Numerical Simulation of Polytetrafluoroethylene Gaskets Under Pressure

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ABSTRACT

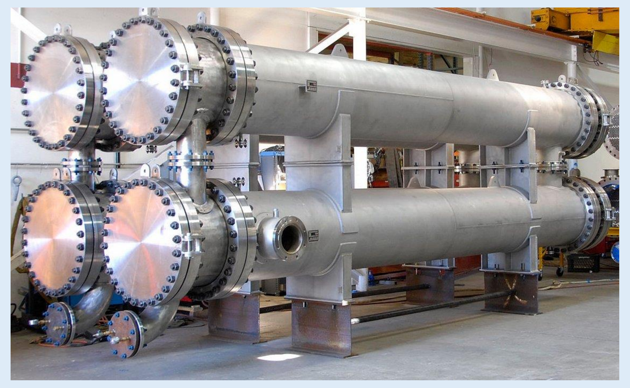
Bolted connections require a gasket to maintain a minimum force to prevent leaking even in extreme environments. The sealing capacity and durability of a gasket while under operational loads is important. Gaskets made from the material polytetrafluoroethylene (PTFE) are an appealing option. However, PTFE exhibits rate-dependent properties and, after being compressed, the material relaxes over time which may result in leakage. Utilizing Siemens NX 12.0, finite element method (FEM) simulations were conducted to quantify stress results of gaskets under constant pressure. Gaskets of different dimensions, mechanical properties, and textures (traditional and textured) were considered. The results obtained show patterns in stress distribution which helps to predict where failure might occur over time in real service usage. These observations can be used to improve and optimize the gasket material and design.

OBJECTIVE

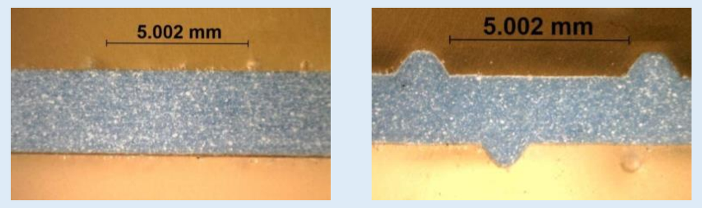
To procure stress results through FEM simulations of a gasket under constant pressure. The patterns in stress help to anticipate where the material may fail during usage. The ultimate goal is gasket design improvement.

INTRODUCTION

Gaskets in flange joints are a key element in the prevention of leaking. While PTFE gaskets are highly durable, the material relaxes over time and deformation occurs. Generally, the study of gaskets has been concentrated towards querying a component of stress (2, 3) or studying the distribution of contact pressure (1) of a flat gasket under compressive loading. Innovations in gasket design feature texture such as a raised hexagonal tessellation on the surface of the gasket. This study focuses on characterizing the changes in stress distribution relating to varying the dimensions and mechanical properties of traditional and textured PTFE gaskets under constant pressure.



