Vulcan Target Area West upgrade support frame design

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Introduction

As a part of the recent Target Area West (TAW) upgrade, a new compressor chamber for the CPA beams has been designed and built. The chamber housed the new double-pass dielectric-grating compressor required for the second short pulse beam and also the gold gratings for the already existing short pulse beam [1].

Integral to the compressor chamber is the support frame for the optical mounts inside the chamber. The support frame has been designed, built and installed by the CLF engineering group. This report details its design.

Support frame design

The support frame for the optical mounts inside the compressor chamber was specified to have two decks with the new double pass dielectric-grating compressor being on the upper level and the existing single pass gold grating compressor being on the lower deck, as shown in Figure 1.

The main requirement specified for the design of the support frame was to have a very stable and rigid structure that could support heavy optical mounts and perform with minimal deflections under static or moving load. It was decided that the latter could be achieved best with the tables on the lower and upper decks made as solid breadboards spanning across the full length of the chamber. Due to the large span, these breadboards needed to be made from sufficiently thick plates and have reinforcement elements. To support the breadboards, a number of vertical columns with sufficiently large cross-sectional area were required.

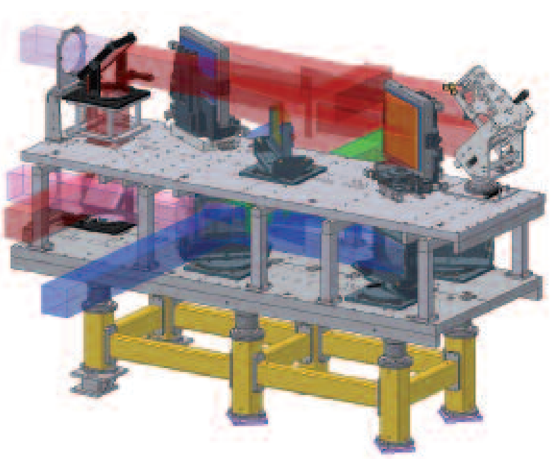

Figure 1. 3D model of support frame with optical mounts.

Preliminary design of the support frame prompted that a welded construction was out of the question and that the whole structure would be too large and heavy to maneuver. Therefore, one of the main restrictions of the design became the ability to assemble the frame in-situ. In other words separate parts of the frame had to be brought in and joined together inside the compression chamber. This placed a limit on the maximum size of support frame elements because only specific ports of the compression chamber were available for access due to the space restrictions in TAW.

It was decided to use a single solid breadboard for the upper deck, as shown in Figure 1. The breadboard spans across the full length of the chamber and its width is less than the width of rectangular ports on the North and South sides of the chamber. The thickness of the breadboard is 60 mm. This value was mainly defined based on the space restrictions. Figure 2 shows reinforcement tubes inside the compressor chamber. As shown in Figure 2, the breadboard had to be positioned above these tubes. A thicker breadboard

Figure 2. Reinforcement tubes inside compressor chamber.

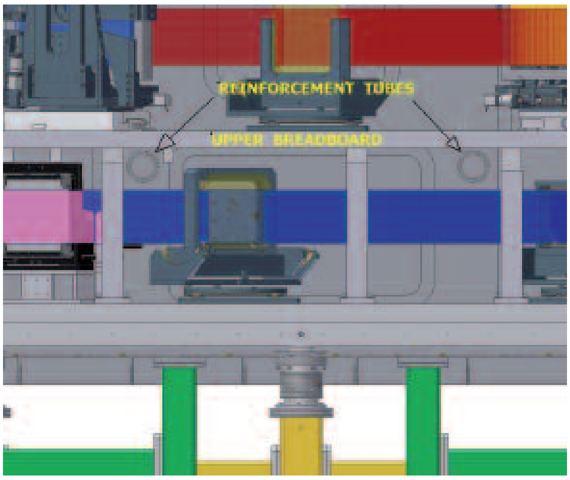

Figure 3. Model of support frame inside compressor chamber showing position of reinforcement tubes and optical mounts.

would leave less room for the optics on the upper deck which was not allowed.

