

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**

ボールスプラインの寿命試験特性データシート  
Data Sheet on Rolling Fatigue Life test of Ball Spline

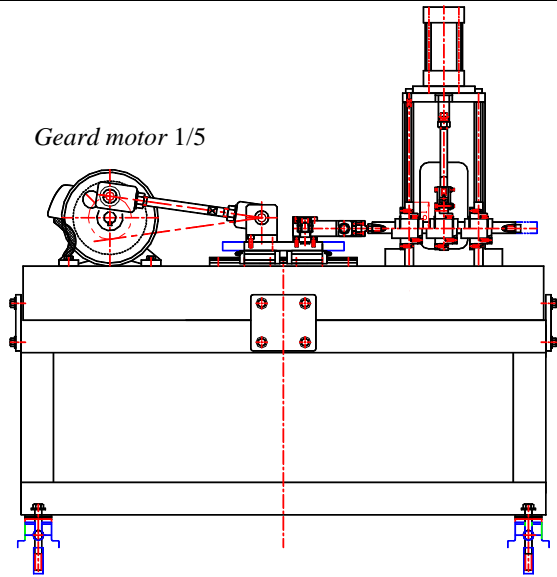
Project of Meiji University Academic Frontier

2010年4月27日（火）

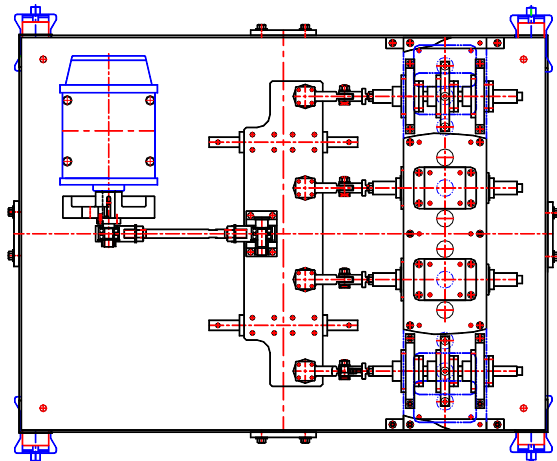
# Rolling Fatigue Life Test of Ball Spline

## BALL SPLINE LIFE TEST RIG

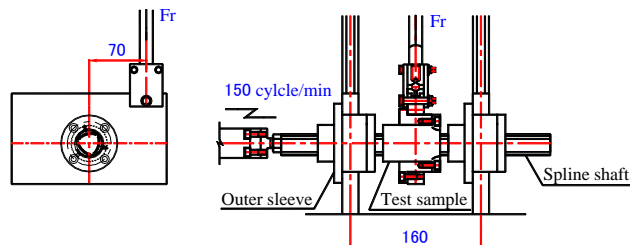
Machine type	Crank driven 4-ball spline life test rig
Motor	$\phi$ 3-4p-1.5kw
Frequency	0~80Hz



Side view of fatigue life test rig



Top view of fatigue life test rig



Side view of fatigue life test rig configuration

## Rolling Fatigue Life Test of Ball Spline

**Table 1 Dimension of ball spline**

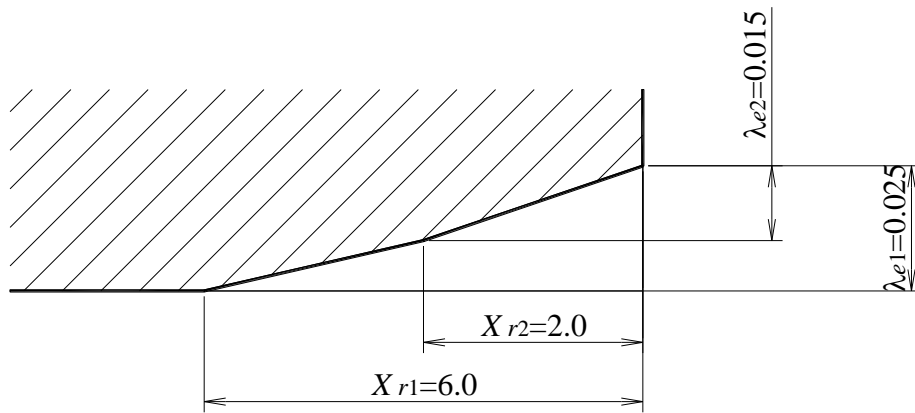
Life test	Test I ~IV	Test V	Test VI
Test sample	A II Type LBF30		
Maximum test speed	30m/min 1.8km/h	40m/min 2.4km/h	50m/min 3.0km/h
Reciprocating speed	150 rpm	200 rpm	250 rpm
Stroke	$S_t = 100 \text{ mm}$		
Raceway length	$l_t = 42.999 \text{ mm}$		
Number of ball circulation	$J = 6$		
Number of effective balls	$Z_t = 9$		
Initial contact angle	$\beta_o = 45^\circ$		
Ball diameter	$D_w = 4.7625 \text{ mm}$		
Factor of ball pitch	$\kappa = 1.003$		
Ball pitch	$\kappa D_w = 4.777 \text{ mm}$		
Conformity factor	$f = 0.52$		
Hertz constant	$C_b = 2.296 \cdot 10^5 \text{ N/mm}^{1.5}$		

