Rotary Bending Fatigue for AT110 and TS Tempers of ToughMet® 3 Alloy

Materion conducted rotary fatigue testing (R=-1) on the TS95, TS120U, TS140, and TS 160U tempers of the ToughMet 3 alloy product line. All the tempers were tested locally in air at ambient temperature using an hour glass type coupon with single force loading meeting the guidelines of ISO 1143. The S-N curves presented are typical for copper alloys in that do not show an endurance limit. There is little difference in high cycle fatigue results between the tempers. The TS 95 temper was tested again both in ambient air and in 2.5 molar chloride solution with a pH of 12 at 125° C to demonstrate that the fatigue performance is unaffected by chlorine exposure.

Introduction

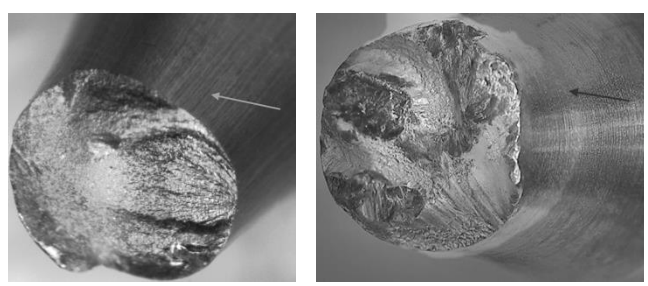
Most material used in demanding applications comes certified to properties that are obtained through a tensile test. These properties are important to determine the maximum amount of stress that can be applied. However, they do little to predict other important aspects of the design such as the expected life. Material can fail well below its tensile strength when subjected to repeat tensile cycling due to the formation and propagation of fatigue cracks. In fact, the majority of in service failures are due to fatigue.

Fatigue tests were developed to characterize this. In a fatigue test, discrete stress levels are applied to a material coupon and cycled until it breaks. There are several types of tests depending on the shape of material.

Materion T3 Testing

Materion tested all of the TS tempers of the ToughMet 3 alloy rod using rotary bending fatigue testing. In this type of test, a constant load creating a bending moment is applied to the sample and the sample is rotated. The maximum stress is determined by the loading configuration and sample geometry. Each rotation creates a fully reversed stress cycle. Rotary bending fatigue testing is covered by ISO 1143. There are several different loading methods and sample types referenced in the specification. Each combination has a unique stress profile, which is important to consider when analyzing the data.

These cracks will always initiate at the highest localized principle stress. Since no surface is perfectly smooth, every surface has stress concentrators. Surface roughness, the amount of the surface exposed to a given stress, and the grind or polish direction will all have a significant effect on the test results. Testing speed can also have an effect when it causes a temperature rise, adds extra vibration, or when the test is done in potentially corrosive environments. When analyzing fatigue data it is important to note the parameters in order to compare it with other tests.



a b

Figure 1: Broken test coupons showing the ground surface. Coupon a was ground longitudinally and coupon b was ground circumferentially

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AT0070/0618

Table 1: Test parameters for the different fatigue tests

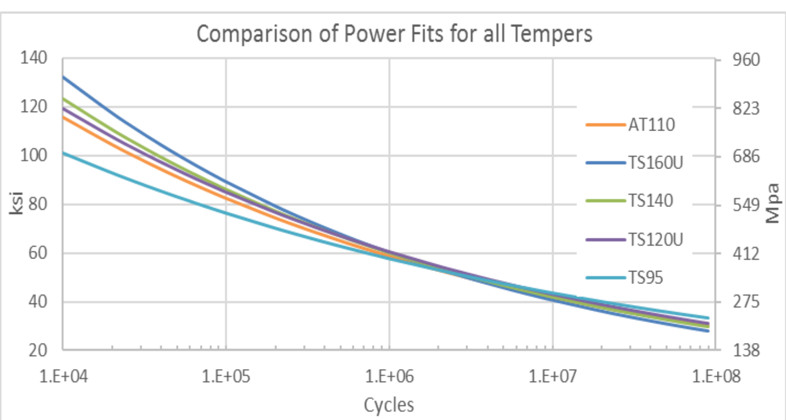
Parameter	ISO 1143 Guideline	ISO 1143 Tests	Chloride Testing
Surface roughness	≤0.2 µm	0.2 µm	0.8 µm
Grinding Direction	Longitudinal	Longitudinal	Circumferential
Sample Geometry	Hour Glass/Parallel/Tapered	Hour Glass	Hour Glass
Hour Glass Radius	≥ 5 x d	9.25 x d	5 x d
Tapered Length	Not Specified	1.5”	0.737”
Loading	Single Point/2-point/4-point	Single Point	4-point
Testing speed	15-200Hz	166 Hz	50 Hz