Five pairs of vertical columns supporting the upper breadboard are positioned along the length of the chamber, as shown in Figure 1. The columns are solid square-section bars bolted down to the lower breadboard. Positions of the vertical support columns were chosen to provide free access through the East and West side chamber ports to the optics on the lower deck.

Opposite columns are linked together with solid rectangular-section cross bars, as shown in Figure 1 and Figure 4. The upper breadboard is bolted to these cross bars with bolts tightened to a known torque. The cross bars help to reinforce the breadboard. To further improve stiffness of the upper breadboard, a number of additional solid reinforcement bars are bolted underneath it, as shown in Figure 4. Sizes and optimal positions of these reinforcement elements were determined based on the results of a Finite Element Analysis (FEA).

The breadboard of the lower deck is 70 mm thick and, as well as the upper breadboard, spans across the entire length of the chamber. The breadboard is made of two parts joined together along the length. Figure 5 shows bolt joints positioned along the length of the breadboard. The joints are inside pockets hidden away with covers as shown in the figure. Having the

Figure 4. Reinforcement elements under upper breadboard.

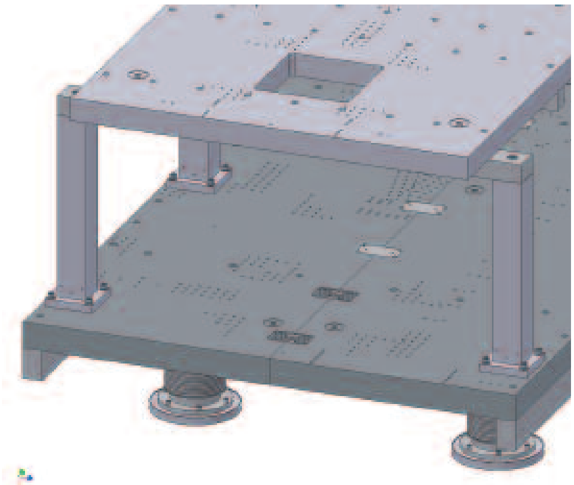

Figure 5. Lower breadboard details.

breadboard made of two parts allowed us to make it much wider than doorways on the North and South sides of the chamber. The thickness of the breadboard was determined based on the FEA results.

As shown in Figure 6, three solid rectangular-section cross bars run across the chamber supporting the lower breadboard. These cross bars rest on six round support columns, see Figure 2, going through the chamber floor. Flexible bellows connecting the columns to the chamber floor make the assembly vacuum tight. Attached to the bottom of the lower breadboard are two reinforcement bars running along the entire length and on each side of the breadboard. It was demonstrated by the FEA that these two reinforcement bars greatly improve stiffness of the lower breadboard alone and of the entire structure as a result.

Pre-machined cast tooling plate was chosen as the material for the upper and lower breadboards due to its very low residual stresses and high stability when machined. ALMAC 500, a 5083 aluminium alloy based plate was specified as the most cost efficient and commonly available material. The use of a higher-strength alloy could potentially result in residual stresses in the material and unavoidable deformations after machining. For the vertical support columns and reinforcement bars, 6082 T6 aluminium alloy was specified. All fasteners are made from stainless steel and were tightened to a known torque.

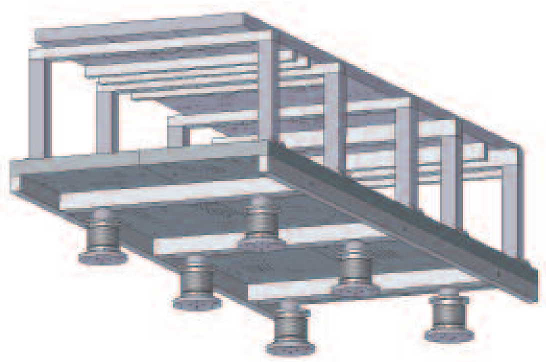

Figure 6. Lower breadboard reinforcement bars and support columns.

