明治大学学術フロンティア
信頼性データバンク疲労データシート

Meiji University Academic Frontier
Reliability Data Bank Fatigue Data Sheet

高炭素クロム鋼 SUJ2 の回転曲げ疲労特性データシート

Data Sheet on Fatigue Properties of SUJ2 Steel
by Rotating Bending Test (HRC60)

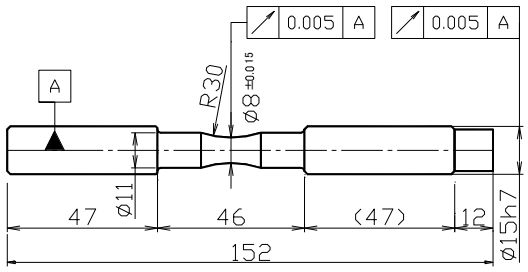
1. 10. 2005

Project of Meiji University Academic Frontier

PARTICULARS FOR MECHANICAL PROPATIES TEST

Pure bending test properties

Table.1 Test piece properties

Hardness	HRC 36, 60
Geometry	

Tension test properties

Table.2 Test piece properties

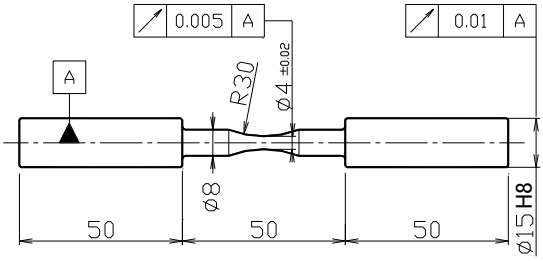
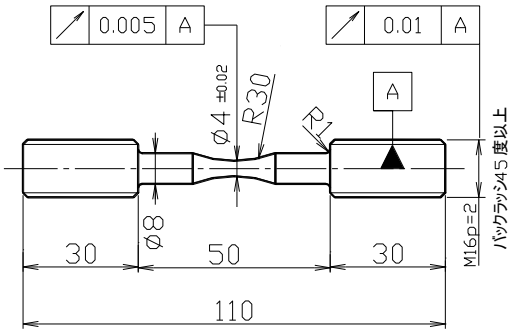
Hardness	HRC36, 60
Geometry	 For HRC36  For HRC60

Table.3 Mechanical properties for test piece

Rockwell hardness [HRC]	N (35.6, 1.45^2)	N (60, 0.65^2)
Proportional limit for bending [GPa]	N (0.947, 0.55^2)	N (2.38, 0.53^2)
Tensile strength [GPa]	N (1.09, 0.014^2)	N (2.1, 0.12^2)

Table.4 Heat treatment conditions of SUJ2 steel

Hardness	**Normalizing**	**Quenching**	**Tempering**
HRC36	—	830℃ /20min	170℃ /120min
HRC60	—	830℃ /20min	600℃ /90min

Table.5 Chemical composition (mass%, O: ppm)

		C	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**Ni**	**Cu**	**O**
Product analysis		0.98	0.18	0.37	0.016	0.003	1.42	0.03	0.07	0.12	6
Requirement	Max	1.10	0.35	0.50	0.03	0.03	1.60	0.08	—	—	—
	Min	0.95	0.15				1.30				

Table.6 Mechanical properties for test piece SUJ2

No	Hardness [HRC]	
	36 HRC	60HRC
1	32.420	58.520
2	32.660	58.980
3	32.740	59.000
4	34.120	59.075
5	34.260	59.080
6	34.280	59.620
7	34.300	59.680
8	34.740	59.720
9	34.840	59.880
10	35.320	59.900
11	35.400	59.940
12	35.440	59.940
13	35.520	59.940
14	35.600	60.000
15	35.600	60.000
16	35.620	60.040
17	35.800	60.220
18	35.820	60.280
19	35.860	60.320
20	35.880	60.340
21	36.460	60.340
22	36.480	60.360
23	36.520	60.420
24	36.700	60.440
25	36.800	60.620
26	36.820	60.640
27	36.820	60.700
28	37.180	60.720
29	37.220	60.800
30	37.780	60.900