# Rolling Fatigue Life Test of Ball Spline

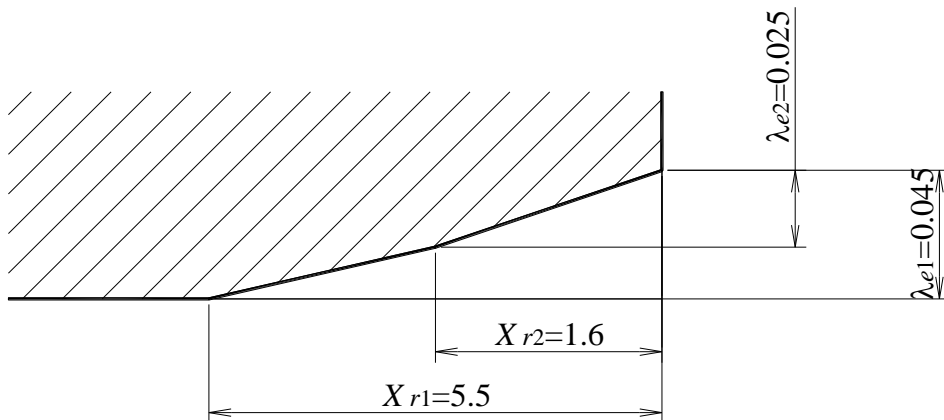
**Table 2 Test condition**

	Life test I	Life test II	Life test III	Life test IV	Life test V (N=30)	Life test VI (N=26)
Test load kN	1.84	2.09	2.09	2.09	1.8	1.9
Test torque Nm	128.8	146.3	146.3	146.3	126	133
Lubricating method	(1)	(1)	(2)	(2)	(2)	(2)
Crowning configuration	Case1	Case2	Case2	Case2	Case2	Case2
$\lambda_e$	0.025	0.045	0.045	0.045*	0.045	0.045
Maximum	30 m/min, 1.8 km/h				40 m/min, 2.4 km/h	50 m/min, 3.0 km/h
Reciprocating speed	150 rpm				200 rpm	250 rpm
Stroke	100 mm					

(1) : Anticorrosive oil (2) : Li-base Grease \* : Abrasive flow finishing



**Fig 1 Crowning configuration in mm (case1)**



**Fig 2 Crowning configuration in mm (case2)**

## Rolling Fatigue Life Test of Ball Spline

**Table 3 Estimation parameters by log-normal distribution function**

	Life test I	Life test II	Life test III	Life test IV	Life test V	Life test VI
Load,kN	1.84	2.09	2.09	2.09	1.80	1.90
Torque,Nm	128.8	146.3	146.3	146.3	126	133
$\mu$	6.30	6.34	6.12	6.50	5.83	6.70
$\sigma$	1.86	1.83	1.55	1.62	1.91	1.54
$\delta$	0.30	0.29	0.25	0.25	0.33	0.23

**Table 4 Estimation parameters by two-parameter Weibull distribution function**

	Life test I	Life test II	Life test III	Life test IV	Life test V	Life test VI
Load,kN	1.84	2.09	2.09	2.09	1.80	1.90
Torque,Nm	128.8	146.3	146.3	146.3	126	133
$m$	1.97	2.12	2.78	2.71	1.88	2.80
$\eta$	6.96	7.38	5.57	8.14	4.55	9.78

**Table 5 Estimation parameters by three-parameter Weibull distribution function**

	Life test I	Life test II	Life test III	Life test IV	Life test V	Life test VI
Load,kN	1.84	2.09	2.09	2.09	1.80	1.90
Torque,Nm	128.8	146.3	146.3	146.3	126	133
$m$	10/9					
$\eta$	6.15	6.96	3.24	7.40	3.12	7.25
$\gamma$	1.29	1.49	2.06	2.25	1.03	2.90

# Rolling Fatigue Life Test of Ball Spline

**Table 6 Travel distance to failure of ball spline**

						(km)
No	Life test I	Life test II	Life test III	Life test IV	Life test V	Life test VI
	Load,Torque					
	1.84kN 128.8Nm	2.09kN 146.3Nm	2.09kN 146.3Nm	2.09kN 146.3Nm	1.80kN 126Nm	1.90kN 133Nm
1	134	167	142	245	116	292
2	138	227	193	265	117	413
3	229	260	255	295	158	448
4	253	280	282	375	160	550
5	269	297	284	375	180	637
6	294	303	291	462	180	641
7	314	317	303	473	198	644
8	319	348	316	499	199	651
9	382	367	343	583	200	665
10	409	390	351	629	205	693
11	454	431	358	637	245	719
12	460	508	369	653	261	761
13	533	598	375	657	270	791
14	539	627	413	674	278	796
15	592	732	415	728	290	839
16	630	739	445	750	294	878
17	658	760	449	774	326	923
18	675	773	490	791	357	1124
19	702	781	498	837	367	1141
20	734	819	499	843	427	1207
21	756	854	557	989	461	1214
22	857	900	573	1095	504	1259
23	944	924	586	1115	583	1284
24	996	953	590	1145	652	1294
25	1005	999	740	1222	671	1364
26	1006	1018	759	1225	692	1415
27	1068	1067	764	1264	773	
28	1078	1125	813	1425	907	
29	1105	1186	1098	1508	949	
30	1164	1210	1148	1570	981	

