



JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS B 8821 : 2013

(JCA/JSA)

**Calculation standards for steel
structures of cranes**

ICS 53.020.20

Reference number : JIS B 8821 : 2013 (E)

PROTECTED BY COPYRIGHT

Date of Establishment: 1976-05-01

Date of Revision: 2013-03-21

Date of Public Notice in Official Gazette: 2013-03-21

Investigated by: Japanese Industrial Standards Committee
Standards Board
Technical Committee on Logistics and Distribution
of Goods

JIS B 8821:2013, First English edition published in 2014-07

Translated and published by: Japanese Standards Association
Mita MT Building, 3-13-12, Mita, Minato-ku, Tokyo, 108-0073 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 2014

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

Printed in Japan

PROTECTED BY COPYRIGHT

Contents

		Page
1	Scope	1
2	Normative references	1
3	Terms and definitions	1
4	Materials	2
5	Determination of grades and classification	3
6	Load and combination of loads	3
7	Allowable stress	3
7.1	Basic allowable stress	3
7.2	Allowable stress for structural members and welded parts	3
7.3	Allowable stress for welded part	4
7.4	Radiographic examination	5
7.5	Bolts and pins	5
7.6	Fatigue allowable stress	6
8	Strength design	6
8.1	Symbols	6
8.2	Calculation on tensile members	7
8.3	Calculation on compressive members	8
8.4	Calculation on members accompanied by axial bending	8
8.5	Calculation on box girders subjected to bending and torsion	8
8.6	Calculation on welded part directly subjected to wheel load	10
8.7	Calculation on joint	10
9	Weld design	12
9.1	Calculation on welded joint	12
9.2	Design details of welded structure	14
10	Fatigue design	16
10.1	Definitions	16
10.2	Application	18
10.3	Range of check against fatigue design	18
10.4	Stress used for fatigue design	18
10.5	Fatigue design curve	19
10.6	Mean stress correction factor C_R	21
10.7	Plate thickness correction factor	21
10.8	Total design repetition number	23
10.9	Equivalent stress range	23
10.10	Design stress range	24

10.11	Allowable stress range for fatigue	24
10.12	Fatigue check method	24
10.13	Fatigue check procedure and flowchart	25
11	Buckling calculation	40
11.1	General	40
11.2	Design of truss and lattice jib	51
11.3	Calculation of local buckling of plates	59
Annex A (normative)	Equivalent stress range when repetition number exceeds 5×10^6 times	66
Annex B (informative)	Calculation example of fatigue	67
Annex C (informative)	Calculation of pillars buckling	72
Annex D (informative)	Basis for calculation of buckling factor ω	89

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Health, Labour and Welfare and 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 Crane 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 8821:2004** 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 Ministers 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.

Calculation standards for steel structures of cranes

1 Scope

This Japanese Industrial Standard applies to the design of the steel structures of cranes specified in **JIS B 0146-1** (including mobile cranes). However, in the cases where reasonable theories or experiments can attest the legitimacy, formulae and values specified in this Standard need not be applied.

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 0146-1 *Cranes—Vocabulary—Part 1: General*

JIS B 0146-2 *Cranes—Vocabulary—Part 2: Mobile cranes*

JIS B 1186 *Sets of high strength hexagon bolt, hexagon nut and plain washers for friction grip joints*

JIS B 8822-1 *Cranes and lifting appliances—Classification—Part 1: General*

JIS B 8822-2 *Cranes and lifting appliances—Classification—Part 2: Mobile cranes*

JIS B 8822-3 *Cranes and lifting appliances—Classification—Part 3: Tower cranes*

JIS B 8822-4 *Cranes and lifting appliances—Classification—Part 4: Jib cranes*

JIS B 8822-5 *Cranes and lifting appliances—Classification—Part 5: Overhead travelling and portal bridge cranes*

JIS B 8831 *Cranes—Design principles for loads and load combinations*

JIS G 3101 *Rolled steels for general structure*

JIS G 3106 *Rolled steels for welded structure*

JIS G 3114 *Hot-rolled atmospheric corrosion resisting steels for welded structure*

JIS G 3128 *High yield strength steel plates for welded structure*

JIS G 3136 *Rolled steels for building structure*

JIS G 3444 *Carbon steel tubes for general structure*

JIS G 3445 *Carbon steel tubes for machine structure*

JIS G 3466 *Carbon steel square and rectangular tubes for general structure*

JIS G 4051 *Carbon steels for machine structural use*

JIS Z 3104 *Methods of radiographic examination for welded joints in steel*

3 Terms and definitions

For the purposes of this Standard, the terms and definitions given in **JIS B 0146-1** and **JIS B 0146-2** apply.

4 Materials

Materials used for structure of cranes are as given in table 1 or those at least equivalent in quality thereto. Constants of steel products are as given in table 2.

Table 1 Materials

Application	Number of standard	Title	Classification symbol
Steel products, sections, flat bars and steel bars	JIS G 3101	Rolled steels for general structure	SS400
	JIS G 3106	Rolled steels for welded structure	SM400 (A, B, C), SM490 (A, B, C), SM490 (YA, YB), SM520 (B, C), SM570
	JIS G 3114	Hot-rolled atmospheric corrosion resisting steels for welded structure	SMA400AW, SMA400AP, SMA400BW, SMA400BP, SMA400CW, SMA400CP, SMA490AW, SMA490AP, SMA490BW, SMA490BP, SMA490CW, SMA490CP, SMA570W, SMA570P
	JIS G 3128	High yield strength steel plates for welded structure	SHY685, SHY685N, SHY685NS
	JIS G 3136	Rolled steels for building structure	SN400A, SN400B, SN400C, SN490B, SN490C
Steel tubes	JIS G 3444	Carbon steel tubes for general structure	STK400, STK490, STK540
	JIS G 3445	Carbon steel tubes for machine structure	STKM13 (A, B, C), STKM18 (A, B, C), STKM19 (A, C), STKM20A
	JIS G 3466	Carbon steel square and rectangular tubes for general structure	STKR400, STKR490
Pins/bolts	JIS G 3101	Rolled steels for general structure	SS400
	JIS G 4051	Carbon steels for machine structural use	S20C, S35C, S45C
High strength bolts and nuts	JIS B 1186	Sets of high strength hexagon bolt, hexagon nut and plain washers for friction grip joints	F8T, F10T, F10 (nut), F35 (washer)

Table 2 Constants of steel products

Characteristics of steel products	Constant
Longitudinal module of elasticity: E N/mm ²	206 000
Shearing modulus of elasticity: G N/mm ²	79 000
Poisson's ratio: ν (1/m)	0.3
Coefficient of linear expansion: α	1.2×10^{-5}
Density: ρ g/cm ³	7.85

5 Determination of grades and classification

Although this Standard is the standard used for the design of the steel structures of cranes, the frequency of usage and the rate of loading for crane (classification and grade of crane) shall clearly be described as the preconditions of design. An agreement shall be made on these load conditions between the designer and the purchaser.

For the crane of which purchasers are unknown, the frequency of usage and the rate of loading for crane shall be determined before starting the design.

The classification and grade of cranes determined by the frequency of usage and the rate of loading for crane are as given in **JIS B 8822-1** to **JIS B 8822-5**. Also, operation factors determined by the load condition and the number of times subjected to loading are as given in **JIS B 8831**.

6 Load and combination of loads

The load and combination of loads are as given in **JIS B 8831**.

