CRYOGENIC TESTING OF 17-7PH FLANGE WASHERS

The purpose of using Solon® Flange Washers in cryogenic flange bolting is to add elasticity to the fastening system. Conceptually, cryogenic flange live loading is an ideal application of Belleville springs (flange washers.) After assembly at ambient temperatures, the flange experiences a differential thermal expansion (DTE) as the cryogenic process is introduced. This DTE occurs for several reasons. One is that the flange and the bolt materials often have very different rates of expansion and contraction. In addition, the flange is closer to the process and will often "shrink" more than the bolts upon startup due to temperature gradient. This tends to cause the bolts to loosen as the flange contracts more than the bolts. The amount of bolt load loss can be estimated by calculating the ratio of DTE to bolting system elasticity.

Solon® Flange Washers

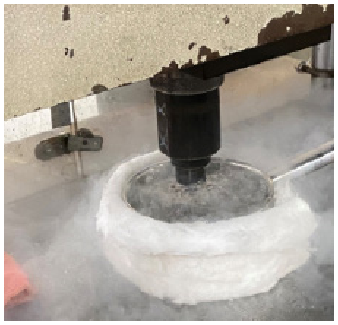
Flange washers are highly stressed Belleville springs that are employed in flange applications. There are several characteristics that differentiate flange washers from typical Belleville designs. One of these is the OD/ID ratio is small enough to allow the flange washer to fit within the spotface on a standard flange. Additionally, flange washers are designed for the high loading often associated with flange bolting.

It is critical that the material used for flange washers provides excellent mechanical spring properties and is able to remain ductile within the temperature limits of the application. This enables the springs to produce elasticity while minimizing the risk of failure at temperature extremes. One common application for flange live loading is for flange bolting in liquefied natural gas process (LNG) piping. ASME Code B31.3 allows for unlisted materials to be used as per paragraph 323.3.4 and note 4. Tests may include tensile elongation, sharp-notch tensile strength (to be compared with unnotched tensile strength), and/or other tests, conducted at or below design minimum temperature. For LNG, the process temperature is considered to be -320F.

Cryogenic testing of 17-7PH stainless flange washers

1. Test Plan – Conduct a compressive load versus deflection tests of several highly stressed flange washers at a test temperature of -320F. Each sample would be tested at least 2X beyond its elastic limit to confirm no risk of cracking even if the parts were overstressed in their application. Test would include samples heat treated to conditions RH1065 (Solon Standard heat treat condition) and TH1050 to compare relative results. All tests to be performed by an accredited third-party testing lab.

2. Test Procedure – Each sample was loaded into a fixture anvil with angled surfaces that allow the springs to be deflected beyond the flat position. The samples and fixture were then placed into an insulated container and the container was filled with liquid nitrogen for a minimum time of five minutes to ensure parts and fixtures reached -320F. Parts were then loaded using a Tinius Olsen Universal Testing Machine and load versus deflection values were measured and recorded.



Cryogenic Test Procedure

3. Parts Tested and Loading – Two samples each of the following parts were tested. Two versions of 16F168177 heat treated to two different conditions were selected. Likewise, two versions of 12F131177 treated to different conditions were selected. Both parts have the same geometry when treated to different heat treat conditions.

PART NO	CONDITION	TEST LOAD (LBS)	ELASTIC DEFL.	DISPL.
16F168177	RH1065	50000	.050	.130
16F168177	TH1050	50000	.050	.130
12F131177	RH1065	20000	.030	.080
12F131177	TH1050	50000	.030	.080

4. Test Curves – A certified test report was issued by Tensile Testing Metallurgical Laboratory in Cleveland, OH. This report contained a description of the test method along with all resultant curves. The figures represent an image of one of the curves. The rest of the curves are available upon request. The curves show much greater displacement than actual displacement of the springs. For example, the elastic displacement of 16F168177 is closer to .018”. This indicates that some of the measured deflection is in the testing equipment. This is acceptable and expected. Each of the curves clearly exhibit a “bend” on increasing loading showing that the springs were stressed at least 2.5X their elastic limits.

