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Cranes

Steel structures
Verification and analyses

DIN 15 018 Part 1

Krane; Grundsätze für Stahltragwerke; Berechnung

Supersedes April 1974 edition.

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Dimensions in mm

DIN 15 018 Part 1 and Part 2 have been published following an abridged procedure as specified in DIN 820 Part 4, in the form of corrected editions. This method of proceeding, as well as the corrections that have now been made, were notified and explained in the *DIN-Mitteilungen* (DIN News) 61, 1982, volume No. 8, pages 496 to 498.

It would have been inadvisable to revise the content of the standard at the present time, in view of the general approval which has greeted its publication, and mainly because of the current discussions on the national basic standards relating to steel structures (DIN 18 800); furthermore, the efforts of ISO/TC 96 to achieve an internationally approved ruling with regard to the loads and load combinations which are to be assumed for the verification by calculation of the performance characteristics of cranes, had to be borne in mind.

The principal corrections, including those which have arisen from the processing of the comments received, are described in the Explanatory notes.

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Translation
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1 Field of application

This standard applies to the steel structures of cranes and crane equipment of any kind, and also to mobile steel structures for continuous conveyors. It does not cover craneways, excavators, ropeways, wagon tipples and mining machinery.

2 Standards and documents referred to

The following standards and documents shall be complied with unless otherwise specified in this standard.

DIN 1055 Part 4	Design loads for buildings; imposed loads, wind loads of structures unsusceptible to vibration
DIN 1055 Part 5	Design loads for buildings; imposed loads, snow load and ice load
DIN 1080 Part 1	Concepts, symbols and units used in civil engineering; principles
DIN 1080 Part 2	Concepts, symbols and units used in civil engineering; statics
DIN 1080 Part 4	Concepts, symbols and units used in civil engineering; steel construction; composite steel construction and steel girders in concrete
DIN 4114 Part 1	Steel structures; stability cases (buckling, collapsing, bulging); design principles, regulations
DIN 4114 Part 2	Steel structures; stability cases (buckling, collapsing, bulging); design principles, guidelines
DIN 4115	Lightweight and tubular steel construction in building; rules relating to approval, design and construction
DIN 8563 Part 3	Quality assurance of welding operations; fusion-welded joints in steel; requirements, evaluation groups
DIN 15001 Part 1	Cranes; terminology; classification according to type
DIN 15003	Lifting appliances; load suspending devices; loads and forces, concepts
DIN 15018 Part 2	Cranes; steel structures, principles of design and construction
DIN 15019 Part 1	Cranes; stability for cranes except non-rail mounted mobile cranes and floating cranes
DIN 15019 Part 2	Cranes; stability for non-rail mounted mobile cranes; test loading and calculation

DASt-Richtlinie (DASt Guideline) 010 *Anwendung hochfester Schrauben im Stahlbau* (Use of high strength bolts in structural steelwork) [1] [2]

Reference is also made in the text of the present standard to the following standards or to certain clauses or concepts thereof.

DIN 267 Part 3	Fasteners; technical delivery conditions; property classes for carbon steel and alloy steel bolts and screws; conversion of property classes
DIN 1626 Part 1	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; general specifications, survey, recommendations for use
DIN 1626 Part 2	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; pipes for general use (commercial quality); technical delivery conditions
DIN 1626 Part 3	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; pipes subject to special requirements; technical delivery conditions
DIN 1626 Part 4	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; high performance pipes; technical delivery conditions
DIN 1629 Part 1	Seamless carbon steel tubes for supply purposes, process plant and tanks; survey, technical delivery conditions; general data
DIN 1629 Part 3	Seamless carbon steel tubes for supply purposes, process plant and tanks; tubes subject to special requirements; technical delivery conditions
DIN 2310 Part 1	Thermal cutting; concepts and nomenclature
DIN 2310 Part 3	Thermal cutting; oxygen cutting; bases of process, quality, dimensional deviations
DIN 4132	Craneways; steel structures; principles of calculation, design and construction
DIN 6914	Hexagon bolts with large widths across flats for high strength friction grip bolting in steel structures[3]
DIN 6915	Hexagon nuts with large widths across flats for high strength friction grip bolting in steel structures
DIN 6916	Round washers for high strength friction grip bolting in steel structures
DIN 6917	Square washers for high strength friction grip bolting of I sections in steel structures
DIN 6918	Square washers for high strength friction grip bolting of channels in steel structures
DIN 17100	Steels for general structural purposes; quality specifications
DIN 17111	Low carbon steels for bolts, nuts and rivets; technical delivery conditions
DIN 18800 Part 1	Steel structures; design and construction

3 Details to be given for design purposes

The following information shall be given for design purposes:

type of crane and method of operation;

assumed total number of all load cycles or operating cycles;

loadbearing systems reflecting the actual service conditions as closely as possible, including outline drawings and main dimensions;

design loads;

lifting classes and loading groups to be considered;

materials of individual members and connections or joints;

shapes, dimensions and static cross-sectional values of all loadbearing members;

verification and analyses relating to said members and to the principal connections or joints.

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[1] Referred to as *HV-Richtlinien* (HV Guidelines) in this standard.

[2] Published by *Stahlbau-Verlag*, Köln.

[3] Referred to as high strength friction grip bolts in this standard.

4 Design loads

The loads acting on the supporting structure are subdivided into main loads, additional loads and special loads.

The main loads comprise:
self weights;
loads arising from bulk materials in bins and on continuous conveyors;
lifted loads;
inertia forces arising from drives;
centrifugal forces;
impact from bulk material.

The additional loads comprise:
wind loads;
forces arising from skewing;
thermal effects;
snow loads;
loads on walkways, stairways, platforms and hand rails;

The special loads comprise:
tilting force arising in crane trolleys with positive guidance of the lifted load;
buffer forces;
test loads.
The above loads are grouped into load cases in clause 5.

4.1 Main loads

4.1.1 Self weights

Self weights are the masses of all the fixed and moving crane components which act permanently during operation, plus the masses of the mechanical and electrical equipment and of a proportion of the carrying means such as ropes for example, with the exception of the self weights described in subclause 4.1.3.

4.1.2 Loads arising from bulk materials in bins and on continuous conveyors

Loads arising from bulk materials in bins and on continuous conveyors shall be treated as self weights; loads of bulk materials on continuous conveyors can act either as a continuous or as a discontinuous line load.

4.1.3 Lifted loads

The lifted loads (hook loads) comprise the useful load and the self weights of members designed to carry the useful load, e.g. the bottom block, the spreader bar, the grab, the lifting magnet and also a proportion of the carrying means such as ropes.

4.1.4 Effects of vertical inertia forces

The effects of vertical inertia forces produced by the motions of the crane or of the crane components and of loads in accordance with subclauses 4.1.1 to 4.1.3 are allowed for by means of a self weight factor φ and a nominal load spectrum factor ψ.

4.1.4.1 Self weight factor φ

The self weights of moving cranes and of moving crane components in accordance with subclause 4.1.1, and the loads described in subclause 4.1.2, or the stress resultants or stresses resulting therefrom, shall be multiplied by a self weight factor φ as given in table 1 below.

In the case of cranes and crane components equipped with spring-suspended wheels running on rails, a self weight factor $\varphi = 1{,}1$ can be adopted for the calculation, irrespective of the travelling speed and type of runway.

Table 1. **Self weight factors φ**

Travelling speed v_F, in m/min		Self weight factor φ
Runways		
with rail joints or irregularities (road)	without rail joints or with welded and machined rail joints	
Up to 60	Up to 90	1,1
Over 60 up to 200	Over 90 up to 300	1,2
Over 200	–	≧ 1,2

Where several motions corresponding to the load cases listed in table 7 occur simultaneously at different speeds, characterized by different self weight factors φ, these factors shall be applied to the respective loads concerned.

Example:

a) Crane trolley travelling speed v = 120 m/min, φ = 1,2.
Crane travelling speed v = 30 m/min, φ = 1,1.

	Trolley travel (Ka)	Crane travel (Kr)
Multiply self weight of trolley by	$\varphi = 1{,}2$	$\varphi = 1{,}1$
Multiply self weight of crane by	$\varphi = 1{,}0$	$\varphi = 1{,}1$

b) Crane trolley travelling speed v = 30 m/min, φ = 1,1.
Crane travelling speed v = 120 m/min, φ = 1,2.

	Trolley travel (Ka)	Crane travel (Kr)
Multiply self weight of trolley by	$\varphi = 1{,}1$	$\varphi = 1{,}2$
Multiply self weight of crane by	$\varphi = 1{,}0$	$\varphi = 1{,}2$

4.1.4.2 Nominal load spectrum factor ψ and lifting classes

The lifted loads as defined in subclause 4.1.3 or the stress resultants or stresses resulting therefrom shall be multiplied by a nominal load spectrum factor ψ as given in table 2. Its value depends on the actual hoisting speed of the carrying means assumed at the commencement of the hoisting of the lifted load, and therefore on the rated hoisting speed v_H. The softer the springing of the hoisting gear, the larger the elasticity of the supporting structure, the smaller the actual hoisting speed at the commencement of the hoisting of the useful load, the smaller and steadier the acceleration and deceleration during changes in the hoisting motion, the smaller the factor ψ.

Accordingly, the cranes are classified into lifting classes H 1, H 2, H 3 and H 4, with different factors ψ as given in table 2 below. Examples of this are given in subclause 10.1. Individual self-contained parts of a crane forming integral parts of the complete unit, such as the trolley and the crane bridge or jib, the slewing unit, portal and tower, may be classified into different lifting classes within the limits defined in table 23 for the various types of crane, provided the hoisting conditions are fully known.

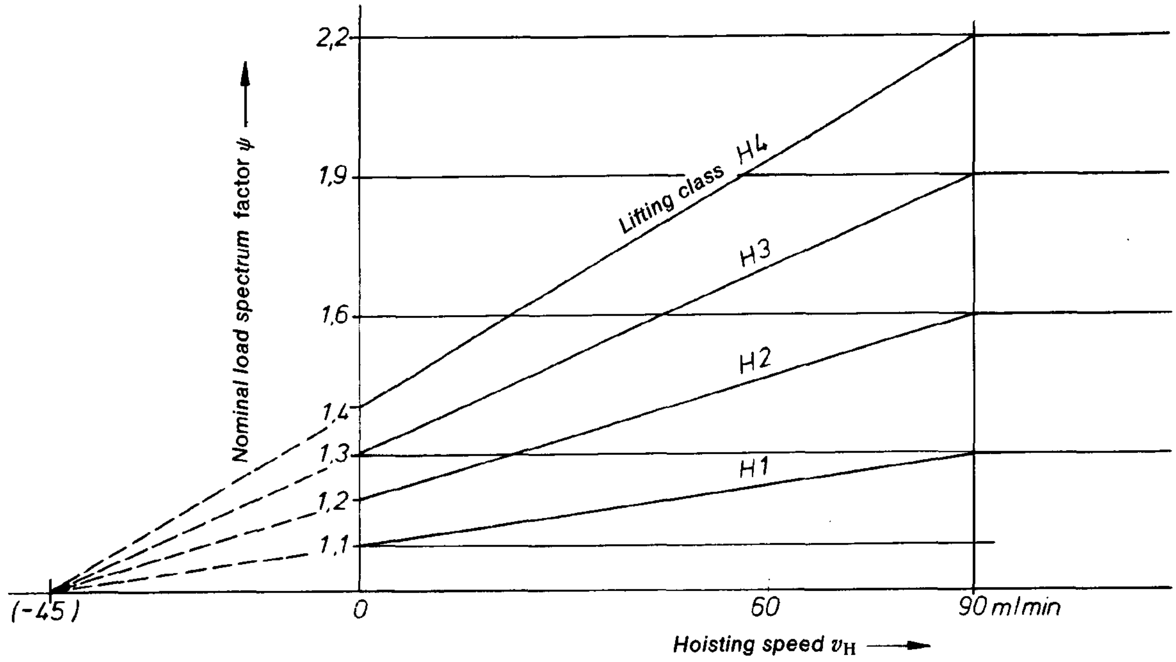


Figure 1. Lifting classes and nominal load spectrum factor ψ

Table 2. **Nominal load spectrum factor ψ**

Lifting class	Nominal load spectrum factor ψ at hoisting speed v_H, in m/min	
	Up to 90	Over 90
H 1	$1{,}1 + 0{,}0022 \cdot v_H$	1,3
H 2	$1{,}2 + 0{,}0044 \cdot v_H$	1,6
H 3	$1{,}3 + 0{,}0066 \cdot v_H$	1,9
H 4	$1{,}4 + 0{,}0088 \cdot v_H$	2,2

4.1.4.3 Dropping or sudden setting down of useful loads in the case of jib cranes

In the case of jib cranes where the dropping or sudden setting down of useful loads represents the usual operating practice, such as for cranes with magnet or grab operation, the resulting inertia force effects shall be taken into account separately. Instead of adopting a precisely computed value for this purpose, the lifted load or the stress resultants or stresses resulting therefrom may be multiplied by −0,25 times the factor ψ specified in table 2. In the case of rope controlled jibs, these negative inertia force effects are limited by the slackening of the ropes, whereby an upward movement of the jib becomes possible. The forces which arise from the subsequent falling back of the jib shall be taken into consideration.

4.1.5 Inertia forces arising from driving mechanisms

The inertia forces acting on the crane structure during acceleration and deceleration of the crane motions, such as travelling, slewing, luffing, shall be determined from the maximum driving forces arising in regular operation. In lieu of a more accurate calculation, the quasi-static forces acting on the structure and resulting from the assessment of the movement of the centre of mass of the system under the effect of the driving forces, of the resistances to motion and of the inertia forces, may be increased by a factor of 1,5 in order to take the dynamic effect into account. In this respect, loads which are not guided shall be deemed to be rigidly attached to the crane; any swinging of the loads shall be ignored. The adoption of a factor of 1,5 is furthermore

Examples of calculating the inertia forces from the frictional contact in the case of bridge cranes:

trolley travel; frictional contact
(the driven track wheels are speed-synchronized)

$$Ka = 1{,}5 \cdot 0{,}2 \cdot \min\,(R_{Ka_1} + R_{Ka_2})$$

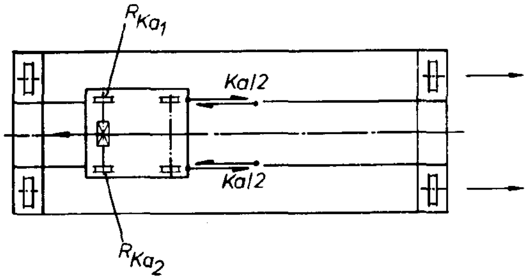


Figure 2. Inertia forces during the start-up and braking of crane trolleys with a central drive mechanism

crane travel; frictional contact
(the driven track wheels are non-speed-synchronized)

$$Kr = 1{,}5 \cdot 0{,}2\,(\min R_{Kr_1} + \min R_{Kr_2})$$

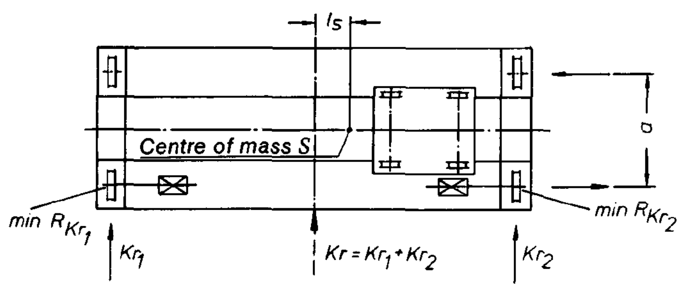


Figure 3. Inertia forces during the start-up and braking of cranes with two individual driving mechanisms ($Kr_1 = Kr_2$)

based on the condition that the driving forces acting on the crane are practically free from backlash.