7 Allowable stress

7.1 Basic allowable stress

The basic allowable stress σ_a shall be the smaller value of either the yield point (or 0.2 % yield strength) or the tensile strength of the material divided by the strength factor given in table 3 for each combination of loads given in clause 6.

Table 3 Strength factor

Load condition	Strength factor	
	For yield point	For tensile strength
Combination of loads A	1.5	1.8
Combination of loads B	Value for load combination A divided by 1.15	Value for load combination A divided by 1.15
Combination of loads C	Value for load combination A divided by 1.30	Value for load combination A divided by 1.30

7.2 Allowable stress for structural members and welded parts

The allowable stress for structural members and welded parts are as given in table 4.

Table 4 Allowable stress of structural members and welded parts

Division		Type of stress		Allowable stress	Cross-section used for calculation
Structural member	Tensile			σ_a	Net cross-section
	Compressive			$\sigma_a/1.15$	Total cross-section
	Bending	Tension side		σ_a	Net cross-section
		Compression side		$\sigma_a/1.15$	Total cross-section
	Shearing			$\sigma_a/\sqrt{3}$	Net cross-section
	Buckling			According to $\sigma_a/1.15$ and clause 11.	Total cross-section
	Bearing			$1.42\sigma_a$	Total cross-section
Welded part	Butt	Tensile	Steel type A	$0.840 \times \sigma_a$	Throat thickness
			Steel type B	$0.800 \times \sigma_a$	
		Compressive	Steel type A	$0.945 \times \sigma_a/1.15$	Throat thickness
			Steel type B	$0.900 \times \sigma_a/1.15$	
		Bending	Tension side	Steel type A	Throat thickness
				Steel type B	
			Compression side	Steel type A	Throat thickness
				Steel type B	
		Shearing	Steel type A	$0.840 \times \sigma_a/\sqrt{3}$	Throat thickness
			Steel type B	$0.800 \times \sigma_a/\sqrt{3}$	
	Fillet	Tensile	Steel type A	$0.840 \times \sigma_a$	Throat thickness
			Steel type B	$0.800 \times \sigma_a$	
		Compressive	Steel type A	$0.840 \times \sigma_a/1.15$	Throat thickness
			Steel type B	$0.800 \times \sigma_a/1.15$	
		Bending	Steel type A	—	—
			Steel type B	—	
		Shearing	Steel type A	$0.840 \times \sigma_a/\sqrt{3}$	Throat thickness
			Steel type B	$0.800 \times \sigma_a/\sqrt{3}$	

Supplemental explanations for this table are shown below.

- In this table, steel type A indicates steels which conform to SN400B, SN400C, SN490B or SN490C specified in **JIS G 3106**, **JIS G 3114**, **JIS G 3128** and **JIS G 3136**, STK490 specified in **JIS G 3444**, STKM18 (A, B, C) specified in **JIS G 3445**, or STKR490 specified in **JIS G 3466**; while steel type B indicates steels not included above.
- The net cross-section shall be at the position of minimum cross-section excluding the area of bolt holes.

7.3 Allowable stress for welded part

The allowable stress for welded part shall be as given in table 4 of 7.2. When performing radiographic examinations, if the welded part of structures (limited to butt welding for the method of weld work) satisfies the following conditions, the value of

the allowable stress (limited to allowable tensile stress, allowable compressive stress and allowable bending stress) used for the calculation of the corresponding welded part may be assumed to be the same as that of the structural member.

- a) There are no Type 3 flaws specified in **JIS Z 3104**.
- b) If either of flaws of Type 1 and Type 4 or those of Type 2 specified in **JIS Z 3104** exist, each of the number and the length of flaws specified in **JIS Z 3104** are less than or equal to respective values indicating the allowable limits for Class 2 of Type 1 or Type 4, or the values indicating the allowable limits for Class 2 of Type 2 specified in **JIS Z 3104**.
- c) If both of flaws of Type 1 and Type 4 and those of Type 2 specified in **JIS Z 3104** exist, each of the number and the length of flaws specified in **JIS Z 3104** are less than or equal to respective values indicating the allowable limits for Class 2 of Type 1 or Type 4, or the half values indicating the allowable limits for Class 2 of Type 2 specified in **JIS Z 3104**.

7.4 Radiographic examination

The radiographic examination shall be as given in **JIS Z 3104**, and as follows.

- a) The length of 20 % or more of the total length of welded part of the structure shall be examined.
- b) The weld reinforcement of welded part of the structure shall be ground to the same level as the surface of parent material. However, if the height at the centre of weld reinforcement is less than or equal to the value in the right column of table 5 corresponding to the thickness of the parent material in the left column, the weld reinforcement need not be ground to the same level as the parent material surface.

Table 5 Height of weld reinforcement

Unit : mm	
Thickness of parent material	Height
12 or under	1.5
Over 12 to and incl. 25	2.5
Over 25	3.0

7.5 Bolts and pins

The allowable stress for bolts and pins shall be as given in table 6.

Table 6 Allowable stress for bolts and pins

Type	Material	Type of stress	Allowable stress	Diameter used for calculation
High strength bolt	F8T, F10T	Apparent shearing	$0.21 \sigma_a$	Bolt trunk diameter
High strength grip bolt		Apparent shearing	$0.24 \sigma_a$	Bolt trunk diameter
Reamer bolt	SS400 S20C S35C S45C	Shearing	$\sigma_a/\sqrt{3}$	Bolt trunk diameter
		Bearing	$1.42 \sigma_a$	
Pin connection		Shearing	$\sigma_a/\sqrt{3}$	Pin diameter (When pin slightly moves, allowable bearing stress only shall be made 50 % of the value given left.)
		Bearing	$1.42 \sigma_a$	
		Bending	σ_a	
Foundation bolt	SS400 S20C	Tensile	$0.6 \sigma_a$	Root diameter
		Shearing	$0.35 \sigma_a$	

Supplemental explanations for this table are shown below.

- High strength bolts and high strength grip bolts are assumed to be tightened with the stress at the root of 75 % and 85 % of the yield strength of the material, respectively.
- For joints using high strength bolts or high strength grip bolts, the friction surface of structure shall be clean and free from oil, paint, etc., and the surface as forged shall be removed by such as sand blasting.
- Allowable bearing stress shall be based on the smaller value of σ_a of either the jointing member or the supporting member.
- Materials used shall be as given in table 6 or those at least equivalent to.

NOTE 1 Apparent shearing is the shear converted from the load transferred by friction joint.

NOTE 2 Basic allowable strength of high strength bolts and high strength grip bolts may be calculated based on the yield strength instead of the yield point.

7.6 Fatigue allowable stress

The fatigue allowable stress shall be as given in clause 10.

8 Strength design

8.1 Symbols

Symbols used in clause 8 shall be as follows.