Data

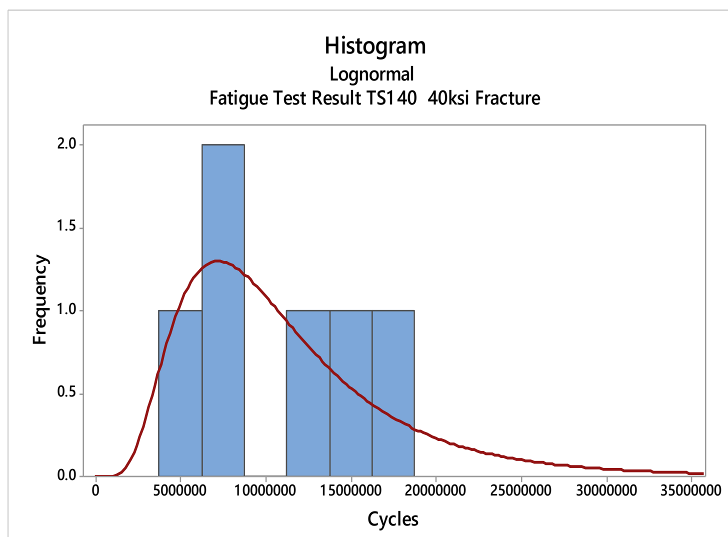
Graph 1 is a comparison of the power fits of all of the tempers tested. Where there were more than three samples tested at one stress level, a lognormal fit was used on the distribution to determine the 5 and 95 percentile values shown in graphs 3 thru 7. Graphs 3 thru 7 are the individual S-N curves of the tempers. They were all tested to ISO 1143 with the samples meeting the guidelines shown in column 3 of table 1.

Graph 8 is the S-N plot of the TS 95 to show the effects of chloride. It contains both the data from a test in air at ambient temperature and from a test at 125°C in the 2.25 molar chloride solution. These samples met the guidelines of column 4 in table 1. The best fit is made with the ambient temperature data points.

The lower fatigue strength compared to the same temper tested under ISO 1143 is likely the result of the rougher surface, grinding direction and the different stress profile created by the loading conditions. It should be noted that the corrosive environment had little effect on the results.