In figures 2 and 3

$\min(R_{Ka_1} + R_{Ka_2})$ / $\min R_{Kr_1} + \min R_{Kr_2}$ = is the determining smallest wheel load total and, respectively, the sum of the smallest wheel loads of the driven track wheels, excluding the useful load and the factors mentioned in subclause 4.1.4, required for the determination of the driving forces on the basis of the frictional contact;

l_s is the distance, measured at right angles to the direction of motion, of the resultant of the driving forces from the centre of mass S of the crane bridge, trolley and lifted load;

a is the centre-to-centre distance of the wheels or of the guide roller or groups of guide rollers for the absorption of the lateral forces, see also figure 4.

In cases where there is a considerable amount of play between structural members (hereinafter briefly referred to as members) which move relatively to one another, for example in the case of the rigid mast and the suspension gear of a stripper crane, a factor larger than 1,5 shall be used.

Where the maximum driving forces are limited by friction-type power transmission, the driving forces may be calculated from the frictional contact between the driven track wheels and the rails, using a coefficient $f = 0{,}2$. In this connection, one should proceed from the smallest wheel load total in the case of speed-synchronized driven track wheels, or from the sum of the smallest wheel loads in the case of non-speed-synchronized driven track wheels, depending on the type of driving mechanism; the factors mentioned in subclause 4.1.4 and the useful load need not be taken into consideration.

The driving forces shall always be distributed among the track wheels in accordance with the type of driving mechanism.

The inertia forces during the start-up and braking of cranes shall be entered in the calculation in each case with the trolley in the most unfavourable position for the member being analysed (see figure 3).

Where lateral forces due to inertia forces act transversely to the runway, they shall be absorbed by the rails through positive and frictional contact in accordance with the systems adopted for the supporting structure and the running gear, and in accordance with the type of guiding means used.

Unidirectional lateral forces, such as those due to inertia force effects during the start-up and braking of crane trolleys (see figure 2) shall be distributed uniformly between all the track wheels or guiding means.

Lateral forces acting in opposite directions arise if a distance l_s exists between the centre of the masses to be moved and the resultant of the driving forces. Where these forces are transmitted through the track wheels, and where there are more than two wheels per runway side, they shall be uniformly distributed between the outer wheels or outer wheel groups as shown in the examples illustrated in figure 4, namely,

where there are not more than four wheels per rail, to one outer wheel per corner,

where there are not more than eight wheels per rail, to the two outer wheels per corner,

where there are more than eight wheels per rail, to the three outer wheels per corner.

As far as the supporting structure is concerned, e.g. the bridge, trolley or balancer, the lateral forces shall, however, be distributed uniformly between all the wheels of a corner, even in the zone of the inner unloaded track wheels as shown in figure 4.

In the case of wide-span bridge cranes and portal cranes with separate driving mechanisms, whose supporting structures are not designed to compensate for resistances to motion, driving forces and inertia forces, but only for a limited elastic forward motion of one side of the running gear ahead of the other side, special devices shall be provided to ensure that the assumptions on which the design calculation is based are not exceeded.

4.1.6 Centrifugal forces

Centrifugal forces on slewing cranes shall be calculated solely on the basis of the self weight of the jib components, and, if applicable, also on the basis of the counterweights and of the lifted load, without application of the factors mentioned in subclause 4.1.4; the lifted load shall be deemed to be suspended from the tip of the jib.

4.1.7 Impact from bulk material

Impact effects on bins and transfer points due to the dropping of bulk material shall only be taken into consideration locally.

4.2 Additional loads

4.2.1 Wind loads

Wind loads shall be taken into account in accordance with DIN 1055 Part 4 in the case of cranes exposed to the wind.

For cranes in service, the wind load shall be entered in the calculation at a dynamic pressure $q = 250\ \text{N/m}^2$. The wind load acting on the useful load shall be assumed at 3 % of the effect of the useful load, but at not less than 500 N, if the wind load area is not precisely known.

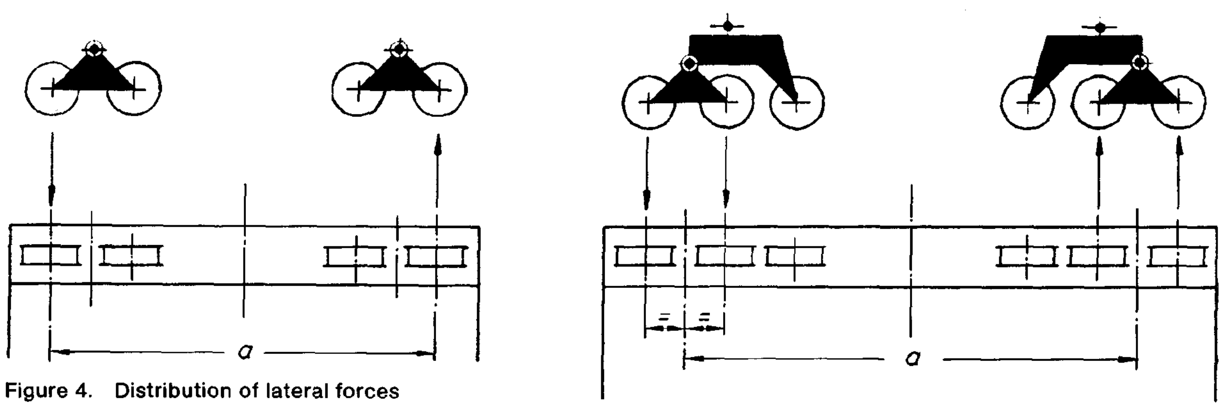


Figure 4. Distribution of lateral forces

Table 3. **Coefficient of frictional contact f as a function of the skew angle α**

α‰	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	6,0	7,0	8,0	9,0	10,0	12,5	15,0	>15,0
f	0,094	0,118	0,139	0,158	0,175	0,190	0,203	0,214	0,233	0,248	0,259	0,268	0,275	0,287	0,293	0,300

For cranes out of service, the wind load shall be entered in the calculation at the dynamic pressures specified in DIN 1055 Part 4.

4.2.2 Forces arising from skewing

When a crane skews at a skew angle α, a positive contact force S, dependent on the running gear and supporting structure, is generated on the front guiding means or group of guiding means (front in the direction of travel); these guiding means may consist of a wheel flange or of a guide roller, and as a result of force S, a group of forces X_{1i}, Y_{1i} and X_{2i}, Y_{2i}, which are connected by friction, acting in the contact areas of the track wheels is generated.

The distribution of the force S resulting from the skewing of cranes with flanged track wheels is similar to that described in subclause 4.1.5, figure 4.

For cranes with a total of n pairs of track wheels arranged each on an axis i, and of which m are speed-synchronized, and whose wheel loads R_{1i} on side 1 and R_{2i} on side 2 are of equal magnitude respectively for each side, and assuming the usual tolerances for track wheel diameter, axial parallelism of track wheel bores and position of the runway, with a linearized frictional contact relationship applying equally to longitudinal and transverse slip, the following applies:

$$f = 0{,}30 \cdot \left(1 - e^{-0{,}25 \cdot \alpha}\right)$$

where

e = 2,71828 (basis of the natural logarithms) and skew angle α to be entered in ‰.

$$S = \lambda \cdot f \cdot \Sigma R$$

$$X_{1i} = \lambda_{1ix} \cdot f \cdot \Sigma R \qquad X_{2i} = \lambda_{2ix} \cdot f \cdot \Sigma R$$

$$Y_{1i} = \lambda_{1iy} \cdot f \cdot \Sigma R \qquad Y_{2i} = \lambda_{2iy} \cdot f \cdot \Sigma R$$

where

ΣR is the sum of all wheel loads arising from self weights and lifted load, excluding the factors mentioned in subclause 4.1.4;

$\alpha = \alpha_F + \alpha_v + \alpha_0 \geqq 15$‰,

skew angle resulting from the sum of all the possible displacements transversely to the runway, related to the distance a of the positive guiding means when the crane is askew;

α_F is the skew angle resulting from 75% of the track clearance between straight rail and positive guiding means, but not less than from 5 mm in the case of guide rollers and not less than from 10 mm in the case of wheel flanges;

α_v is the skew angle resulting from abrasive wear of not less than 3% of the rail head width in the case of guide rollers, and not less than 10% of the rail head width in the case of wheel flanges;

α_0 = 1‰ skew angle resulting from tolerances of the crane and craneway.

Other values of the skew angle α shall be agreed.

Factors λ, λ_{1ix}, λ_{1iy} and λ_{2ix}, λ_{2iy} for the calculation of forces S, X_{1i}, Y_{1i}, X_{2i}, Y_{2i} and of the position h of the slip pole are determined in accordance with tables 4 and 5 by the dimensions of the crane according to figure 5, by the position of the overall centre of mass due to the self weights and to the lifted loads, and by the running gear system and structure system as defined by the following symbols:

W = pair of track wheels speed-synchronized by a mechanical or electrical shaft;

E = pair of track wheels individually supported on bearings or individually driven;

F = fixed bearing of track wheel and supporting structure: lateral displaceability;

L = movable bearing of track wheel or supporting structure: lateral displaceability.

Table 4. **Position h of the slip pole and factor λ for the calculation of the positive contact force S**

System	h	λ
FF	$\dfrac{m \cdot \xi \cdot \xi' \cdot l^2 + \Sigma e_i^2}{\Sigma e_i}$	$1 - \dfrac{\Sigma e_i}{n \cdot h}$
FL	$\dfrac{m \cdot \xi \cdot l^2 + \Sigma e_i^2}{\Sigma e_i}$	$\xi' \left(1 - \dfrac{\Sigma e_i}{n \cdot h}\right)$

Table 5. **Factors λ_{1ix}, λ_{1iy} and λ_{2ix}, λ_{2iy} for the calculation of the frictional forces, X_{1i}, Y_{1i} and X_{2i}, Y_{2i}**

System	λ_{1ix}	λ_{1iy}	λ_{2ix}	λ_{2iy}
WFF	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	$\dfrac{\xi}{n}\left(1 - \dfrac{e_i}{h}\right)$
EFF	0	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	0	$\dfrac{\xi}{n}\left(1 - \dfrac{e_i}{h}\right)$
WFL	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	0
EFL	0	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	0	0

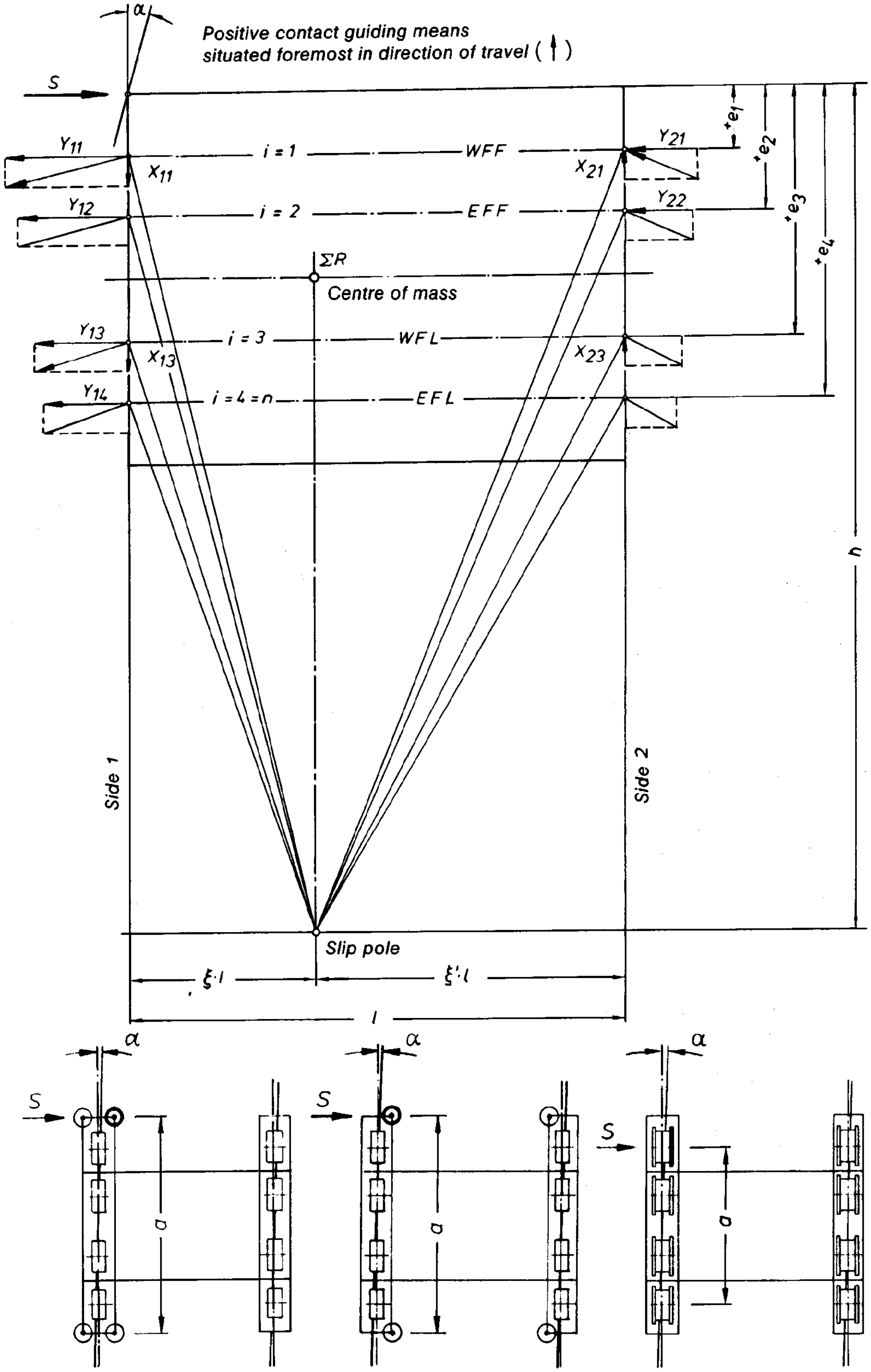


Figure 5. Dimensions and forces due to skewing of a crane with four pairs of track wheels representing different system characteristics

4.2.3 Thermal effects

Thermal effects shall only be taken into consideration in special cases. When this is the case for cranes installed outdoors at an assumed ambient installation temperature of +10 °C, temperature variations of ±35 K shall be assumed for the calculation, or in the case of non-uniform temperature rises in individual members, temperature variations of ±15 K shall be assumed.

