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Fatigue test method for transmission precision roller chains

Méthode d'essai de fatigue pour chaînes de transmission de précision à rouleaux

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15654 was prepared by Technical Committee ISO/TC 100, *Chains and chain wheels for power transmission and conveyors*.

Fatigue test method for transmission precision roller chains

1 Scope

This International Standard specifies an axial force fatigue test method for transmission roller chains, the tests being of the fluctuating tension type, carried out at room temperature in air, with the force applied along the longitudinal axis of the chain. It also specifies procedures for statistically analyzing the test results and gives formats and elements for presenting the results of fatigue tests and analyses.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 606, *Short-pitch transmission precision roller and bush chains, attachments and associated chain sprockets*

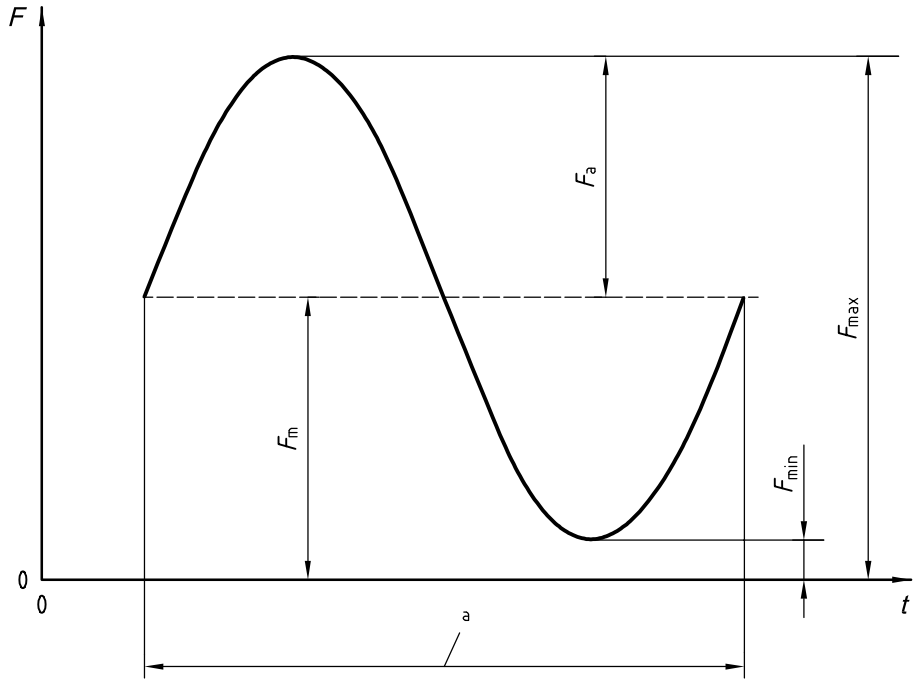
ISO 10190, *Motor cycle chains — Characteristics and test methods*

3 Symbols

See Table 1 and Figure 1.

Table 1 — Symbols

Symbol	Description	Unit
d	Step size — interval between adjacent force levels in a staircase test [see Equation (5)]	N
F_{max}	Maximum force — maximum value of force in the cycle	N
F_{min}	Minimum force — minimum value of force in the cycle	N
F_m	Mean force — half the sum of the maximum and minimum forces in the force cycle [see Equation (1)]	N
F_a	Force amplitude — half the difference between the maximum force and minimum force [see Equation (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 Equation (6)]	N
F_d	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 — approximates the force below which a chain may endure an indefinite number of force cycles [see Equation (8)]	N
F_t	Test force — maximum force, corrected to zero minimum force, at which a test is run [see Equation (3)]	N
F_u	Minimum UTS — minimum tensile strength of chain as specified in ISO 606 or ISO 10190	N
N	Number of cycles, at a given alternating force, applied to a specimen chain at a particular time in the test	—
N_e	Endurance — predetermined number of cycles at which a test will be discontinued without failure of the specimen chain	—
n	Number of test data points included in the analysis	—
p	Chain pitch	mm
S	Standard deviation of the staircase test data [see Equation (7)]	N



$$F_m = \left(\frac{F_{max} + F_{min}}{2} \right) \quad (1)$$

$$F_a = \left(\frac{F_{max} - F_{min}}{2} \right) \quad (2)$$

Key

F force
t time

a 1 cycle.