No	Pure Bending Proportional limit [GPa]	
	36HRC	60HRC
1	0.768	2.186
2	0.776	2.216
3	0.776	2.272
4	0.790	2.332
5	0.826	2.344
6	0.840	2.352
7	0.899	2.360
8	0.921	2.369
9	0.935	2.373
10	0.955	2.375
11	0.975	2.379
12	0.995	2.405
13	0.995	2.413
14	0.995	2.427
15	1.005	2.431
16	1.084	2.433
17	1.114	2.439
18	1.154	2.465
19	1.194	2.475

No	Tensile strength [GPa]	
	36HRC	60HRC
1	1.051	1.812
2	1.072	1.857
3	1.073	1.902
4	1.079	1.917
5	1.088	1.985
6	1.088	2.005
7	1.088	2.019
8	1.089	2.023
9	1.089	2.033
10	1.090	2.043
11	1.092	2.054
12	1.093	2.071
13	1.094	2.075
14	1.095	2.080
15	1.095	2.083
16	1.095	2.083
17	1.095	2.097
18	1.096	2.100
19	1.097	2.109
20	1.097	2.113
21	1.099	2.135
22	1.099	2.138
23	1.099	2.145
24	1.100	2.148
25	1.100	2.153
26	1.101	2.155
27	1.101	2.172
28	1.101	2.179
29	1.101	2.183
30	1.102	2.204
31	1.107	2.216
32	1.112	2.262
33	1.114	2.266
34	1.114	2.275
35	1.120	2.318