# Rolling Fatigue Life Test of Ball Spline

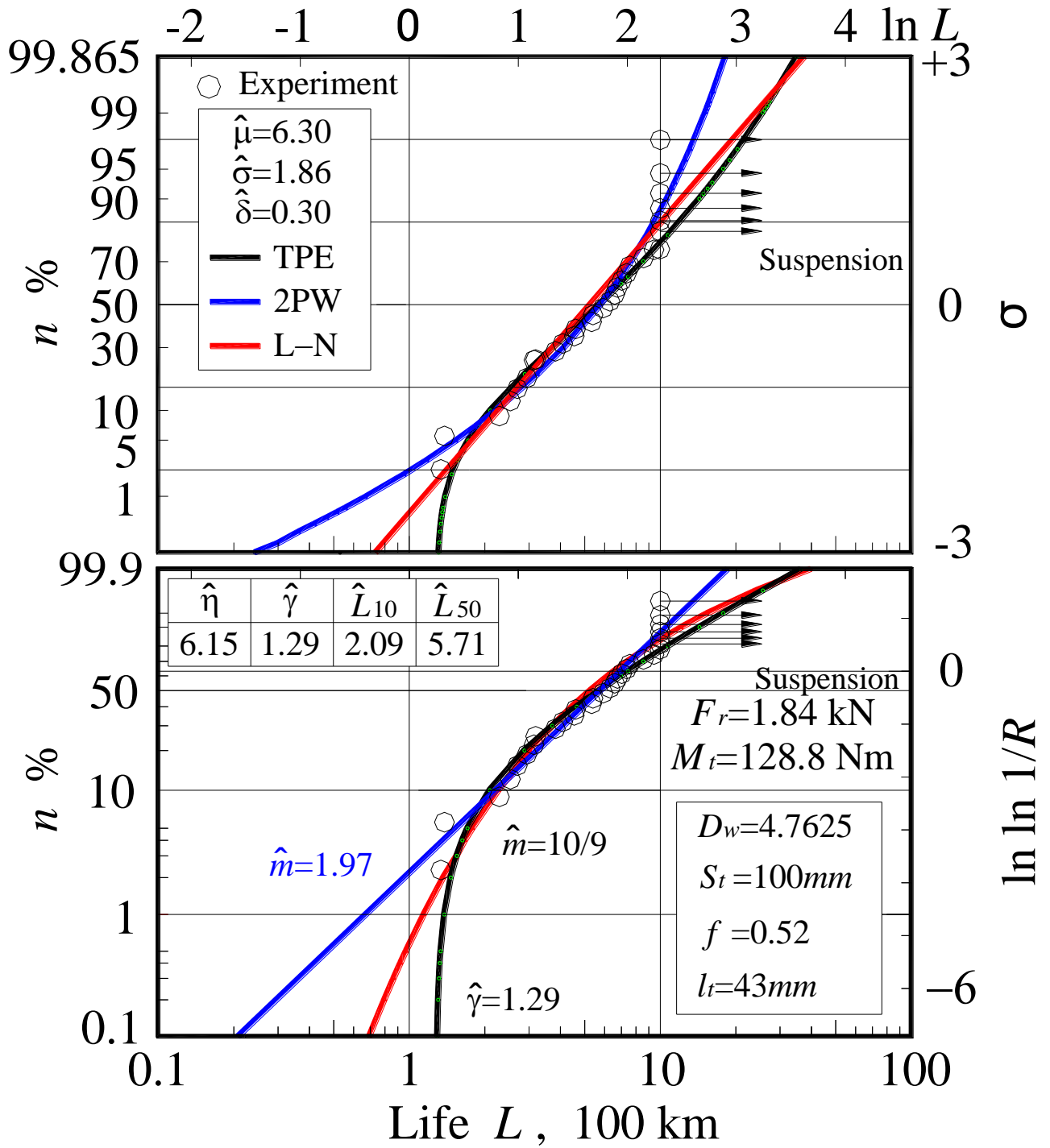


Fig 3 Weibull and log-normal plot for ball spline life test data (Test I)

