

Impact of Bearing Face Knurling on Bolt Load Relaxation at Elevated Temperature

BACKGROUND



FIGURE 1

Reaction and backup washers such as those defined in ASTM F3394/F3394M include knurls on the bearing surfaces. These knurls act as friction patches, counteracting rotation while allowing the washer to function as a reaction point. Knurling on the backup washer also serves as a locking feature, thereby removing the need for a backup wrench.

Relaxation in bolted joints can originate from material microstructure changes and as a result of bearing surface embedment between components. Relaxation losses may be exacerbated by both time and temperature. This study was designed to isolate and illuminate the effects of bearing surface knurls on embedment relaxation after operating at elevated temperature. A 6" thick ANSI B16.5 1500# ASTM A105 blind flange was utilized for load loss testing. The blind flange was chosen to eliminate typical bending and gasket effects that might overshadow the bearing surface embedment under investigation.

TEST PROCEDURE

The 12-bolt blind flange shown in Figure 1 was loaded with test hardware (knurled washers) and control hardware (no washers). All hardware was assembled with Jetlube™ 550 Extreme and then torqued to 60ksi. All bolt loads were derived from elongation measurements. Relaxation in respect to assembly load was measured at 4 and 24 hours after initial assembly. After holding the assembly at 750°F(399°C) for 336 hours, relaxation was measured at intervals of 24 and 48 hours post furnace removal. Each of the 1-1/2"-8 Grade B16 bolts were equipped with elongation rods by RT-Bolt and oriented as shown in Fig 2. Elongation measurements were conducted with the RT-Bolt supplied dial indicator. All nuts were ASTM A194 Grade 7. The test hardware group included ASTM F3394/F3394M reaction and backup washers. Both washers were manufactured with AISI 4140 conditioned at 40-44 HRC. The Control hardware group was loaded without washers creating a 4% difference in grip length.

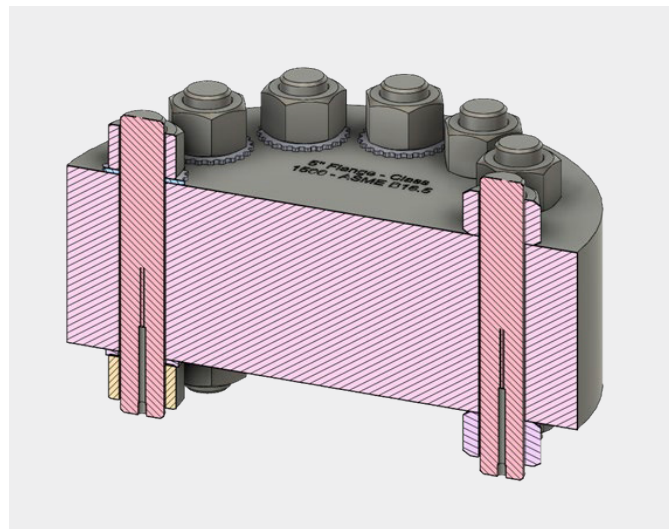


FIGURE 2

(Continued on the following page.)

RESULTS

Average relaxation relative to initial assembly loads is graphed in Fig 3. The control and test hardware had only minor differences in relaxation at 4 and 24 hours after assembly. Significant variances between the control group and the test group were noticed after 336 hours at 750°F (399°C). All elongation measurements were recorded as an average of 3 separate readings shown in Fig 4. The test setup cooled to 150°F(65°C) 24 hours after removal from the furnace. At this 24-hour point average relaxation on the test group was 16.3%, while the control group was at 27.5%. The test flange fully cooled to ambient temperature after 48 hours. At this 48-hour point, the average relaxation on the test group was 24.8%, while the control group was at 33.9%.

CONCLUSION

During this controlled relaxation study, the test group hardware assembled with ASTM F3394/F3394M knurled washers resulted in 9.2% less relaxation than the control hardware. For these specific conditions which included elevated stress, temperature and time, it has been shown that knurled washers will reduce the magnitude of relaxation.