Graph 1: Power fit comparison



Graph 2 Sample distribution with lognormal fit

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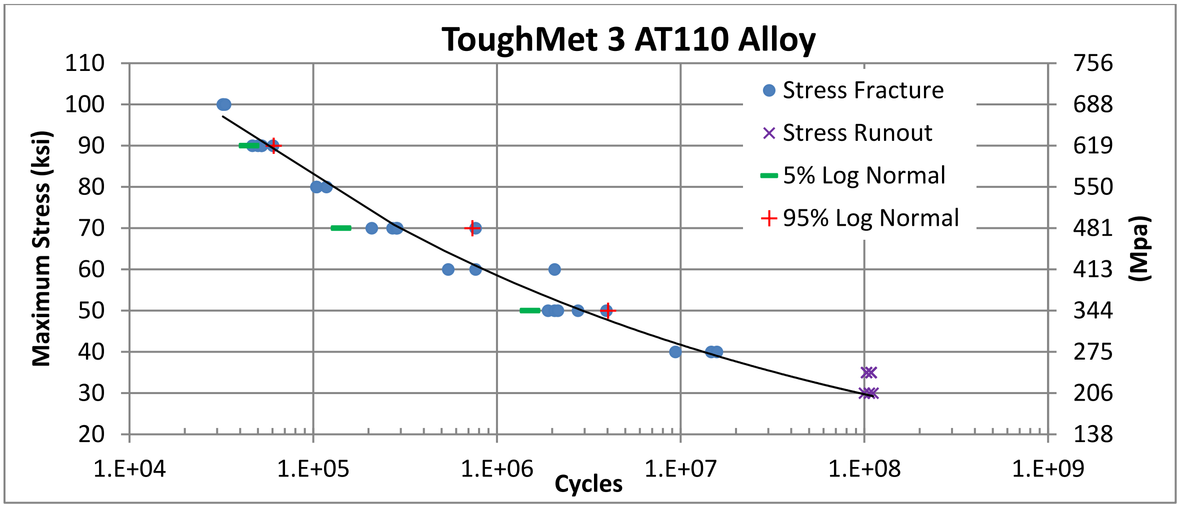
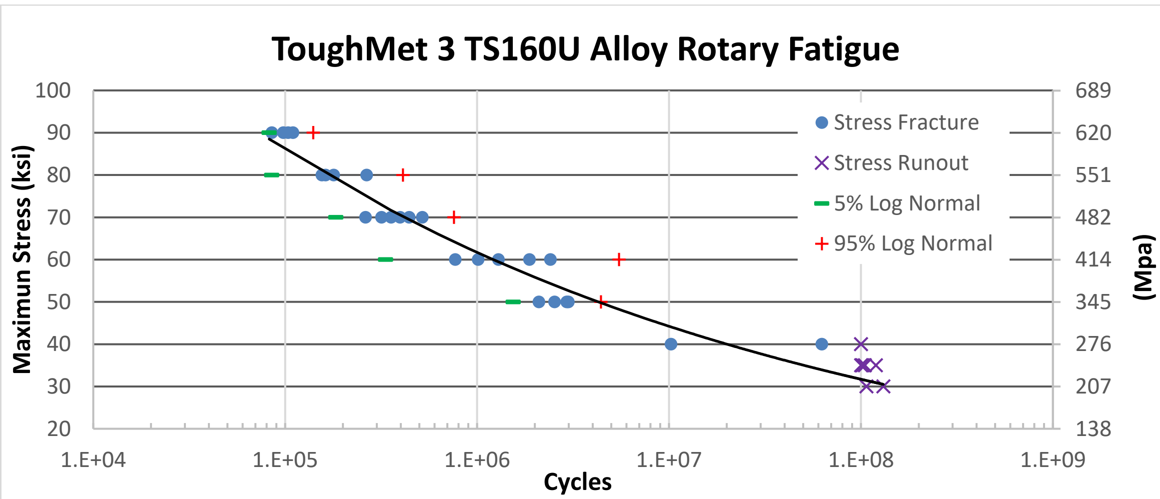
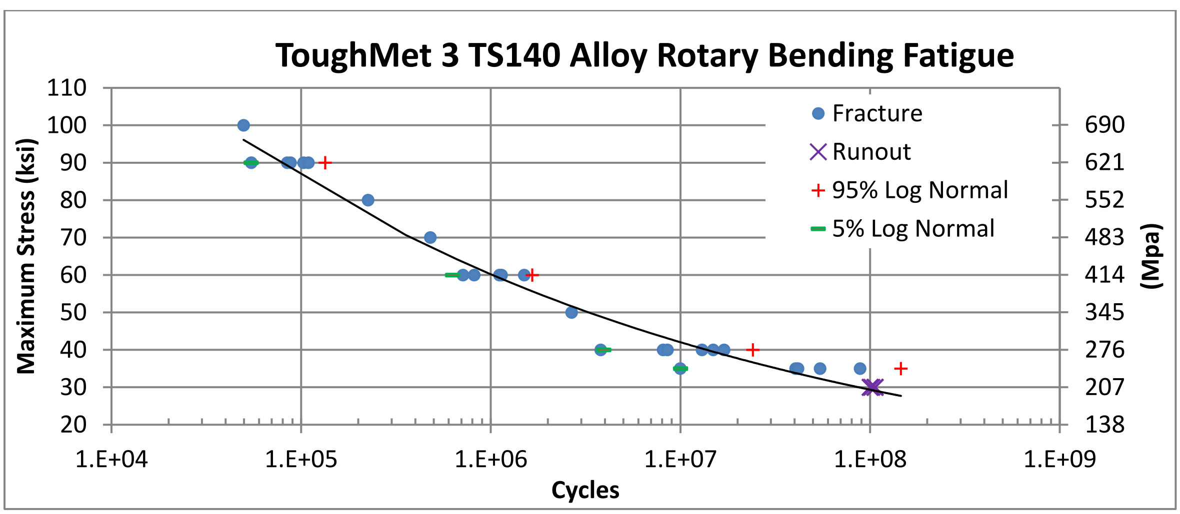