- A : area enclosed by web and centre line of flange (mm²)
- A_F : total cross-sectional area of tensile flange (mm²)
- A_{Fn} : net cross-sectional area of tensile flange (mm²)
- A_{Wn} : net cross-sectional area of web subjected to shearing (mm²)
- A_n : net cross-sectional area (mm²)
- e_c : distance from neutral axis to compressed edge (mm)
- e_t : distance from neutral axis to tensile edge (mm)
- F_B : shearing force caused by bending (N)

- F_J : maximum shearing force at joint (N)
 f : factor (see table 7)
 h : distance between outermost bolts connecting webs (mm) (see table 7)
 I : geometrical moment of inertia (mm⁴)
 I_G : geometrical moment of inertia around neutral axis of total cross-section of girder (mm⁴)
 I_W : geometrical moment of inertia of web around neutral axis of total cross-section of girder (mm⁴)
 M : bending moment (N·mm)
 M_J : bending moment applied to girder at joint (N·mm)
 M_W : bending moment applied to web (N·mm)
 N : tensile force in axial direction (N)
 n : total number of jointing bolts on one side of jointing line
 R : resultant force applied to one bolt at y_n (N)
 T : torsion moment around shearing centre (N·mm)
 t : thickness of web or flange (mm)
 y_n : distance from neutral axis to farthest bolt (mm) (see figure 5)
 Σy^2 : total sum of squared distances from jointing bolts on one side of jointing line to neutral axis (mm²)
 σ_{ca} : allowable compressive stress given in clause 7 (N/mm²)
 σ_{ce} : compressive edge stress (N/mm²)
 σ_t : tensile stress (N/mm²)
 σ_{ta} : allowable tensile stress given in clause 7 (N/mm²)
 σ_{te} : tensile edge stress (N/mm²)
 τ : shearing stress caused by bending (N/mm²)
 τ_a : allowable shearing stress given in clause 7 (N/mm²)
 τ_t : shearing stress caused by torsion moment (N/mm²)

8.2 Calculation on tensile members

The tensile stress shall be calculated according to formula (1) using the net cross-sectional area excluding the bolt holes.

$$\sigma_t = \frac{N}{A_n} \leq \sigma_{ta} \dots\dots\dots (1)$$

- where, σ_t : tensile stress (N/mm²)
 A_n : net cross-sectional area (mm²)
 N : tensile force in axial direction (N)
 σ_{ta} : allowable tensile stress given in clause 7 (N/mm²)

If the members are subjected to alternate stress varying in values as in a periodical time function, the fatigue strength in clause 10 shall be taken into consideration.

In determining the net cross-sectional area of tensile member, areas of bolt holes shall be reduced appropriately according to their positions. In figure 1, if the cross-section a-c-c-a from which areas of bolt holes are reduced is smaller than that of a-a, areas of four bolt holes shall be reduced from the cross-sectional area of the member.

For angles and U-sections of construction without eccentricity, the above shall apply after developing legs and flanges.

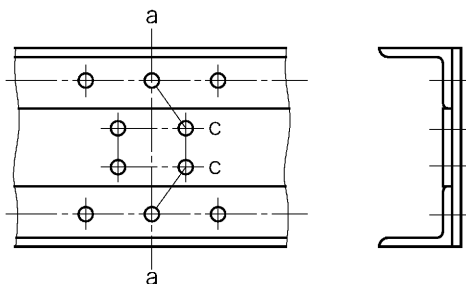


Figure 1 Effective net cross-sectional area

8.3 Calculation on compressive members

The calculation on compressive members shall be as given in clause 11.

8.4 Calculation on members accompanied by axial bending

The calculation on members accompanied by axial bending shall be as given in clause 11.

8.5 Calculation on box girders subjected to bending and torsion

The box girders subjected to bending and torsion shall be respectively calculated according to the following a) to c) on bending and torsion. However, for ordinary overhead travelling cranes, if the ratio of (span)/(girder width) does not exceed 40, lateral buckling caused by bending need not be considered.

- a) **Calculation of bending stress and shearing stress** The tensile edge stress, compressive edge stress and shearing stress caused by bending shall be according to formula (2) to formula (4).

$$\sigma_{te} = \frac{M}{I} \cdot \frac{A_F}{A_{Fn}} \cdot e_t \leq \sigma_{ta} \dots\dots\dots (2)$$

$$\sigma_{ce} = \frac{M}{I} e_c \leq \sigma_{ca} \dots\dots\dots (3)$$

$$\tau = \frac{F_B}{A_{Wn}} \leq \tau_a \dots\dots\dots (4)$$

where, σ_{te} : tensile edge stress (N/mm²)
 σ_{ce} : compressive edge stress (N/mm²)
 τ : shearing stress caused by bending (N/mm²)

- M : bending moment (N·mm)
 I : geometrical moment of inertia (mm⁴)
 A_F : total cross-sectional area of tensile flange (mm²)
 A_{Fn} : net cross-sectional area of tensile flange (mm²)
 e_c : distance from neutral axis to compressive edge (mm) (see figure 2)
 e_t : distance from neutral axis to tensile edge (mm) (see figure 2)
 F_B : shearing force caused by bending (N)
 A_{Wn} : net cross-sectional area of web subjected to shearing (mm²)
 σ_{ta} : allowable tensile stress given in clause 7 (N/mm²)
 σ_{ca} : allowable compressive stress given in clause 7 (N/mm²)
 τ_a : allowable shearing stress given in clause 7 (N/mm²)

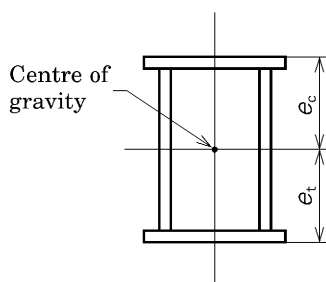


Figure 2 Box girder subjected to bending

- b) **Calculation of shearing stress caused by torsion moment** The calculation of shearing stress caused by torsion moment τ_t shall be according to formula (5).

$$\tau_t = \frac{T}{2 \cdot A \cdot t} \leq \tau_a \dots\dots\dots (5)$$

- where, τ_t : shearing stress caused by torsion moment (N/mm²)
 T : torsion moment around shearing centre (N·mm) (see figure 3)
 A : area enclosed by centrelines of web and flange (mm²)
 t : thickness of web or flange (mm)
 τ_a : allowable shearing stress given in clause 7 (N/mm²)

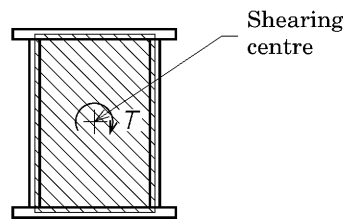


Figure 3 Box girder subjected to torsion

- c) **Combined stress of shearing by bending and by torsion** The combined stress becomes largest at the side where the directions of shearing stress by bending τ and that by the torsion moment τ_t coincide, and shall be calculated according to formula (6).

$$\tau + \tau_t \leq \tau_a \quad \dots\dots\dots (6)$$

where, τ : shearing stress caused by bending (N/mm²)
 τ_t : shearing stress caused by torsion moment (N/mm²)
 τ_a : allowable shearing stress given in clause 7 (N/mm²)

8.6 Calculation on welded part directly subjected to wheel load

The welded part directly subjected to wheel load shall be as shown in figure 4.

If the rail is situated directly above the web and the precise calculation is not especially required, the wheel load shall be assumed to be uniformly distributed within the direction of 45° from the width of 50 mm directly under the wheel as shown in figure 4.