In the case of cranes operating in hot environments, the assumed values shall correspond to the local conditions, e.g. for cranes in foundries and pit furnace shops.

A linear expansion coefficient in accordance with table 8 shall be entered in the calculations.

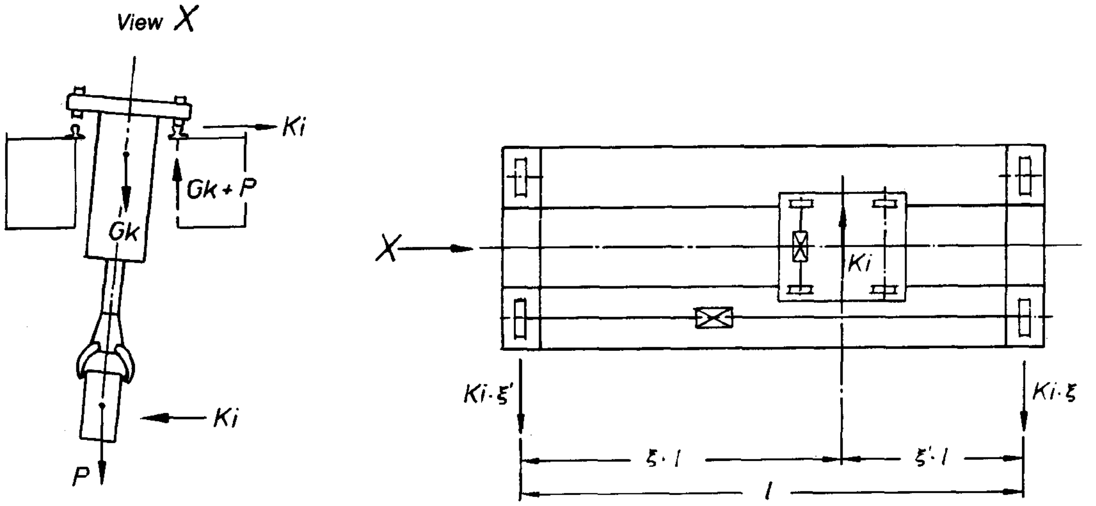


Figure 6. Example of the distribution of forces due to tilting of a crane trolley with positive guidance of the lifted load in the direction of crane travel

4.2.4 Snow loads

Snow loads need only be considered in special cases, and when they are, DIN 1055 Part 5 shall be observed.

4.2.5 Loads on walkways, stairways, platforms and hand rails

In the case of walkways, stairways and platforms, a moving concentrated load shall be entered in the calculation in addition to the self weights, and this shall be

3000 N to allow for persons carrying loads,

1500 N to allow for persons not carrying loads.

As regards hand rails, a moving horizontal concentrated load acting outwardly or inwardly shall be assumed, amounting to

300 N to allow for persons carrying loads,

150 N to allow for persons not carrying loads.

The above-mentioned concentrated loads need not be taken into account in respect of any member stressed by lifted loads in accordance with subclause 4.1.3, such as the main girders of crane bridges.

4.3 Special loads

4.3.1 Tilting force arising in crane trolleys with positive guidance of the lifted load

The force due to the tilting of crane trolleys with positive guidance of the lifted load shall be determined from the tilting conditions without regard for the factors described in subclause 4.1.4, as a horizontal load Ki acting at floor level or obstacle level, and in the direction of trolley or crane travel. The trolley shall be assumed to be located in the most unfavourable position for this purpose. Unless a more accurate calculation is made, Ki shall be distributed proportionally between both sides of the craneway without considering any inertia force effects or any skidding of the driven track wheels (see figure 6). The value of Ki may be limited to ¼ of the sum of the self weight of the trolley G_K plus the lifted load P.

If there is an operational possibility of the tilted trolley tilting back again to its normal position due to the sudden yielding of the obstacle, then the forces arising from such an occurrence shall be taken into account.

4.3.2 Buffer forces

As regards this special load case, it is assumed that in normal operation cranes or trolleys collide with one another or collide against buffer stops only on rare occasions. The buffer forces Pu due to cranes or trolleys crashing against stops or colliding with one another shall be limited by buffers or by similar energy absorbing means. The required energy absorption capacity of the buffers and the maximum buffer forces Pu shall be determined on the basis of 85 % of the rated travelling speed of cranes and 100 % of the rated travelling speed of trolleys.

In cases where automatic devices for slowing down the motion are installed, the required energy absorption capacity of the buffers and the maximum buffer forces Pu may be computed on the basis of the highest travelling speed likely to arise in such a case, but this shall be not less than 70 % of the rated speed.

Furthermore, the kinetic energy released on the collision of two cranes characterized by the moving masses m_1 and m_2 and by the amounts $|v_{F1}|$ and $|v_{F2}|$ of the maximum travelling speed shall be determined by the following equation:

$$E = \frac{m_1 \cdot m_2 \cdot (|v_{F1}| + |v_{F2}|)^2}{2\,(m_1 + m_2)}$$

For the verification of the buffers and of the strength of the supporting structure, the forces arising from the moving masses of the self weights and of the positively guided lifted loads situated in the most unfavourable position, if applicable, shall be entered in the calculation in each case, but the factors mentioned in subclause 4.1.4 shall not be used. Loads suspended from carrying means and freely oscillating loads need not be considered. An appropriate substitute mass shall be entered in the calculation in lieu of that of the rotating parts of the running gear. The buffer forces shall be distributed in accordance with the buffer characteristics and the possible movements of the supporting structure. In this connection, the resistances to motion due to the frictional contact between track wheels and rails may be allowed for by means of a factor $f = 0{,}20$.

In the case of cranes or trolleys with or without useful load, no negative wheel loads may result from 1,1 times the buffer force and from the self weights and lifted loads previously mentioned. Unless a more accurate stress analysis is carried out, the buffer forces shall be multiplied by an oscillation coefficient in accordance with table 6 for the stress analysis, depending on the shape of the area beneath the buffer characteristic.

Table 6. **Oscillation coefficients for simplified computation**

Area beneath the buffer characteristic, approximating a	Oscillation coefficient in respect of collision with	
	crane	trolley
triangle	1,25	1,35
square	1,50	1,60

In the case of tower cranes and of portal slewing cranes, a verification of the energy absorption capacity of the buffers and of the effect of the buffer forces on the supporting structure may be dispensed with, on condition that the rated travelling speed is less than 40 m/min, and that reliably operating limit switches are installed in addition to the buffer stops.

4.3.3 Test loads

In the case of cranes for which a verification of stability is required in accordance with DIN 15019 Part 1 or Part 2, the small and large test loads respectively which are specified in the above-mentioned standards shall be used as the basis for the stress analysis.

In the case of cranes which do not require a verification of stability to be carried out, the test loads are obtained by multiplying the lifted load P by the following factors:

small test load: $Pk = 1{,}25 \cdot P$;

large test load: $Pg = 1{,}33 \cdot P$, for lifting classes H 1 and H 2;

(subject to particular agreement): $Pg = 1{,}50 \cdot P$, for lifting classes H 3 and H 4.

For the stress analysis, the small test load shall be multiplied by $\frac{1+\psi}{2}$.

The design loads used in the stress analysis with the crane subjected to the test load are based on the following procedure.

If the crane is loaded with the small test load, all the permissible motions shall be carried out individually with the load situated in the most unfavourable position; however, due care should be observed during the test. A new motion shall only be initiated after the oscillations arising from the previous motion have ceased completely.

If the crane is loaded with the large test load, then the small test load shall first be raised to a short distance from the floor. Thereafter, the remainder of the load (making it up to the large test load) shall be attached with all due care, so as to avoid any oscillations if possible.

Testing with test load Pk or Pg shall be carried out in the absence of wind.

5 Load cases

The main loads, additional loads and special loads specified in clause 4 are classified into load cases H, HZ and HS in table 7.

All the loads in one column of the zones framed in thick black lines under the heading "normal load cases" taken together constitute load case H. All the loads in a column under the heading "normal load cases" taken together constitute load case HZ.

6 Calculation

6.1 General

The calculations shall conform to the generally accepted rules of statics, dynamics and to the science of the strength of materials.

In cases where additional tests are carried out to determine stresses within the framework of the design loads specified in clauses 4 and 5, the test results may be used as the basis for the calculation, using the same safety factors.

All references to systems, dimensions and cross sections made on drawings shall coincide with those made in the calculations. Deviations are permitted if the safety of all components concerned is increased thereby beyond any doubt.

6.2 Alignment of craneway

Unless the crane operator has specified anything to the contrary, the calculation shall be made on the assumption that the craneway has been carefully laid and that it has been properly aligned both vertically and horizontally.

6.3 Imposed loads (live loads)

Imposed loads shall be entered in the calculation of the members concerned at the most unfavourable positions, values and directions.

6.4 Materials

The materials used shall be specified. Materials other than the steel grades specified in table 8 may be used on condition that their mechanical properties, their chemical composition and if applicable their weldability are guaranteed by the manufacturer of the material concerned.

In the general stress analysis and the verification of service strength, the permissible stresses and the stability criteria may be derived, at equal ratio at best, from the dangerous limit states (guaranteed yield stress or 0,2 % proof stress, service strength at 90 % survival expectancy, buckling, collapsing, bulging), as in the case of the steel grades listed in table 8, by reliably reasoned calculation or tests closely reflecting actual operating conditions, for example on welded joints subjected to static loading or to loading variable with time.

6.5 Cross-sectional values and hole deductions for members and cross-sectional values for welds

The governing cross-sectional values and hole deductions for members shall be determined in accordance with DIN 18800 Part 1, March 1981 edition, subclause 3.4, and for welds they shall be determined in accordance with subclauses 7.3.1.1 and 7.3.1.2 of the same standard. The *HV-Richtlinien* are applicable to high strength bolted joints, see clause 2.

Elastic deformations, required for the calculation of statically indeterminate structures for example, shall be determined on the basis of cross-sectional values without any deduction for holes.

6.6 Tension members

Tension members, which may be subjected to compressive stresses in the case of slight deviations from the design loads originally planned, shall exhibit a slenderness ratio λ not exceeding 250 and shall be capable of absorbing a reasonable compressive force.

6.7 Determination of stresses

The stresses shall be determined for the individual load cases in accordance with clause 5 and table 7 on the basis of the cross-sectional values given in subclause 6.5.

In the case of fillet welds subjected to compressive loading in the direction normal to the weld, such as between web plate and flange plate, no allowance shall be made for contact between the members to be joined.

6.8 Connections and joints

In the areas of force diversions and cut-outs, the stress patterns which are disturbed thereby shall be verified, unless adequate structural measures have been taken to allow for such disturbances.

The individual parts of a member etc. shall each be separately connected or jointed and covered.

Where in composite members a stress resultant is passed on by a system of welds, rivets and bolts, it shall be possible for this stress resultant to be distributed unambiguously and proportionally among the individual parts of the cross section, and to be transmitted by only one type of connection to each part of the cross section.

Angle cleats shall be connected with the structure either taking 1,5 times the value of the applicable proportion of the stress resultant for one leg and the given value itself for the other leg, or taking 1,25 times the value for both legs. Welded-on lug plates shall be connected with the structure taking 1,5 times the value of the applicable proportion of the stress resultant.

Table 7. **Load cases**

Types of load			Symbol	Normal load cases									Special load cases							
4.1 Main loads	4.1.1 Self weight		G	$\varphi \cdot G$				$\varphi \cdot G$			G	$\varphi \cdot G$	G	G	$\varphi \cdot G$				G
	4.1.4.1 Self weight factor		φ	$\varphi \cdot Gm$				$\varphi \cdot Gm$			Gm	$\varphi \cdot Gm$	–	$\varphi \cdot Gm$	–				–
	4.1.2 Loads arising from bulk materials in bins and on continuous conveyors		Gm																
	4.1.3 Lifted load		P	$\psi \cdot P$				–			–	$\varphi \cdot P$	P	P	–				–
	4.1.4.2 Nominal load spectrum factor		ψ									–	–	–	–				–
	4.1.4.3 Dropping or sudden setting down of useful loads		$-0{,}25 \cdot \psi \cdot P$	–				$-0{,}25 \cdot \psi \cdot P$			–	–	–	–	–				–
	4.1.3 Lifted load without effect of useful load		Po								Po	–	–	–	–				–
	4.1.5 Inertia forces arising from driving mechanisms	Trolley travel	Ka	Ka	–	–	–	Ka	–	–	–	–	–	–	Ka	–	–	–	–
		Crane travel	Kr	–	Kr	–	–	–	Kr	–	–	–	–	–	–	Kr	–	–	–
		Slewing	Dr	Dr	Dr	Dr	Dr	Dr	Dr	Dr	–	–	–	–	–	–	Dr	–	–
		Luffing	Wp	–	–	Wp	–	–	–	Wp	–	–	–	–	–	–	–	Wp	–
	4.1.6 Centrifugal forces		Z	–	–	–	Z	–	–	–	–	–	–	–	–	–	Z	–	–
4.2 Additional loads	4.2.1 Wind load, with crane	in service	Wi	Wi				Wi			–	Wi	–	–	–				–
		out of service	Wa	–				–			Wa	–	–	–	–				–
	4.2.2 Forces arising from skewing		S	–				–			–	S	–	–	–				–
4.3 Special loads	4.3.1 Tilting force arising in crane trolleys with positive guidance of the lifted load		Ki	–				–			–	–	Ki	–	–				–
	4.3.2 Buffer forces		Pu	–				–			–	–	–	Pu	–				–
	4.3.3 Test loads	Small	Pk	–				–			–	–	–	–	$\frac{1+\psi}{2} \cdot Pk$				–
		Large	Pg	–				–			–	–	–	–	–				Pg

The wind loads shall always be entered in the calculation at their full value. Acceleration forces and deceleration forces acting simultaneously with wind loads shall only be entered in the calculation to an extent which ensures that the driving forces specified in subclause 4.1.5 are not exceeded.