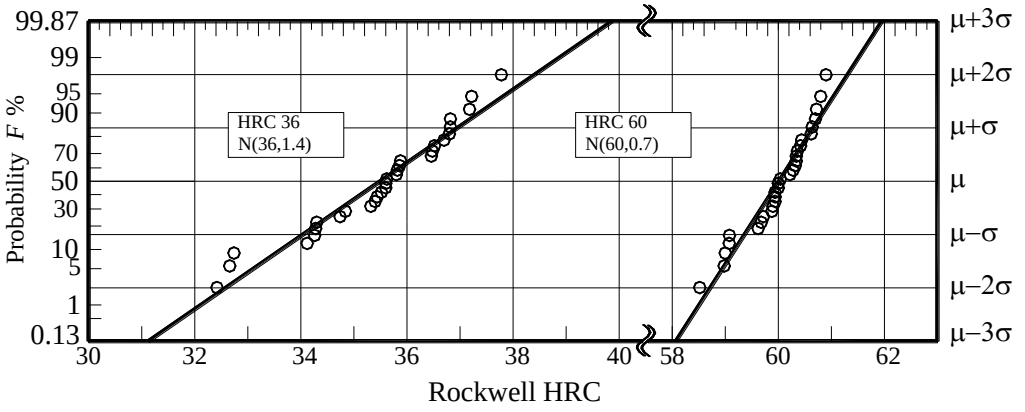


Fig.1 Distribution of Surface hardness

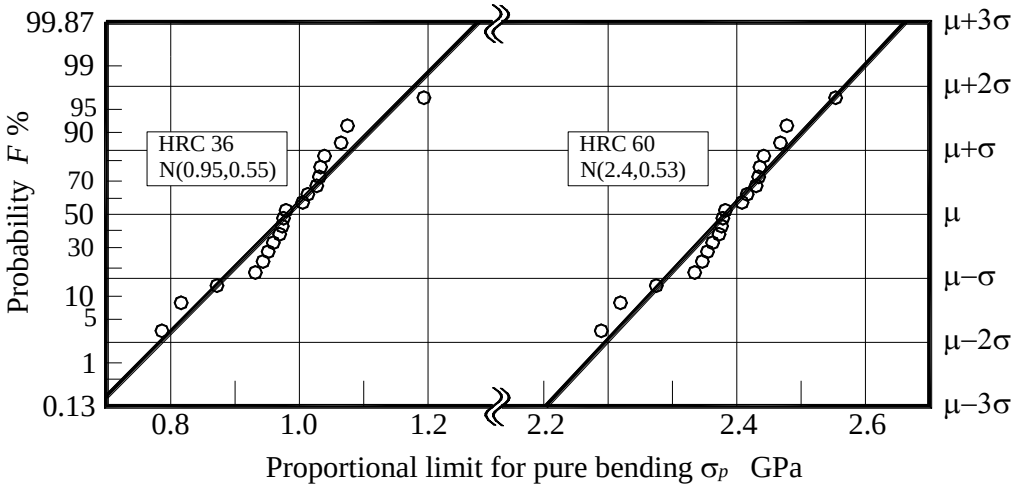


Fig.2 Distribution of Proportional limit for pure bending

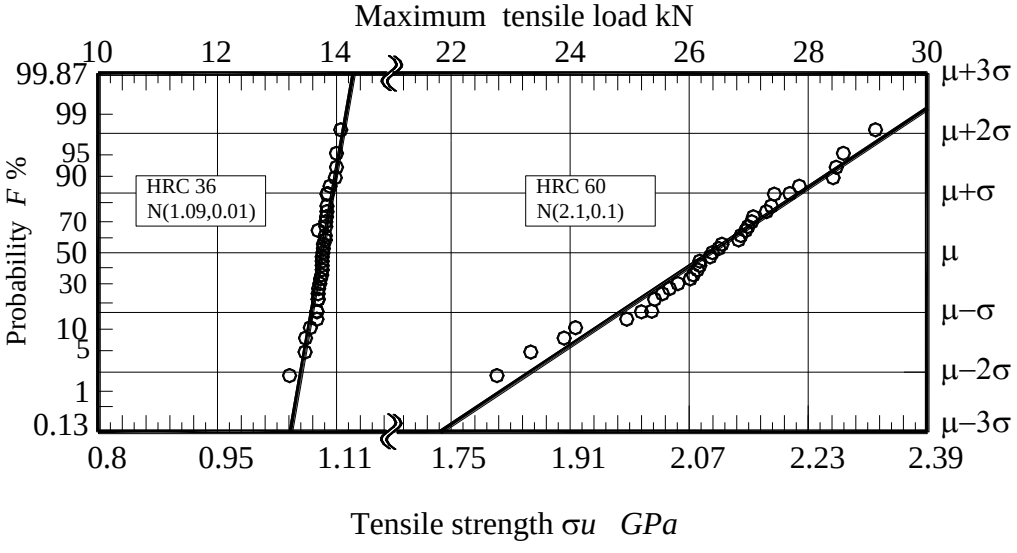


Fig.3 Distribution of Tensile strength

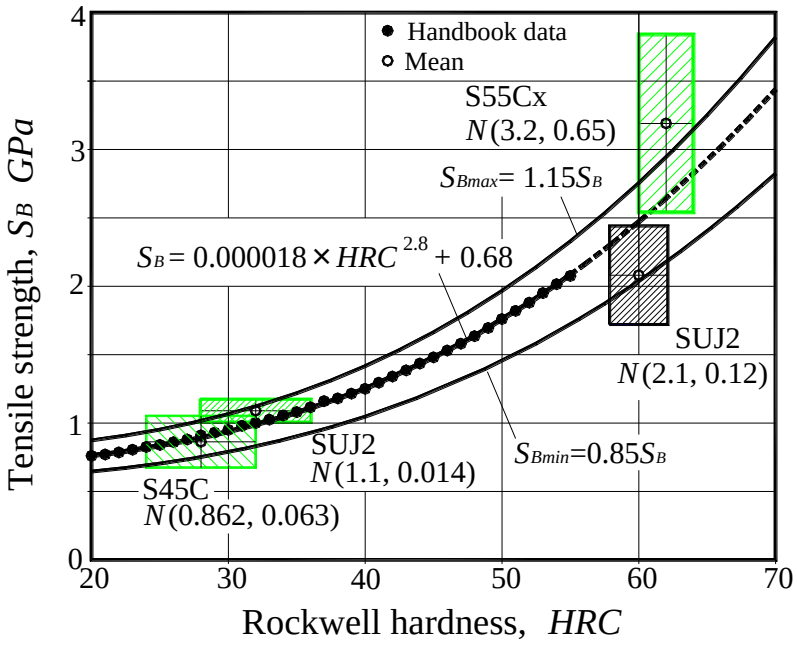


Fig.4 Correlation between Tensile strength and Rockwell hardness

PARTICULARS FOR MECHANICAL P-S-N TEST

Table.7 Test machine properties

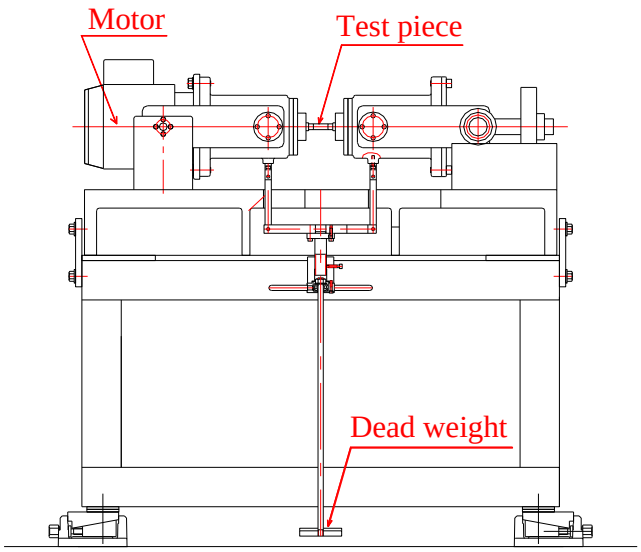
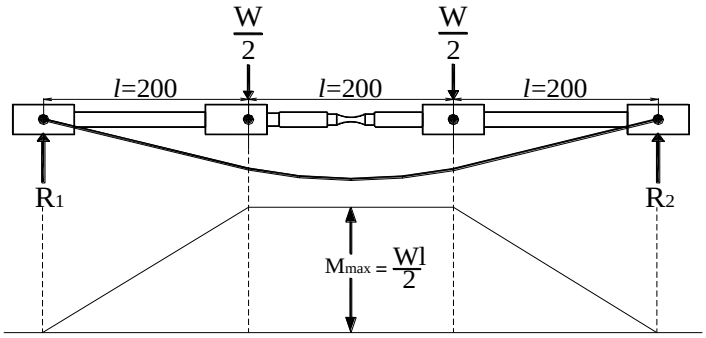
Machine type	4-point rotating bending
Motor	φ 3-2p-0.75kw
Frequency	0~80Hz
	 

Table.8 Test piece properties

