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**Fatigue test method for transmission pre-
cision roller chains and leaf chains**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Chain Association (JCA)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS B 1811:2008** is replaced with this Standard.

This **JIS** document is protected by the Copyright Law.

Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, applications for a patent after opening to the public or utility model rights. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying any of such patent rights, applications for a patent after opening to the public or utility model rights.

Fatigue test method for transmission precision roller chains and leaf chains

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 15654** : 2015, Edition 2, with some modifications of the technical contents to conform to the usage situations unique to Japan.

The vertical lines on both sides and dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard specifies the fatigue test method for transmission precision roller chains and leaf chains (hereafter referred to as chains). This Standard is applicable to the fluctuating tension type test of chains, made at room temperature with the force applied along the longitudinal axis of the chain. This Standard also specifies procedures for statistic analyses of the test results, and gives formats and elements for presenting the results of fatigue tests and analyses.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 15654 : 2015 *Fatigue test method for transmission precision roller chains and leaf chains* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 1801 *Short-pitch transmission precision roller chains and bush chains*

NOTE : Corresponding International Standard : ISO 606 : 2015 *Short-pitch transmission precision roller and bush chains, attachments and associated chain sprockets*

JIS B 1804 *Leaf chains*

NOTE : Corresponding International Standard : ISO 4347 : 2015 *Leaf chains, clevises and sheaves — Dimensions, measuring forces, tensile strengths and dynamic strengths*

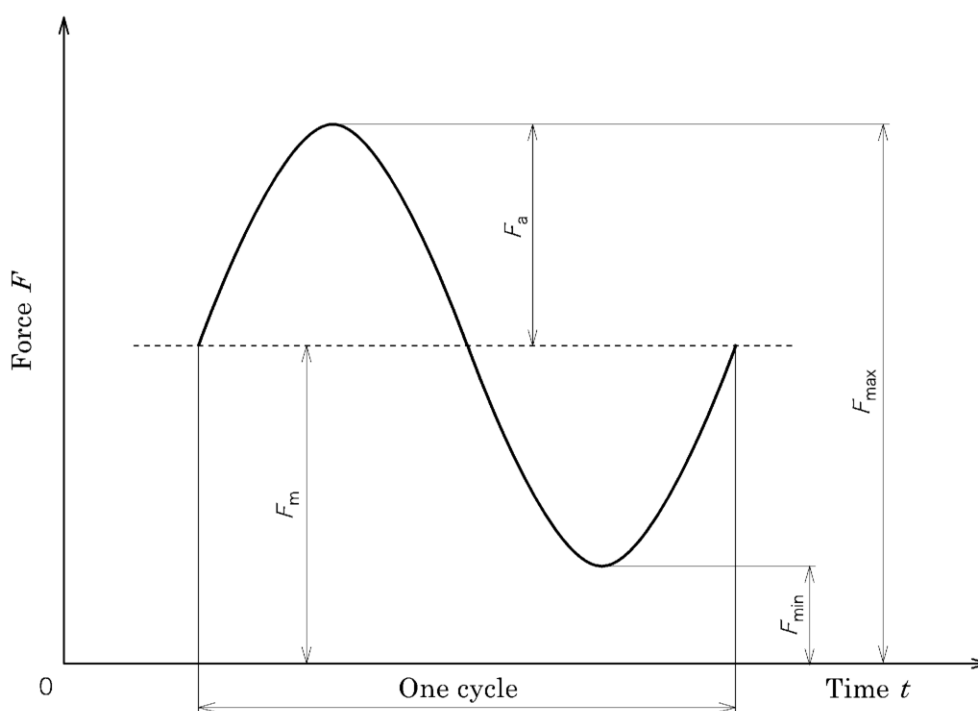
JIS B 1812... Glossary of terms relating to chains, sprockets and accessories

3 Symbols, terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS B 1812**, and Table 1 apply. Figure 1 shows a typical force cycle used in the test.