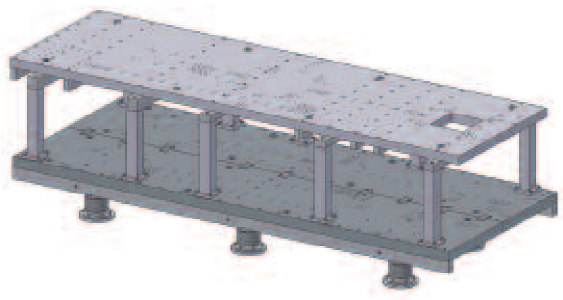

Figure 7. 3D model of support frame in its final design.

In order to have a structure with the highest stiffness and smallest deflections, we had to go through several design iterations. A number of designs have been attempted, the sizes and positions of different frame elements had to be adjusted in order to find an optimum solution. Figure 7 shows the final design of the frame.

Figure 8 and Figure 9 show FEA maps of calculated frame deformations in the vertical direction. Footprints of all optical mounts being at their physical positions are outlined on the upper and lower breadboards. A fixed constraint has been applied to the support legs under the lower breadboard to simplify the analysis. Static load from optical mounts representing weight of the physical units has been applied to the breadboards in the outlined regions. Gravitational force acting on the parts of the support frame has also been applied and taken into account.

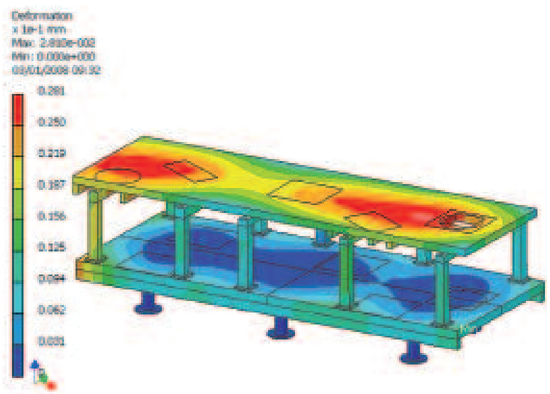

Figure 8. FEA map of calculated deformations.

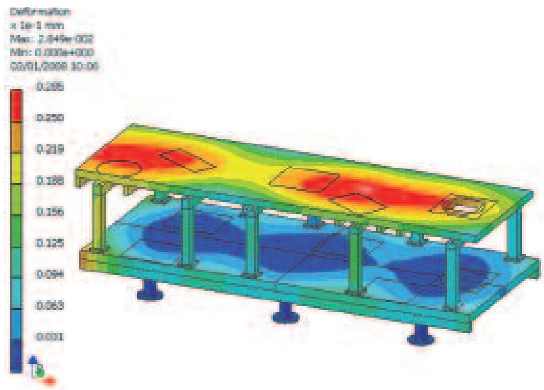

Figure 9. FEA map of calculated deformations – one of the grating mounts is at a different position.

While Figure 8 shows FEA map of frame deformations with all optical mounts being at their nominal positions, Figure 9 shows a similar map, but with one of the dielectric grating mounts on the upper deck moved with the linear slide to one of the extreme positions, that is 150 mm towards the middle of the frame. Comparing the two figures, we can see that the upper breadboard deflects more under the moving load, but the difference in absolute values of maximum deformations is well under 1 μm. The calculated deflection is therefore negligible as compared to the thickness of the upper breadboard, which is 60 mm. It is worth noticing that the FEA was done on a simplified model, but it prompts that very small deformations of the real world assembly can be expected. Subsequent tests done on the physical unit installed inside the compressor chamber and populated with optical mounts, demonstrated stable operation of the support frame as originally specified.

Conclusions

The considerable amount of time and effort invested in the design and analysis paid back enabling us to identify the optimal design and then perform a trouble free installation of the assembly.

References

1. C. Hernandez-Gomez, CLF Annual Report, 260, (2007-2008).