# Rolling Fatigue Life Test of Ball Spline

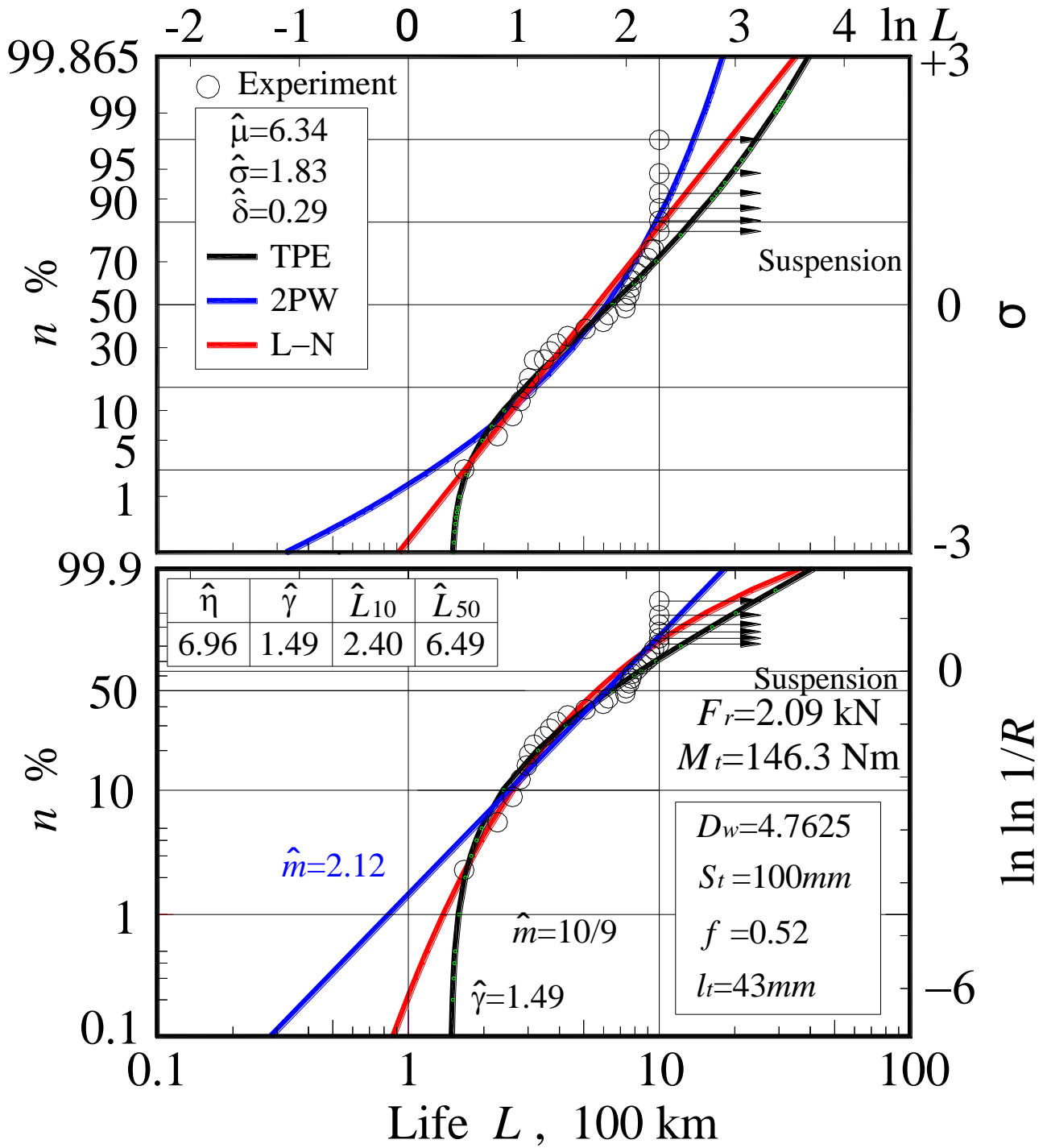


Fig 4 Weibull and log-normal plot for ball spline life test data (Test II)