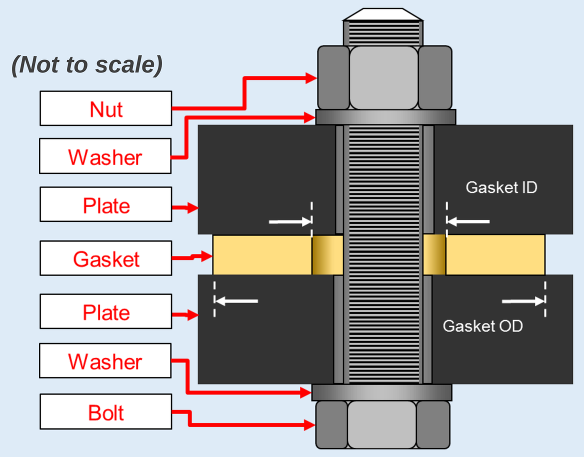
Heat Exchanger



Traditional (left) and Textured (right) Gasket Cross-Sections

Textured Gasket Top View

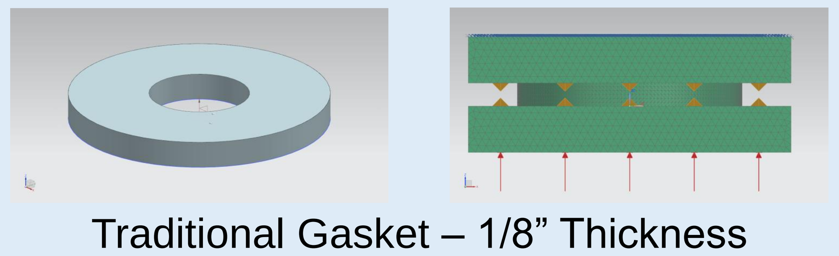
METHODOLOGY



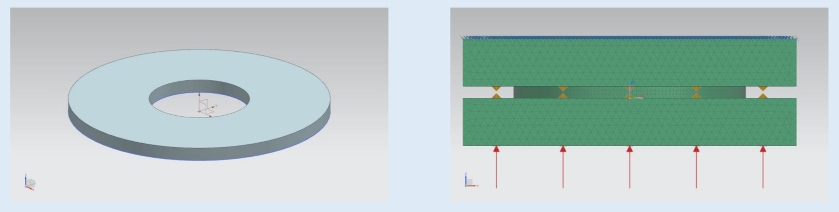
Simulation Conditions

No.	Style (Configuration)	Thickness	Coefficient of Static Friction	No. Elements/Nodes
1	Traditional	1/8”	0.0001	73,320/113,339
2	Traditional	1/16”	0.0001	44,890/73,903
3	Traditional	1/8”	1	73,320/113,339
4	Traditional	1/16”	1	44,890/73,903
5	Textured (Aligned)	3/32”	0.05	299,675/467,972
6	Textured (Offset)	3/32”	0.05	298,476/467,076

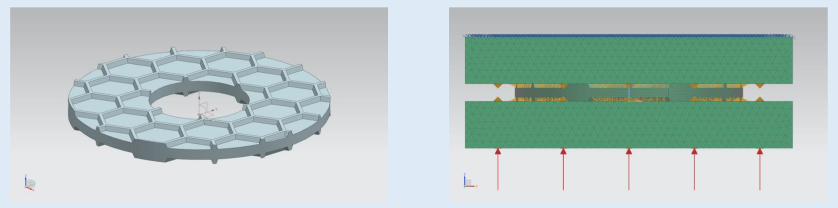
To mimic the behavior of gaskets under service-like loads, several simplified versions of the single-bolt relaxometer pictured above were modeled. The simplified models feature a PTFE gasket between two steel compression plates. In each simulation, the gasket's inner diameter and outer diameter measures 0.4687 *in.* and 1.2187 *in.* respectively. Comprising the gasket is linearly elastic PTFE (E = 90 *ksi* and ν = 0.46). The steel plates measure 1.75 *in.* by 1.75 *in.* with a height of 0.25 *in.* and are comparatively rigid (E = 29,000 *ksi* and ν = 0.3). A constant pressure of 5 *ksi* is applied to the bottom plate. Additional dimensions and properties are listed in the simulation matrix above.



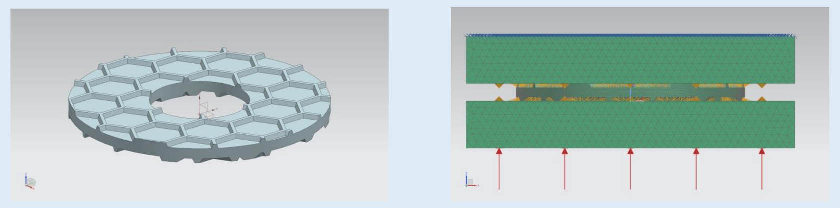
Traditional Gasket – 1/8” Thickness



Traditional Gasket – 1/16” Thickness



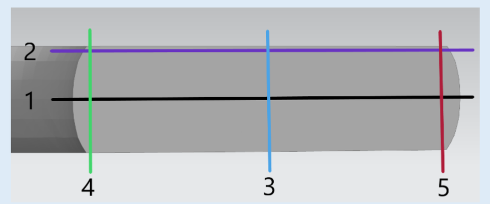
Textured Gasket – Aligned

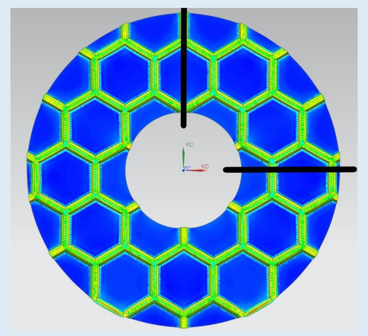


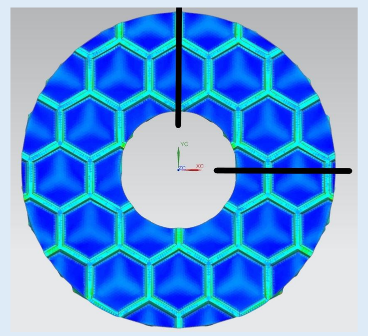
Textured Gasket – Offset

RESULTS

The changes in vertical stress are quantified along the paths designated below on the traditional gasket cross section. For the traditional gasket, friction and thickness are varied. In the textured gasket simulations, two different cross sections and texture alignments were considered. To the right is the top view of the aligned (top) and offset (bottom) gaskets with lines along the cross section locations.