Table 1 Symbols, terms and definitions

Symbol	Term	Definition	Unit
d	Step size	Interval between adjacent force levels in staircase test, <u>and standard deviation required in finite life test</u> [see Formula (5)]	N
$F_{\max}$	Maximum force	Maximum value of force in cycle <u>for testing</u>	N
$F_{\min}$	Minimum force	Minimum value of force in cycle <u>for testing</u>	N
F_m	Mean force	Half the sum of maximum force and minimum force [see Formula (1)]	N
F_a	Force amplitude	Half the difference between maximum force and minimum force [see Formula (2)]	N
F_b	Mean fatigue strength	Test force, corrected to zero minimum force, at which there is a 50 % probability of failure at endurance [see Formula (8)]	N
F_{dx}	Minimum fatigue limit	Test force, corrected to zero minimum force, at which there is a calculated 0.135 % probability of failure at 10^7 force cycles. This force approximates the force that a chain can endure an indefinite number of force cycles [see Formula (10)].	N
F_d	Test force	Maximum force, corrected to zero minimum force, at which a test is run [see Formula (3)]	N
F_u	Minimum tensile strength	Tensile strength specified in JIS B 1801 and JIS B 1804	N
N	Number of cycles	Number of applied forces in the test (see Figure 1)	—
N_e	Endurance	Predetermined number of cycles at which a test will be discontinued even without a failure of chain	—
n	—	Number of test data included in analysis	—
p	Chain pitch	Chain pitch	mm
S	Standard deviation	Standard deviation of staircase test data [see Formula (9)]	N



$$\text{Mean force : } F_m = \frac{F_{\max} + F_{\min}}{2} \dots\dots\dots(1)$$

$$\text{Force amplitude : } F_a = \frac{F_{\max} - F_{\min}}{2} \dots\dots\dots(2)$$

Figure 1 Typical force cycle

4 Principle

Tests are made on chains to confirm whether or not the minimum dynamic strength described in Annex JC of **JIS B 1801** and Annex JC of **JIS B 1804** for reference is satisfied, or to determine the fatigue property shown in F - N (force — number of cycles) diagram of chain.

The conformity test shall apply for the confirmation of minimum dynamic strength. The combined test shall apply for the determination of fatigue property. The estimation of fatigue strength to the chain length is exemplified in Annex A.

5 Test equipment

5.1 Testing machine

The maximum force to be loaded on the specimen shall be 10 % to 100 % of the maximum capacity of the testing machine.

Tests shall be made by a machine capable of applying a sinusoidal force to the specimen along the longitudinal axis.

The test frequency shall be chosen so as not to induce a damaging temperature increase in the specimen.

The machine shall be calibrated to within ± 2 % of its maximum capacity.

A force-monitoring system should be mounted in series to ensure that the force cycle is maintained throughout the test.

The testing machine shall also be equipped with the following devices.

- a) Counter to record the number of force cycles
- b) Device to stop the machine when the chain fails
- c) Device to prevent the machine from restarting after an emergency stop due to power failure, etc.

5.2 Test fixtures

The test fixtures shall be capable of applying the force on the specimen along the longitudinal axis without twisting and bending.

Examples of the test fixtures ¹⁾ are shown in Figure 2.

Note ¹⁾ The specimens in Figure 2 are an example of five-free link.

The test fixtures shall permit free movement in both directions of articulation and width. The diameter of the hole for fixing the specimen in the test fixtures shall be almost equal to the bush bore of roller chain or the inner plate bore of leaf chain under test.

