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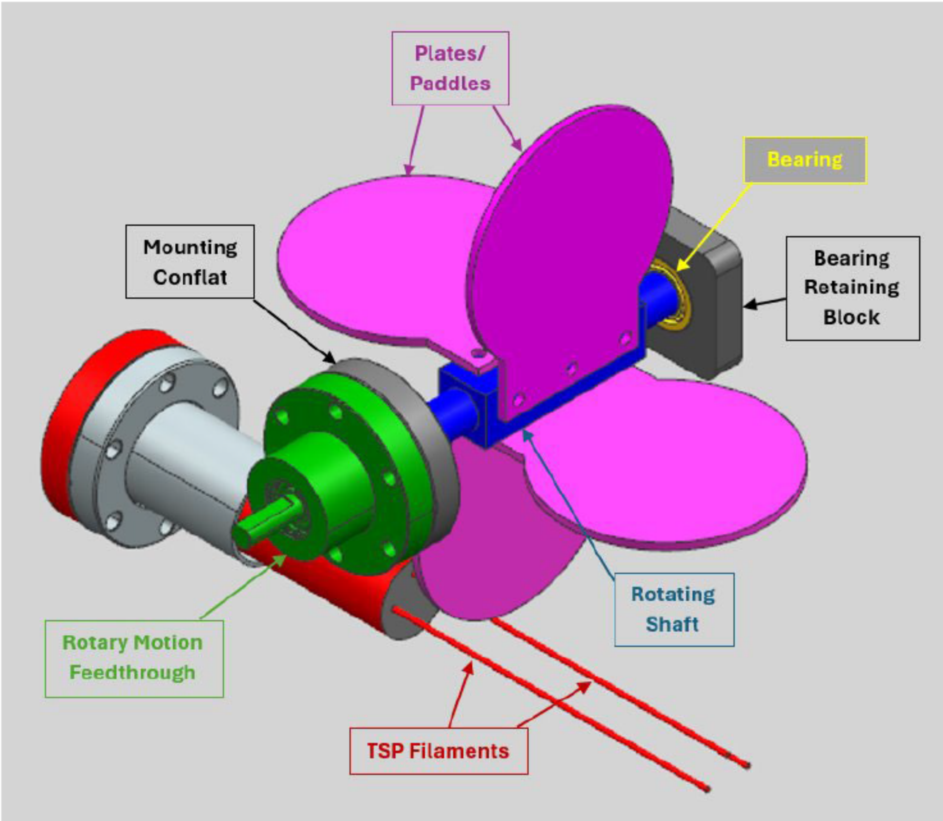
Deployable Element Ultra High Vacuum Pump

Problem Statement

Conventional Ultra-High-Vacuum (UHV) pumps are stationary. Their operation depends upon molecules bouncing at random into the effective pumping volume. The pumping speed (and related quantities like ultimate pressure or pump-down time) can be limited by the size or conductance of the pumping port or of the process volume itself. We have envisioned a UHV pump with a pumping element that can deploy into the process volume to present greater capture area and/or swept volume to optimize the capture of gas molecules, thereby reducing conductance length. Such a device could be used to improve vacuum performance across a diverse range of systems in research and industrial environments. These advancements come with a series of technical challenges such as altering existing pump technology, interfering with the process (laser, particle beam), and radiative heat transfer in vacuum. The specific technical challenge chosen to address was the radiative heat transfer.

Final Design/Deliverables

The final design, the "Windmill" Deployable Element Ultra High Vacuum Pump (DE-UHV), successfully addressed the challenge of improving vacuum performance by incorporating titanium sublimation pump (TSP) technology with a deployable element. This innovative feature allows the pump's capture area to expand into the process volume, enhancing its ability to trap gas molecules and optimize pumping efficiency. The deployable mechanism increases the effective pumping surface area and swept volume. This helps overcome the limitations of conventional UHV pumps, which are restricted by the size of the pumping port and their stationary nature. Through extensive modeling, prototype fabrication, and testing, the design demonstrated its potential to reduce pump-down times and improve ultimate vacuum levels. Although full vacuum testing could not be completed due to time and equipment constraints, the results showed promise in optimizing vacuum performance for scientific and industrial applications, particularly in research environments like FNAL and LIGO.



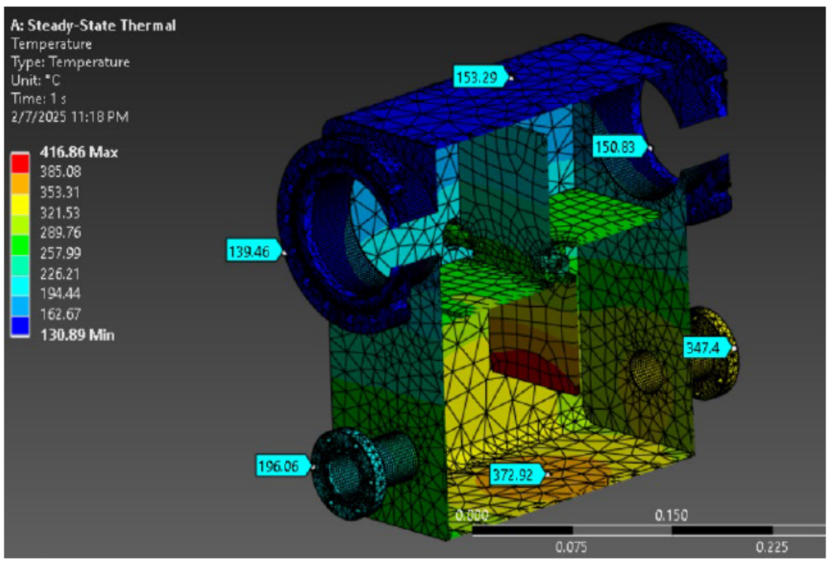
Model of mechanical components of Windmill TSP

Design Tasks

- **Design a Deployable Pump Element**: Develop a mechanism for a UHV pump that allows the pumping element to extend into the process volume, increasing the surface area and swept volume for gas molecule capture.
- **Maximize Surface Area for Capture**: Focus on expanding the capture area by deploying the pump element into regions that are otherwise difficult to access, enhancing the trapping of gas molecules.
- **Enable Continuous Pumping**: Ensure the deployable pump element can maintain continuous and efficient pumping over extended periods, avoiding interruptions in the process and improving overall vacuum performance.
- **Evaluate Integration in UHV Systems**: Assess how this deployable pump design can be integrated into various UHV systems, ensuring compatibility with existing vacuum environments and research applications.
- **Test and Validate Performance**: Conduct rigorous testing to measure the effectiveness of the new design in improving pump-down times and ultimate pressure levels in real-world settings. Calculate the effect of radiant heat transfer on internal components.

Project Impact

The Windmill Deployable Element Ultra High Vacuum Pump represents a significant advancement in accelerating the pump-down process in ultra-high vacuum environments. The design is integral to increasing pumping speeds, as it allows continuous pumping while being directly implemented into the process space. This feature ensures that the pump operates efficiently without disrupting ongoing processes, addressing a key challenge in vacuum systems where interruptions can slow down experiments and testing. One of the most notable aspects of the design is its ability to seamlessly integrate into existing pumping environments. The pump can be adapted to various systems with minimal modifications, offering flexibility and ease of use in different high vacuum setups. These advancements contribute to the field by reducing pump-down times and improving the overall efficiency of vacuum operations in research environments. The design offers a practical solution that can be implemented with simple adjustments, making it a valuable tool for speeding up scientific experiments and enhancing productivity in high-stakes research fields such as particle physics and gravitational wave detection.



Steady-State heat transfer results in ANSYS

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