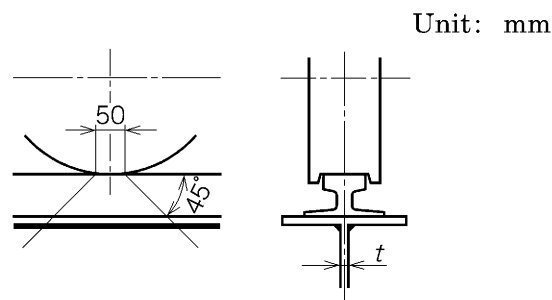


Figure 4 Distribution of wheel load

8.7 Calculation on joint

8.7.1 Calculation on web joint of girder subjected to bending

The web joint of plate girder subjected to bending moment shall be designed according to the shearing force and the bending moment, and the maximum resultant force applied to the jointing bolts shall be calculated according to formula (7). In this case, the allowable strength of bolts shall be reduced according to the ratio of the distance from flange to neutral axis of plate girder and the value of y_n in the formula.

$$R = \sqrt{\left(\frac{F_J}{n}\right)^2 + \left(\frac{M_W}{\Sigma y^2} \cdot y_n\right)^2} \dots\dots\dots (7)$$

provided that $M_W = M_J \cdot \frac{I_W}{I_G}$

- where, R : resultant force applied to one bolt at y_n (N)
 n : total number of jointing bolts on one side of jointing line
 F_J : maximum shearing force at joint (N)
 M_W : bending moment applied to web (N·mm)
 M_J : bending moment applied to girder at joint (N·mm)
 I_W : geometrical moment of inertia of web around neutral axis
 of total cross-section of girder (mm⁴)
 I_G : geometrical moment of inertia around neutral axis of
 total cross-section of girder (mm⁴)
 Σy^2 : sum of squared distances from jointing bolts on one side
 of jointing line to neutral axis (mm²)
 y_n : distance from neutral axis to farthest bolt (mm) (see figure 5)

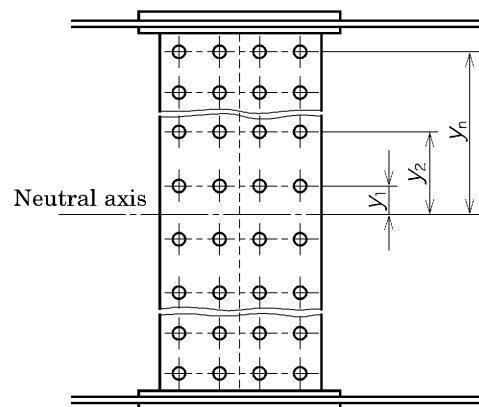
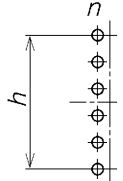
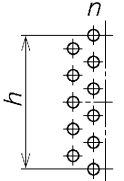
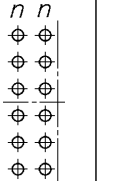
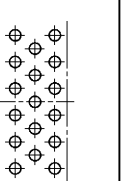
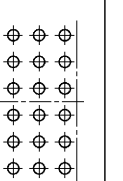
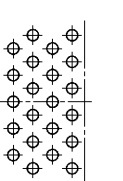
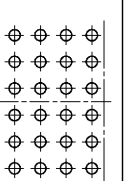


Figure 5 Joints of girder

Instead of $\frac{M_W}{\Sigma y^2} \cdot y_n$ in formula (7), $\frac{M_W}{h} \cdot f$ may be used for calculation. The values for factor f are as given in table 7.

Table 7 Value of factor f

Number of bolts in one column n	1-column bolt connection	2-column bolt connection		3-column bolt connection		4-column bolt connection	
							
	$f_1 = \frac{6(n-1)}{n(n+1)}$	$f_2 = \frac{6(n-1)}{n(2n-1)}$	$f_2 = \frac{f_1}{2}$	$f_3 = \frac{2(n-1)}{n^2}$	$f_3 = \frac{f_1}{3}$	$f_4 = \frac{3(n-1)}{n(2n-1)}$	$f_4 = \frac{f_1}{4}$
4	0.900	0.643	0.450	0.375	0.300 0	0.322	0.225 0
5	0.800	0.533	0.400	0.320	0.266 7	0.267	0.200 0
6	0.714	0.455	0.357	0.278	0.238 0	0.227	0.178 5
7	0.643	0.396	0.322	0.249	0.214 3	0.198	0.106 8
8	0.583	0.350	0.292	0.219	0.194 3	0.175	0.145 8
9	0.533	0.314	0.267	0.198	0.177 7	0.157	0.133 2
10	0.491	0.284	0.246	0.180	0.163 7	0.142	0.122 8
11	0.455	0.260	0.228	0.165	0.151 7	0.130	0.113 8
12	0.423	0.239	0.212	0.153	0.141 0	0.120	0.105 8
13	0.396	0.222	0.198	0.142	0.132 0	0.111	0.099 0
14	0.371	0.206	0.186	0.133	0.123 7	0.103	0.092 8
15	0.350	0.193	0.175	0.124	0.116 7	0.097	0.087 5
16	0.331	0.181	0.166	0.117	0.110 3	0.091	0.082 8
17	0.314	0.171	0.157	0.111	0.104 7	0.086	0.078 5
18	0.298	0.162	0.149	0.105	0.099 3	0.081	0.074 5
19	0.284	0.153	0.142	0.100	0.094 7	0.077	0.071 0
20	0.271	0.146	0.136	0.095	0.090 3	0.073	0.067 8

9 Weld design

9.1 Calculation on welded joint

9.1.1 Stress of joint subjected to tensile, compressive or shearing force

The stress generated in the butt welded part or the fillet welded part shall be calculated according to formula (8) and formula (9).

$$\sigma = \frac{P}{\Sigma a \cdot l} \dots\dots\dots (8)$$

$$\tau_w = \frac{P}{\Sigma a \cdot l} \dots\dots\dots (9)$$

where, σ : tensile or compressive stress generated in welded part (N/mm²)

τ_w : shearing stress generated in welded part (N/mm²)

P : force applied to joint (N)

a : throat thickness of welded part (see **9.2.2**) (mm)

l : effective length of welded part (see **9.2.3**) (mm)

9.1.2 Stress according to bending moment

For joints subjected to both bending moment and shearing stress at the same time such as the continuous welded part connecting web and flange, vertical or horizontal butt welded part of web and fillet welded part connecting I-shaped girders to walls [figure 6 a)], the combined stress shall be calculated according to formula (10).

$$\sqrt{\sigma_w^2 + 3\tau^2} \leq \sigma_a \quad \dots\dots\dots (10)$$

where, σ_w : bending stress (N/mm²), provided that $\sigma_w \leq \sigma_a$
 τ : shearing stress (N/mm²), provided that $\tau \leq \tau_a$
 σ_a : allowable tensile stress (N/mm²)

The bending moment and the shearing stress shall be as follows.

a) Stress according to bending moment

$$\sigma_w = \frac{M}{I} \cdot y \quad \dots\dots\dots (11)$$

where, M : bending moment applied to joint (N·mm)
 I : geometrical moment of inertia around neutral axis of throat thickness
 For the case of fillet welding, geometrical moment of inertia of effective cross-section generated by developing throat thickness on jointing surface as shown in figure 6 b) (mm⁴)
 y : distance between stress calculation point and neutral axis (mm)
 σ_w : bending stress (N/mm²), provided that $\sigma_w \leq \sigma_a$

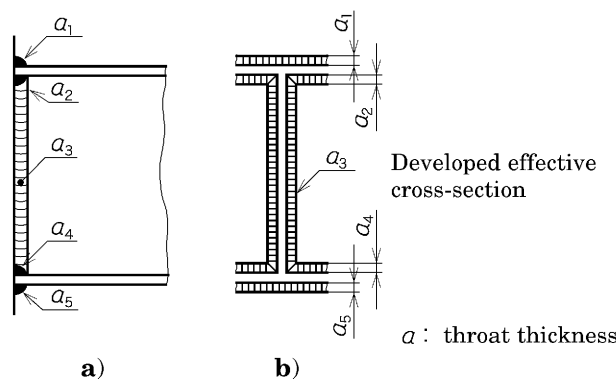


Figure 6 Development of throat thickness

b) Shearing stress

$$\tau = \frac{P \cdot Q}{I \cdot a} \quad \dots\dots\dots (12)$$

where, τ : shearing stress generated in welded part (N/mm²)
 P : force applied to joint (N)

