Pressurized Bellows in Motion Components for Semiconductor Applications

Graduate

Daniel Frei

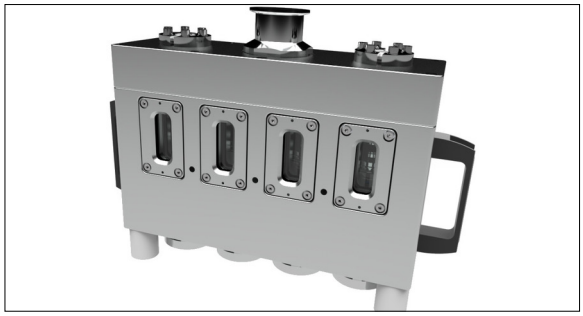
Introduction: Processes in the semiconductor industry are getting more complicated and more advanced. Along with these advancements, the necessary process temperature range is continuously getting wider. 15 years ago, the lowest requested negative operating temperature value was -20°C. Today's requirements are in the range of -50°C. These operating temperatures exhibit massive challenges for VAT pneumatically actuated products, such as Motion Components. Traditional approaches which apply elastomer based dynamic sealings are no longer sufficient. VAT products often include an edge welded metal bellows as a flexible seal between inside vacuum and outside atmospheric pressure. This thesis investigates the possibility of using the bellows as a pneumatic piston to provide a translational movement.

Approach: First, the raw material that is used to manufacture these thin-walled bellows structures is further investigated. It is crucial to know the material behavior under loading. To quantify that, tensile testing of various raw materials is performed, and the results are summarized in corresponding elastic-plastic material models. These material models can be used in finite element analyses in the future.
This thesis then investigates the bellows manufacturing process as well as the operational use case by performing a finite element analysis. The obtained material models are used for these analyses. The simulation model is compared to real measurement results to evaluate the accuracy of the simulation. The non-pressurized and pressurized bellows use cases are compared in the finite element analysis and differences are discussed.
Lastly, such bellows generally complete a life cycle test as part of the development process. For the new pressurized bellows use case, alternative equipment is needed. This thesis provides a test device to complete such life cycle testing in the future. The design and function of the test device is explained, and first testing of a pressurized bellows is carried out and documented. Furthermore, a digital twin of the test device is implemented and compared to real measurement values. The digital twin replicates the behavior of the test device and can be used to test configurations virtually before testing on the real test device.

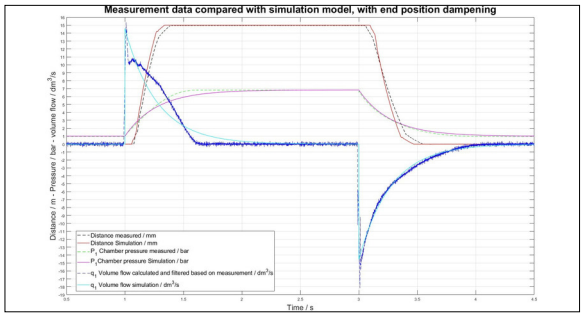
Conclusion: This thesis shows that the concept of the pressurized bellows is a promising alternative to fulfill extreme temperature requirements in the future and needs to be further investigated. This thesis delivers reliable material models that can be used for further development of new bellows products. The finite element analysis' initial results are valid but need additional improvement and consideration. Certain features, such as the welding geometry or the initial residual stresses in the membranes, are not yet considered in the simulation model. The developed test device as well as the implemented digital twin have proven to work as intended, but further improvements have been identified.

VAT Edge Welded Metal Bellows
VAT Vakuumventile AG

New Test Device for Pressurized Bellows
Own presentment



Digital Twin of Test Device
Own presentment



Advisor
Stefan Uhlar

Co-Examiner
Dr. Adrian Kauf

Subject Area
Mechanical Engineering

Project Partner
VAT Vakuumventile AG, Haag, St. Gallen