PIP-II Warm Unit

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***Abstract*—**The Warm Units are a vacuum manifold that joins the superconducting cryomodules of the PIP-II linear accelerator (linac). The primary function of the Warm Unit is to provide vacuum pumping for the cryomodules. There are no vacuum pumps in the linac other than the ones provided by the Warm Units. They also provide the opportunity for beam characterization instrumentation to be installed periodically along the linac. The key design tasks were defining the geometry for the instrumentation that will be included in the Warm Unit and the interface to the cryomodules. Coordinating with the groups responsible for these systems was the key to the successful designing of the support structure and bellow restraints for the Warm Units.

I. Introduction

PIP-II is a $900 million project to upgrade the Fermilab accelerator complex to provide a higher intensity beam to run multiple experiments at Fermilab. This upgrade will include a super-conducting linear accelerator (linac) that is consists of several super-conducting cryomodules. Between each pair of cryomodules is a warm unit that will contain the vacuum pumping for the cryomodule as well as beam characterization instrumentation. The warm units will have to interface with the cryomodules in 2 ways. The Warm Units will have to attach to the cryomodule structurally so that the warm unit and the cryomodule can be aligned to each other and the warm unit will have to attach to the cryomodule at the beamline with a hydroformed bellows. The structural interface is a reinforced bracket and the hydroformed bellows requires tooling to be designed to safely compress it and protect it from damage during installation. This bellows restraint must be able to compress the bellows far enough to gain clearance for installation, but it must not compress the bellows to the point the bellows becomes damaged. The bellows restraint will also act as a bellows protector by not allowing the bellows to be over extended and to limit access to the convolutions.

II. Design and Validation of Support Bracket

The load bearing capability, stiffness, location, and clearance from other features are all factors that went into the design of Warm Unit Support Bracket. The Warm Unit bracket needs to be able to support the load of the Warm Unit which will be a maximum of 100kg. The warm unit will also be sensitive to frequencies below 10Hz and at 30 Hz, so a modal analysis needed to be performed to make sure it does not resonate at any of those frequencies. The location and size had to be chosen such that it does not interfere with other features on the cryomodule and gives enough clearance to allow for the installation of the bolts for the end plates. The location relative to other features was also chosen so that the brackets could be manufactured accurately, and their position would be repeatable since several cryomodules would have to be joined by the warm units.

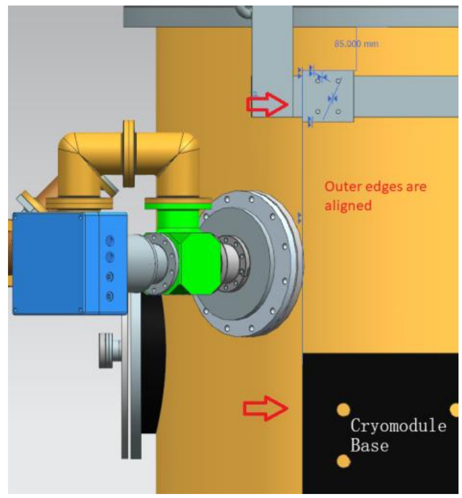

Figure 1 Bracket Positioning

The outside edge of the bracket is aligned with the outside edge of the base of the cryomodule. This alignment will help ensure the brackets are located perpendicular to the horizontal surface of the cryomodule stands. The edge of the bracket facing the end of the cryomodule is spaced out 85mm to give room for the end plate bolts to be installed and for wrenches to get in and tighten the bolts.

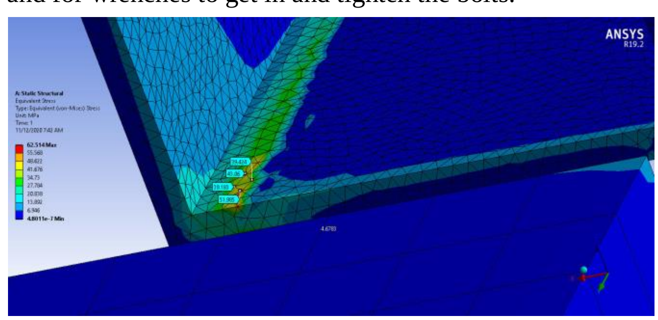

Figure 2 Stress Probes

A structural Finite Element Analysis (FEA) was performed to validate the structural capacity of the bracket. The highest stress shown in the FEA was 52Mpa. The material used for the brackets has a yield stress of 250Mpa.

The brackets were able to safely support the required load with the exposed stress over material yield stress being 5.

To address the vibration constraints a modal analysis was conducted. The analysis was setup using the brackets and the entire warm unit support structure with "dummy load" to simulate the instrumentation and its center of gravity. The only mode were the brackets played a large role is the one shown above at 22.85Hz. This is not a frequency that is an issue but there was a mode at 30Hz as well. To help stiffen the structure to move the mode out of the 30Hz frequency a gusset used, along with other stiffening methods all the modes were able to be shifted above 30Hz.