Q : geometrical moment of area around neutral axis of cross-section outside the weld line to calculate stress (mm^3)

I : geometrical moment of inertia around neutral axis of throat thickness

For the case of fillet welding, geometrical moment of inertia of effective cross-section generated by developing throat thickness on jointing surface as shown in figure 6 b) (mm^4)

a : throat thickness of welded part (mm)

For simplified calculation, formula (13) may be applied, assuming that the sharing stress is applied only to the web.

$$\tau = \frac{P}{A_a} \dots\dots\dots (13)$$

where, τ : shearing stress generated in welded part (N/mm^2)

P : force applied to joint (N)

A_a : total cross-section area of web

For the fillet welding, total area of throat thickness of fillet of web (mm^2)

9.2 Design details of welded structure

9.2.1 Welding of main members

The main members shall generally be welded in factories.

9.2.2 Effective thickness of welded joint part

The effective thickness of welded joint which transfers the stress shall be the throat thickness of weld, and as follows.

- a) For the group welding, the throat thickness shall be the thickness of members to be jointed and the smaller thickness when the thickness differs, as shown in figure 7.

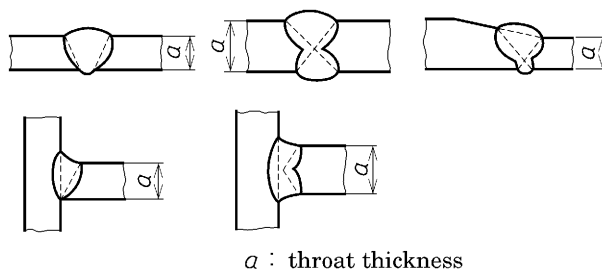


Figure 7 Throat thickness of groove welding

- b) For fillet welding, the throat thickness shall be the height of isosceles triangle of which equivalent two sides are same as the smaller size, as shown in figure 8.

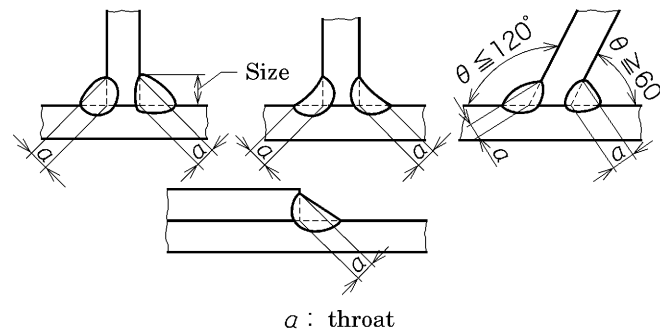


Figure 8 Throat thickness of fillet welding

9.2.3 Effective length of welded joint part

The effective length of welded joint shall be the length of throat of full penetration weld as follows.

- When the butt weld line is not perpendicular to the direction of stress, the effective length shall be the length of the weld line perpendicularly projected [see figure 9 a)].
- Boxing of fillet welding shall not be included in the effective length [see figure 9 b)].

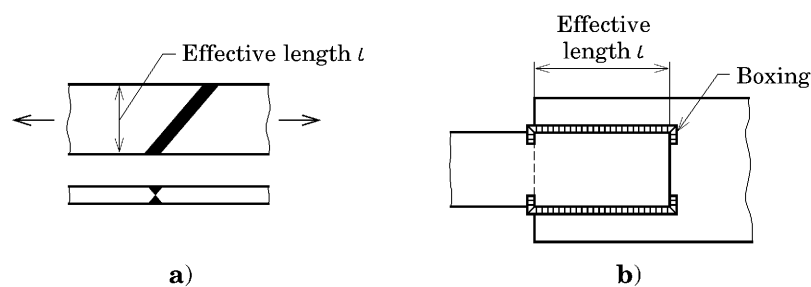
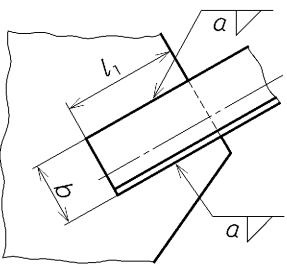
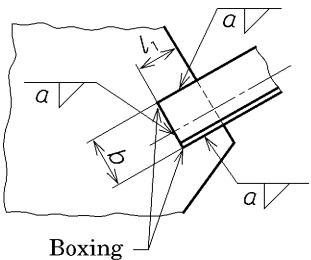
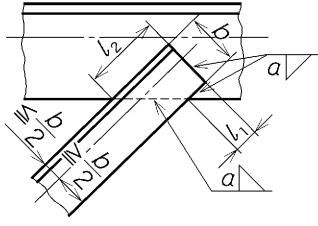
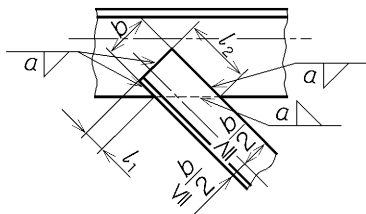


Figure 9 Effective length welding

- The effective length of weld of inclined edges are as given in table 8. However, it shall be not more than $150a$ (150 times the throat thickness).

In applying this table, it is not necessary to consider the eccentric moment of the weld line to the central axis of the inclined member. This applies also to the sections other than angles.

Table 8 Calculated length of weld line of inclined edge Σl

No.	Type of joint	Diagram	Calculated length of joint Σl
1	Side fillet welding		$\Sigma l = 2l_1$
2	Front and side fillet welding		$\Sigma l = b + 2l_1$
3	Circular fillet welding (central axis is near longer weld line)		$\Sigma l = l_1 + l_2 + 2b$
4	Circular fillet welding (central axis is near shorter weld line)		$\Sigma l = 2l_1 + 2b$

10 Fatigue design

10.1 Definitions

The terms and definitions used in clause 10 shall be as follows.

nominal stress:	stress based on cross-sectional force determined by general theory such as beam theory
stress range:	difference between maximum stress and minimum stress during one stress cycle
stress amplitude:	half of difference between maximum stress and minimum stress during one stress cycle
mean stress:	half of sum of maximum stress and minimum stress during one stress cycle

maximum stress range:	maximum stress range expected during design life
straight stress:	stress generated in cross-section perpendicular to direction of load, i.e., perpendicular stress
stress ratio:	ratio of minimum stress to maximum stress
equivalent stress range:	stress range subjected to fatigue damage equivalent to constant stress range by the same repetition number as that of varying stress
truncation limit:	stress range where or below which no fatigue damage occurs
fatigue life:	repetition number of stresses until fatigue damage occurs
fatigue strength:	stress range corresponding to particular fatigue life
type of joint:	classification of joint according to shape and fatigue strength of joint
fatigue strength grade:	fatigue strength depending on type of joint ("fatigue strength grade 100" indicates 2×10^6 times fatigue strength is 100 N/mm ²)
fatigue design curve:	curve indicating relation between stress (straight stress and shearing stress) range and fatigue life
basic allowable stress range:	allowable stress range determined by stress range-repetition number chart ($\Delta\sigma$ -N chart or $\Delta\tau$ -N chart)
2×10^6 times basic allowable stress range:	basic allowable stress range for repetition number of 2×10^6
allowable stress range:	allowable stress range determined by correcting basic allowable stress range considering influence of mean stress and plate thickness
design life:	usable period of structural member expected in design
total design repetition number:	total expected repetition number of stress during design life or total repetition number in stress range equal to or more than truncation limit
design stress range:	stress range determined by correcting equivalent stress range calculated in design by design stress correction factor
unit period:	period of unit used for counting design life, e.g., day, month and year
damage influence factor:	factor considering influence of fatigue damage of target joint or member on strength or function of whole structure
criticality factor:	factor considering criticality or influence of damage of structure

inspection factor:	factor indicating easiness for inspection and maintenance
redundancy factor:	factor expressed as the product of damage influence factor, criticality factor and inspection factor