Impact from bulk material as specified in subclause 4.1.7, thermal effects as specified in subclause 4.2.3, snow loads as specified in subclause 4.2.4, loads on walkways etc. as specified in subclause 4.2.5 need only be taken into consideration in special cases.

Table 8. **Characteristic values of steel grades used for the calculation**

Steel grade: Brief designation	Steel grade: Specified in	Characteristic values: Yield stress σ_S N/mm²	Characteristic values: Modulus of elasticity (tension, compression) E N/mm²	Characteristic values: Shear modulus G N/mm²	α_T $\frac{mm}{mm \cdot K}$
Structural steel St 37*)	DIN 17100	240	210000	81000	$12 \cdot 10^{-6}$
Tube steel St 35*)	DIN 1629 Parts 1 and 3				
Structural steel St 52-3	DIN 17100	360			$12 \cdot 10^{-6}$
Rail steel with a tensile strength of not less than 600 N/mm²					
*) Covers all quality groups, steelmaking and casting processes.					

See DIN 15018 Part 2 for selection of quality groups, steelmaking and casting processes of the steels.

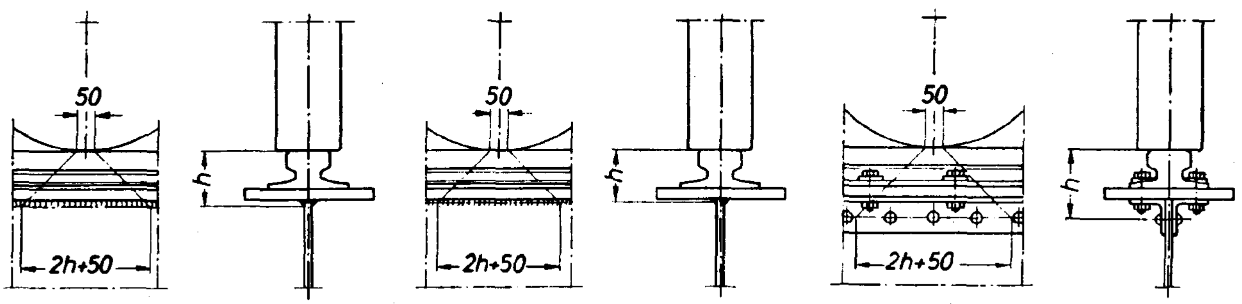
6.9 Longitudinal distribution of wheel loads

The local stresses in the rail, rail foot, flanges, double fillet welds or web rivets and webs of rail bearing beams which arise from wheel loads acting normally and transversely to the rail shall be determined in accordance with the rail and flange system.

Unless a more accurate calculation is made, the individual wheel load may be distributed uniformly in the direction of the rail over a length of ($2\,h$ + 50 mm), on condition that the rail is directly supported on the flange as illustrated in figure 7. The height h, related to the top edge of the rail, shall be entered as follows for the purpose of analysing

the web: as the distance to the bottom edge of the fillet weld or of the flange boss (see figure 7 a);
the fillet weld: as the distance to the centroidal axis of the fillet weld (see figure 7 b);
the web rivets: as the distance to the centre line of the rivets (see figure 7 c).

Dimensions are given in mm.



a) web b) fillet weld c) web rivets

Figure 7. Height h for the analysis

If the rail rests on an elastic support, the transverse and the longitudinal distribution of the bearing pressure under the rail shall be taken into consideration in their most unfavourable pattern in each case for the calculation of the rail bearing beam and of the rail.

7 Verification and analyses

7.1 General

The verification and analyses described in subclauses 7.2, 7.3 and 7.4 shall be carried out individually for the load-bearing members and for the principal connections and joints. No such verification need be made for design purposes in respect of subordinate components such as walkways, stairways, platforms, hand rails and cabins.

The overall stresses governed by the type of crane, load case and verification shall not exceed the permissible stresses in each case, and the safety factors shall not be less than the values specified.

In the special cases listed in table 9, the permissible stresses in accordance with tables 10 to 12 may be exceeded, and the factors of safety against bulging may be below those specified in DIN 4114 Part 1 and Part 2 and in table 13. Where several special cases occur simultaneously, the total amount of the maximum permissible stresses or the minimum factors of safety shall be limited to the greater of the values allowed for one of such special cases, provided however that the percentage allowed for each individual special cases is not exceeded.

7.2 General stress analysis

7.2.1 Load cases and permissible stresses

The general stress analysis in respect of safety against attaining the yield point shall be carried out separately for load cases H and HZ, using the permissible stresses listed in tables 10 to 12. As regards load case HS, the stresses of load case HZ multiplied by a factor of 1,1 may be used.

The values in the "zul σ_z" column are also permitted in respect of compressive stresses in the immediate vicinity of points of introduction of forces.

Welds shall exhibit a tensile strength and a yield strength not less than those of the steel of which the welded components are made. Longitudinal stresses shall remain within the permissible stresses in members specified in table 10.

The permissible tensile stresses in welds for transverse loading may only be used if the plates required for the transmission of the tensile forces, which are thereby stressed transversely in their rolling plane, are suitable for this purpose (see table 24, test method associated with letter symbol D).

See clause 9 for permissible tensile forces on prestressed bolts.

In normal cases, the following fasteners shall be used:

for members made of ST 37 steel, USt 36 rivets and bolts of property class 4.6;

for members made of St 52 steel, RSt 44-2 rivets and bolts of property class 5.6.

If the above rules are followed, the specified bolt or rivet bearing stresses shall also apply for members.

7.2.2 Combined stresses

Where states of combined plane stresses exist, the comparison stress shall be verified in addition for members as specified in table 10, paying attention to the plus or minus signs, as follows:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^2} \leq \text{zul } \sigma_z$$

for welds as specified in table 11, the comparison value shall be verified as follows:

$$\sigma_v = \sqrt{\bar{\sigma}_x^2 + \bar{\sigma}_y^2 - \bar{\sigma}_x \cdot \bar{\sigma}_y + 2 \cdot \tau^2} \leq \text{zul } \sigma_z$$

(continued on page 14)

Table 9. **Permissible deviations for stresses and factors of safety against bulging**

No.	Special case	Permitted plus deviation, in %	Permitted minus deviation, in %
1	Deviations from design loads, in total	3% of permissible stresses	3% of safety factors
2	Unintentional changes in the support conditions	10% of permissible stresses	6% of safety factors
3	Construction conditions	10% of permissible stresses for load case HZ	6% of safety factors for load case HZ

Table 10. **Permissible stresses in members for the general stress analysis and the verification of stability**

Steel grade of member: Symbol	Steel grade of member: Specified in	Load case	Permissible comparison stress / Permissible tensile stress zul σ_z N/mm²	Permissible compressive stress zul σ_d N/mm²	Permissible shear stress zul τ N/mm²
St 37*)	DIN 17100	H	160	140	92
		HZ	180	160	104
St 52-3	DIN 17100	H	240	210	138
		HZ	270	240	156

*) Covers all quality groups, steelmaking and casting processes.

In the verification carried out in accordance with DIN 4114 Part 1 and Part 2, the values specified in the "zul σ_d" column above shall always be entered in the calculation for "zul σ".

Table 11. **Permissible stresses in welds for the general stress analysis**

Steel grade of welded member: Symbol	Steel grade of welded member: Specified in	Load case	Permissible comparison value: All types of weld	Permissible tensile stress for transverse loading zul σ_{wz} N/mm^2: Butt weld, double bevel butt weld; special quality	Double bevel butt weld; standard quality	Fillet weld	Permissible compressive stress for transverse loading zul σ_{wd} N/mm^2: Butt weld, double bevel butt weld	Fillet weld	Permissible shear stress zul τ_w N/mm^2: All types of weld
St 37*)	DIN 17100	H	160		140	113	160	130	113
		HZ	180		160	127	180	145	127
St 52-3	DIN 17100	H	240		210	170	240	195	170
		HZ	270		240	191	270	220	191

*) Covers all quality groups, steelmaking and casting processes.

Table 12. **Permissible stresses in fasteners for the general stress analysis**

Type of connection: Fastener	Joint	Steel grade/property class	Specified in	Load case	Permissible shear stress zul τ_a N/mm^2		Permissible bolt or rivet bearing stress zul σ_l N/mm^2		Permissible tensile stress zul σ_z N/mm^2
Rivets	Single shear	USt 36	DIN 17111	H	0,6 · zul σ_d	84	1,5 · zul σ_d	210	(30)
				HZ		96		240	
		RSt 44-2	DIN 17111	H		126		315	(45)
				HZ		144		360	
	Multiple shear	USt 36	DIN 17111	H	0,8 · zul σ_d	113	2 · zul σ_d	280	(30)
				HZ		128		320	
		RSt 44-2	DIN 17111	H		168		420	(45)
				HZ		192		480	
Fit bolts	Single shear	4.6	DIN 267 Part 3	H	0,6 · zul σ_d	84	1,5 · zul σ_d	210	100
				HZ		96		240	110
		5.6	DIN 267 Part 3	H		126		315	140
				HZ		144		360	154
	Multiple shear	4.6	DIN 267 Part 3	H	0,8 · zul σ_d	112	2 · zul σ_d	280	100
				HZ		128		320	110
		5.6	DIN 267 Part 3	H		168		420	140
				HZ		192		480	154
Non-fit bolts		4.6	DIN 267 Part 3	H	–	70	–	160	100
				HZ		80		180	110
		5.6	DIN 267 Part 3	H		70		160	140
				HZ		80		180	154
Diameter to be considered for		rivets		Diameter of hole					
		bolts		Diameter of unthreaded shank					Minor thread diameter

The tensile stress values for rivets given in brackets are permitted for exceptional cases only.

where

$$\bar{\sigma}_x = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wz}} \cdot \sigma_x \text{ or } \bar{\sigma}_x = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wd}} \cdot \sigma_x$$

$$\bar{\sigma}_y = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wz}} \cdot \sigma_y \text{ or } \bar{\sigma}_y = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wd}} \cdot \sigma_y$$

with the permissible tensile stresses zul σ_z in members as specified in table 10, the permissible tensile stresses zul σ_{wz} and the permissible compressive stresses zul σ_{wd} in welds as specified in table 11, and with the calculated stresses σ_x, σ_y and τ in the welds.

If the worst case under the above conditions is not evident from the correlated stresses σ_x, σ_y and τ, separate verification shall be made for the conditions max σ_x, max σ_y and max τ, using the correlated worst case stresses for these conditions.

7.3 Verification of stability

7.3.1 General

The verification of stability in respect of safety against buckling, collapsing and bulging of the web plates and bulging of the rectangular plates forming part of a compression member shall be carried out as described in DIN 4114 Part 1 and Part 2 for load cases H, HZ and HS.

Load case H corresponds to load case 1 as defined in DIN 4114 Parts 1 and 2, and load case HZ corresponds to load case 2.

In the special load case HS, the safety against buckling shall be $\nu_{Ks} = \nu_{K1} \cdot \frac{1{,}35}{1{,}71}$, ν_{K1} being the safety against buckling in load case 1 as defined in DIN 4114 Parts 1 and 2.

Verification of the safety against bulging of plates shall also be carried out in accordance with DIN 4114 Part 1 and Part 2, but in lieu of the factors of safety, ν_B, specified in DIN 4114, the values given in subclause 7.3.3, table 13, shall be used.

Table 13. **Factors of safety against bulging ν_B**

	Load case	ν_B
Full panel	H	1,71 + 0,180 (ψ−1)
	HZ	1,50 + 0,125 (ψ−1)
	HS	1,35 + 0,075 (ψ−1)
Partial panel	H	1,50 + 0,075 (ψ−1)
	HZ	1,35 + 0,050 (ψ−1)
	HS	1,25 + 0,025 (ψ−1)
Circular cylindrical shells	H	1,71
	HZ	1,50
	HS	1,35

A full panel, stiffened or non-stiffened, extends over the area of a plate in compression, the edges of which are rigidly supported transversely in the direction of bulging by other members such as transverse bulkheads, flange plates or web plates; a partial panel is a non-stiffened partial area of the full panel. In the factors above, ψ is the larger of the two quotients $\psi_x = \sigma_{x2} : \sigma_{x1}$ or $\psi_y = \sigma_{y2} : \sigma_{y1}$ from the correlated normal stresses σ_{x1}, σ_{x2} or σ_{y1}, σ_{y2} at the corners of the respective edges of a full panel or of a partial panel; see also DIN 4114 Part 1, subclause 16.5 (July 1952xx edition) and DIN 4114 Part 2, subclause 17.1 (February 1953x edition).

In cases where ψ is less than −1, ψ shall be entered at a value of −1.

7.3.2 Verification of safety against bulging of circular cylindrical shells

Thin-walled circular cylindrical shells, such as large-diameter pipes, which are subjected to systematic centric or eccentric axial loading shall be verified in respect of local bulging if

$$\frac{t}{r} \leq \frac{25 \cdot \sigma_s}{E}$$

where

t is the wall thickness;

r is the radius related to the center of the wall thickness;

σ_s is the yield stress of steel grade specified in table 8;

E is the modulus of elasticity specified in table 8.

The ideal bulging stress σ_{Bi} can be determined by means of the relationship

$$\sigma_{Bi} = 0{,}2 \cdot \frac{E \cdot t}{r}$$

In all cases where σ_{Bi} is situated above the proportionality limit of the structural steel, it shall be reduced to σ_B, as specified in DIN 4114 Part 1 (July 1952xx edition), table 7.

Transverse stiffenings shall be arranged at spacings not exceeding $10 \times r$, whose moment of inertia J, calculated in accordance with DIN 4114 Part 2 (February 1953x edition), Ri 18.13, shall be not less than

$$J = \frac{r \cdot t^3}{2} \cdot \sqrt{\frac{r}{t}}$$

It may be assumed that the above verification of safety against bulging of circular cylindrical shells makes adequate allowance for geometric deviations between the actual and the ideal shell centre plane resulting from inaccuracies of fabrication in magnitudes up to $t/2$.

7.3.3 Safety against bulging

The factors of safety against bulging of the flat plates,

$$\nu_B = \frac{\sigma_{VKi}}{\sigma_V} \text{ or } \nu_B = \frac{\sigma_{VK}}{\sigma_V},$$

and the factors for circular cylindrical shells with σ_d as the largest edge compressive stress,

$$\nu_B = \frac{\sigma_{Bi}}{\sigma_d} \text{ or } \nu_B = \frac{\sigma_B}{\sigma_d},$$

shall not be lower than the values specified in table 13 for each load case.

