ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOST037

ANALYSIS WITH MECAMASTER ON THE CHAIN OF DESIGN TOLERANCES FOR THE TARGET SYSTEMS AT THE EUROPEAN SPALLATION SOURCE - ESS

A. Bignami†, N. Gazis, S. Ghatnekar Nilsson, ESS, Lund, Sweden
B. Nicquevert[1], CERN, Geneva, Switzerland
[1]also at ESS, Lund, Sweden

Abstract

The European Spallation Source - ESS, has achieved its major construction in Lund, Sweden and is currently continuing in parallel to commissioning its first systems. ESS is characterized by installing and commissioning the most powerful proton LINear ACcelerator (LINAC) designed for neutron production and a 5MW Target system for the production of pulsed neutrons from spallation. The highly challenging and complex design of the Target and Neutron Scattering System (NSS) requires an in-depth analysis of the impact of the stringent manufacturing requirements and tight design tolerances. A campaign of several MECAmaster simulations was performed by ESS Target Division (TD) and Engineering and Integration Support (EIS) Division, focusing on those components that successively come close to their installation and are known for their criticality in terms of achieving the final installation tolerances. The aim of this current study is to investigate and statistically list the possibilities of eventual criticality on the assembly and installation processes, allowing for potential design optimization, tooling implementation and adjustment of the installation procedures.

INTRODUCTION

The European Spallation Source – ESS in Lund undergoes currently its major manufacturing project phase with the aim to deliver Beam On Target (BOT), in the current decade and welcome the First Science results under the Start Of User Program (SOUP). In this context, the Engineering & Integration Support (EIS) division centralizes mechanical engineering expertise under the Mechanical Engineering & Technology (MET) section. Among the expert services of MET, special focus is given on the engineering reviews and tolerance stack-up analysis.

The different types of requirements for all ESS equipment pass through reviews and inspections that allow then for their mechanical design realization under the Single-Point-of-Truth in CAD [1]. Design standardization under ISO GPS plays a decisive role since there has been a tangible effort, including ESS resource investment, in the direction to improve the quality of drawings but also depict the detail level between the different kinds, i.e., drawings for conceptual, detailed, manufacturing and verification.

As part of the standardization, review and engineering training project, tolerance stack-up analysis was introduced on the ESS master model under MECAmaster [2] s/w. MECAmaster is a powerful tool on 3D CAD environment and fully integrated in CATIA V6 (official and central ESS CAD design tool), that allows for large assemblies' tolerance analysis, validation of installation procedures, study of assembly clearances and produce input for post-process kinematic calculations. One of the many unique features in use is the combined consideration of design tolerances with respect to the applicable alignment specifications.

† andrea.bignami@ess.eu

ESS MECAMASTER WAY OF WORKING

MECAmaster analysis is a great asset for big projects such as ESS, in which large and complicated assemblies are vastly present. To optimize the results, a Way of Working (WoW) has been implemented that foresees an exhaustive gathering of information through drawings and experts' contributions, the involvement of working package owners and the methodical implementation of tolerances and assembly procedures. The approach is the following: consider and then calculate the worst-case scenario, in which the max/min value of the tolerances are arithmetical added up and once the critical points are underlined, perform a statistical run (with uniform or gaussian distribution) to have the probability of the potential out-of-tolerance scenario or misalignment. In the following paragraphs the main ESS case studies analysed up-to-date are presented.

Pilot Case (Inner Shielding First Layer)

The first assembly taken into consideration is the first layer of the inner shielding of the Target [3] vessel. The inner shielding has been designed with a "pancake" configuration, with each layer correctly aligned and decoupled from the previous ones, to the most possible extend. Even with these precautions, the impact of the stack of tolerances is not negligible. For this reason, the positioning of the first layer on the bottom of the vessel and its correct alignment are crucial for reducing as much as possible its influence on the whole structure. Therefore, the analysis takes into account both the tolerances from the manufacturing and installation drawings and the whole assembly strategy, including the alignment process, with the intrinsic error, due to the resolution of the instrumentation and the human influence.

As depicted in Fig. 1, the inner shielding is made of three parts that are independently aligned. Once in position, special brackets are inserted in between, with the sole purpose of limiting the relative displacement in case of earthquake; there are not used as fixtures.

13th Int. Particle Acc. Conf. IPAC2022, Bangkok, Thailand JACoW Publishing
ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOST037

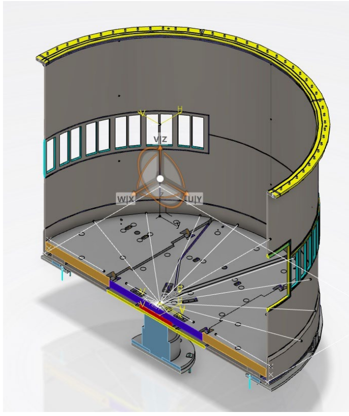

Figure 1: ESS Target Vessel Inner Shielding First Layer.