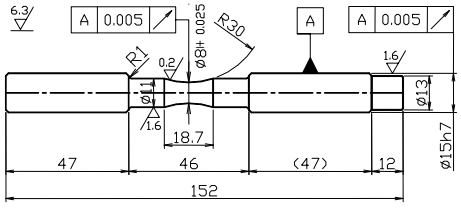
Hardness	HRC 60
Geometry	

Table.9 Parameter of Log-normal

Stress[GPa]	0.94	0.98	1.07	1.11	1.17	1.27
μ	17.93	17.57	15.7	15.03	14.75	12.99
σ	0.53	0.64	0.77	0.63	0.68	0.76
σ/μ	0.03	0.039	0.049	0.042	0.046	0.059

Table.10 Parameter of 2-parameter Weibull

Stress[GPa]	0.94	0.98	1.07	1.11	1.17	1.27
m	2.17	1.84	1.75	1.95	1.89	1.71
εεφση	77.80	54.90	9.40	4.45	3.30	0.63

Table.11 Parameter of 3-parameter Weibull

Stress[GPa]	0.94	0.98	1.07	1.11	1.17	1.27
m	1.5					
η	56.47	48.41	6.24	3.57	2.31	0.5
γ	17.1800	5.9600	1.0880	0.8390	0.6900	0.0430

Table.12 Number of cycle to failures of rotating bending fatigue test for SUJ2 steel (HRC60)