7.4 Verification of service strength

7.4.1 Concepts

A verification of service strength in respect of safety against failure under frequently repeated stresses variable with time need only be carried out for members and fasteners for load cases H and for numbers of stress cycles exceeding 2×10^4.

The permissible stresses are equal for each loading group and are dependent upon the stress collective and the number of stress cycles; they have been laid down for various steel grades, types of stress, notch cases and limiting stress ratios, see subclause 7.4.4.

The limiting stress ratio $\varkappa$ = min σ/max σ or min τ/max τ etc. is the ratio of the numerically smaller limiting stress (min σ, min τ) to the numerically larger limiting stress (max σ, max τ). Depending on the (plus or minus) sign of these limiting stresses, the ratio fluctuates from −1 to 0 in the alternating stress range, and from 0 to +1 in the pulsating stress range.

The six loading groups, B 1 to B 6, are correlated to specific ranges of the stress cycles and to specific stress collectives in accordance with subclause 7.4.2 and table 14.

Table 14. **Loading groups according to stress cycle ranges and stress collectives**

Stress cycle range	N 1	N 2	N 3	N 4
Total number of anticipated stress cycles $\hat{N}$	Over $2\cdot10^4$ up to $2\cdot10^5$ Occasional irregular use with long periods of non-use	Over $2\cdot10^5$ up to $6\cdot10^5$ Regular use in intermittent operation	Over $6\cdot10^5$ up to $2\cdot10^6$ Regular use in continuous operation	Over $2\cdot10^6$ Regular use in heavy-duty continuous operation
Stress collective	Loading group			
S_0, very light	B 1	B 2	B 3	B 4
S_1, light	B 2	B 3	B 4	B 5
S_2, medium	B 3	B 4	B 5	B 6
S_3, heavy	B 4	B 5	B 6	B 6

The four stress cycle ranges, N 1 to N 4, given in table 14 comprise the probable total number or the cumulative frequency $\hat{N}$ at which the smallest maximum stress $\check{\sigma}_o$ of the stress collective is attained or exceeded. The total number $\hat{N}$ of stress cycles imposed on a member can be equal to the number of load cycles or of operating cycles, or to a multiple thereof, depending on the type of crane; in this respect, a load cycle shall be deemed to mean a single lifting motion and a single lowering motion taking place between the picking up and the setting down of a lifted load, whilst an operating cycle shall be deemed to mean all the motions necessary for the performance of a complete transport and handling operation.

The four stress collectives, S_0 to S_3, denote the relative cumulative frequency with which a specific maximum stress σ_o is attained or exceeded. The anticipated stress collectives shall be correlated roughly to the idealized stress collectives; if necessary, a cumulative damage calculation may be carried out for this purpose. The idealized stress collectives are defined by the maximum and minimum limit values of the stress amplitudes, $\hat{\sigma}_o - \sigma_m$ and $\check{\sigma}_o - \sigma_m$, and by a distribution approximating the Gaussian distribution (see figure 8 in this respect).

The eight notch cases, W 0 to W 2 and K 0 to K 4, as specified in subclause 7.4.3 and in tables 25 to 32 allow for the decrease in service strength of conventional structural shapes with increasing influence of notch effects.

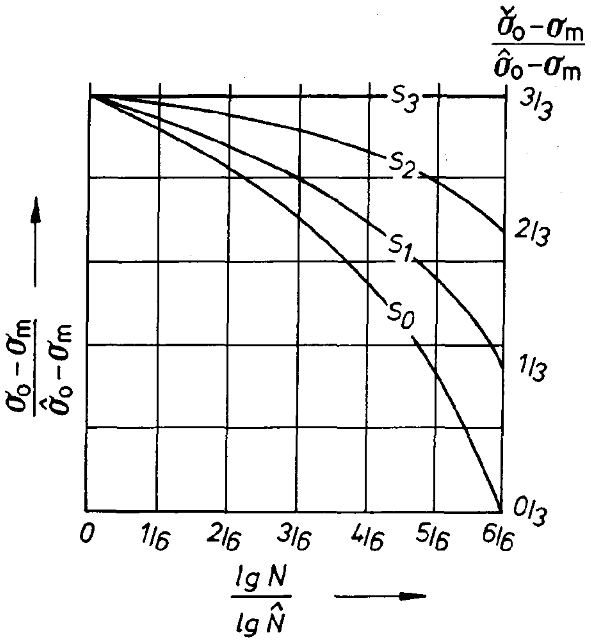


Figure 8. Idealized related stress collectives

7.4.2 Loading groups

The loading groups listed in table 14 are correlated to the stress cycle ranges and to the stress collectives.

The cranes may be classified into loading groups according to the operating conditions of the most severely loaded part of the crane. Individual elements which are clearly separated from the rest, or which form self-contained structural units may be classified into different loading groups on condition that their operating conditions are precisely known.

Table 15. **Related stresses** $\frac{\sigma_o-\sigma_m}{\hat{\sigma}_o-\sigma_m}$ **of the idealized stress collectives**

	$\frac{\lg N}{\lg \hat{N}}$	0	1/6	2/6	3/6	4/6	5/6	6/6
Stress collective	S_3	1	1	1	1	1	1	1
	S_2	1	0,975	0,944	0,906	0,856	0,787	0,666
	S_1	1	0,952	0,890	0,814	0,716	0,579	0,333
	S_0	1	0,927	0,836	0,723	0,576	0,372	0,000

where

$\sigma_m = \frac{1}{2}(\max\sigma + \min\sigma)$ = amount of the constant mean stress;

σ_o is the amount of the maximum stress which is attained or exceeded N times;

$\hat{\sigma}_o$ is the amount of the largest maximum stress of the idealized stress collective;

$\check{\sigma}_o$ is the amount of the smallest maximum stress of the idealized stress collective;

$\hat{N} = 10^6$, extent of the idealized stress collective.

7.4.3 Notch cases

The most widely used structural shapes, connections and joints are correlated to the eight notch cases, W 0 to W 2 and K 0 to K 4, as specified in subclause 10.3, tables 25 to 32, according to the notch influences dependent on their shape, structural design, hole pattern or type and quality of the welds etc.

The most widely used types of welds are classified in table 24 of subclause 10.2 according to grades in relation to their execution and inspection.

Table 16 deleted.

Table 17. **Basic values of the permissible stresses zul $\sigma_{D(-1)}$, in N/mm², for $\varkappa = -1$ in members, for the verification of service strength**

Steel grade	St 37			St 52-3			St 37					St 52-3				
Notch case	W 0	W 1	W 2	W 0	W 1	W 2	K 0	K 1	K 2	K 3	K 4	K 0	K 1	K 2	K 3	K 4
Loading group	Permissible stresses zul $\sigma_{D(-1)}$ for $\varkappa = -1$															
B 1	180	180	180	270	270	247,2	180	180	180	180	152,7	270	270	270	254	152,7
B 2			168		249	199,2				180	108			252	180	108
B 3		161,4	141,3	252,2	200,6	160,5			178,2	127,3	76,4	237,6	212,1	178,2	127,3	76,4
B 4	169,7	135,8	118,8	203,2	161,1	129,3	168	150	126	90	54	168	150	126	90	54
B 5	142,7	114,2	99,9	163,8	130,3	104,2	118,8	106,1	89,1	63,6	38,2	118,8	106,1	89,1	63,6	38,2
B 6	120	96	84	132	105	84	84	75	63	45	27	84	75	63	45	27

The step ratio between the stresses of two consecutive loading groups is 1,1892 for St 37 and 1,2409 for St 52-3, for notch cases W 0 to W 2; for notch cases K 0 to K 4, the step ratio is 1,4142 for St 37 and for St 52-3.

7.4.4 Permissible stresses

The permissible maximum stress values of the normal stresses and shear stresses in members and welds, and of the shear stresses and hole bearing stresses in fasteners and perforated members are specified in tables 18 and 19 as a function of the basic values of the permissible stresses zul $\sigma_{D(-1)}$ (table 17) and of the limiting stress ratio.

All permissible stresses for the verification of service strength are limited on the upper side by the permissible stresses applicable to load case HZ in the general stress analysis specified in subclause 7.2.1, tables 10 to 12. With regard to compressive stresses in members, the values in the zul σ_z column shall apply.

The permissible stresses zul $\sigma_{D(-1)}$ listed in table 17 correspond, at a factor of safety of $\nu_D = 4/3$, to the bearable stresses based on a 90% survival probability.

The relationships illustrated in figure 9 exist between the permissible stresses zul $\sigma_{D(-1)}$ and zul $\sigma_{D(\varkappa)}$.

The relationships specified in table 18 shall apply for the permissible normal stresses in members.

The relationships specified in table 19 shall apply for the permissible shear stresses in members and welds and for the permissible shear stresses and hole bearing stresses in fasteners and perforated members.

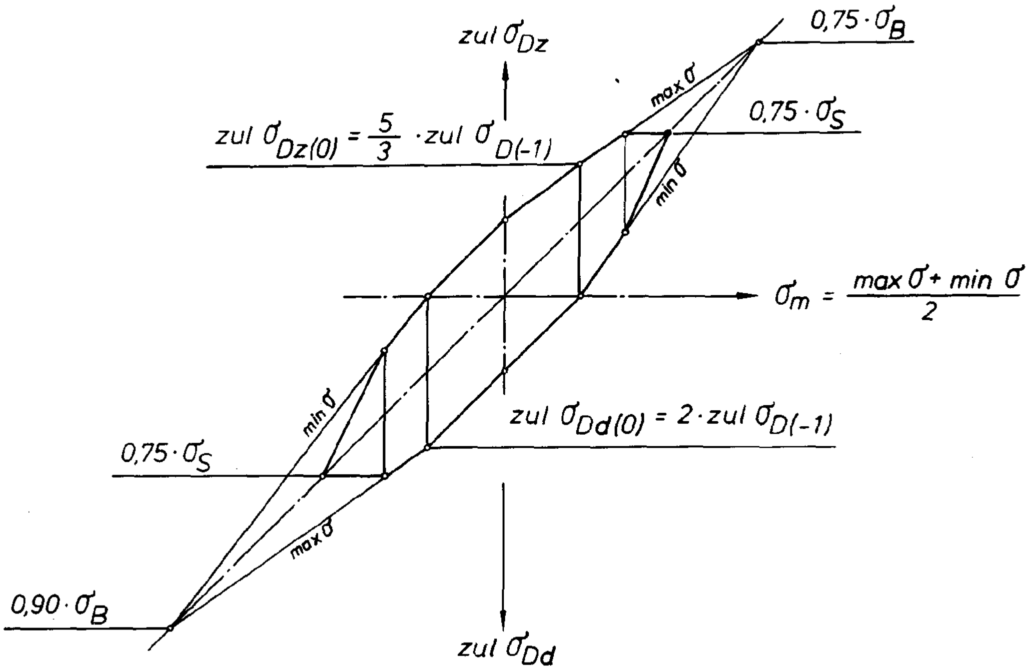


Figure 9. Relationships between zul $\sigma_{D(\varkappa)}$ and zul $\sigma_{D(-1)}$

Table 18. **Equations relating to the permissible maximum stresses according to figure 9 as a function of $\varkappa$ and of zul $\sigma_{D(-1)}$ as specified in table 17**

Alternating stress range $-1 < \varkappa < 0$	Tension	$\text{zul}\,\sigma_{Dz(\varkappa)} = \frac{5}{3-2\varkappa} \cdot \text{zul}\,\sigma_{D(-1)}$
	Compression	$\text{zul}\,\sigma_{Dd(\varkappa)} = \frac{2}{1-\varkappa} \cdot \text{zul}\,\sigma_{D(-1)}$
Pulsating stress range $0 < \varkappa < +1$	Tension	$\text{zul}\,\sigma_{Dz(\varkappa)} = \frac{\text{zul}\,\sigma_{Dz(0)}}{1-\left(1-\frac{\text{zul}\,\sigma_{Dz(0)}}{0{,}75\cdot\sigma_B}\right)\cdot\varkappa}$
	Compression	$\text{zul}\,\sigma_{Dd(\varkappa)} = \frac{\text{zul}\,\sigma_{Dd(0)}}{1-\left(1-\frac{\text{zul}\,\sigma_{Dd(0)}}{0{,}90\cdot\sigma_B}\right)\cdot\varkappa}$

Table 19. **Permissible stresses zul $\tau_{D(x)}$ for members and welds and permissible stresses zul $\tau_{aD(x)}$ and zul $\sigma_{lD(x)}$ for fasteners**

Members	zul $\tau_{D(x)} = \frac{\text{zul}\,\sigma_{Dz(x)}}{\sqrt{3}}$	zul $\sigma_{Dz(x)}$ as for W 0
Weld*)	zul $\tau_{D(x)} = \frac{\text{zul}\,\sigma_{Dz(x)}}{\sqrt{2}}$	zul $\sigma_{Dz(x)}$ as for K 0
Multiple-shear rivets and fit bolts	zul $\tau_{aD(x)} = 0{,}8 \cdot$ zul $\sigma_{Dz(x)}$ zul $\sigma_{lD(x)} = 2{,}0 \cdot$ zul $\sigma_{Dz(x)}$	zul $\sigma_{Dz(x)}$ as for W 2
Single-shear (unsupported) rivets and fit bolts	zul $\tau_{aD(x)} = 0{,}6 \cdot$ zul $\sigma_{Dz(x)}$ zul $\sigma_{lD(x)} = 1{,}5 \cdot$ zul $\sigma_{Dz(x)}$	zul $\sigma_{Dz(x)}$ as for W 2

*) Until further notice, the permissible shear stresses specified in DIN 4132, February 1981 edition, subclause 4.4.5, second paragraph and equation (5) shall be taken into consideration as appropriate for fillet welds and for welds with root notches.

7.4.5 Combined stresses

In the case of combined stresses, the following condition shall also be satisfied, paying attention to the plus or minus signs and to the applicable limiting stress ratios for the members or for the weld or for both:

$$\left(\frac{\sigma_x}{\text{zul}\,\sigma_{xD}}\right)^2 + \left(\frac{\sigma_y}{\text{zul}\,\sigma_{yD}}\right)^2 - \left(\frac{\sigma_x \cdot \sigma_y}{|\text{zul}\,\sigma_{xD}| \cdot |\text{zul}\,\sigma_{yD}|}\right) + \left(\frac{\tau}{\text{zul}\,\tau_D}\right)^2 \leq 1{,}1$$

where

σ_x, σ_y is the calculated normal stress in x and y directions;

zul σ_{xD}, zul σ_{yD} is the permissible normal stress corresponding to stresses σ_x and σ_y respectively;

$|\text{zul}\,\sigma_{xD}|$, $|\text{zul}\,\sigma_{yD}|$ is the amount of zul σ_{xD} and zul σ_{yD} respectively;

τ is the calculated shear stress:

zul τ_D is the permissible shear stress corresponding to the stress τ.