10.2 Application

The criteria given in this clause shall be applied to check the safety against fatigue of crane structures using steel products. However, if there is reasonable theoretical background, reliable experimental data or sufficient use data, the formulae and values specified in this Standard are not necessarily applied.

10.3 Range of check against fatigue design

If the check against fatigue strength is required, this clause shall apply. However, this check shall not apply to the following cases.

- In the case where the maximum nominal stress of the crane structure exceeds the yield point or the yield strength of the material
- For use in the corrosive environment or supposedly corrosive environment under the condition without appropriate anti-corrosive treatment
- For use in high temperature all the time
- In the case where the maximum stress range $\Delta\sigma_{\max}$ satisfies the following condition.

$$\Delta\sigma_{\max} < 36 \text{ N/mm}^2$$

- In the case where the total design repetition number is 10^4 times or less.

10.4 Stress used for fatigue design

The nominal stress of members shall be determined with respect to the load F calculated according to formula (14) for cranes other than mobile cranes or formula (15) for mobile cranes. The nominal stress shall be calculated according to the theory of structures and the like assuming linear elastic behaviour of material. However, local stress concentration caused by such as welded joint shall not be considered.

$$F = K[(\Psi \cdot F_1) + F_2 + F_3] \dots\dots\dots (14)$$

$$F = (\gamma \cdot F_1) + (\phi \cdot F_2) + F_3 \dots\dots\dots (15)$$

where, F : load applied to target member (N)
 K : operation factor
 Ψ : impact factor
 F_1 : vertical dynamic load (N)
 F_2 : vertical static load (N)
 F_3 : horizontal dynamic load (N)
 γ : dynamic load factor
 ϕ : static load factor

The operation factor K , impact factor Ψ , dynamic load factor γ and static load factor ϕ are as given in **JIS B 8831**.

10.5 Fatigue design curve

In fatigue design, for the joint subjected to straight stress, $\Delta\sigma$ - N chart (figure 10) shall be used and for joints subjected to shearing stress, $\Delta\tau$ - N chart (figure 11) shall be used. The $\Delta\sigma$ - N chart for joint subjected to straight stress shall be according to formula (16) and $\Delta\tau$ - N chart for joint subjected to shearing stress shall be according to formula (17).

$$\Delta\sigma^m \cdot N = C_0 \dots\dots\dots (16)$$

$$\Delta\tau^m \cdot N = D_0 \dots\dots\dots (17)$$

where, $\Delta\sigma$: straight stress range (N/mm²)
 $\Delta\tau$: shearing stress range (N/mm²)
 m : constant indicating inclination of $\Delta\sigma$ - N chart or $\Delta\tau$ - N chart
 N : repetition number of stresses
 C_0 : constant in $\Delta\sigma$ - N chart
 D_0 : constant in $\Delta\tau$ - N chart

C_0 , D_0 and m are obtained in table 9.

NOTE 1 Sixteen lines in $\Delta\sigma$ - N chart in figure 10 and two lines in $\Delta\tau$ - N chart in figure 11 are drawn depending on the fatigue strength grade of joint, and are parallel one another on a double logarithmic chart.

The $\Delta\sigma$ - N chart for joint subjected to straight stress as given in figure 10 is expressed by straight lines inclined by 1/3 (inverse number of $m=3$) for $10^4 < N \leq 5 \times 10^6$ on a double logarithmic chart, and inclined by 1/5 (inverse number of $m=5$) for $5 \times 10^6 < N \leq 10^8$. For $N > 10^8$, $\Delta\sigma$ indicates the straight line independent on N , i.e., the truncation limit. The $\Delta\tau$ - N chart as shown in figure 11 is expressed by two parallel straight lines inclined by 1/5 (inverse number of $m=5$) for $10^4 < N \leq 10^8$ on a double logarithmic chart. For $N > 10^8$, $\Delta\tau$ indicates the straight line independent on N .

NOTE 2 The fatigue strength grade of joint gives the lower limit of fatigue test results of joint, and the value indicating the fatigue strength grade, e.g., 100, shows that 2×10^6 times fatigue strength is 100 N/mm².

Table 10 shows 2×10^6 times fatigue strength, constant C_0 in $\Delta\sigma$ - N chart, 5×10^6 times fatigue strength and the truncation limit of stress range for each fatigue strength grade of joint subjected to straight stress. Table 11 shows 2×10^6 times fatigue strength, constant D_0 in $\Delta\tau$ - N chart and the truncation limit of stress range for each fatigue strength grade of joint subjected to the shearing stress.

Table 9 Values of C_0 , D_0 and m

Type of joint	Range of N					
	$10^4 < N \leq 5 \times 10^6$		$5 \times 10^6 < N \leq 10^8$		$10^4 < N \leq 10^8$	
	Constant					
	C_0	m	C_0	m	D_0	m
Non-welded joint (parent material)	$2 \times 10^6 \cdot \Delta\sigma_c^m$	3	$2 \times 10^7 \cdot \Delta\sigma_K^m$	5	—	—
Plate and welded joint of hollow cross-section	$2 \times 10^6 \cdot \Delta\sigma_c^m$	3	$2 \times 10^7 \cdot \Delta\sigma_K^m$	5	—	—
Joint subjected to shearing	—	—	—	—	$2 \times 10^6 \cdot \Delta\tau_c^m$	5
NOTE : In table 9, $\Delta\sigma_c$ and $\Delta\tau_c$ are 2×10^6 times basic allowable stress range and $\Delta\sigma_K$ is 2×10^7 times basic allowable stress range.						