	Stress[GPa]					
No	**1.27**	**1.17**	**1.11**	**1.07**	**0.97**	**0.94**
1	8.00×10^{4}	8.91×10^{5}	1.28×10^{6}	3.32×10^{6}	1.02×10^{7}	2.32×10^{7}
2	9.90×10^{4}	1.05×10^{6}	1.42×10^{6}	3.50×10^{6}	1.53×10^{7}	3.47×10^{7}
3	1.50×10^{5}	1.17×10^{6}	1.70×10^{6}	3.55×10^{6}	1.78×10^{7}	3.67×10^{7}
4	1.87×10^{5}	1.19×10^{6}	1.81×10^{6}	4.28×10^{6}	2.28×10^{7}	4.29×10^{7}
5	2.14×10^{5}	1.21×10^{6}	1.83×10^{6}	4.54×10^{6}	2.50×10^{7}	4.46×10^{7}
6	2.25×10^{5}	1.22×10^{6}	2.96×10^{6}	4.59×10^{6}	2.58×10^{7}	4.53×10^{7}
7	2.53×10^{5}	1.49×10^{6}	3.21×10^{6}	4.73×10^{6}	2.86×10^{7}	4.99×10^{7}
8	2.95×10^{5}	1.65×10^{6}	3.26×10^{6}	4.87×10^{6}	2.98×10^{7}	5.19×10^{7}
9	3.26×10^{5}	1.69×10^{6}	3.34×10^{6}	4.91×10^{6}	3.01×10^{7}	5.37×10^{7}
10	3.31×10^{5}	1.70×10^{6}	3.38×10^{6}	5.12×10^{6}	3.13×10^{7}	5.80×10^{7}
11	3.44×10^{5}	1.76×10^{6}	3.41×10^{6}	5.63×10^{6}	3.43×10^{7}	5.88×10^{7}
12	3.83×10^{5}	2.05×10^{6}	4.46×10^{6}	6.06×10^{6}	3.44×10^{7}	6.00×10^{7}
13	4.04×10^{5}	2.12×10^{6}	4.47×10^{6}	7.24×10^{6}	3.91×10^{7}	6.83×10^{7}
14	4.12×10^{5}	2.24×10^{6}	4.70×10^{6}	7.72×10^{6}	4.18×10^{7}	7.43×10^{7}
15	4.60×10^{5}	2.30×10^{6}	4.78×10^{6}	7.84×10^{6}	4.56×10^{7}	7.48×10^{7}
16	4.71×10^{5}	2.51×10^{6}	5.35×10^{6}	7.98×10^{6}	4.65×10^{7}	9.06×10^{7}
17	5.12×10^{5}	2.57×10^{6}	5.46×10^{6}	8.35×10^{6}	4.91×10^{7}	9.50×10^{7}
18	5.50×10^{5}	2.67×10^{6}	8.26×10^{6}	8.60×10^{6}	5.19×10^{7}	1.01×10^{8}
19	5.57×10^{5}	3.00×10^{6}	1.13×10^{7}	8.89×10^{6}	5.22×10^{7}	1.21×10^{8}
20	6.59×10^{5}	3.05×10^{6}	1.32×10^{7}	9.21×10^{6}	5.58×10^{7}	1.53×10^{8}
21	6.70×10^{5}	3.46×10^{6}		9.60×10^{6}	5.66×10^{7}	
22	6.96×10^{5}	3.58×10^{6}		1.15×10^{7}	6.35×10^{7}	
23	7.18×10^{5}	3.73×10^{6}		1.16×10^{7}	6.47×10^{7}	
24	7.64×10^{5}	3.99×10^{6}		1.39×10^{7}	7.11×10^{7}	
25	7.67×10^{5}	4.48×10^{6}		1.53×10^{7}	7.43×10^{7}	
26	8.57×10^{5}	5.71×10^{6}		1.95×10^{7}	8.65×10^{7}	
27	8.91×10^{5}	7.33×10^{6}		2.08×10^{7}	9.08×10^{7}	
28	1.11×10^{6}	7.89×10^{6}		2.18×10^{7}	1.06×10^{8}	
29	1.27×10^{6}	8.28×10^{6}		2.22×10^{7}	1.11×10^{8}	
30	1.69×10^{6}	8.37×10^{6}		2.83×10^{7}	1.50×10^{8}	