# Rolling Fatigue Life Test of Ball Spline

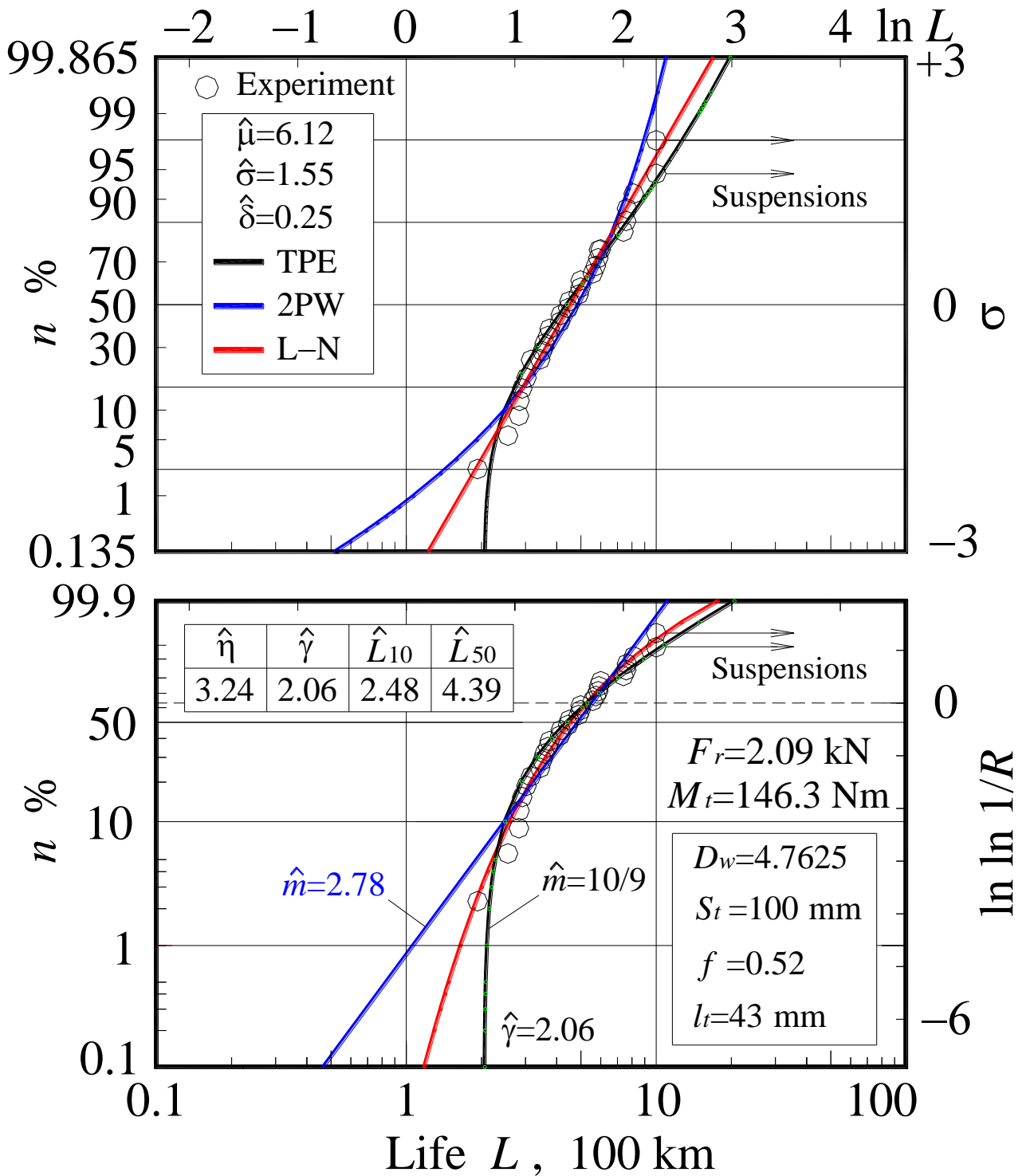


Fig 5 Weibull and log-normal plot for ball spline life test data (Test III)