Figure 1 — Typical force cycle

4 Principle

Tests are made on transmission chains to determine fatigue properties of chain plates such as those shown on a F–N diagram or to verify conformance to dynamic strength requirements in ISO 606 and ISO 10190.

5 Apparatus

5.1 Testing machine

The size of the testing machine shall be selected so that the maximum force on the test specimen is $\geqslant$ 10 % of the maximum capacity of the machine. Tests shall be conducted on a machine capable of applying a sinusoidal fluctuating force to the test specimen in axial tension.

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

The machine shall be calibrated periodically in order to maintain suitable accuracy and should be calibrated to within $\pm$ 2 % of its maximum capacity. A force-monitoring system could be mounted in series with the test specimen to ensure that the force cycle is maintained throughout the test.

The testing machine shall also have

a) a counter to record the number of force cycles,

b) a device to stop the machine when the chain fails, and

c) a 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 transmitting an axial force to the test piece without inducing a subsidiary force caused by the fixtures. Universal type fixtures shall be used for fatigue testing of transmission chains.

The universal fixtures shall be designed according to the chain dimensions specified in the separate standards. Examples of the structure of the fixtures are shown in Figure 2.

Universal fixtures shall permit free movement on both sides of the chain centreline in both the normal plane of articulation and in the transverse plane. The hole in the fixture shall be a size equal to the bush hole diameter of the chain under test.

NOTE The test specimens all illustrate five free pitches.

When testing chain on sheaves, the chain shall be restrained from moving around the sheaves to ensure that only specific pitches of the chain are tested.

6 Test specimens

6.1 At least five free pitches of chain shall be used as a fatigue test specimen, except for chain pitch over 50,8 mm where a minimum of three free pitches are acceptable.

Free pitches are those chain pitches that do not contact the fixtures.

6.2 The test specimens shall be unused, undamaged chains on which all phases of manufacture have been completed. The final lubricant type is discretionary.

7 Test procedure

7.1 Test forces

7.1.1 Minimum force

The minimum force for the test shall be at least 1 % but not more than 5 % of the minimum tensile strength given for the subject chain in ISO 606 or ISO 10190.

7.1.2 Maximum force

The maximum force for the test shall be determined in accordance with 7.2 for a conformity test or in accordance with 7.3 for a staircase test.