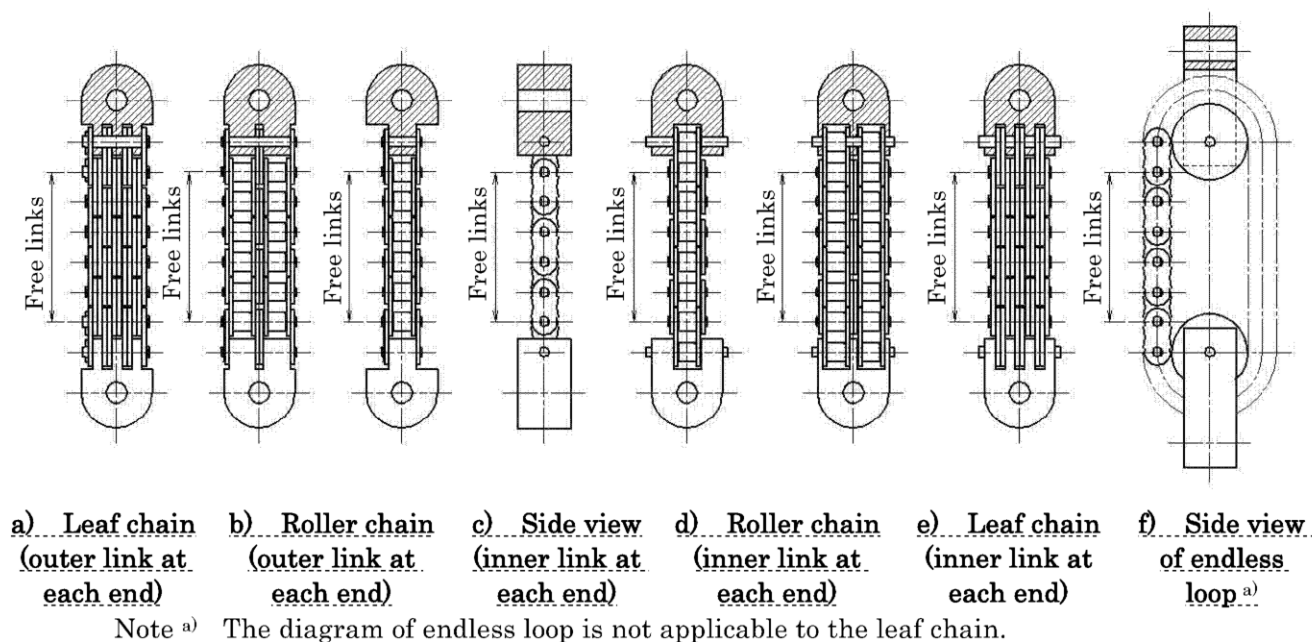


Figure 2 Examples of structure and mounting method of test fixtures

6 Specimens

6.1 Free links of specimen

The free links mean the chain links that do not contact the test fixtures. Chains of at

least five-free link shall be used as a specimen, except the chains of pitch over 50.8 mm where a minimum of three-free link is acceptable.

6.2 Specimen condition

Specimens shall be undamaged and unused chains on which all phases of manufacture have been completed.

The lubricant condition is discretionary.

7 Force setting

7.1 Minimum force

The minimum force for the test shall be at least 1 % but not more than 5 % of the minimum tensile strength of the chains specified in **JIS B 1801** and **JIS B 1804**.

7.2 Maximum force

The maximum force for the test shall be determined in accordance with the conformity test, finite life test, staircase test or combined test.

7.3 Test force

For analyses of fatigue test data, the maximum force shall be corrected to zero minimum force.

A test force is obtained by the Johnson — Goodman method [see Formula (3)].

The Johnson — Goodman diagram is shown in Figure 3.

$$F_d = \frac{F_u (F_{\max} - F_{\min})}{F_u - F_{\min}} \dots\dots\dots (3)$$

As an example, $F_{\min}$ is $0.05 \times F_u$ and $F_{\max}$ is $0.3 \times F_u$, and the resulting F_d is $0.263 2 \times F_u$.