# Rolling Fatigue Life Test of Ball Spline

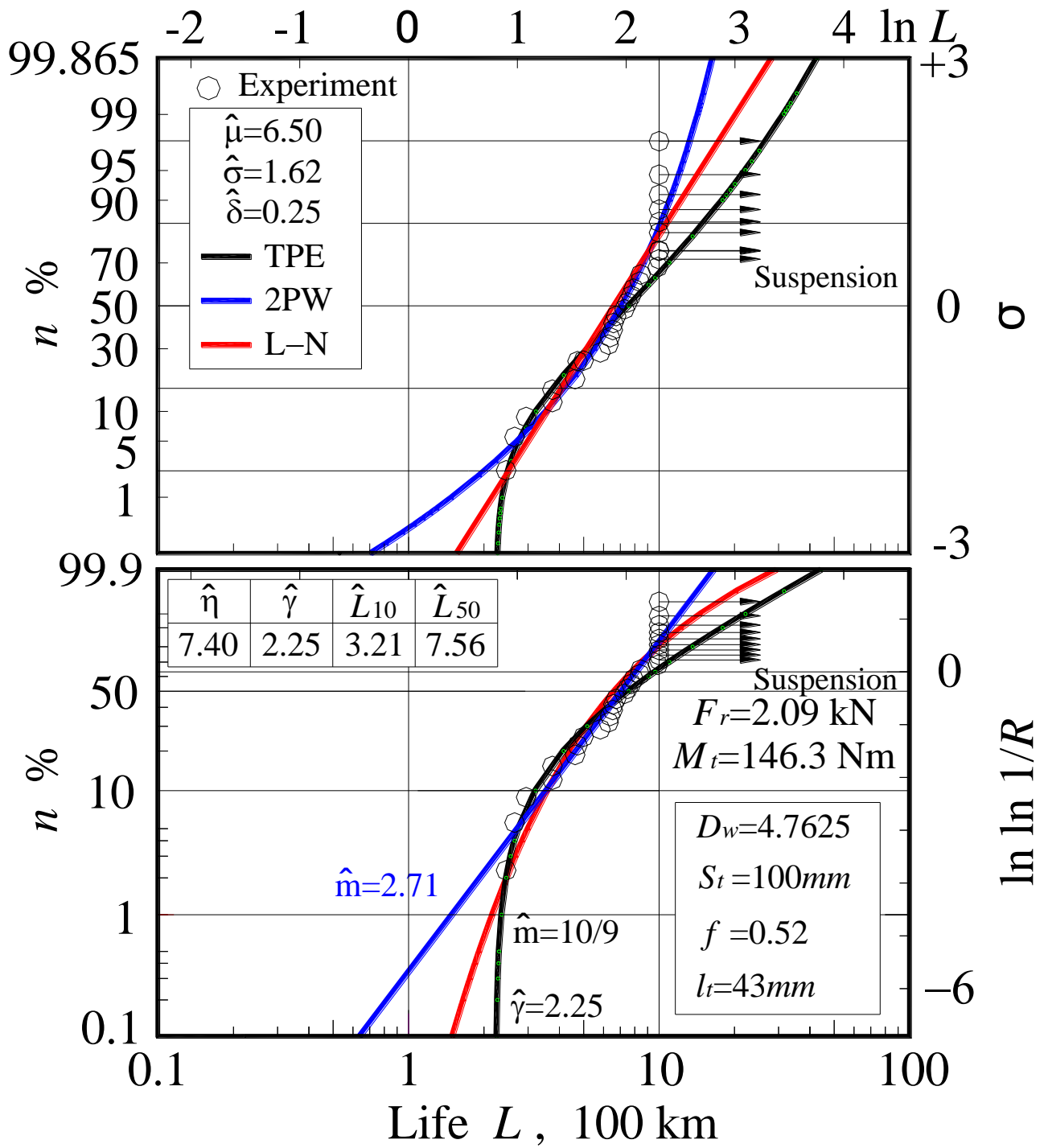


Fig 6 Weibull and log-normal plot for ball spline life test data (Test IV)

# Rolling Fatigue Life Test of Ball Spline

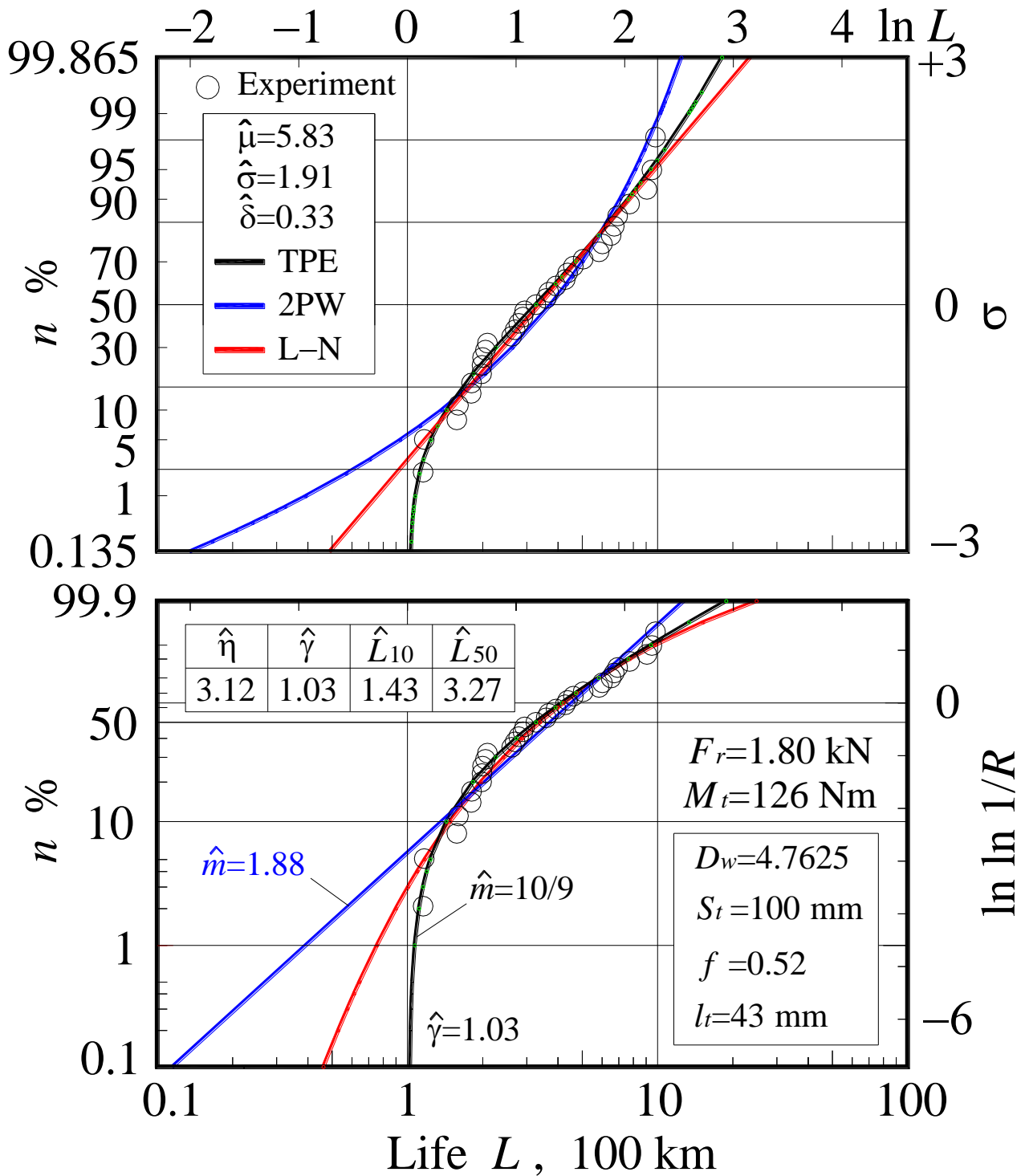


Fig 7 Weibull and log-normal plot for ball spline life test data (Test V)