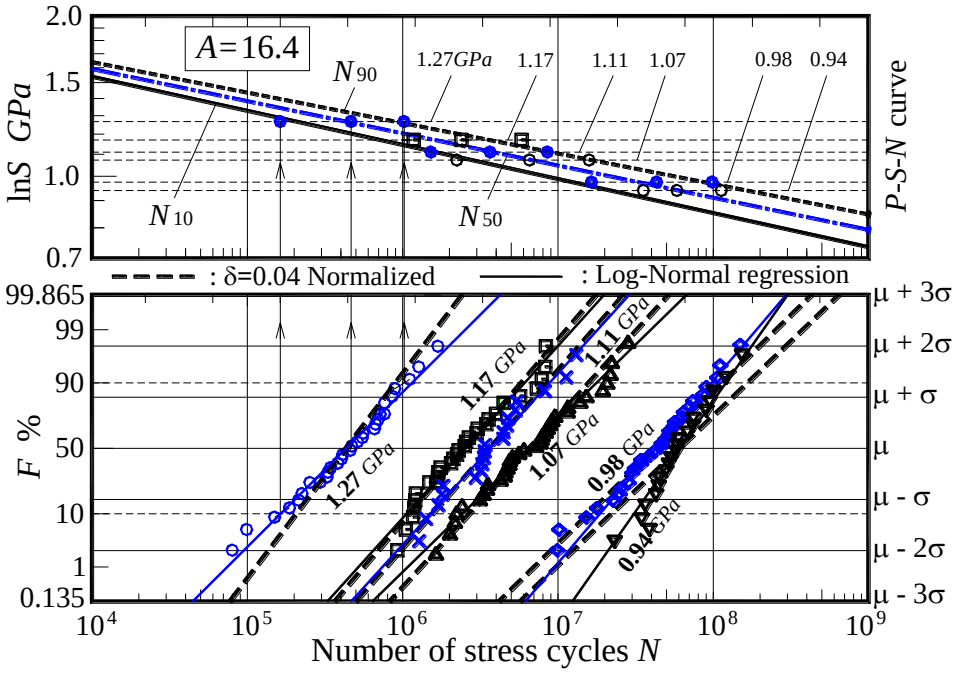


Fig. 5 Life distribution and Log-normal plot, and Log-normal-based *P-S-N* curve

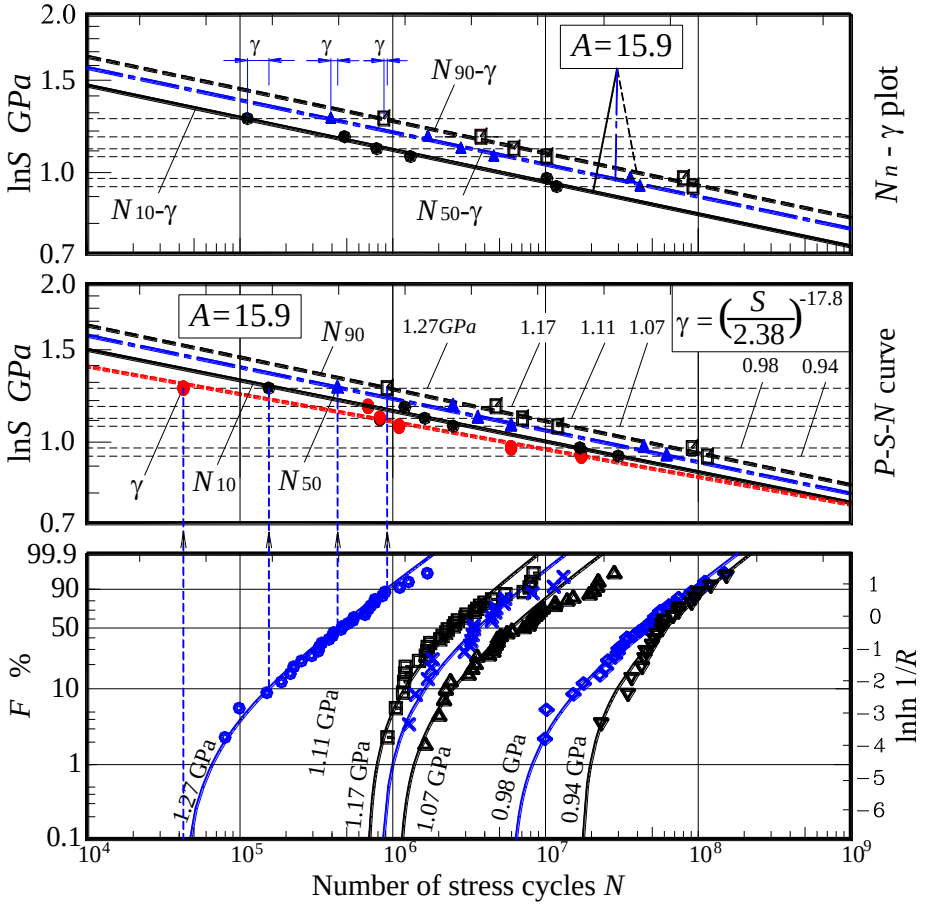


Fig. 6 Life distribution and Weibull plot, and 3-parameter Weibull-based *P-S-N* curve