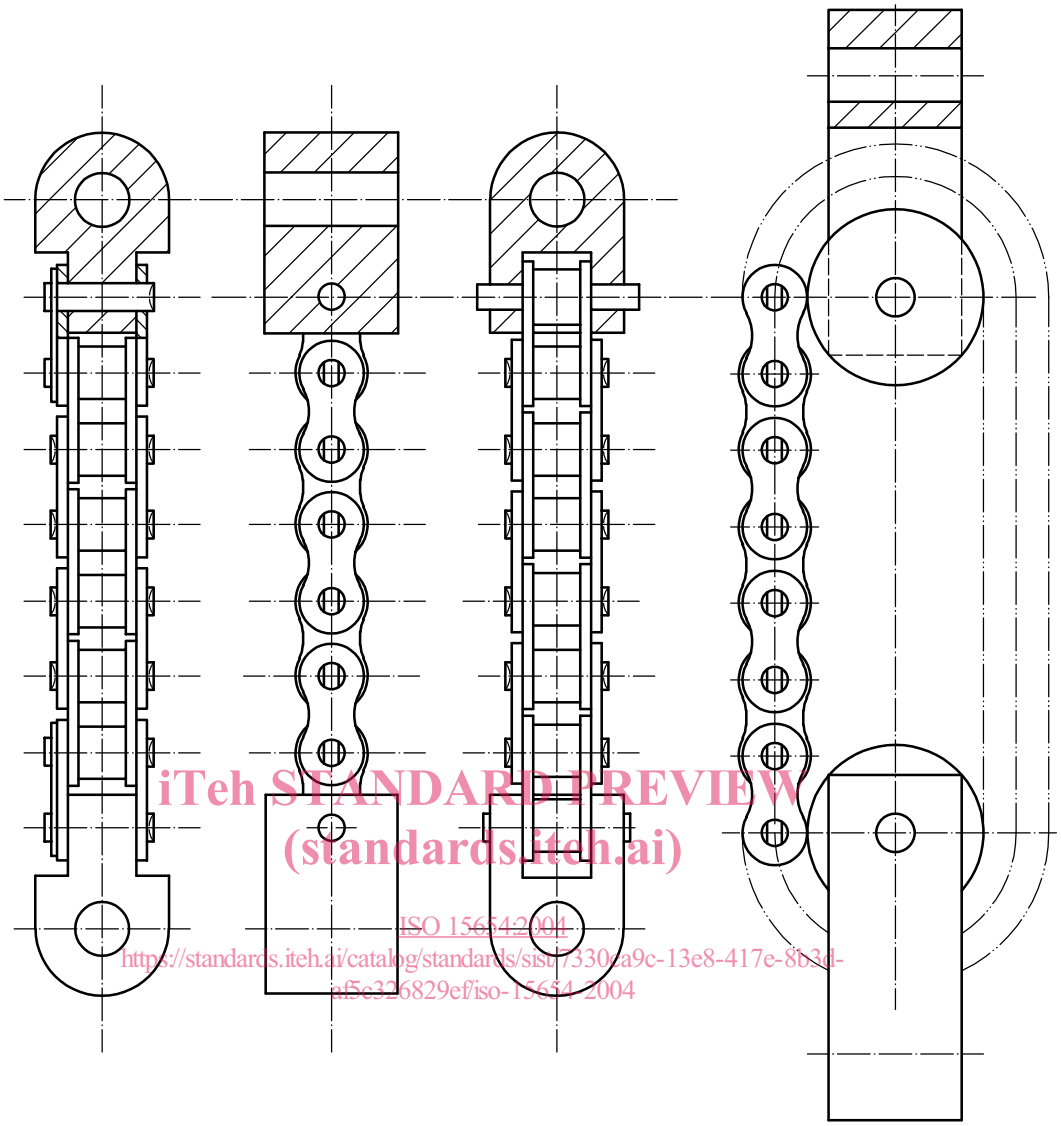
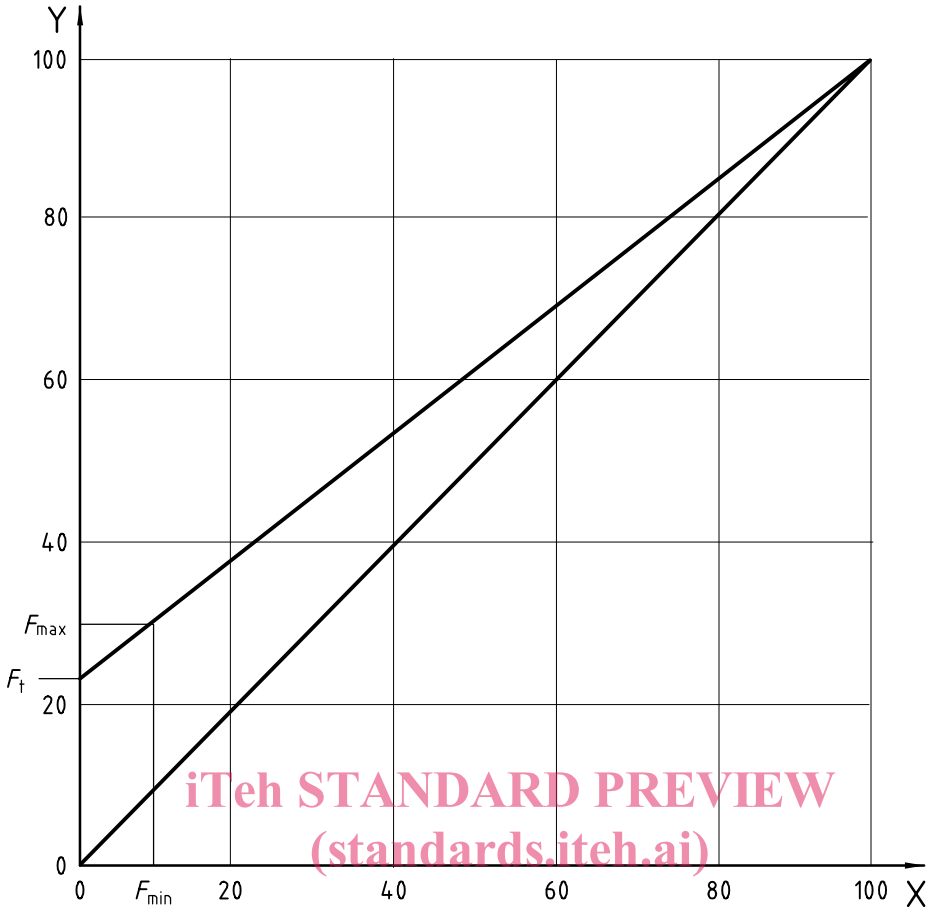