If the worst case for the above condition is not evident from the correlated stresses σ_x, σ_y and τ, separate verification shall be made for the conditions max σ_x, max σ_y and max τ using the correlated worst case stresses for these conditions.

7.5 Verification of stability

The stability and the safety against drifting under wind pressure shall be verified as specified in DIN 15019 Part 1 and Part 2 respectively.

8 Holding ropes and guy ropes

Holding ropes and guy ropes are wire ropes which are not guided over pulleys or drums, and over which no pulleys travel.

The strength of such ropes, without local transverse loading, e.g. via clips or saddles, depends amongst other things on the construction, diameter and fastening of these ropes.

The general stress analysis shall be carried out for load cases HZ and HS. The verification of service strength specified in subclause 7.4 shall be carried out for load case H and only for such ropes as are intended as permanent members of the crane structure.

The permissible stresses in the metallic cross section of wire ropes composed of individual wires with a nominal strength $\sigma_z = 1570$ N/mm^2 are specified at a value of zul $\sigma_z = 450$ N/mm^2 in the general stress analysis for all load cases HZ; as regards the verification of service strength, the permissible stresses shall be those listed in table 20 and shown in figures 10 and 11, depending on the wire rope diameter and on the loading group concerned.

If individual wires with a nominal strength of more than 1570 N/mm^2 are used, it is not permitted to increase the permissible stresses proportionately. A justification shall be submitted for the increase in permissible stresses adopted.

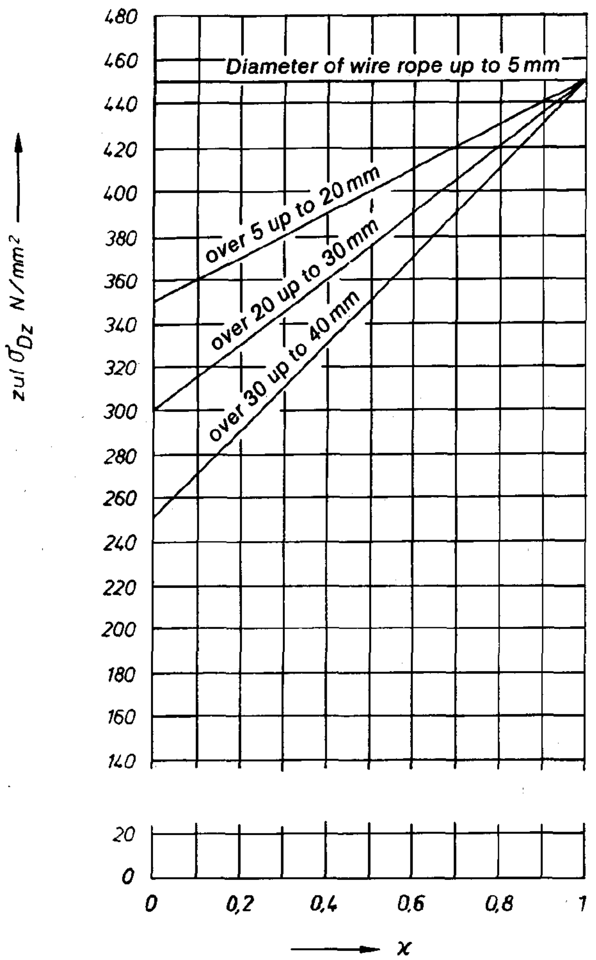


Figure 10. Permissible stresses for loading groups B1, B2 and B3

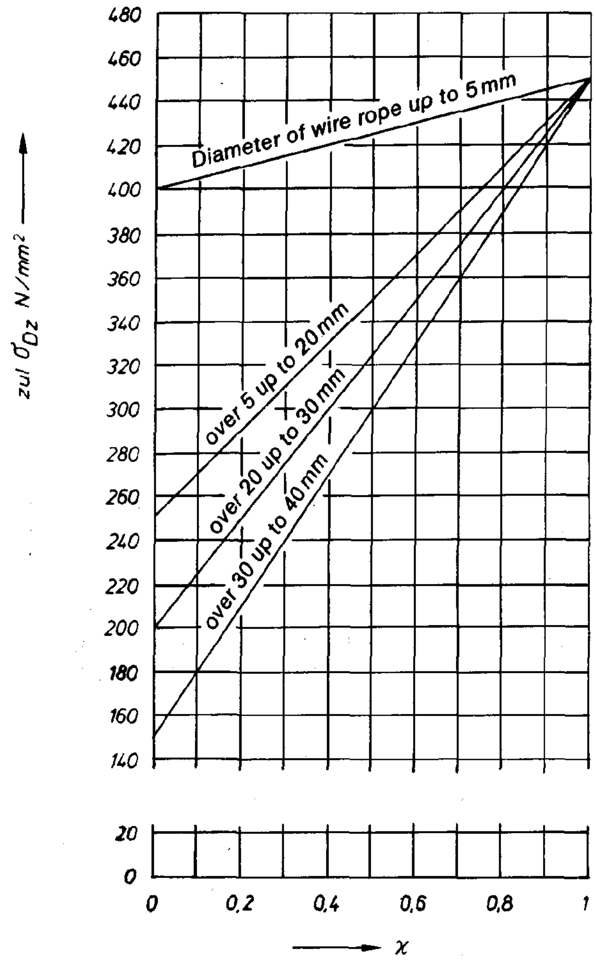


Figure 11. Permissible stresses for loading groups B4, B5 and B6

Table 20. **Permissible stresses for holding ropes and guy ropes composed of individual wires with a nominal strength of 1570 N/mm² for the verification of service strength**

Diameter of wire rope, in mm	Permissible stress zul σ_{Dz}, in N/mm², for loading groups	
	B1, B2 and B3	B4, B5 and B6
Up to 5	450	$400 + 50 \cdot \varkappa$
Over 5 up to 20	$350 + 100 \cdot \varkappa$	$250 + 200 \cdot \varkappa$
Over 20 up to 30	$300 + 150 \cdot \varkappa$	$200 + 250 \cdot \varkappa$
Over 30 up to 40	$250 + 200 \cdot \varkappa$	$150 + 300 \cdot \varkappa$

All the permissible stresses shall apply for stranded ropes and until further notice also to fully locked coil ropes and to open spiral ropes; they may be exploited to the following extent, depending on the method of rope fastening adopted:

securing by sweating or by attachment to bollards,	up to 100 %;
securing by compression clamps,	up to 90 %**);
securing by rope sockets or splicing,	up to 80 %;
securing by rope clamps,	up to 40 %;

The modulus of elasticity depends on the design and construction of the rope and increases with the frequency and magnitude of the pull force exerted on the rope; in the case of fully stretched ropes, it may be assumed to be

90 000 to 120 000 N/mm²	for stranded ropes with hemp core;
100 000 to 130 000 N/mm²	for stranded ropes with steel core;
140 000 to 170 000 N/mm²	for fully locked coil ropes and open spiral ropes.

9 Tension on prestressed bolts

9.1 General

Bolted connections consisting of non-treated (non-galvanized, non-cadmium plated) bolts, nuts and washers complying with DIN 6914 to DIN 6918, assigned to property class 10.9, which are prestressed against plane parallel, and in certain cases machined solid steel plates specified in table 21, with a deviation not exceeding ±10 %, and wich are intended to transmit a tensile force Z, shall be verified in accordance with subclause 9.2 for the applicable load cases H, HZ and HS specified in table 7.

**) The permissible stresses may only be exploited up to the above specified values if the compression clamps and the mode of their attachment permit it.

Table 21. **Prestressing forces and tightening torques for property class 10.9 high strength friction grip bolts (complying with DIN 6914 to DIN 6918)**

Bolt diameter	Prestressing force, in N P_v	Tightening torque, in Ncm M_a
M 16	93300	28400
M 20	145600	55400
M 22	180100	76200
M 24	209800	95800
M 27	272800	142000

The tightening torque which has to be applied with torque wrenches in order to achieve the required prestressing force produces a combined tensile and torsional load calculated at 90% of the minimum yield stress ($\sigma_{0,2}$ = 90000 N/cm²). All calculations are based on the more unfavourable of the two limit coefficients of friction, $\mu = 0{,}14$ or $\mu = 0{,}18$ [4]).

9.2 General stress analysis

The tensile force to be absorbed in load cases H, HZ and HS specified in table 7 shall not exceed the permissible tensile forces zul Z_1 or zul Z_2:

$$\text{zul}\, Z_1 = \frac{S_1}{\Phi} \quad \text{or zul}\, Z_2 = \frac{S_2}{1-\Phi}$$

where

S_1 is the longitudinal bolt force specified in table 22, which is just sufficient to increase the state of stress of the bolt prestressed according to table 21 until the minimum yield stress is attained, when subjected to a ν-fold tensile force.

S_2 is the longitudinal bolt force specified in table 22, which is just sufficient to cancel out the surface contact pressure of the bolt prestressed according to table 21, when subjected to a ν-fold tensile force; the joint just begins to gape open. This verification is only of any significance for $\Phi < \Phi_0 = 0{,}2038$.

Φ is the clamping factor [5]) shown in figure 12, which is dependent on the clamping length l_k and on the nominal diameter d of the bolt.

Table 22. **Longitudinal bolt forces S_1 and S_2, in N**

Bolt diameter d	Load case H		Load case HZ		Load case HS	
	S_1	S_2	S_1	S_2	S_1	S_2
M 16	10000	39000	11400	44450	12650	49400
M 20	15600	60850	17750	69350	19750	77050
M 22	19250	75250	21950	85750	24400	95300
M 24	22450	87650	25600	99950	28450	111050
M 27	29200	114000	33250	129950	36950	144350
Factor of safety	1,71		1,50		1,35	

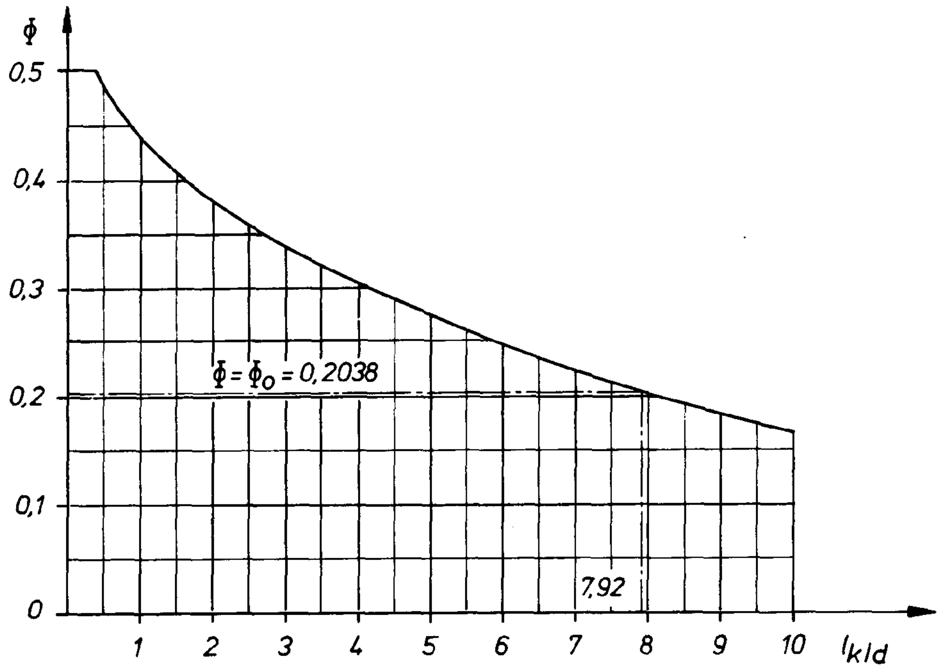


Figure 12.
Clamping factor Φ for solid steel plates and hexagon head bolts complying with DIN 6914, hexagon nuts complying with DIN 6915, washers complying with DIN 6916 and square washers complying with DIN 6917 and DIN 6918

4) *Neue Wege einer systematischen Schraubenberechnung* (New methods of systematic calculation of bolted connections), by *G. Junker* and *D. Blume*. Scientific publication of Messrs. *Bauer und Schaurte*, Neuss/Rhein, published by *Michael Triltsch Verlag*, Düsseldorf, 1965.

5) *Grundlagen einer genauen Berechnung statisch und dynamisch beanspruchter Schraubenverbindungen* (Fundamental principles for the precise calculation of statically and dynamically loaded bolted connections), by *Fritsche*, dissertation at Berlin Technical University 1962.

9.3 Verification of service strength

Bolted connections complying with the specifications laid down in subclauses 9.1 and 9.2 shall be deemed as meeting the requirements in respect of service strength if a calculated factor of safety of 1,33 in respect of the tensile forces actually arising and permissible is allowed for.

10 Tables

10.1 Examples of classification of types of crane into lifting classes and loading groups

Table 23. **Lifting classes (subclause 4.1.4.2) and loading groups (subclause 7.4.2)**

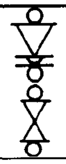
Item No.	Type of crane		Lifting classes	Loading groups
1	Hand-operated cranes		H 1	B 1, B 2
2	Erection cranes		H 1, H 2	B 1, B 2
3	Powerhouse cranes		H 1	B 2, B 3
4	Storage cranes	Intermittent operation	H 2	B 4
5	Storage cranes, spreader bar cranes, scrap yard cranes	Continuous operation	H 3, H 4	B 5, B 6
6	Workshop cranes		H 2, H 3	B 3, B 4
7	Bridge cranes, ram cranes	Grab or magnet operation	H 3, H 4	B 5, B 6
8	Casting cranes		H 2, H 3	B 5, B 6
9	Soaking pit cranes		H 3, H 4	B 6
10	Stripper cranes, charging cranes		H 4	B 6
11	Forging cranes		H 4	B 5, B 6
12	Transporter bridges, semi-portal cranes, portal cranes with trolley or slewing crane	Hook operation	H 2	B 4, B 5
13	Transporter bridges, semi-portal cranes, portal cranes with trolley or slewing crane	Grab or magnet operation	H 3, H 4	B 5, B 6
14	Travelling belt bridges with fixed or sliding belt(s)		H 1	B 3, B 4
15	Dockyard cranes, slipway cranes, fitting-out cranes	Hook operation	H 2	B 3, B 4
16	Wharf cranes, slewing cranes, floating cranes, level luffing slewing cranes	Hook operation	H 2	B 4, B 5
17	Wharf cranes, slewing cranes, floating cranes, level luffing slewing cranes	Grab or magnet operation	H 3, H 4	B 5, B 6
18	Heavy duty floating cranes, gantry cranes		H 1	B 2, B 3
19	Shipboard cargo cranes	Hook operation	H 2	B 3, B 4
20	Shipboard cargo cranes	Grab or magnet operation	H 3, H 4	B 4, B 5
21	Tower slewing cranes for the construction industry		H 1	B 3
22	Erection cranes, derrick cranes	Hook operation	H 1, H 2	B 2, B 3
23	Rail-mounted slewing cranes	Hook operation	H 2	B 3, B 4
24	Rail-mounted slewing cranes	Grab or magnet operation	H 3, H 4	B 4, B 5
25	Railway cranes authorized on trains		H 2	B 4
26	Truck cranes, mobile cranes	Hook operation	H 2	B 3, B 4
27	Truck cranes, mobile cranes	Grab or magnet operation	H 3, H 4	B 4, B 5
28	Heavy-duty truck cranes, heavy-duty mobile cranes		H 1	B 1, B 2

Cranes which are designed to operate using two different useful loads and under different conditions may be classified separately if the plant operator demands it. The higher of the two useful loads shall be referred to as "exceptional load" and shall not be given on the nameplate of the crane.