Graph 3: R=-1 ISO 1143 hour glass coupon single-point loading



Graph 4: R=-1 ISO 1143 hour glass coupon single-point loading



Graph 5: R=-1 ISO 1143 hour glass coupon single-point loading

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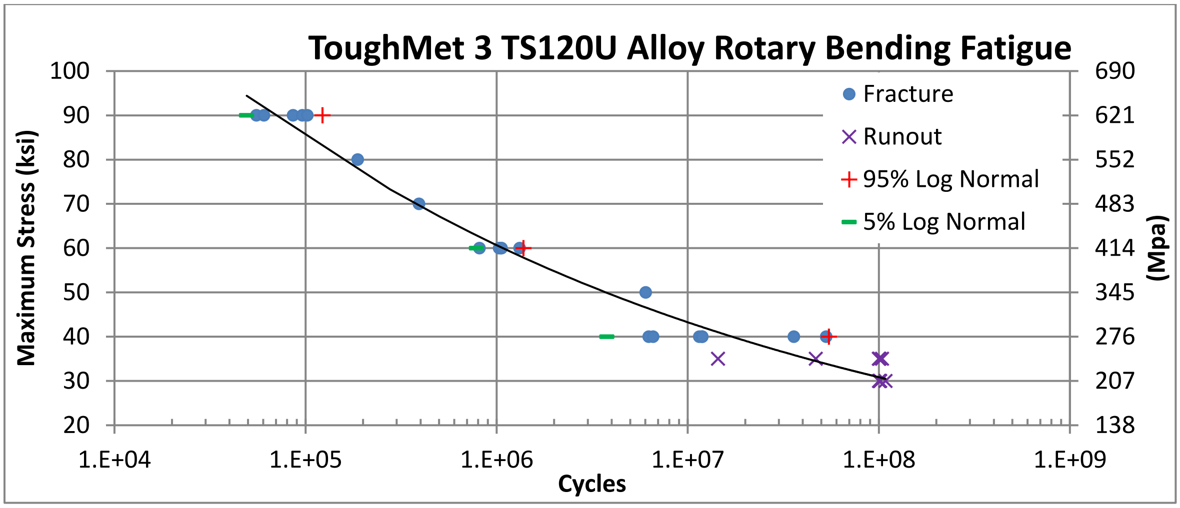