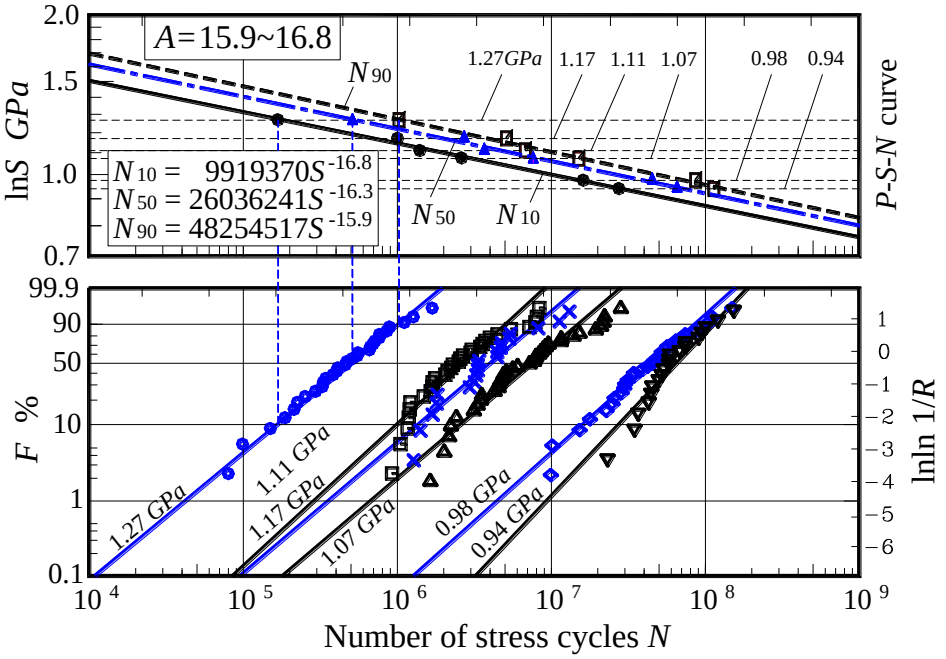


Fig. 7 Life distribution and Weibull plot, and 2-parameter Weibull-based *P-S-N* curve

NON-METARIC INCLUSION

Table.13 Result of fracture surface[0.98GPa]

Depth[mm]	Diameter of inclusion[mm]	Kind of inclusion
0.11	19.5	$MgO\text{-}CaO\text{-}Al_2O_3$
0.03	6.7	TiN
0.08	12.1	TiN
0.47	18.4	$CaO\text{-}Al_2O_3$
0.03	9.7	TiN
0.07	8.7	TiN

Table.14 Result of fracture surface[1.07GPa]

Depth[mm]	Diameter of inclusion[mm]	Kind of inclusion
0.02	8.1	TiN
0.31	14.8	TiN
0.06	13.6	TiN
0.01	11.2	TiN
0.03	9.0	TiN
0.09	10.4	TiN

Table.15 Result of fracture surface[1.17GPa]

Depth[mm]	Diameter of inclusion[mm]	Kind of inclusion
0.08	15.3	TiN
0.02	14.9	$CaO\text{-}Al_2O_3$
0.01	6.7	TiN
0.36	19.5	$MgO\text{-}CaO\text{-}Al_2O_3$
0.28	14.3	TiN

Table.16 Result of fracture surface[1.27GPa]

Depth[mm]	Diameter of inclusion[mm]	Kind of inclusion
0.00	9.8	TiN
0.01	11.8	TiN
0.24	21.5	$MgO\text{-}CaO\text{-}Al_2O_3$
0.04	8.9	TiN
0.04	15.0	$CaO\text{-}Al_2O_3$
0.05	10.2	TiN

