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RUPTURE PROPERTIES OF LOW CARBON-HIGH SILICON "17-22-A"S + 1Mo STEEL

by

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THE TIMKEN ROLLER BEARING COMPANY
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RUPTURE PROPERTIES OF LOW CARBON - HIGH SILICON "17-22-A"S + 1Mo STEEL

Two heats of "17-22-A"S + 1Mo steel made with 0.20 percent carbon and about 1.25 percent silicon were investigated for creep-rupture properties at 1000° and 1100°F. The investigation was undertaken to determine the level of rupture test properties to be expected of the steel when lower carbon and high silicon might improve other properties. Secondly, the data would evaluate the possibility of the alloy being an improvement over "17-22-A"S steel. A previous investigation (Report No. 199) of increasing the Mo from 0.5 to 1.0 percent had shown no improvement in properties.

CONCLUSIONS

The 0.2 percent carbon 1.25 percent Si "17-22-A"S + 1Mo steel proved to be extremely brittle in the rupture tests and indicated rupture strengths at 1000° and 1100°F that were similar to those for regular "17-22-A"S steel.

Short time strengths seemed to be higher than the regular grade. Ductility in tensile tests and in short time rupture tests seemed quite high, however, the ductility fell off rapidly with testing time to low values.

It is not known if the compositional effects on transformation characteristics were responsible for the embrittlement, or if some other feature was introduced which made the alloy brittle.

EXPERIMENTAL MATERIAL

The Timken Roller Bearing Company furnished machined 0.505-inch diameter tensile specimens from two heats. One heat, A276, was made in a laboratory induction furnace. The other heat, 02694, was an arc furnace heat. The material had been rolled to bar stock and heat treated as follows:

Heat A276 - Normalized from 1825°F and tempered at 1200°F for 6 hours to a BHN of 363

Heat 02694 - Normalized from 1725°F and tempered at 1200°F for 6 hours to a BHN of 321-341

The chemical composition reported by Timken for the two heats were as follows:

Heat No.	C	Mn	P	S	Si	V	Mo	Ni
A276	.21	.58	.010	.014	1.23	.25	1.03	-
02694	.20	.57	.008	.010	1.23	.22	.94	.18

For all rupture tests at stresses above 40,000 psi, the diameter of the specimens was reduced to keep the loads within the limits of the test machines.

RESULTS

The rupture tests at 1000° and 1100°F (Table 1) showed that the modified alloy had very low ductility in rupture tests except for very short time periods. Normalizing the material from Heat 02694 from 1725°F instead of the 1825°F for Heat A276 resulted in only a slight improvement in ductility.

The ductility fell off with increasing rupture time to a marked extent. The short time tensile specimens from Heat 02694 had excellent ductility.

For rupture time periods only slightly longer than 100 hours the elongation fell to about 1 and 2 percent. Also the ductility was so poor that fracture tended to occur in the fillets with their slight stress concentration.

The stress-rupture time curves at 1000°F (Figure 1) are not well established, particularly for Heat 02694. The available data suggest about the same rupture strengths as regular "17-22-A"S steel. The curves at 1100°F also suggest about the same strength as regular grade. (See Table 2).

There is an indication that the modified alloy might be somewhat more resistant to tempering than the regular grade, At least the shorter time strength and hardness tended to be somewhat higher. (See Table 2).

Further testing was discontinued when the very low ductility in rupture tests became evident.

The complete data for the tensile tests on Heat 02694 were as follows:

Temp. (°F)	Tensile Strength (psi)	Offset Yield Strength (psi)		Elongation (% in 2 ins.)	Reduction of Area (%)
		0.1%	0.2%		
1000	104,750	89,500	96,000	20.5	72.5
1100	90,500	75,500	81,200	22.0	74.0

The microstructures (Plates 1 through 6) showed Bainitic structures with readily etched grain boundaries. The structures indicated that fracture propagated quite readily through the grain boundary in rupture tests at 1000°F. Extensive intergranular cracking occurred at 1100°F, indicating nucleation of cracks was extremely easy in the rupture tests. This must have been the case to have so many cracks with such low elongation.

