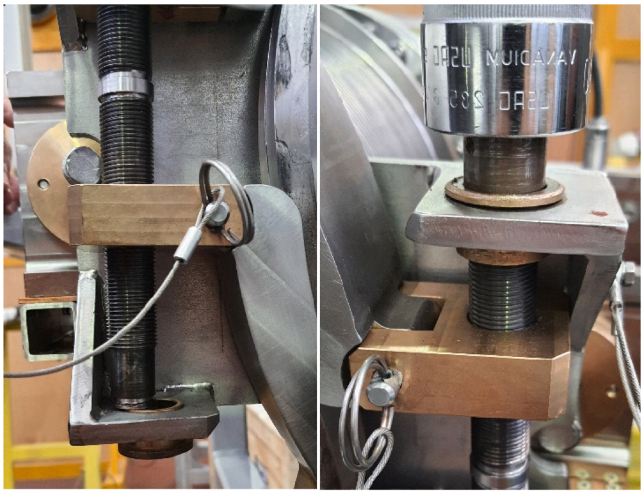


Fig. 10. FDS test set-up in the DRP lab.

One of the objectives of the campaign was also to test the safety and security subsystems included in the FDS. The safety systems of the FDS include pins that detach the chain segments and bolts that detach the segments from the interface if stuck on the flange. The pins are foreseen to be used by the robotic arm thanks to steel wires. However, when the FDS is tightened at nominal torque, it is impossible to detach the pins without dealing reaction damage to the robotic arm. Tests were done by the operator to remove the pins at nominal torque, although with negative results, thus counting as a failure for the safety systems of the FDS. One further issue arose when assessing if the tightening of the FDS induced further travel of the moving flange and thus extended the bellow. Indeed, by using micrometers placed before the moving flange and fixed on the connecting system support, it was observed that one side of the FDS travels by approximately 7 mm, while the other just by 2 mm. This further pull of the FDS on the bellow then transmits load to the interface between the FDS flange and the linear shafts. Indeed, during the campaign, it was observed that the bolts that secure the interface between the FDS flange and the linear shafts loosened during the bolting/unbolting cycles of the FDS. In future designs of the connecting system the possibility to include a component which, when the position is reached, detaches the FDS flange from the linear shafts, will be explored. This component would allow the bellow to compensate for the minor movements when tightening the FDS or due to thermal deformations during operation by detaching it from the linear rods. One further issue reported during the experimental campaign is that the FDS and its rods are kept in position with respect to the OPM with two circlips, one per threaded rod. However, during operations, one of the circlips came loose, and one of the threaded rods (shown in Fig. 11) violently burst out of the seating. No permanent damage was observed, and the rod was safely put back in its seating. However, the circlips must be reinforced to avoid similar situations in operation.

Table 2
Results of the FDS testing with different gaskets.

Gasket type	Torque (Nm)	Leak rate ($Pa{\cdot}m^3/s$)
AISI 304	60	7.9×10^{-7}
AISI 304	90	2.2×10^{-8}
AISI 304	110	1.4×10^{-8}
AISI 304	200	3.8×10^{-8}
AISI 304	220	3.7×10^{-8}
AISI 304	240	3.2×10^{-8}
AISI 304	270	3.0×10^{-8}
INCONEL 718	20	5.8×10^{-8}
INCONEL 718	40	3.2×10^{-9}
INCONEL 718	60	1.0×10^{-10}
INCONEL 718	80	1.5×10^{-12}



a) b)

Fig. 11. Different views, a) lower and b) top, of the FDS threaded rods coming out of the seating due to circlip failure.

4. Conclusions

This work deeply analyzed the developed OPM-FDS connecting system, designed as a joint effort between ENEA and the University of Granada and then manufactured by ARQUIMEA®. The experimental activities were then carried out at the ENEA DRP lab in a joint effort between ENEA, Politecnico di Milano, and the University of Basilicata. The validation activity was divided into two main sub-steps: the analysis of the OPM and the analysis of the FDS.

The analysis of the OPM indeed achieved positive results even after multiple repeated tests (~50). Indeed, the interfaces of the systems are easily reachable and visible, with the system being able to operate correctly by acting on the main polygonal bolt. The system requires a low level of torque to drive the FDS flange towards the beamlines and is always able to correctly position the FDS so that when tightened, it correctly seals the connection between the two flanges. Finally, the OPM was also found to be able to operate when one of the flexible shafts yields, but the behavior of the irradiated shafts and their embrittlement must be assessed before adoption in DONES. One possible replacement for the flexible shafts was identified during the activities in rigid shafts with universal joints. The validation of the FDS also reported positive results. Indeed, the RH interfaces are easily visible and reachable. Furthermore, the system performed well when using the INCONEL 718 gasket, achieving a leak rate suitable to the one established by the project. However, the safety system included in the prototype could not operate when at nominal torque and thus requires redesign. Furthermore, issues were reported regarding the circlips that held the FDS in the seating, and modifications are necessary to avoid situations where the pull of the FDS on the bellow could damage the threaded shafts driving the bellow. Finally, torque reaction support must be introduced in the connection system.

In general, the OPM-FDS connecting system indeed can satisfy the requirements of providing a vacuum tight connection from the TA to the accelerator, albeit some design improvements are necessary. In particular, the OPM has shown remarkable performances, while the FDS design requires further iterations. Furthermore, the system is indeed able to work in a clean unirradiated environment. So that further future activities will involve the irradiation of the flexible shafts and of the OPM gearboxes to assess for neutron-induced damages, which could occur during operation. Then future manufacturing of the FDS chain must deliver the relation between torque applied to the threaded rods and load induced on the gasket. The safety-related features also need to be improved, and the INCONEL 718 gasket must be tested in lithium and potentially irradiated to assess their suitability to being used in DONES.

CRediT authorship contribution statement

G. Benzoni: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **D. Bernardi:** Writing – review & editing, Supervision, Conceptualization. **D. Fuentes-Calero:** Writing – review & editing, Resources, Conceptualization. **A. Cammi:** Writing – review & editing, Supervision. **V. Claps:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation, Formal analysis. **C. Introini:** Writing – review & editing, Supervision. **G. Miccichè:** Writing – review & editing, Validation, Supervision, Investigation, Formal analysis. **F.S. Nitti:** Writing – review & editing, Supervision. **D. Sánchez-Herranz:** Writing – review & editing, Supervision, Resources, Conceptualization. **R. Mozzillo:** Writing – review & editing, Supervision. **C. Tripodo:** Writing – review & editing, Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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