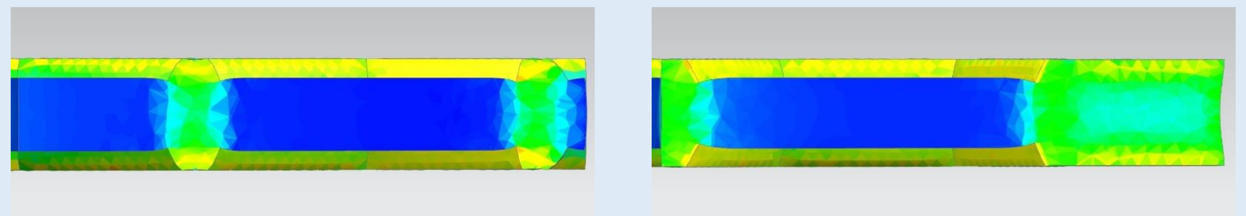






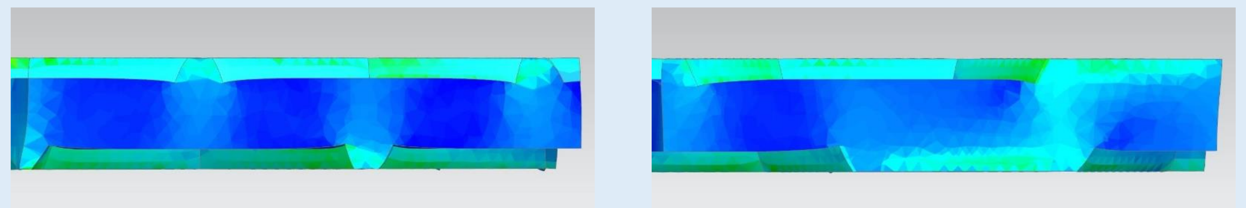
Textured Gasket – Aligned Cross Sections