DISCUSSION

For some reason reducing the carbon content to about 0.2 percent and increasing the silicon to about 1.25 percent resulted in remarkably low ductility under rupture test conditions. The tendency to rupture in fillets with only their slight stress concentrations indicates the degree of embrittlement. (Under rupture test conditions a slight stress concentration usually raises rupture strength unless the material is very brittle.)

The investigation was not sufficiently extensive to determine if the embrittlement was due to the type of transformation product or to some other effect of carbon-silicon-molybdenum. It is therefore possible that modifications of heat treatment could improve properties.

TABLE I

Stress-Rupture Data at 1000° and 1100°F for Low Carbon-High Silicon "17-22-A"S + 1Mo Steel

Temperature (°F)	Stress (psi)	Rupture Time (Hours)	Elongation (% in 2 ins.)	Reduction of Area (%)
		Heat A276 Normalized at 1825°F-Tempered at 1200°F (363 BHN)		
1000	76,000	336	3.0	3.5
1000	68,000	448	1.0	1.0
1000	50,000	1357	<1	(a)
1100	45,000	120	1.5	(a)
1100	33,000	283	<1	<1
1100	20,000	928	<1	(a)
		Heat 02694 Normalized at 1725°F-Tempered at 1200°F (321/341 BHN)		
1000	104,700	STTT	20.5	72.5
1000	82,000	90.7	10.0	48.0
1000	75,000	328	7.0	19.5
1000	68,000	647	1.5	2.5
1100	90,500	STTT	22.0	74.0
1100	42,000	164	1.5	(a)
1100	33,000	294	1.5	(a)
1100	20,000	1709	2.0	3.0

(a) Broke in or near fillet

TABLE II

Comparative Rupture Strength and Fracture Elongations for "17-22-A"S and Modified "17-22-A"S Steel

Material			Heat				Rupture Strength (psi) and Fracture Elongation (%)			
C	Si	Mo	No.	Source	Condition	BHN	100 hr.	1000 hr.	10,000 hr.	100,000 hr.
					1000°F					
*Combined Data for Standard "17-22-A"S					N. 1725°F+T. 1200°F	331	74,000	58,000 (3)	26,500 (2)	(12,000)
					N. 1725°F+T. 1300°F	255	62,000	43,000 (6)	24,500 (2)	(12,000)
.21	1.34	1.03	A276	Current	N. 1825°F+T. 1200°F	363	-	54,000 (1)	(28,000)	-
.20	1.20	.94	02694	Current	N. 1725°F+T. 1200°F	321/341	81,000 (10)	60,000 (1)	(31,000)	-
					1100°F					
.21	1.34	1.03	A276	Current	N. 1825°F+T. 1200°F	363	59,000 (1.5)	19,500 (1)	(7,600)	-
.20	1.20	.94	02694	Current	N. 1725°F+T. 1200°F	321/341	58,000 (1.5)	22,000 (2)	(10,000)	-
.335	.68	1.04	A111	Rpt. 199	N. 1850°F+T. 1225°F	311/331	40,000 (4)	-	-	-
.325	.62	.99	2152	Rpt. 199	N. 1725°F+T. 1200°F	311	51,000 (5)	>26,000 (3)	-	-
.32	.74	.49	16030	Rpt. 198	N. 1725°F+T. 1200°F	311/331	41,000 (3)	20,500 (5)	(9,600)	-