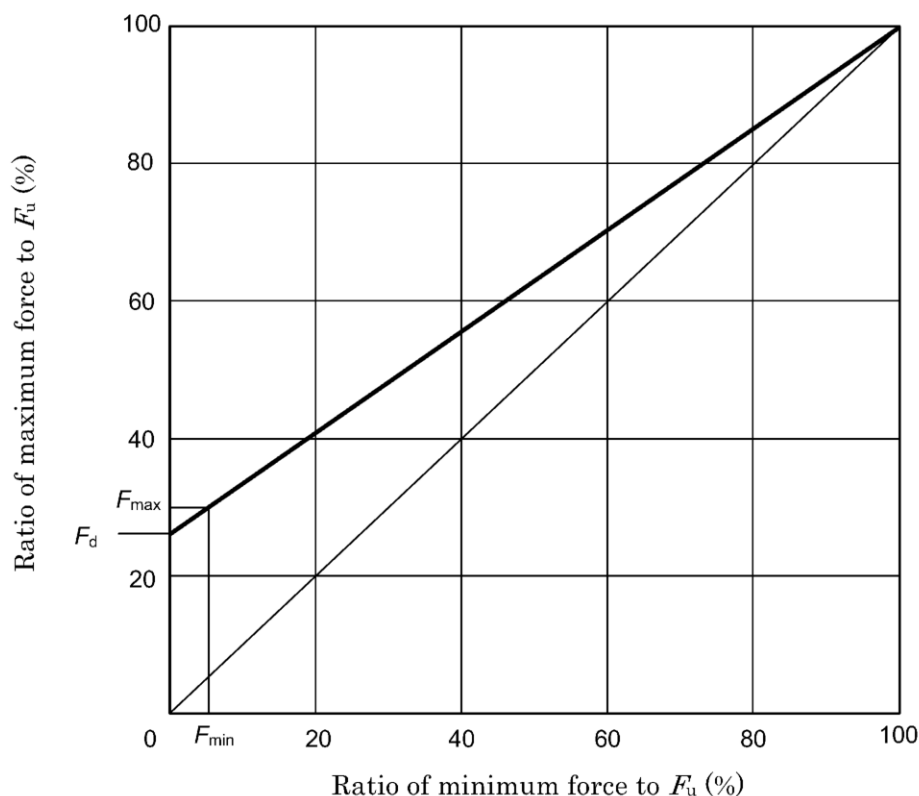


Figure 3 Johnson — Goodman diagram

7.4 Force application condition

A force shall be applied along the longitudinal axis, sinusoidally varying between the minimum force determined according to 7.1 and the maximum force determined according to 7.2. The test shall continue up to endurance or until the specimen fails, whichever is sooner.

8 Conformity test

8.1 Purpose

The purpose of this test is to determine whether or not a chain satisfies the minimum dynamic strength requirements specified in Annex JC of JIS B 1801 and Annex JC of JIS B 1804.

8.2 Endurance

The endurance shall be 3×10^6 cycles.

8.3 Minimum test force

The minimum force for the test $F_{\min}$ shall be set in accordance with 7.1.

8.4 Maximum test force

The maximum force for the test $F_{\max}$ shall be determined according to Formula (4) for test force F_d .

$$F_{\max} = \frac{F_d F_u + [F_{\min} (F_u - F_d)]}{F_u} \dots\dots\dots (4)$$

In the conformity test, determine the maximum test force $F_{\max}$ and the minimum test force $F_{\min}$, so that the test force F_d becomes equal to the minimum dynamic strength, and apply it to the specimen.

8.5 Number of tests

Three specimens shall be tested.

8.6 Acceptance

All specimens shall survive to endurance without failure.

9 Finite life test

9.1 Purpose

The purpose of this test is to determine the fatigue strength at N cycles (inclination) in the F - N diagram of the subject chain. The standard deviation obtained in this test shall be used for the step size of the staircase test.

9.2 Summary

In the 14 F - N test method to obtain the probability of survival $R = 90\%$, 8 specimens shall be tested at four-force levels. In the 24 F - N test method to obtain the probability of survival $R = 95\%$, 14 specimens shall be tested at four-force levels. The test shall be carried out until all the specimens are failed.

9.3 Test and analysis procedure

The test procedure shall be in accordance with 11.3.4.2, and the analysis procedure shall be in accordance with 11.4.1.

9.4 Determination of step size

The standard deviation [see Formula (20)] obtained in this analysis shall be used for the step size of the staircase test.

Other methods shown below may apply.