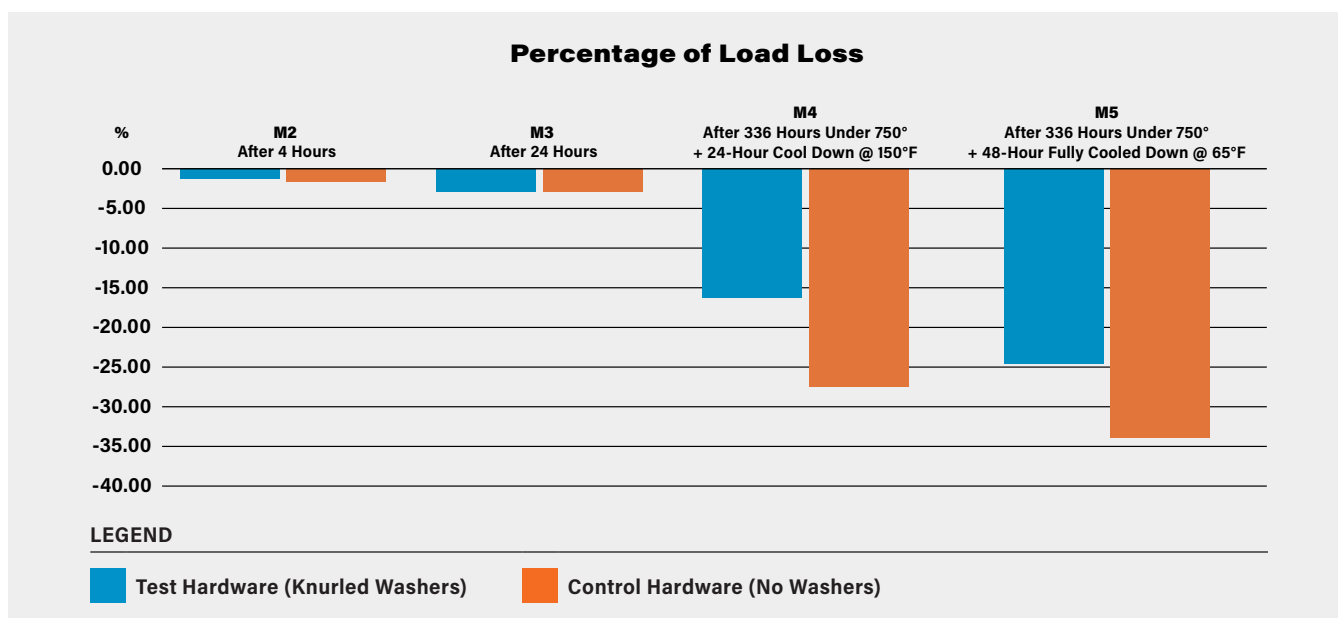


FIGURE 3

AMBIENT TEMPERATURE TESTING														HIGH TEMPERATURE TESTING														
TEST HARDWARE (KNURLED WASHERS)																												
TEST	M1-KSI				M2-KSI				RESULTS		M3-KSI				RESULTS		M4-KSI				RESULTS vs M1		M5-KSI				RESULTS vs M1	
	1 ST	2 ND	3 RD	AVERAGE	1 ST	2 ND	3 RD	AVERAGE	M2-M1	%	1 ST	2 ND	3 RD	AVERAGE	M3-M1	%	1 ST	2 ND	3 RD	AVERAGE	M4-M1	%	1 ST	2 ND	3 RD	AVERAGE	M5-M1	%
1	64	64	64	64.00	61	60	60	60.33	-3.67	-5.73	59	59	58	58.67	-5.33	-8.33	54	55	52	53.67	-10.33	-16.15	48	48	48	48.00	-16.00	-25.00
2	68	66	66	66.67	64	63	65	64.00	-2.67	-4.00	64	63	64	63.67	-3.00	-4.50	52	53	52	52.33	-14.33	-21.50	52	52	50	51.33	-15.33	-23.00
3	66	65	64	65.00	66	65	66	65.67	0.67	1.03	64	64	63	63.67	-1.33	-2.05	70	68	50	62.67	-2.33	-3.59	48	48	49	48.33	-16.67	-25.64
4	61	61	61	61.00	60	61	60	60.33	-0.67	-1.09	59	59	59	59.00	-2.00	-3.28	55	54	56	55.00	-6.00	-9.84	48	49	48	48.33	-12.67	-20.77
5	57	57	57	57.00	56	56	58	56.67	-0.33	-0.58	56	56	56	56.00	-1.00	-1.75	46	43	45	44.67	-12.33	-21.64	42	41	42	41.67	-15.33	-26.90
6	69	66	66	67.00	66	69	70	68.33	1.33	1.99	68	68	69	68.33	1.33	1.99	50	52	48	50.00	-17.00	-25.37	48	48	50	48.67	-18.33	-27.36
-	-	-	-	-	-	-	-	-	-	-1.40	-	-	-	-	-	-2.99	-	-	-	-	-	-16.35	-	-	-	-	-15.72	-24.78
CONTROL HARDWARE (NO WASHERS)																												
TEST	M1-KSI				M2-KSI				RESULTS		M3-KSI				RESULTS		M4-KSI				RESULTS vs M1		M5-KSI				RESULTS vs M1	
	1 ST	2 ND	3 RD	AVERAGE	1 ST	2 ND	3 RD	AVERAGE	M2-M1	%	1 ST	2 ND	3 RD	AVERAGE	M3-M1	%	1 ST	2 ND	3 RD	AVERAGE	M4-M1	%	1 ST	2 ND	3 RD	AVERAGE	M5-M1	%
7	57	57	57	57.00	56	56	56	56.00	-1.00	-1.75	56	56	56	56.00	-1.00	-1.75	48	48	38	44.67	-12.33	-21.64	40	40	41	40.33	-16.67	-29.24
8	56	56	57	56.33	57	58	58	57.67	1.33	2.37	56	56	57	56.33	0.00	0.00	43	42	42	42.33	-14.00	-24.85	40	40	39	39.67	-16.67	-29.59
9	58	58	58	58.00	56	56	57	56.33	-1.67	-2.87	56	56	56	56.00	-2.00	-3.45	40	42	41	41.00	-17.00	-29.31	39	40	39	39.33	-18.67	-32.18
10	60	60	60	60.00	57	58	58	57.67	-2.33	-3.89	57	57	57	57.00	-3.00	-5.00	43	45	43	43.67	-16.33	-27.22	42	41	41	41.33	-18.67	-31.11
11	58	58	58	58.00	56	57	57	56.67	-1.33	-2.30	55	56	55	55.33	-2.67	-4.60	38	38	38	38.00	-20.00	-34.48	30	31	30	30.33	-27.67	-47.70
12	57	57	57	57.00	55	56	56	55.67	-1.33	-2.34	54	55	54	54.33	-2.67	-4.68	40	40	40	40.00	-17.00	-29.82	37	36	35	36.00	-21.00	-36.84
-	-	-	-	-	-	-	-	-	-	-1.69	-	-	-	-	-	-2.96	-	-	-	-	-	-27.50	-	-	-	-	-19.67	-33.96

FIGURE 4



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