The analysis aims at evaluating the impact of the stack-up of tolerances and the alignment process on the reduction of the offset between the shielding and the vessel. The reduction of the gap in between the three parts and the misalignment of the pockets in which the brackets are later positioned are also part of the study and contribute to the results of the tolerance analysis.

Inner Shielding (Full Stack)

After the analysis of the first layer, the whole stack is taken into consideration. As presented in Fig. 2, the inner shielding is divided in three main subassemblies, containing the apertures to allow the installation of the target wheel, all the inserts for diagnostic as well as the inserts for neutron extraction.

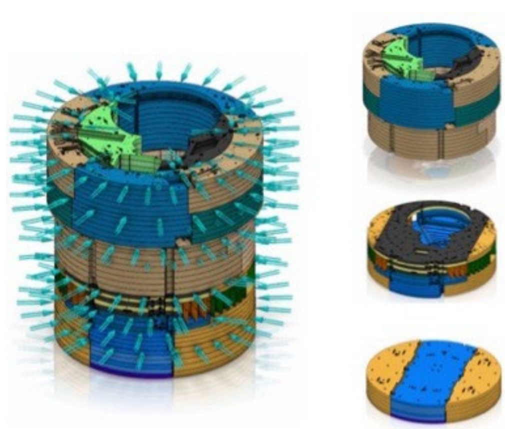

Figure 2: ESS Target Inner Shielding.

As for the first layer, both the alignment process and the installation procedure have been taken into consideration in the analysis. The decoupling through realignment of the different layer is foreseen by design to uncouple the stack-up of tolerances, but its influence on the entire assembly cannot be completely avoided in the real installation.

For this reason, the scope of the analysis is, as for the first layer, to enquire the gap reduction between the shielding and the target vessel along the whole height. Secondarily, to spot the critical areas where the design tolerances and the assembly process potentially combined can lead to critical misalignment of the parts involved.

Port Tube Assembly

The third assembly analysed is the Port Tube assembly. As shown in Fig. 3, the Port Tube (PT) is the component that connects the Target Vessel with the external part of the Bunker and contains the optical system that guides and transports the neutrons to the experiments all around the Target after they are generated by the spallation process and moderated. As the interface between two critical systems, the correct alignment is crucial, considering the sensitivity of the neutron optics for relevant positioning. The choice of the precise assembly and proper installation procedure is therefore critical in reducing the impact of the eventual out-of-tolerances scheme for the involved components.

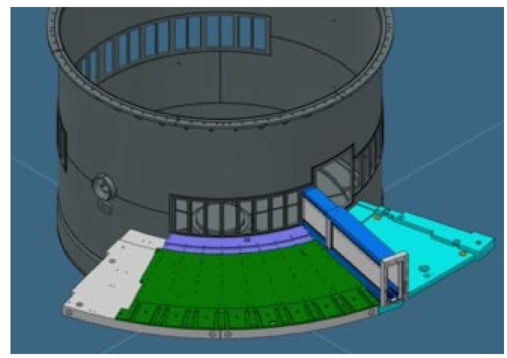

Figure 3: ESS Target Port Tube Assembly.

The aim of the analysis is to investigate the impact of the stack-up of tolerances originated from the vessel installation and the one originated from the installation of the plates on which the port tubes are mounted on the final position of the three interfaces:

- the interface between the PT and the neutron windows in the vessel;
- the interface between the PT and the rails on which the system is installed;
- the interfaces between the PT and the outer system, represented by the flange opposite to the Target.

The results are intended to validate the installation procedure with the scope of minimizing the eventual misalignments within a range of ±50 µm.

ANALYSES OUTCOME & DERIVED RECOMMENDATIONS

The results of the above-described analyses and the consequent rectifying measures that were implemented to mitigate the potential critical scenarios are presented below.

Pilot Case (Inner Shielding First Layer)

The outcome of the simulation has underlined a reduction of the external clearance that, in the worst-case scenario, can reach 8.96 mm (considering both the contribution of the vessel and the inner shielding, as shown in Fig. 4.