Table 10 Constant in $\Delta\sigma$ -N chart, fatigue strength and truncation limit of stress range

Fatigue strength grade	2×10^6 times fatigue strength N/mm ²	C_0 for $10^4 < N \leq 5 \times 10^6$ $m=3$	5×10^6 times fatigue strength N/mm ²	C_0 for $5 \times 10^6 < N \leq 10^8$ $m=5$	Truncation limit of stress range N/mm ²
36	36	9.331×10^{10}	26.5	6.562×10^{13}	14.6
40	40	1.280×10^{11}	29.5	1.110×10^{14}	16.2
45	45	1.823×10^{11}	33.2	2.005×10^{14}	18.2
50	50	2.500×10^{11}	36.8	3.393×10^{14}	20.2
56	56	3.512×10^{11}	41.3	5.979×10^{14}	22.7
63	63	5.000×10^{11}	46.4	1.078×10^{15}	25.5
71	71	7.158×10^{11}	52.3	1.957×10^{15}	28.7
80	80	1.024×10^{12}	58.9	3.557×10^{15}	32.4
90	90	1.458×10^{12}	66.3	6.408×10^{15}	36.4
100	100	2.000×10^{12}	73.7	1.086×10^{16}	40.5
112	112	2.810×10^{12}	82.5	1.913×10^{16}	45.3
125	125	3.906×10^{12}	92.1	3.314×10^{16}	50.6
140	140	5.488×10^{12}	103.2	5.488×10^{16}	56.7
160	160	8.192×10^{12}	117.9	1.138×10^{17}	64.8
180	180	1.166×10^{13}	132.6	2.052×10^{17}	72.9
200	200	1.600×10^{13}	147.4	3.475×10^{17}	80.9

Table 11 Constant in $\Delta\tau$ -N chart, fatigue strength and truncation limit of stress range

Fatigue strength grade	2×10^6 times fatigue strength N/mm ²	D_0 for $10^4 < N \leq 10^8$ $m=5$	Truncation limit of stress range N/mm ²
80	80	6.554×10^{15}	36.6
100	100	2.000×10^{16}	45.7

10.5.1 Relation between fatigue strength grade and fatigue design curve of non-welded joint subjected to straight stress

The fatigue strength grade of non-welded joint shall be four grades of 100, 125, 160 and 200. For $\Delta\sigma$ -N chart, figure 10 shall be used. The classification for fatigue strength grade of non-welded joint is as given in table 15.

10.5.2 Relation between fatigue strength grade of plate and welded joint of hollow cross-section subjected to straight stress, and fatigue design curve

The fatigue strength grade of plate and welded joint of hollow cross-section shall be 16 grades from 36 to 200. For $\Delta\sigma$ -N chart, figure 10 shall be used. The classification for fatigue strength grade of plate and welded joint of hollow cross-section is as given in table 16. According to the finishing condition and the non-destructive inspection of welded joint, a higher grade may be applied.

10.5.3 Fatigue design curve of joint subjected to shearing stress

The fatigue strength grade of non-welded joint and welded joint subjected to shearing stress shall be two grades of 80 and 100. For $\Delta\tau$ -N chart figure 11 shall be used.

10.6 Mean stress correction factor C_R

The influence on mean stress shall usually be ignored, and the mean stress correction factor C_R shall be set to 1. If the stress ratio R (= minimum stress $\sigma_{\min}$ /maximum stress $\sigma_{\max}$) is negative, formula (18) may be used, provided that the upper limit shall be $C_R = 1.3$. When both the maximum stress and the minimum stress are in the compressive region, $C_R = 1.3$ shall also be applied.

Normally, $C_R = 1$

For $R \leq 0$,

$$C_R = \frac{1.3(1-R)}{1.6-R} \dots\dots\dots (18)$$

where, C_R : mean stress correction factor

R : stress ratio ($\sigma_{\min}/\sigma_{\max}$)

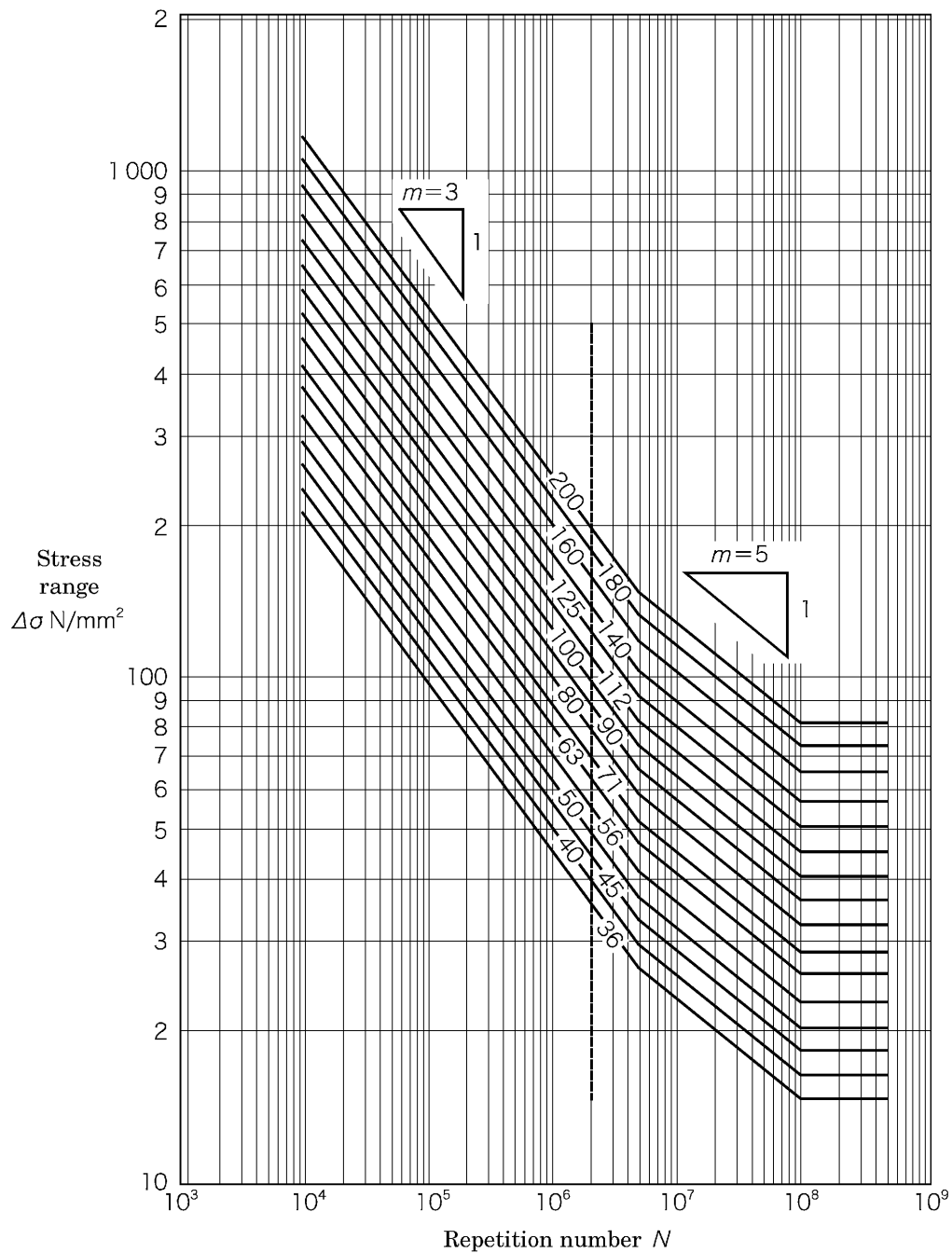
10.7 Plate thickness correction factor

For joints of which plate thickness exceeds 25 mm, the allowable stress range shall be obtained by multiplying the basic allowable stress range by the plate thickness correction factor given by formula (19).