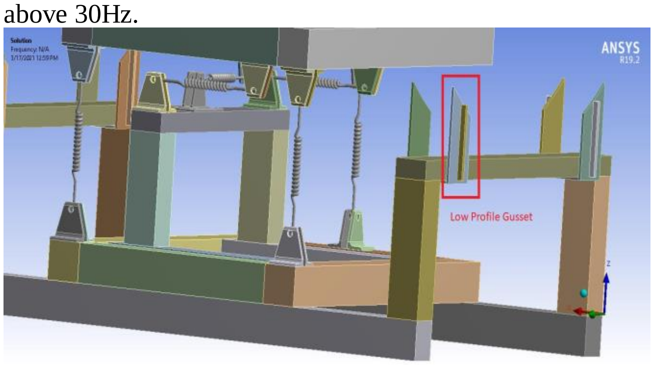

Figure 3 Stiffening Gussets

III. Design and Validation of Bellows Restraint

To safely install and handle the warm unit beamline hydroformed bellows a restraint and protection fixture was required. This fixture needed to be made from vacuum safe materials that would not rust over time and create iron oxide. The fixture needed to be able to be easily disassembled so it could be cleaned regularly to maintain the cleanliness of the cleanroom and vacuum space environments. When these cleaned materials rub against another component of the same material they will gall and fuse together. The fixture design had to take this into account as well and all the components that contact each other must be of dissimilar materials.

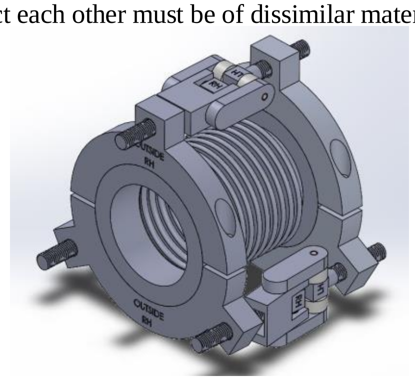

Figure 4 Bellows Restraint Fixture Attached to a Bellows

To provide a locking force the pin holes in the locking handle were off set. The off-set holes will force the handle down once the handle is closed.

The threaded rods have a left-handed thread end and a right-hand thread end this allows for fixture length adjustment while it is attached to a bellows. Based on the length of the bellows used, the restraint fixture can compress the bellows up to 9.25mm maximum.

The fixture must be able to compress and resist the pressure applied by the compressed bellows. To verify the strength of the fixture's design a structural FEA was performed. A 35N force was used. A max stress of 5.2Mpa was found.

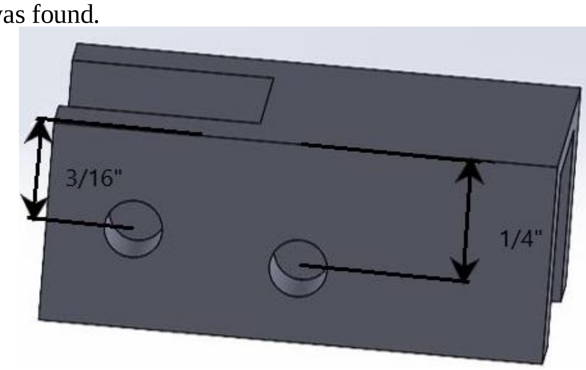

Figure 5 Locking Handle with Off-Set Pin Holes

This maximum is located on a Titanium rod which has a yield stress of 827 MPa which is well above the maximum exposed stress.

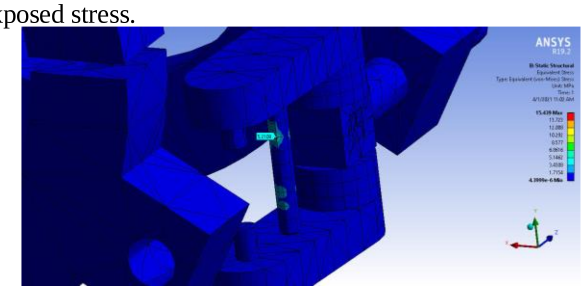

Figure 6 Location of Max Stress

IV. Conclusion

These components had very specific requirements that were dictated by their location and application. The support bracket had loading and location constraints that drove its design. The bellows fixture had to be able to resist the force of a compressed bellows, it also had to be able to be cleaned for use in a cleanroom. For the bellows restraint to be properly cleaned it must be able to be easily disassembled and the components had to withstand the cleaning process without rusting. All these parameters had to be carefully considered and designed for to make a viable product for the PIP-II project.

References

[1] Ball, M., Burov, A., Chase, B., Chakravarty, A., Chen, A., Dixon, S., Edelen, J., Grassellino, A., Johnson, D., Holmes, S., Kazakov, S., Klebaner, A., Kourbanis, I., Leveling, A., Melnychuk, O., Neuffer, D., Nicol, T., Ostiguy, J. -F., Pasquinelli, R., Passarelli, D., Ristori, L., Pellico, W., Patrick, J., Prost, L., Rakhno, I., Saini, A., Schappert, W., Shemyakin, A., Steimel, J., Scarpine, V., Vivoli, A., Warner, A., Yakovlev, V., Ostroumov, P., and Conway, Z. *The PIP-II Conceptual Design Report*. United States: N. p., 2017. Web. doi:10.2172/1346823.