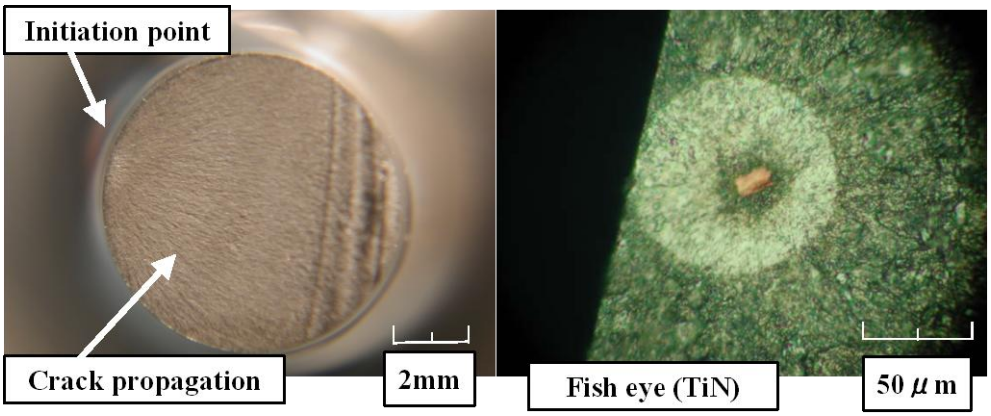
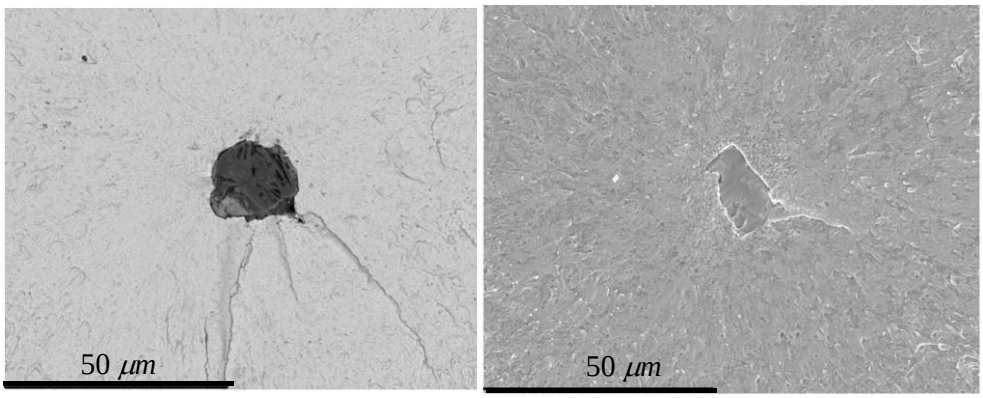
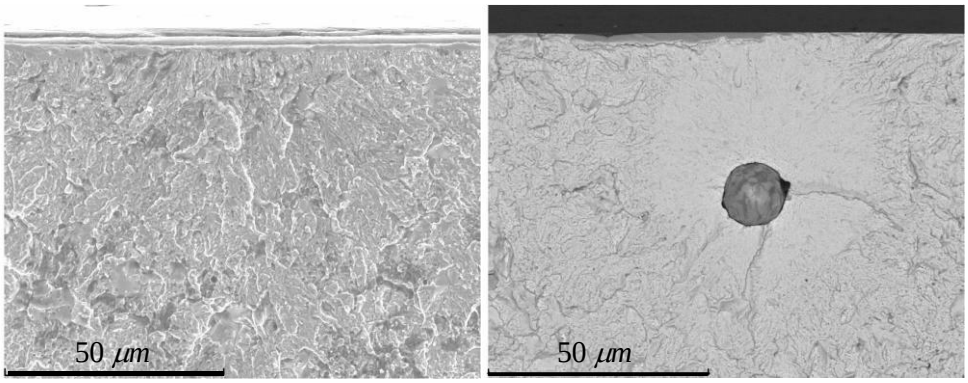


Fig.8 Fatigue failure of 4-point bending test specimen, SUJ2 HRC58- 62



TP6014 (CMA, COMPO) TP6059 (TiN, SEM)

Fig. 9 TP1014 ($CaO\text{-}MgO\text{-}Al_2O_3$), TP6059 (TiN) inclusions and cracks



TP6179 (Surface, SEM) TP6102 (C-A, COMPO)

Fig. 10 TP6179 (Surface), TP6102 ($CaO\text{-}Al_2O_3$) inclusion and its crack