0° or XZ-axis 90° or YZ-axis



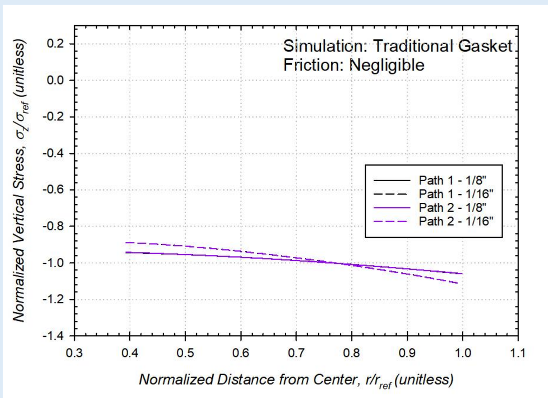
Textured Gasket – Offset Cross Sections

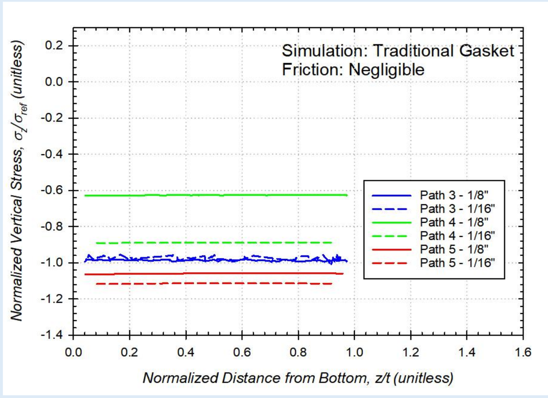
0° or XZ-axis 90° or YZ-axis



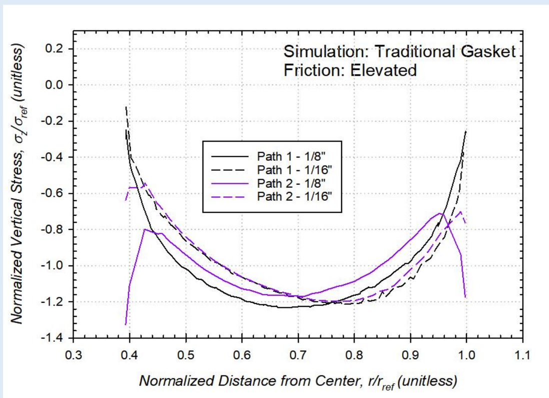
TRADITIONAL GASKET

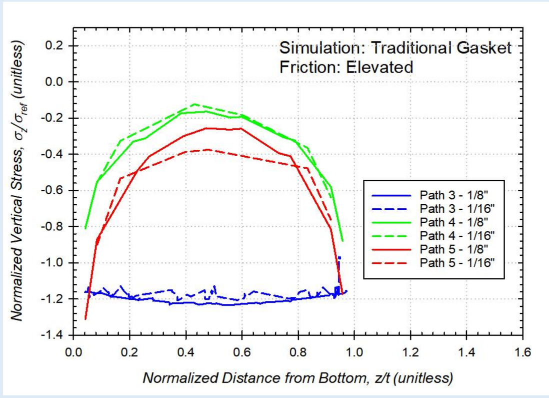
Negligible Friction





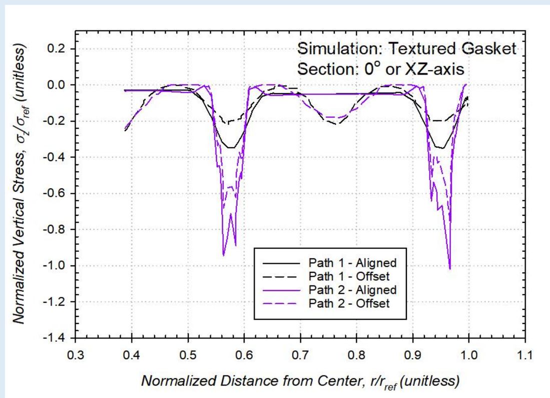
Elevated Friction

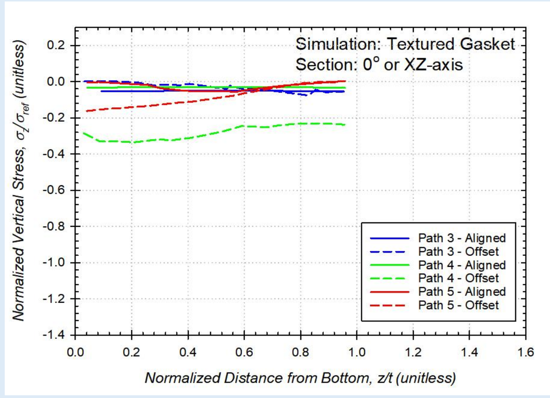




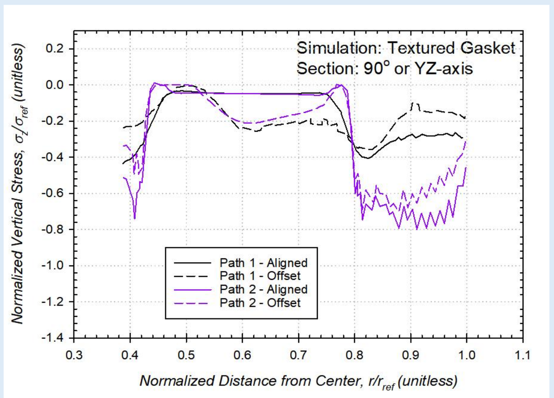
TEXTURED GASKET

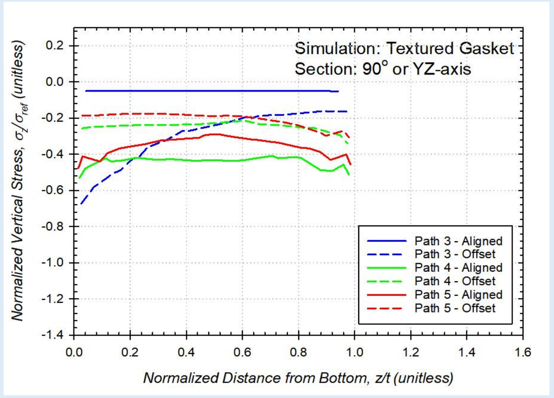
0° or XZ-axis





90° or YZ-axis





DISCUSSION

TRADITIONAL GASKETS

- Vertical stress remains relatively constant across all paths for negligible friction
- The maximum stress for elevated friction is generally located near the center
- Decreasing the thickness shifts maximum stress location towards the outer diameter
- Near the inner and outer edges, vertical stress increases

TEXTURED GASKETS

- The texture peaks and the columnar sections within contain the highest stress
- Vertical stress is generally higher for the aligned texture compared to the offset texture
- The aligned texture shows more intense fluctuation in vertical stress across horizontal paths than the offset texture
- For the offset texture, vertical stress increases in the presence of an opposing peak

FUTURE WORK

Gaskets with larger inner and outer diameters are being developed to compare to existing results. This study also serves as a preliminary step to understanding the viscoelastic behavior and characterizing the time-dependent stress and strain distribution of gaskets under creep relaxation loading.

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