# Rolling Fatigue Life Test of Ball Spline

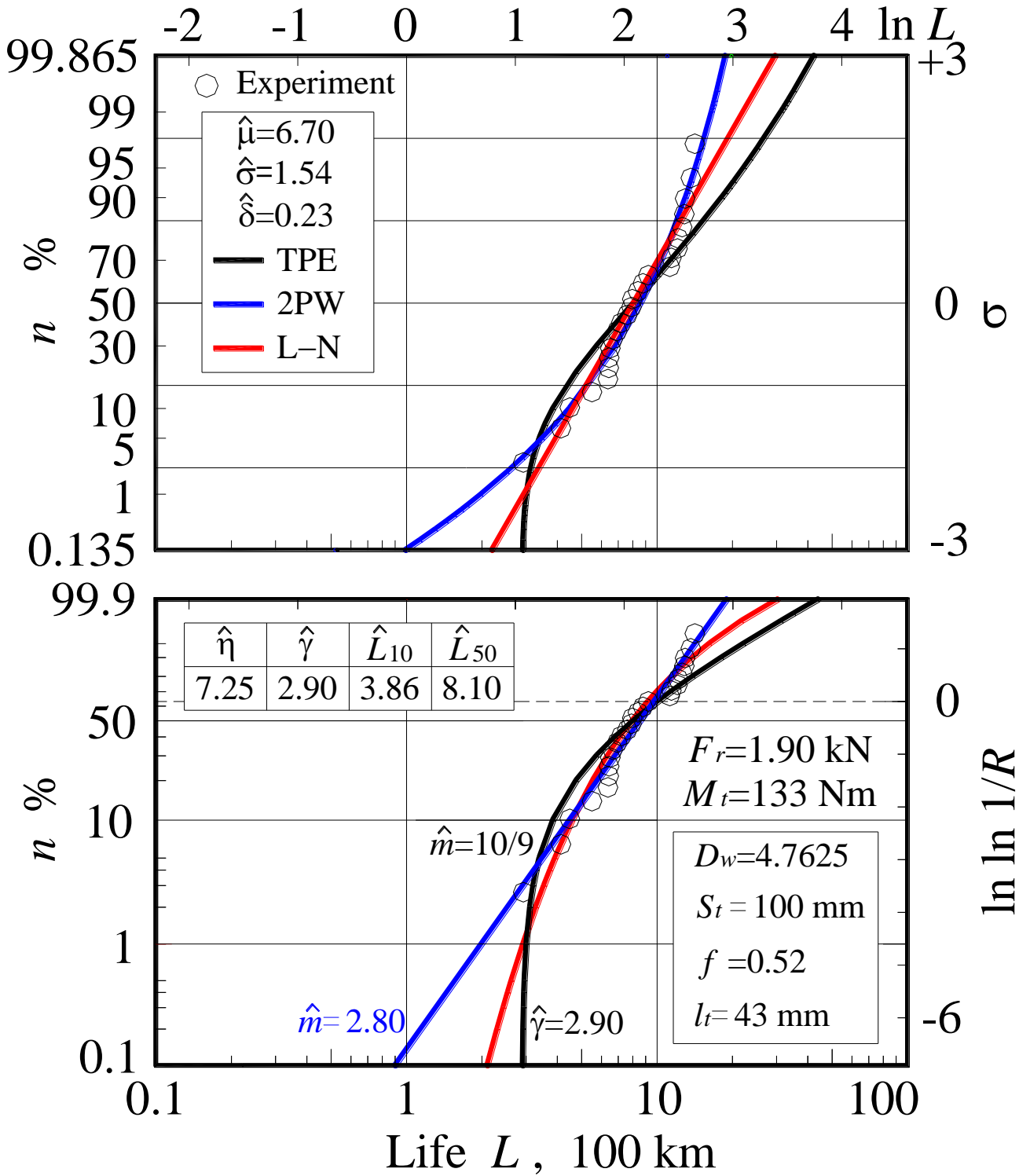


Fig 8 Weibull and log-normal plot for ball spline life test data (Test VI)

## Rolling Fatigue Life Test of Ball Spline

**Table 7 Result of ball spline life test**

	Life test I	Life test II	Life test III	Life test IV	Life test V	Life test VI
$m$	1.97	2.12	2.78	2.71	1.88	2.80
$\eta$	6.15	6.96	6.65	7.40	3.12	7.25
$\gamma$	1.29	1.49	2.06	2.25	1.03	2.90
$L_{10}$ km	2.09	2.40	2.48	3.21	1.43	3.86
$F_r$ kN	1.84	2.09	2.09	2.09	1.80	1.90
$M_x$ Nm	128.8	146.3	146.3	146.3	126	133
$C_{ex(\gamma)}$ Nm	151	178	138	156	117	131
$C_{ex(\gamma=0)}$ Nm	208	247	250	248	179	209
$C_{iso}$ Nm	228	228	228	228	228	228
$C_{th}$ Nm	272	267	267	267	262	266