- a) **Application of survival test with abridged Probit analysis** Determine the step size in accordance with Annex B.
- b) **Using empirical method** Determine the step size according to Formula (5) to Formula (7).

$$\text{Simplex roller chain : } d \approx 14p^{1.5} \dots\dots\dots (5)$$

$$\text{Multiplex roller chain : } d \approx 0.7n_s \times 14p^{1.5} \dots\dots\dots (6)$$

where, n_s : number of multiplex roller chains (2 or more)

$$\text{Leaf chain } d \approx f_L \frac{n_L}{4} \times 14p^{1.5} \dots\dots\dots (7)$$

where, f_L : lacing factor (see Table 2)

n_L : total number of plates ($n_L = 3 + 4 = 7$ for BL634)

Table 2 Lacing factor of leaf chain (f_L)

Number of plates of outer link $\times$ number of plates of inner link	f_L
2×2	1.000
2×3	0.880
3×4	0.713
4×4	0.750
4×6	0.633
6×6	0.667

10 Staircase test

10.1 Purpose

The purpose of this test is to determine the minimum fatigue limit of the subject chain.

10.2 Summary

A staircase test is the one in which specimens are tested sequentially at predetermined, equally spaced, force levels. The first specimen is tested at a force level slightly greater than the estimated mean fatigue strength of the chain. If the first specimen runs out to endurance (no-failure), the next specimen is tested at the next higher predetermined force level. If the first specimen fails before endurance, the next specimen is tested at the next lower predetermined force level. Force levels for subsequent tests are determined in the same manner, and the test continues until the required number of data shown in Table 3 are achieved.

10.3 Endurance

The endurance shall be 10^7 cycles for the fatigue limit test.

10.4 Required number of data

The data from one step before, when no-failure is followed by a failure or a failure is followed by a no-failure, shall be deemed as effective. The test shall have at least 10 data to determine the mean with 95 % confidence and at least 6 data to determine the mean with 90 % confidence.

Table 3 Required number of data

Confidence	3-step staircase	4-step staircase	5-step staircase
90 %	6	11	16
95 %	10	15	20

10.5 Staircase test data analysis

10.5.1 Phantom point

In the case of staircase test, when the test in accordance with 10.2 is terminated

without failure, the next test is to be run at one-step-higher force level; when the next test fails, run at one-step-lower force level.

This permits the force level at which a test would be run after the final actual test in a staircase to be determined. The final data of the staircase test can be determined without making the test. This final data is called “phantom point” and shall be included in the analysis as follows.

If the final test is terminated without failure, add a phantom point at one step higher test force. If the final test fails, add a phantom point at one step lower test force.

There is no way of knowing if the phantom point would be a failure or no-failure, only one phantom point after the final test point can be determined.

10.5.2 Plotting staircase test data

It is customary to tabulate as shown in Table 4, and plot the data as a staircase test progresses to ensure that the rules for constructing a staircase are followed. An example of such a data plot (three force levels and 95 % confidence) is shown in Table 4.

Table 4 Example of staircase test data plot

Test force	Invalid tests		Valid tests									
$F_d + 2d$	×											
$F_d + d$		×						×		×		#
F_d			×		×		○		○		○	
$F_d - d$				○		○						
○ : no-failure × : failure # : phantom point												

10.5.3 Statistical calculations

10.5.3.1 Mean fatigue strength : 50 % probability of survival

The mean fatigue strength shall be calculated according to Formula (8).

$$F_b = \frac{1}{n} \sum_{i=1}^n F_{di} \quad \dots\dots\dots (8)$$

where, n : total number of valid data in staircase test calculation

10.5.3.2 Standard deviation

The standard deviation of the staircase data shall be calculated according to Formula (9).

$$S = \left(\frac{1}{n} \sum_{i=1}^n F_{di}^2 - F_b^2 \right)^{0.5} \quad \dots\dots\dots (9)$$

where, n : total number of valid data in staircase test calculation

10.5.3.3 Minimum fatigue limit : 99.865 % probability of survival

The minimum fatigue limit shall be calculated according to Formula (10).

$$F_{dx} = F_b - 3S + d \dots\dots\dots (10)$$

NOTE Justification for adding one step size to the minimum fatigue limit in the staircase analysis is shown in Annex C for reference.