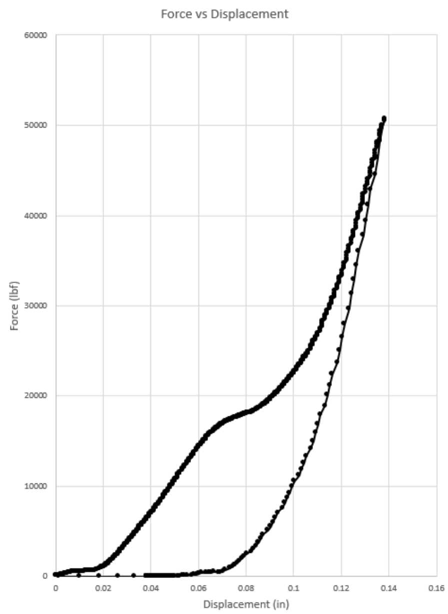


Figure 1: Typical load vs. displacement curve

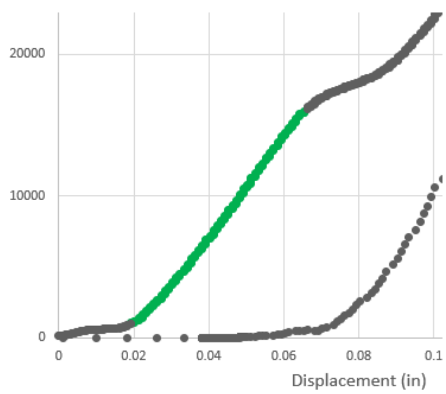


Figure 2: 16F168177 curve (Green line shows elastic displacement on increasing force)

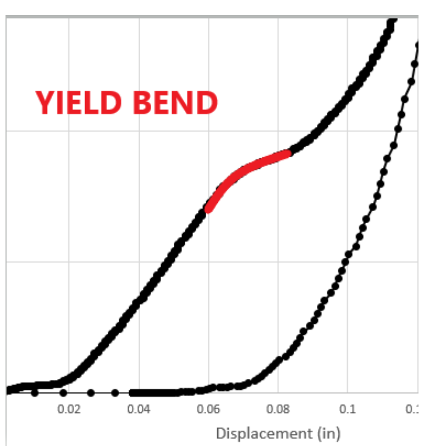


Figure 3: 16F168177 graph showing the yield point of the washer on increasing force

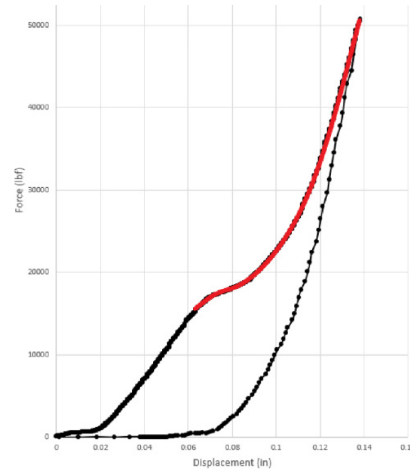


Figure 4: 16F168177 curve showing the plastic deflection on increasing force

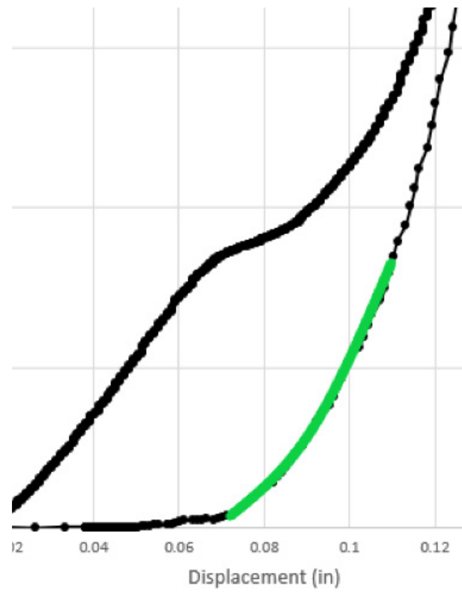


Figure 5: 16F168177 graph showing the elastic deflection of the spring on decreasing force

5. Results - All samples passed the overstress testing to at least 2.5X the elastic limit at temperature without failure. Further, each of the tests shows comparable elasticity on decreasing loading versus increasing.

Conclusion

When a Belleville is installed in a live loaded bolted joint, the amount of overstressing is limited because once the washer is loaded to the flat position, the flange mating surface prevents any addition deflection. Specimens tested in the study were intentionally permitted to deflect 2.5X as far as any flange application. No failures occurred. The material in the tested conditions offer high strength and ductility at cryogenic temperatures. 17-7PH is suitable for use in Belleville spring live loading applications at -320F in either condition RH1065 or TH1050.

For additional information, please contact Solon Manufacturing Co.
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