*URL* 100km

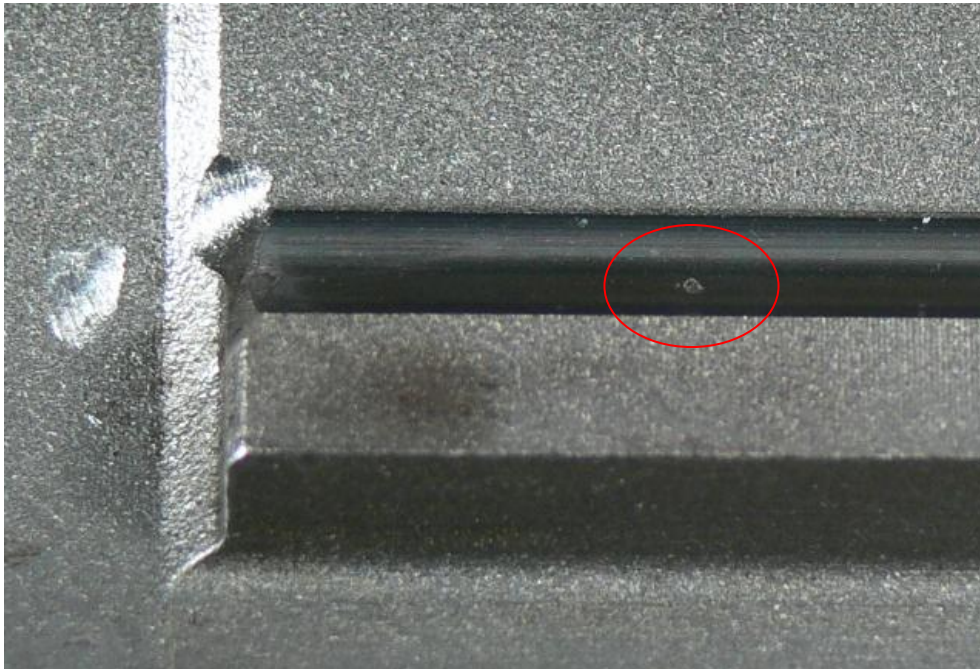
**Table 8  $\lambda_{bm}$  factor of basic dynamic load rating for ball spline**

$\lambda_{bm}$	Life test I	Life test II	Life test III	Life test IV	Life test V	Life test VI
$C_{ex(\gamma)} / C_{th}$	0.56	0.67	0.52	0.68	0.45	0.49
$C_{ex(\gamma=0)} / C_{th}$	0.76	0.93	0.94	1.02	1.02	0.79
$C_{iso} / C_{th}$	0.84	0.85	0.85	0.85	0.85	0.86

## Rolling Fatigue Life Test of Ball Spline



**Fig 9 Flaking of nut raceway**

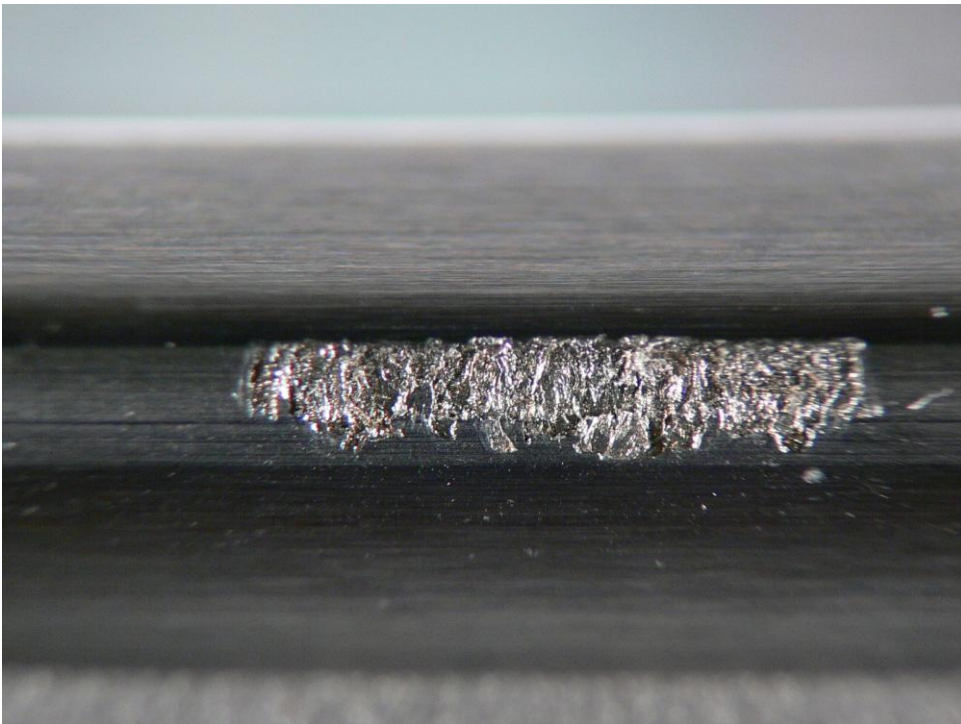


**Fig 10 Flaking of nut raceway**

## Rolling Fatigue Life Test of Ball Spline



**Fig 11 Flaking of shaft raceway**



**Fig 12 Flaking of shaft raceway**