11 Combined test

11.1 Purpose

This test is the combination of the finite life test and the staircase test. The purpose is to determine the fatigue property shown in the $F-N$ diagram for the subject chain.

11.2 Summary

The number of specimens shall be determined according to the different probabilities of survival, R , of the mean $F-N$ diagram. The 14 $F-N$ test method for determining $R = 90\%$, and the 24 $F-N$ test method for determining $R = 95\%$, are specified herein.

The 14 $F-N$ test method is a procedure in which 8 specimens are tested at four-force levels in the finite life range, and 5 specimens plus 1 phantom point are tested in a staircase range. The 24 $F-N$ test method is a procedure in which 14 specimens are tested at four-force levels in the finite life range, and 9 specimens plus 1 phantom point are tested in a staircase range.

The mean $F-N$ diagram and the standard deviation of fatigue life are determined by statistical calculation.

11.3 Test procedure

11.3.1 Specimens

Prepare at least 13 specimens for the 14 $F-N$ test method, or 23 specimens for the 24 $F-N$ test method in accordance with Clause 6 with all specimens from the same production batch.

Provide additional specimens for preliminary or invalid tests.

11.3.2 Endurance

In the staircase range, set the endurance at 10^7 cycles. If the endurance is set 3×10^6 or over to and excluding 10^7 cycles, extrapolate the results to 10^7 cycles by the method given in Annex D.

11.3.3 Force level

In the finite life range, establish four force levels ($F_A > F_B > F_C > F_D$) in accordance with 11.3.4.1.

For the staircase range of the test, an initial test force level should be set at the force of two steps plus the force where the mean $F-N$ diagram intersects 10^6 cycles, with additional force levels in increments of the step size.

11.3.4 Tests

11.3.4.1 Preliminary test

Test one specimen at the lowest force level (F_D) in the finite life range. If the measured fatigue life departs significantly from 5×10^5 cycles, test an additional specimen at an adjusted force level. When the resulting fatigue life is near 5×10^5 cycles, use that force level. Then, test one specimen at the highest force level (F_A) in the finite life range, with this highest force level set at not more than 60 % of the minimum tensile strength specified in **JIS B 1801** and **JIS B 1804**.

Calculate the test force values according to Formula (11) to Formula (13).

$$\Delta = \frac{F_A - F_D}{3} \dots\dots\dots(11)$$

$$F_B = F_A - \Delta \dots\dots\dots(12)$$

$$F_C = F_A - 2\Delta \dots\dots\dots(13)$$

11.3.4.2 Finite life test

For the 14 $F-N$ test method, complete the finite life range by testing a total of two specimens at each force level.

For the 24 $F-N$ test method, complete the finite life range by testing a total of four specimens at force levels F_A and F_B , and three specimens at force levels F_C and F_D .

Determine the formula for the $F-N$ diagram according to Formula (14) to Formula (18). Calculate the estimated standard deviation of logarithmic life according to Formula (19), and obtain the estimated standard deviation of force according to Formula (20).

11.3.4.3 Staircase test

The step size for the staircase test shall be equal to the calculated standard deviation of force determined according to Formula (20). Make a six-staircase test (five valid data plus one phantom point) for the 14 $F-N$ test method, or a ten-staircase test (nine valid data plus one phantom point) for the 24 $F-N$ test method in accordance with 11.2.