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOST037

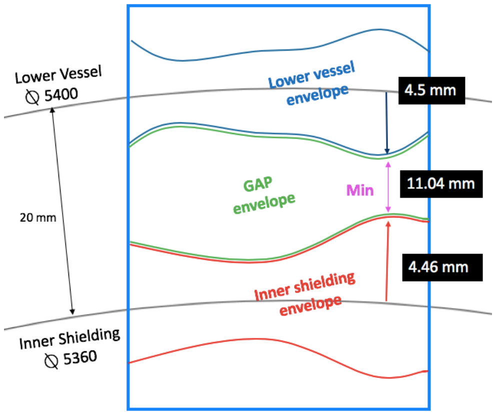

Figure 4: Inner Shielding First Layer Gap Reduction Results.

Once a uniform distribution has been introduced, the results are mitigated to the point of reducing any critical faults on the installation. On the other hand, the misalignment of the pockets in which the clamps are afterwards installed, remains critical even considering the stochastic outcome. As a result, the re-machining of the clamps or alternatively the introduction of different sets of them have been taken into consideration.

Inner Shielding (Full Stack)

The results obtained in the first study are magnified in the analysis of the full stack, where the complexity and length of the chain of tolerances expand the criticalities encountered in the first layer. As shown in Fig. 5, the reduction of the gap is greater so it increases the height of the stack, while also the clearance for the X-clamp is reduced. A forward criticality is also the misalignment of one of the layers with respect to the next one below.

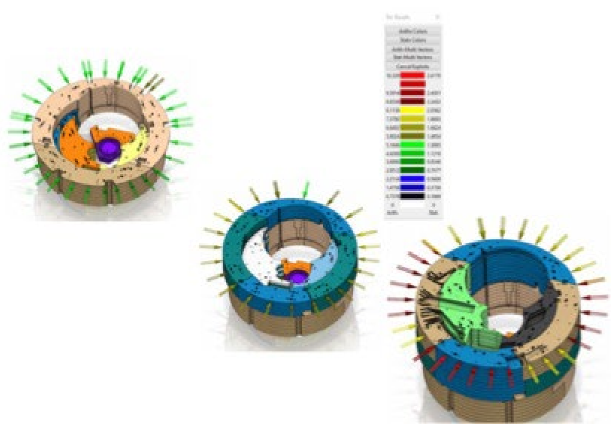

Figure 5: Inner Shielding Gap Reduction Results.

These results contribute to evaluate the necessity of countermeasures, also foreseen by design, to decouple the stack-up of tolerances and differentiate as much as possible the consecutive layers in the sense of:

- Eccentric pins, to allow for an efficient decoupled alignment of each subassembly from the one below;
- Shimming of different thicknesses, to reproduce the correct parallelism for the stack and compensate for the eventual possible deficiency of height;
- Machined clamps, to allow for their installation despite of any reduced clearance scenario.

Port Tube Assembly

Even in the worst-case scenario the misalignment of the PT with the vessel window is compatible with the welding maximum range (±0.5 mm) and therefore it is trivial for the assembly process.

The alignment procedure, that starts minimizing the misalignment with the vessel windows and then compensates the results on the outer side is unaffected in reality by the lever effect combined with the chain of tolerances. By using the clearances of the rail system and an eventual shimming process the influence of the lever effect is minimized. This is especially true if a uniform distribution of the maximum values of tolerances is taken into consideration instead of the combined worst-case scenario analysis.

CONCLUSIONS & FUTURE DEVELOPMENT

The methodology for combining ISO GPS standardization with MECAmaster tolerance chain analysis and ISO GPS design engineering training is currently deployed at ESS. Although it has produced tangible results in terms of quality and information capacity on the engineering drawings, further requirements are captured pointing towards a more in-depth integration of this review process to the projects. The analyses conducted so far, have been focused on critical parts of the ESS Target; so, the Neutron Scattering Systems (NSS) instruments and experimental apparatuses are now also in the pipeline for engineering reviews and tolerance chain analyses. Therefore, the expansion of the usage of this valuable engineering tool is ongoing shifting the focus towards the parts of the ESS machines that will soon go in production, assembly and installation.

ACKNOLEDGMENTS

The author would like to thank Krister Blomberg and Fabien Rey for their valuable input and Valentin Fazenda for his involvement in the inner shielding full stack simulation.

REFERENCES

[1] N. Gazis, E. Tanke, M. Lindroos, M. Tacklind, P. Radahl, and K. Jonsdottir, "Mechanical Engineering, Design and Structural Health Monitoring at the ESS facility to enable science", *World Scientific, International Journal of Modern Physics: Conference Series*, vol. 50, p. 2060006, 2020., doi:10.1142/S201019452060006X

[2] MECAmaster, http://www.mecamaster.com

[3] R. Garoby *et al.*, "The European Spallation Source Design", *Physica Scripta*, vol 93, p. 014001, 2018. doi:10.1088/1402-4896/aa9bff