$$C_t = \sqrt[4]{25/t} \dots\dots\dots (19)$$

where, C_t : plate thickness correction factor

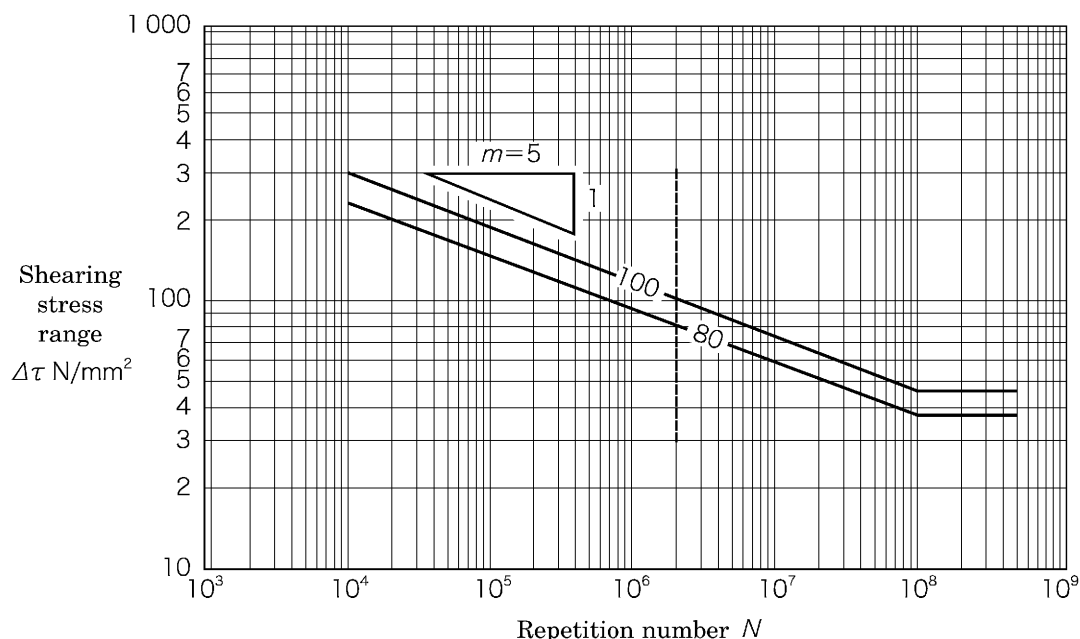
t : plate thickness (mm)



NOTE 1 Values in the chart indicate the strength grade.

NOTE 2 Refer to table 10 for the coordinate of intersection.

Figure 10 $\Delta\sigma$ -N chart for non-welded joint and welded joint subjected to straight stress



NOTE 1 Values in the chart indicate the strength grade.

NOTE 2 Refer to table 11 for the coordinate of intersection.

Figure 11 $\Delta\tau$ -N chart for joint subjected to shearing stress

10.8 Total design repetition number

The total design repetition number shall be according to formula (20).

$$n_t = T \cdot \Sigma n_i \quad \dots\dots\dots (20)$$

where, n_t : total design repetition number

Σn_i : total repetition number of stress during unit period

T : number of unit periods in design life

10.9 Equivalent stress range

Under the repetition number same as that of varying stress, the stress range subjected to fatigue damage in a constant stress range and equivalent, i.e., the equivalent stress range or the equivalent shearing stress range shall be according to formula (21) or formula (22).

For the equivalent stress range whose repetition number is exceeding 5×10^6 shall be as given in Annex A.

$$\Delta\sigma_e = \sqrt[m]{\Sigma \Delta\sigma_i^m (n_i / \Sigma n_i)} \quad \dots\dots\dots (21)$$

$$\Delta\tau_e = \sqrt[m]{\Sigma \Delta\tau_i^m (n_i / \Sigma n_i)} \quad \dots\dots\dots (22)$$

where, $\Delta\sigma_e$: equivalent stress range (N/mm²)

$\Delta\tau_e$: equivalent shearing stress range (N/mm²)

$\Delta\sigma_i$: a certain stress range in stress range histogram (N/mm²)

$\Delta\tau_i$: one shearing stress range in shearing stress range histogram (N/mm²)

n_i : repetition number of $\Delta\sigma_i$ or $\Delta\tau_i$ in stress range histogram

m : constant indicating inclination of $\Delta\sigma$ -N chart or $\Delta\tau$ -N chart

10.10 Design stress range

The design stress range shall be according to formula (23) and formula (24).

$$\Delta\sigma_d = \alpha \Delta\sigma_e \dots\dots\dots (23)$$

$$\Delta\tau_d = \alpha \Delta\tau_e \dots\dots\dots (24)$$

where, $\Delta\sigma_d$: design stress range (N/mm²)

$\Delta\tau_d$: design shearing stress range (N/mm²)

α : design stress correction factor (to be multiplied when calculated stress evidently differs from actual stress)

For crane, $\alpha = 1$

$\Delta\sigma_e$: equivalent stress range (N/mm²)

$\Delta\tau_e$: equivalent shearing stress range (N/mm²)

10.11 Allowable stress range for fatigue

The allowable stress range for total design repetition number and the allowable shearing stress range for total design repetition number shall be according to formula (25) and formula (26).

$$\Delta\sigma_R = \sqrt[m]{(C_0/n_t)} \cdot C_R \cdot C_t \dots\dots\dots (25)$$

$$\Delta\tau_R = \sqrt[m]{(D_0/n_t)} \dots\dots\dots (26)$$

where, $\Delta\sigma_R$: allowable stress range for total design repetition number (N/mm²)

$\Delta\tau_R$: allowable shearing stress range for total design repetition number (N/mm²)

C_0 : constant in $\Delta\sigma$ -N chart (see table 9)

D_0 : constant in $\Delta\tau$ -N chart (see table 9)

m : constant indicating inclination of $\Delta\sigma$ -N chart or $\Delta\tau$ -N chart (see table 9)

n_t : total design repetition number

C_R : mean stress correction factor

C_t : plate thickness correction factor

10.12 Fatigue check method

The establishment of formula (27) and formula (28) shall be confirmed.

$$(\gamma_b \cdot \gamma_w \cdot \gamma_i) \Delta \sigma_d \leq \Delta \sigma_R \quad \dots\dots\dots (27)$$

$$(\gamma_b \cdot \gamma_w \cdot \gamma_i) \Delta \tau_d \leq \Delta \tau_R \quad \dots\dots\dots (28)$$

where, γ_b : damage influence factor (see table 12)
 γ_w : criticality factor (see table 13)
 γ_i : inspection factor (see table 14)
 $\Delta \sigma_d$: design stress range (N/mm²)
 $\Delta \sigma_R$: allowable stress range for total design repetition number (N/mm²)
 $\Delta \tau_d$: design shearing stress range for total design repetition number (N/mm²)
 $\Delta \tau_R$: allowable shearing stress range for total design repetition number (N/mm²)

The upper limit and the lower limit of the redundancy factor ($\gamma_b \cdot \gamma_w \cdot \gamma_i$) shall be 1.25 and 0.80, respectively.

Table 12 Value for damage influence factor γ_b

γ_b	Condition
1.1	When fatigue damage leads to total destruction of crane
1.00 to 1.10	When fatigue damage affects strength or function of crane
0.80	When fatigue damage does not cause particular problems of strength or function of crane

Table 13 Value for criticality factor γ_w

γ_w	Condition
0.80 to 1.10	Depends on criticality, normally 1

Table 14 Value for inspection factor γ_i

γ_i	Condition
0.90 to 1.00	When having structure easy for inspection and management
1.10	When inspection is difficult

10.13 Fatigue check procedure and flowchart

The fatigue check procedure shall be as follows.

- Determine the part to be checked.
- Determine the maximum stress $\sigma_{\max}$ and the minimum stress $\sigma_{\min}$ acting on the target member from vertical dynamic load, vertical static load, horizontal dynamic load, operation factor, impact factor, dynamic load factor and static load factor applied to the member, and determine the maximum stress range.
- Determine the total design repetition number of the target member.