10.2 Welds

In addition to the welds satisfying the requirements of the quality classes laid down in DIN 8563 Part 3, the present standard specifies welds which meet more exacting requirements in table 24.

Table 24. **Special quality welds**

Type of weld	Quality of weld	Execution of weld	Symbol, examples	Test for flawless execution Test method	Symbol
Butt weld	Special quality	Root broached, back-welded sealing run, weld machined flush with plate surface in the direction of stress, no end craters.		Non-destructive testing of the weld along 100 % of the weld length, e.g. by radiographic examination.	P 100
	Standard quality	Root broached, back-welded sealing run, no end craters.		As for special quality welds, but only for tensile stresses (specified in subclause 7.2) amounting to max. $\sigma_z \geqq 0{,}8 \cdot \text{zul}\,\sigma_z$; in the pulsating tensile stress range (specified in subclause 7.4), amounting to max $\sigma_z \geqq 0{,}8 \cdot \text{zul}\,\sigma_{zD}$; in the alternating stress range (specified in subclause 7.4), amounting to max $\sigma_z \geqq 0{,}8 \cdot \text{zul}\,\sigma_{zD}$, or max $\sigma_d \geqq 0{,}8 \cdot \text{zul}\,\sigma_{dD}$.	P 100
				Non-destructive testing, e.g. radiographic examination, of the most important remaining welds on a random sample basis, amounting to not less than 10 % of the total length of welds made by *each* welder.	P
Double-bevel butt weld with double fillet weld	Special quality	Root broached, through-welded (root fusion), weld interface notch-free, machined if necessary.		Non-destructive testing of the plate subjected to tension at right angles to its plane, in respect of lamination and structure discontinuities in the weld zone, e.g. by ultrasonic testing.	D
	Standard quality	Width of residual root gap up to 3 mm or up to 0,2 times the thickness of the piece welded on, whichever is the smaller.			
Fillet weld	Special quality	Weld interface notch-free, machined if necessary.			
	Standard quality	–			

In order to simplify the captions in tables 25 to 32 which follow, the term "fillet weld" in the "Description and illustration" column shall be deemed to apply also to double fillet welds if both symbols are depicted. In cases where a double fillet weld is required for a given notch case, this is specified in the "Description and illustration" and "Symbol" columns.

10.3 Examples of classification of commonly used structural shapes into notch cases

Table 25. **Notch case W 0**

Code	Description and illustration		Symbol
W 01	Non-perforated components with normal surface finish, if no notch effects are present, or if they are taken into account in the stress analysis. The quality of flame-cut surfaces shall be not inferior to the quality specified under symbol 11 in DIN 2310 Part 1 and Part 3.		—

Table 26. **Notch case W 1**

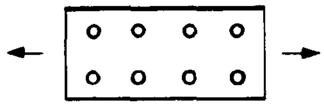
Code	Description and illustration		Symbol
W 11	Components with flame-cut surfaces at least of the quality specified under symbol 22 in DIN 2310 Part 1 and Part 3.		—
W 12	Perforated components, also with rivets and bolts, where the rivets and bolts are stressed to 20 % max. of the permissible values, or to 100 % max. of the permissible values in the case of high strength friction grip bolts.		—

Table 27. **Notch case W 2**

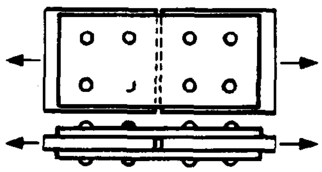
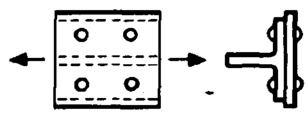
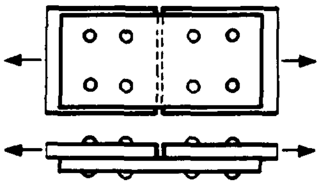
Code	Description and illustration		Symbol
W 21	Perforated components in double-shear riveted or bolted connection.		—
W 22	Perforated components in single-shear, but supported, riveted or bolted connection.		—
W 23	Perforated components in single-shear, but unsupported riveted or bolted connection, the eccentric force effects being verified.		—

Table 28. **Notch case K 0 (slight notch effect)**

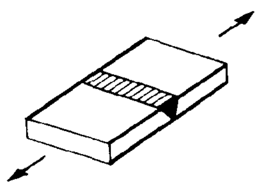
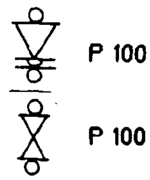
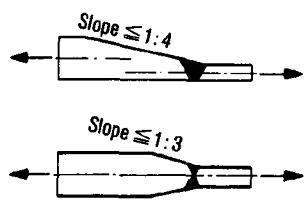
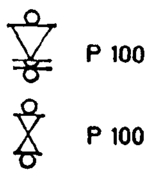
Code	Description and illustration		Symbol
011	Components jointed by special quality butt weld running at right angles to the direction of force.		
012	Components of different thicknesses jointed by special quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 4 or with symmetric joint and slopes not exceeding 1 : 3.		

Table 28. **Notch case K 0 (slight notch effect)** (continued)

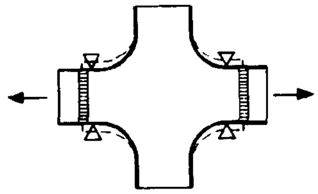
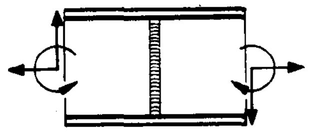
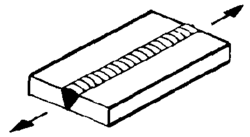
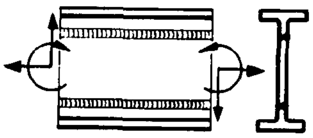
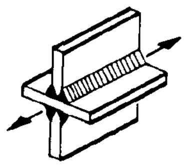
Code	Description and illustration		Symbol
013	Gusset plate welded-in by special quality butt weld running at right angles to the direction of force.		P 100 P 100
014	Web plates jointed transversely by special quality butt weld.		P 100 P 100
021	Components jointed by normal quality butt weld running longitudinally to the direction of force.		P or P 100 P or P 100
022	Web plates and flange plates made from steel sections or steel bars, with the exception of flat steel, jointed by normal quality butt weld.		P or P 100 P or P 100
023	Components jointed longitudinally to the direction of force by double bevel butt weld with double fillet weld.		

Table 29. **Notch case K 1 (moderate notch effect)**

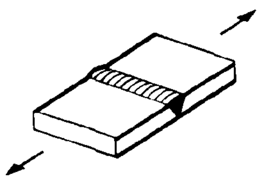
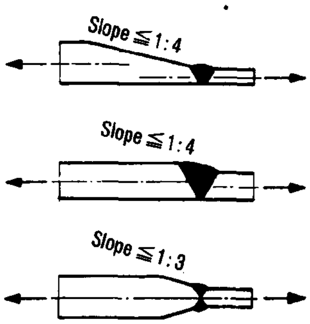
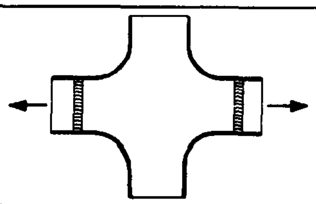
Code	Description and illustration		Symbol
111	Components jointed by normal quality butt weld running at right angles to the direction of force.		P or P 100 P or P 100
112	Components of different thicknesses jointed by normal quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 4 or with symmetric joint and slopes not exceeding 1 : 3.		P or P 100 P or P 100
113	Gusset plate welded-in by standard quality butt weld running at right angles to the direction of force.		P or P 100 P or P 100

Table 29. **Notch case K 1 (moderate notch effect)** (continued)

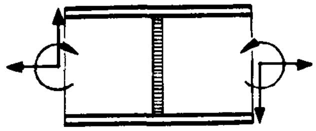
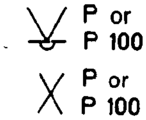
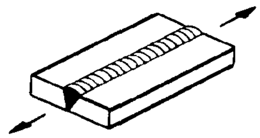
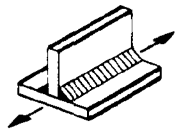
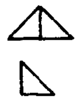
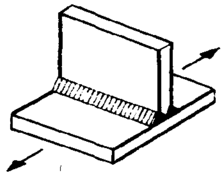
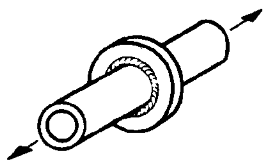
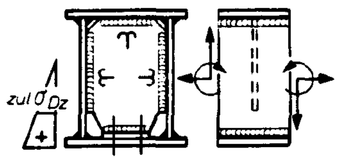
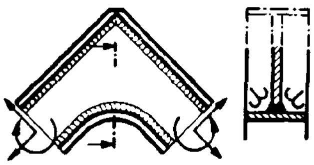
Code	Description and illustration		Symbol
114	Web plates jointed transversely by standard quality butt weld.		
121	Components jointed by standard quality butt weld running longitudinally to the direction of force.		
123	Components jointed by standard quality fillet weld running longitudinally to the direction of force.		
131	Continuous component onto which other components are welded by special quality continuous double bevel butt weld with double fillet weld running at right angles to the direction of force.		
132	Continuous component onto which discs are welded by special quality double bevel butt weld with double fillet weld running at right angles to the direction of force.		
133	Compression flanges and web plates onto which transverse bulk-heads or stiffeners with cut-off edges are welded by special quality double fillet welds. The classification into the present notch case applies only to the zone of the double fillet welds.		
154	Web plates and curved flange plates jointed by special quality double bevel butt weld with double fillet weld.		

Table 30. **Notch case K 2 (medium notch effect)**

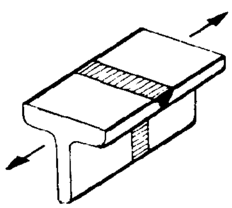
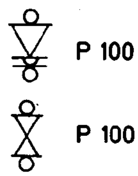
Code	Description and illustration		Symbol
211	Components made from steel sections or steel bars, with the exception of flat steel, jointed by special quality butt weld running at right angles to the direction of force.		

Table 30. **Notch case K 2 (medium notch effect)** (continued)

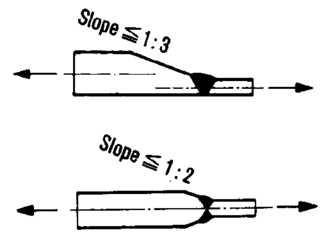
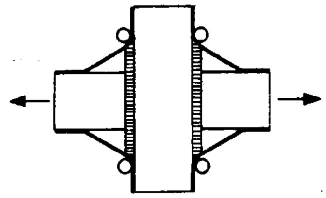
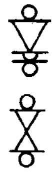
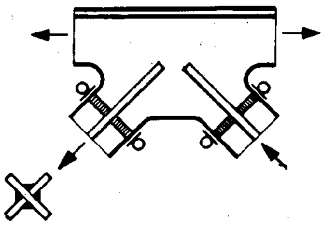
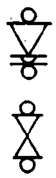
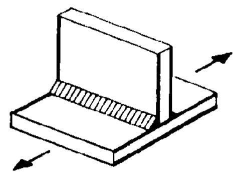
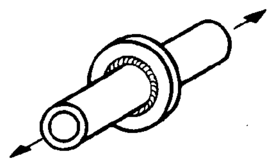
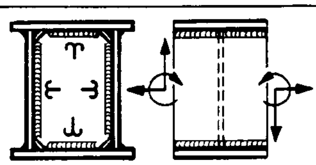
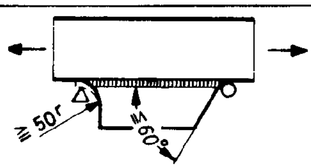
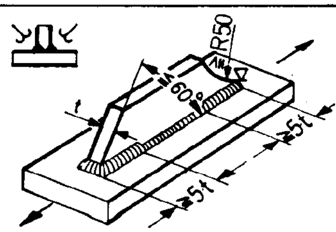
Code	Description and illustration		Symbol
212	Components of different thicknesses jointed by normal quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 3 or with symmetric joint and slopes not exceeding 1 : 2.		 P or P 100 P or P 100
213	Special quality butt weld and continuous component, both at right angles to the direction of force, at flange plate junctions, with welded-on corner plates. Weld ends machined to avoid notch effect.		 P 100 P 100
214	Components welded onto gusset plates by special quality butt weld running at right angles to the direction of force.		 P 100 P 100
231	Continuous component onto which other components are welded by continuous special quality double fillet weld running at right angles to the direction of force.		
232	Continuous component onto which discs are welded by special quality double fillet weld running at right angles to the direction of force.		
233	Flange plates and web plates onto which transverse bulkheads or stiffeners with cut-off edges are welded by special quality double fillet weld running at right angles to the direction of force.		
241	Continuous component onto the edge of which other components with chamfered or radiused ends are welded by a normal quality butt weld running longitudinally to the direction of force. Weld ends machined to avoid notch effect.		
242	Continuous component onto which other components or stiffeners with chamfered or radiused ends are welded longitudinally to the direction of force. The end welds in the zone not less than 5 × t in width are made in the form of special quality double bevel butt weld with double fillet weld.		 End welds only.