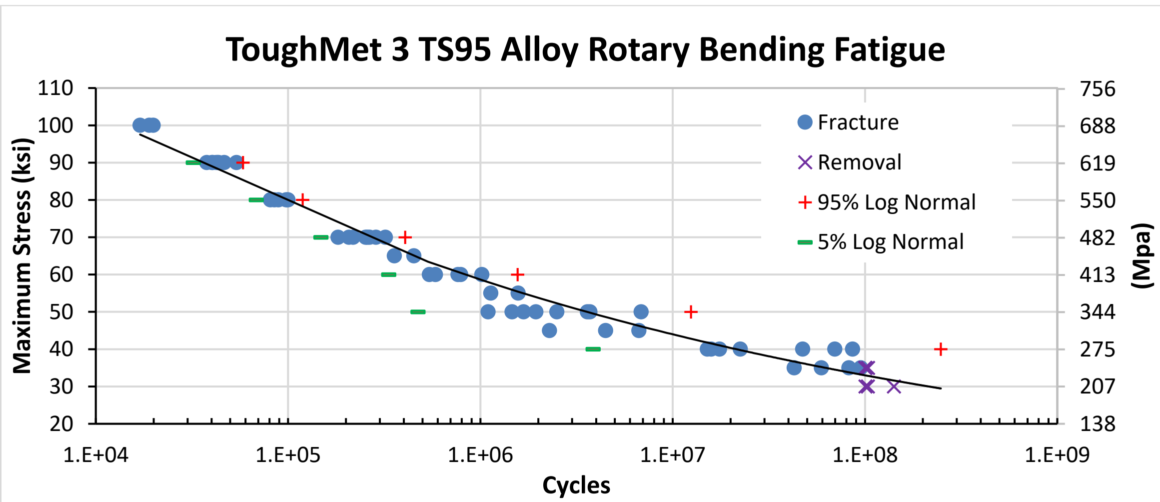
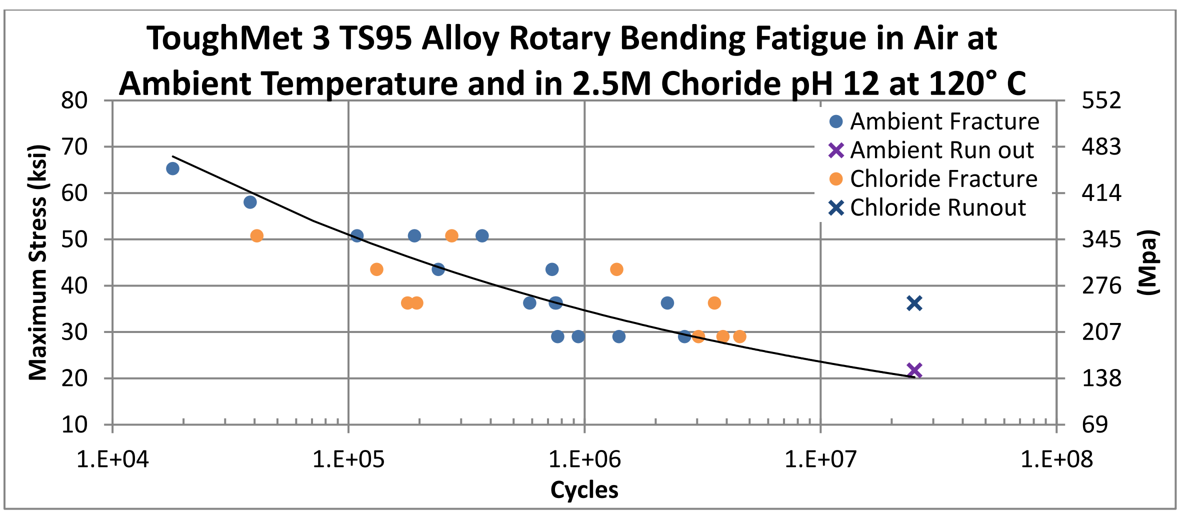


Graph 6: R=-1 ISO 1143 hour glass coupon single-point loading



Graph 7: R=-1 ISO 1143 hour glass coupon single-point loading



Graph 8: R=-1 BHI SP04 hour glass coupon 4-point loading

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