* Data from Reports numbered 198 and 238

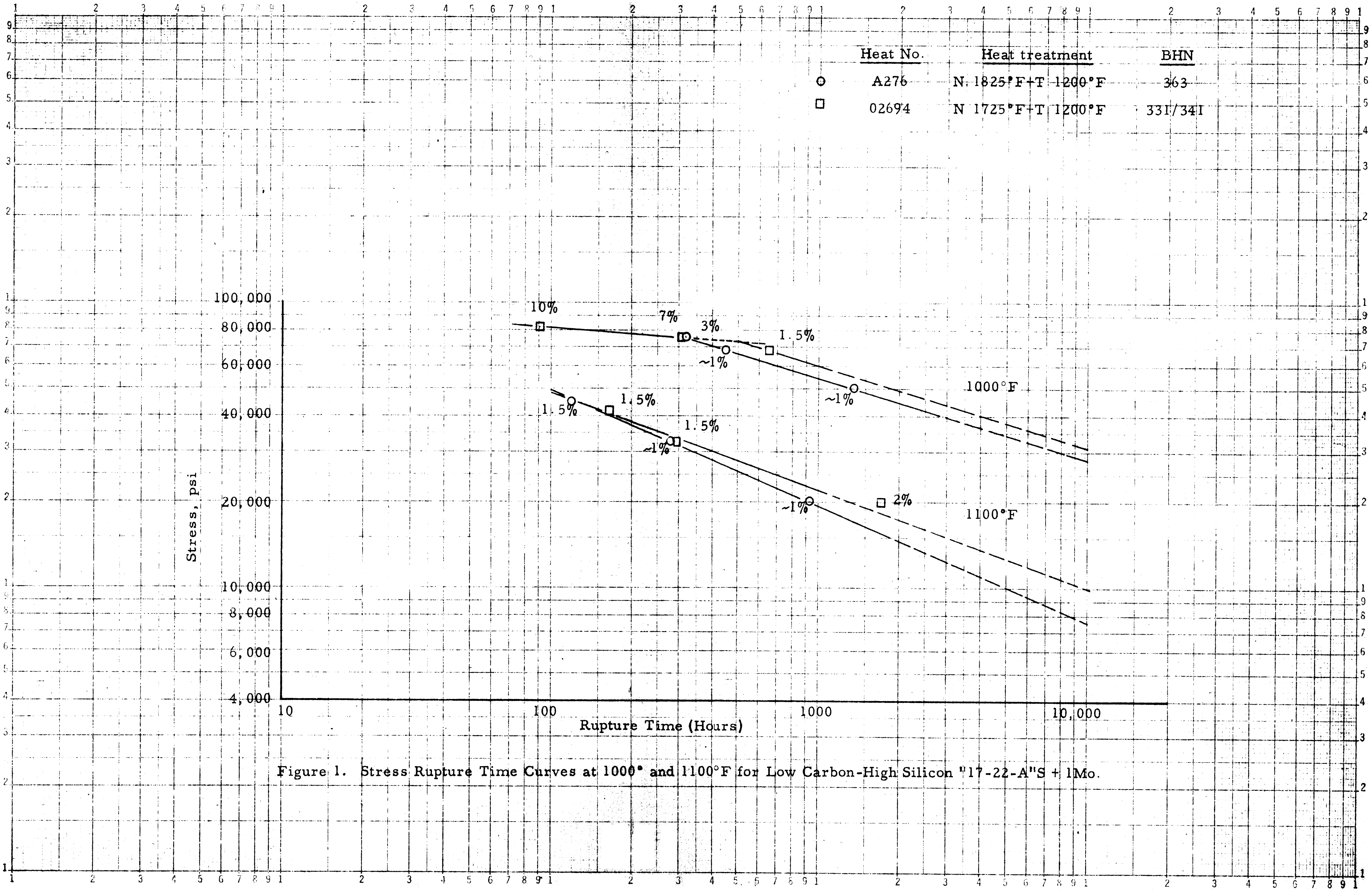

Figure 1. Stress Rupture Time Curves at 1000° and 1100°F for Low Carbon-High Silicon "17-22-A"S + 1Mo.