Figure 2 — Examples of test specimens mounted in universal fixtures

7.1.3 Test force

For analyses of fatigue test data, maximum forces shall be corrected to zero minimum force. A test force is obtained by correcting the maximum force to zero minimum force by means of the Johnson–Goodman method [Equation (3)]. The Johnson–Goodman relationship is illustrated by Figure 3, where F_{min} is 0,05 × F_u, and F_{max} is 0,3 × F_u, and the resulting F_t is 0,263 2 × F_u.

$$F_t = \frac{F_u(F_{max} - F_{min})}{F_u - F_{min}} \quad (3)$$



Key

X minimum force, % of F_u

Y maximum force, % of F_u

Figure 3 — Johnson–Goodman diagram

7.1.4 Force application

A longitudinal tensile force shall be applied, sinusoidally varying between the minimum test force determined according to 7.1.1 and the maximum test force determined according to 7.1.2. The test shall continue to endurance or until the specimen fails, whichever is sooner.

7.2 Conformity test

7.2.1 Purpose

The purpose of this test is to determine whether or not a chain meets the dynamic strength requirements given for it in ISO 606 or ISO 10190.

7.2.2 Endurance

Endurance shall be 3×10^6 cycles.

7.2.3 Minimum test force

The minimum force for the test shall be set in accordance with 7.1.1.

7.2.4 Maximum test force

The maximum test force shall be determined using Equation (4):

$$F_{max} = \frac{F_t F_u + \left[F_{min} \left(F_u - F_t \right) \right]}{F_u} \quad (4)$$

7.2.5 Number of tests

Three specimens shall be tested.

7.2.6 Acceptance

All specimens shall survive to endurance without failure.

7.3 Staircase test

7.3.1 Purpose

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

7.3.2 Description

For the purposes of this International Standard, a staircase test is 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 to endurance (runs-out), 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 a like manner, and the testing continues until the required number of tests are completed.

7.3.3 Endurance

Endurance shall be 10^7 cycles when testing for fatigue limit.

7.3.4 Rules for conducting a staircase test

The test shall begin with a response reversal, then a run-out followed by a failure, or a failure followed by a run-out.

The test shall have at least ten data points to determine the mean with 95 % confidence and six data points to determine the mean with 90 % confidence. It shall have the minimum number of data points in accordance with Table 2 to detect a difference in the mean of approximately one-half step size.

Table 2 — Required sample sizes

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

The highest force level in a staircase shall contain only failures.

The lowest force level in a staircase shall contain only run-outs.

Intermediate force levels in a staircase shall contain both failures and run-outs.

7.3.5 Determining step size

7.3.5.1 Using survival test with Probit analysis

See Annex A. The step size shall be determined in accordance with A.5.

7.3.5.2 Using combined test method (CTM)

See Annex B. The step size shall be determined in accordance with B.3.4.3 [see Equation (B.10)].

7.3.5.3 Using empirical method

Extensive testing has shown that reliable results can be obtained when the step size, expressed in newtons (N), is set according to Equation (5):

$$d \approx 14\,p^{1,5} \tag{5}$$

8 Staircase test data analysis

8.1 Data

The data for a staircase test analysis shall be gathered in accordance with 7.3.