11.4 Analysis procedure

11.4.1 Finite life range

In this combined test method, the fatigue life is plotted on a logarithmic scale and the force is plotted on a linear scale. The $F-N$ diagram, estimated standard deviation of logarithmic life, and estimated standard deviation of force are determined according to Formula (14) to Formula (20).

$$\log N = \hat{\alpha} + \hat{\beta} F_d \dots\dots\dots(14)$$

$$\hat{\alpha} = \overline{\log N} - \hat{\beta} \overline{F_d} \dots\dots\dots(15)$$

$$\hat{\beta} = \frac{\sum_{i=1}^n (F_{di} - \overline{F_d})(\log N_i - \overline{\log N})}{\sum_{i=1}^n (F_{di} - \overline{F_d})^2} \dots\dots\dots(16)$$

$$\overline{\log N} = \frac{1}{n} \sum_{i=1}^n \log N_i \quad \dots\dots\dots (17)$$

$$\overline{F_d} = \frac{1}{n} \sum_{i=1}^n F_{di} \quad \dots\dots\dots (18)$$

where, N : number of cycles
 F_d : test force
 n : number of test data (8 for 14 F - N test method, and 14 for 24 F - N test method)

Estimated standard deviation of logarithmic life :

$$\hat{\sigma}_{\log N} = \sqrt{\frac{1}{n-2} \sum_{i=1}^n [\log N_i - (\hat{\alpha} + \hat{\beta} F_{di})]^2} \quad \dots\dots\dots (19)$$

Estimated standard deviation of force :

$$\hat{\sigma}_F = \frac{1}{|\hat{\beta}|} \hat{\sigma}_{\log N} \quad \dots\dots\dots (20)$$

11.4.2 Staircase range

The estimated mean fatigue strength F_b shall be calculated according to Formula (21).

$$F_b = \frac{1}{n} \sum_{j=1}^n F_{dj} \quad \dots\dots\dots (21)$$

Where, the number of tests, n is 6 for the 14 F - N test method, and 10 for the 24 F - N test method.

The standard deviation of fatigue strength shall be calculated according to Formula (9) specified in 10.5.3.2.

11.5 R - F - N curve

For the mean R - F - N curve at $R = 50$ % probability of survival, the finite life range is defined according to Formula (14), and the endurance at the staircase test range according to Formula (21).

Using data collected by the 14 F - N test method, for the R - F - N curve at $R = 90$ % probability of survival, the finite life range is defined according to Formula (22), and the endurance at the staircase test range according to Formula (23). The parameter, q , is 1.28.

Using data collected by the 24 F - N test method, for the R - F - N curve at $R = 95$ % probability of survival, the finite life range is defined according to Formula (22), and the endurance at the staircase test range according to Formula (23). The parameter, q , is 1.64.

$$\log N = \hat{\alpha} + \hat{\beta} F_d - q \hat{\sigma}_{\log N} \quad \dots\dots\dots (22)$$

$$F_{0.90} = F_b - \frac{q}{|\beta|} \hat{\sigma}_{\log N} \text{ or } F_{0.95} = F_b - \frac{q}{|\beta|} \hat{\sigma}_{\log N} \dots\dots\dots(23)$$

For either case, extrapolate the results to 10^7 cycles using the method given in Annex D, link this point with the point at endurance, and extend that line to connect to a line at the finite life range.

12 Report of test results

12.1 General matters

In the test report, include all items given in 12.2 to 12.4.

12.2 Test chain information

- a) Brand name, or other identifying name or mark of test chain
- b) JIS nominal number, ISO standard number or nominal number by manufacturer, and pitch of test chain
- c) Number of free links of test chain
- d) Lubricant condition of test chain
- e) Minimum dynamic strength (fatigue strength at 3×10^6 cycles) of test chain in the case of conformity test

12.3 Test equipment and procedures

12.3.1 Test equipment

- a) Brand name and type of testing machine
- b) Maximum rated capacity of testing machine
- c) Number of testing machines used (if more than one)
- d) Dynamic force verification and monitoring method
- e) Calibration method and most recent calibration date

12.3.2 Test procedures

- a) Type of test : conformity test, finite life test, staircase test or combined test
- b) Endurance
- c) Any ambient conditions that could affect test results

12.4 Test results

- a) Identification of test chain
- b) Test sequence : order of specimens tested
- c) Maximum/minimum force for each test
- d) Test force corrected to zero minimum force for each test
- e) Test force frequency