An additional test point at the end of a staircase test can be determined by the rules for conducting a staircase test (see 7.3). This additional test point, sometimes called a "phantom" point, shall be included in the analysis.

8.2 Plotting staircase data

It is customary to tabulate 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 (3 levels and 95 % confidence level) is shown in Table 3.

Table 3 — Staircase data plot — Example

Test force	Invalid tests		Valid tests									
$F_t + 2d$	x											
$F_t + d$		x						x		x		#
F_t			x		x		o		o		o	
$F_t - d$				o		o						
o run-out x failure # phantom point												

8.3 Statistical calculations

8.3.1 Mean fatigue strength: 0,50 probability of survival

The mean fatigue strength shall be calculated using Equation (6).

$$F_b = \frac{\sum_{i=1}^{n} F_{ti}}{n} \tag{6}$$

where n is the total number of valid tests in the staircase calculations.

8.3.2 Standard deviations

The standard deviations of the staircase data shall be calculated using Equation (7).

$$S = \left[\frac{\sum_{i=1}^{n} F_{ti}^2}{n} - F_b^2 \right]^{0,5} \tag{7}$$

8.3.3 Fatigue limit: 0,99865 probability of survival

The fatigue limit shall be calculated using Equation (8).

$$F_d = F_b - 3S + d \tag{8}$$

9 Report of test results

9.1 Test chain information

The originator shall provide to the user

a) the brand name or other identifying name or mark of the test chain,

b) the ISO number or manufacturer's number and the pitch of the test chain, and

c) the length in free pitches of the test specimens.

9.2 Test equipment and procedures

9.2.1 Test equipment

The originator shall provide to the user

a) the brand name and type of testing machine,

b) the maximum rated capacity of the test machine,

c) the number of machines used if more than one,

d) the method of dynamic force verification and monitoring, and

e) the method of calibration and the most recent date calibrated.

9.2.2 Test procedures

The originator shall provide to the user

a) the type of test; conformity or staircase,

b) the number of cycles to endurance, and

c) any ambient conditions that could affect the test results.

9.3 Test results for conformity and staircase tests

The originator shall provide a table of test results to the user, which shall include

a) identification of the test specimen,

b) the test sequence, the order in which the specimens were run,

c) the maximum and minimum force for each test,

d) the test force, corrected to zero minimum force, for each test,

e) the force cycling frequency,

f) the number of cycles at which each test was terminated,

g) the reason each test was terminated and, if a failure, the component of the chain that failed,

h) a brief summary of the post-test examination, if any, and

i) the machine used for each test, if more than one machine was used.

For a staircase test, the originator shall also provide the user with

— the mean fatigue strength, F_b, and

— the minimum fatigue strength, or fatigue limit.

Annex A
(informative)

Survival test with abridged Probit analysis

A.1 Principle

The purpose of this test is determine the mean fatigue limit and its standard deviation. A survival test with abridged Probit analysis may also be used to determine the step size for future staircase testing of the subject chain model.

A.2 Description

The survival test is a procedure in which groups of chain specimens are tested at different force levels such that the central force level contains approximately 50 % failures, the highest force level contains 90 % to 95 % failures, and the lowest force level contains 5 % to 10 % failures.

The Probit analysis is used to estimate the mean fatigue limit and standard deviation of the tested population. The step size is then set equal to between 67 % and 150 % of the standard deviation for future staircase testing of the subject chain model.

A.3 Test procedure

A.3.1 Test specimens

Prepare at least fifty, and preferably a hundred, test specimens in accordance with Clause 6, with all test specimens from the same production batch.

Provide additional test specimens for preliminary or invalid tests.

A.3.2 Endurance

Set endurance at 10^7 cycles.

A.3.3 Force levels

Use five force levels in the survival test; one giving approximately 50 % failures before endurance (very close to the mean), two force levels above that, and two below. There may be only four force levels if the mean falls approximately midway between two force levels.

Ensure that the interval between adjacent force levels is uniform.

The central force level may be selected by means of a brief (five or six tests) staircase test.

A.3.4 Testing

Allocate test specimens to each level according to Table A.1 or Table A.2 in order to make the precision at each force level comparable. At least five specimens at each level, and fifty specimens in total, are required for acceptable accuracy.