Table 30. **Notch case K 2 (medium notch effect)** (continued)

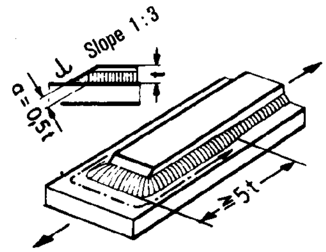
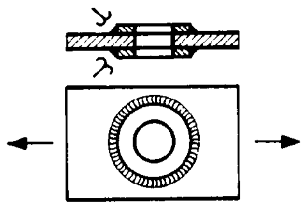
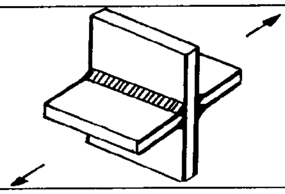
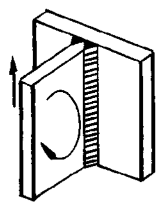
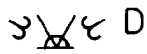
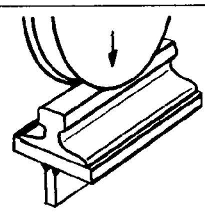
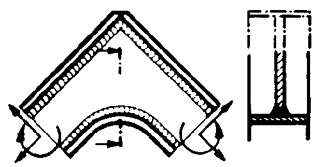
Code	Description and illustration		Symbol
244	Continuous component onto which a flange plate with chamfered end (slope ≦ 1 : 3) is welded. The end weld in the zone not less than ≧ 5 × t in width (as shown in the illustration) is made in the form of a special quality fillet weld with $a = 0{,}5 \times t$.		 End weld only.
245	Continuous component onto which bosses are welded by special quality fillet welds.		
251	Components jointed in a cross joint by special quality double bevel butt weld with double fillet weld running at right angles to the direction of force.		
252	Special quality double bevel butt weld with double fillet weld used for connections subjected to bending and shear.		
253	Special quality double bevel butt weld with double fillet weld between flange and web for concentrated loads acting in the web plane at right angles to the weld.		
254	Web plates and curved flange plates jointed by standard quality double bevel butt weld with double fillet weld.		K

Table 31. **Notch case K 3 (strong notch effect)**

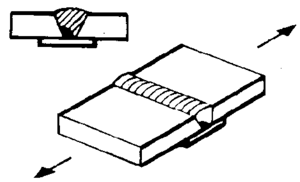
Code	Description and illustration		Symbol
311	Components jointed by one-sided butt weld with root backing, running at right angles to the direction of force.		V

Table 31. **Notch case K 3 (strong notch effect)** (continued)

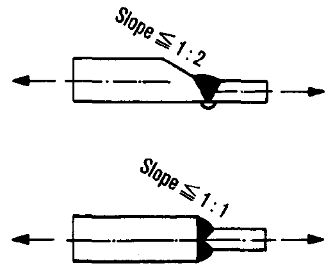
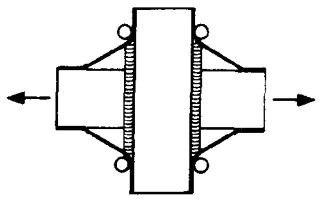
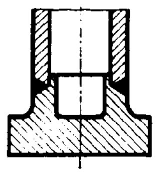
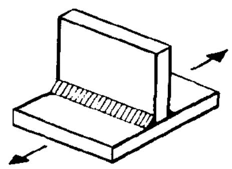
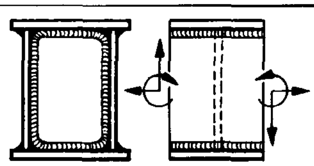
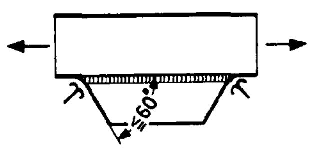
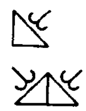
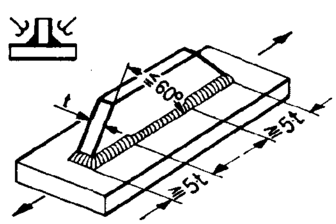
Code	Description and illustration		Symbol
312	Components of different thicknesses jointed by standard quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 2 or with symmetric joint and slopes not exceeding 1 : 1.		 P or P 100  P or P 100
313	Normal quality butt weld and continuous component, both at right angles to the direction of force, at flange plate junctions, with welded-on corner plates. Weld ends machined to avoid notch effect.		 P or P 100  P or P 100
314	Pipes jointed by backed butt weld without sealing weld.		
331	Continuous component onto which other components are welded by standard quality double fillet weld running at right angles to the direction of force.		
333	Flange plates and web plates onto which transverse bulkheads or stiffeners are welded by standard quality continuous double fillet weld running at right angles to the direction of force. The classification into notch case K 3 applies only to the zone of the fillet welds.		
341	Continuous component onto the edge of which other components with chamfered ends are welded by special quality fillet weld running longitudinally to the direction of force. Weld ends machined to avoid notch effect.		
342	Continuous component onto which other components or stiffeners with chamfered ends are welded longitudinally to the direction of force. The end welds in the zone not less than $5 \times t$ in width are made in the form of special quality double fillet welds.		 End weld only.

Table 31. **Notch case K 3 (strong notch effect)** (continued)

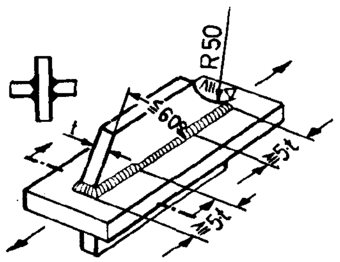
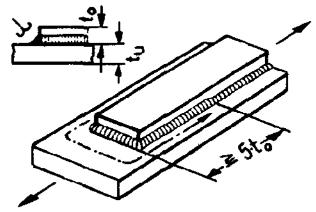
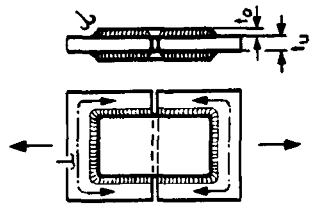
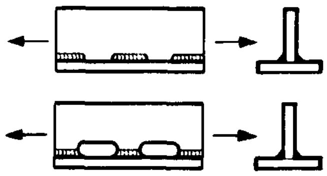
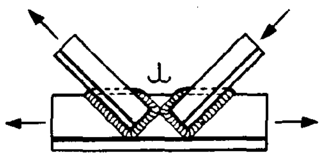
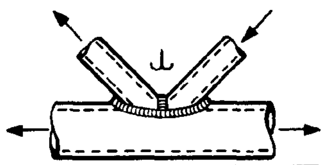
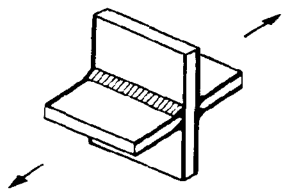
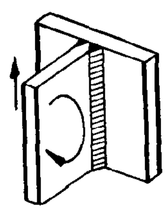
Code	Description and illustration		Symbol
343	Continuous component slotted to accommodate a plate with chamfered or radiused ends, which is welded on. The end welds in the zone not less than $5 \times t$ in width are made in the form of double bevel butt weld with double fillet welds and machined to avoid notch effect.		 End weld only.
344	Continuous component onto which a flange plate is welded with t_o not exceeding $1{,}5 \times t_u$. The end welds in the zone not less than $5 \times t_o$ in width (as shown in the illustration) are made in the form of special quality fillet welds.		 End weld only.
345	Components onto the ends of which butt straps of t_o not exceeding t_u are welded by special quality fillet weld. The end welds are in the form of special quality fillet welds in the zone shown in the illustration. In the case of one-sided overlapping of the joint, the eccentric force effect shall be taken into account.		 End weld only.
346	Continuous component onto which longitudinal stiffeners are welded by intermittent double fillet weld or by standard quality double fillet cut-out weld. The classification into notch case K 3 applies to the weld between the end welds as designed for the stiffeners.		
347	Continuous component onto which members made from steel sections or steel bars are welded by special quality fillet weld running all round.		
348	Tubular members welded together by special quality fillet weld.		
351	Components jointed by cross joint by standard quality double bevel butt weld with double fillet weld running at right angles to the direction of force.		
352	Standard quality double bevel butt weld with double fillet weld used for connections subjected to bending and shear.		

Table 31. **Notch case K 3 (strong notch effect)** (continued)

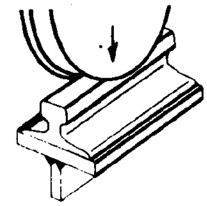
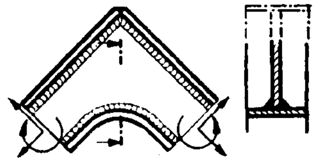
Code	Description and illustration	Symbol
353	Standard quality double bevel butt weld with double fillet weld between flange and web for concentrated loads acting in the web plane at right angles to the weld. 	
354	Web plate and curved flange plate jointed by standard quality double fillet weld. 	

Table 32. **Notch case K 4 (very strong notch effect)**

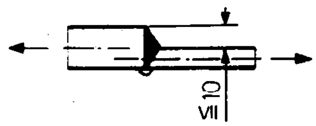
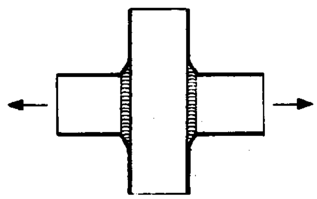
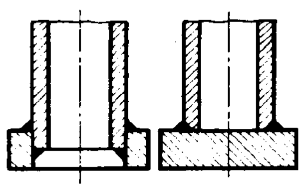
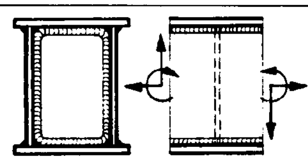
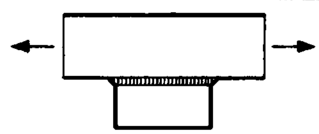
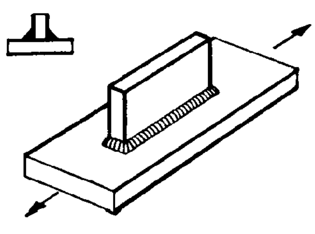
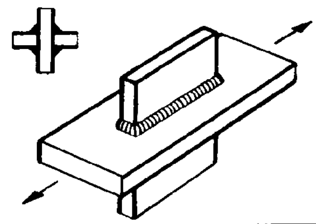
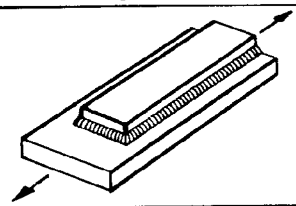
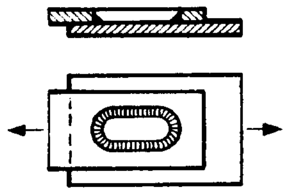
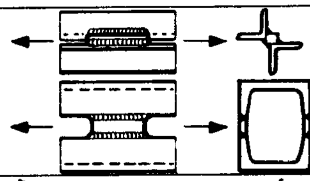
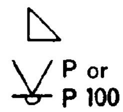
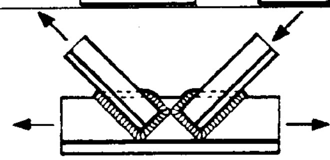
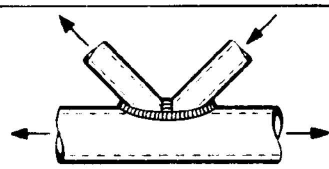
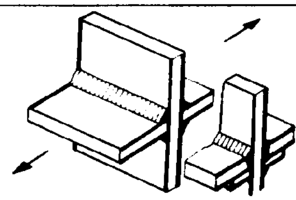
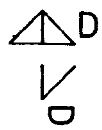
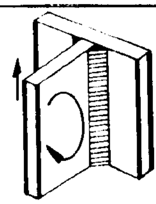
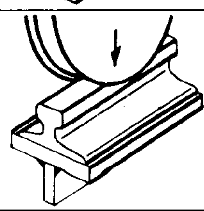
Code	Description and illustration	Symbol
412	Components of different thicknesses jointed eccentrically by standard quality butt weld running at right angles to the direction of force, with supported asymmetric joint without slope. 	 P P
413	Components jointed by standard quality butt weld running at right angles to the direction of force, at flange plate junctions. 	 P P
414	Flanges and pipes jointed by two fillet welds or by single-bevel butt weld with fillet weld. 	
433	Flange plates and web plates onto which transverse bulkheads are welded by standard quality one-sided continuous fillet weld running at right angles to the direction of force. 	
441	Continuous component onto the edge of which other components with right-angled ends are welded longitudinally to the direction of force. 	
442	Continuous component onto which other components or stiffeners with right-angled ends are welded by standard quality double fillet weld running longitudinally to the direction of force. 	

Table 32. **Notch case K 4 (very strong notch effect)** (continued)

Code	Description and illustration		Symbol
443	Continuous component slotted to accommodate a plate with right-angled ends which is welded on by standard quality double fillet weld.		
444	Continuous component onto which a flange plate is welded by a fillet weld.		
445	Holed or slotted components welded to other components by fillet welds in the holes or slots.		
446	Continuous components with batten plates welded in between by standard quality fillet weld or butt weld.		
447	Continuous components onto which members are welded by fillet weld.		
448	Tubular members welded together by fillet weld.		
451	Components jointed by cross joint, by standard quality double fillet weld or by one-sided single-bevel butt weld with fillet weld and root backing, running at right angles to the direction of force.		
452	Standard quality double fillet weld used for connections subjected to bending and shear.		
453	Standard quality double fillet weld between flange and web for concentrated loads acting in the web plane at right angles to the weld.		

Explanatory notes relating to the April 1974 edition

Standard DIN 120 Part 1, November 1936 edition, and its supplements issued at later dates were originally intended to serve as guidelines for the building inspectorate, covering steel structures for both cranes and craneways. Such structures shall be designed and constructed in accordance with most modern techniques of current engineering practice. Since crane structures are constituent parts of machines, whereas craneways are static structures or components thereof, different conditions obviously apply to these two cases; consequently, it was decided right from the start when revising DIN 120 Part 1 to separate the standards according to the subject matter covered by them (DIN 15018 to deal with cranes and DIN 4132 to deal with craneways). They differ where necessary, as in the case of the design loads, but they agree wherever possible, such as in the verification of service strength of the components and connections and joints. The technical committee entrusted with the revision was able on the one hand to make good use of the many years of experience gained with DIN 120 Part 1, and on the other hand to take into account the most recent and well substantiated results of research. In this context, the Supplement to DIN 120, November 1944 edition, has also been withdrawn.

The purpose of the new standards is to enable designers to achieve an economic design and construction which fully meets all safety requirements, on the basis of assumptions closely reflecting actual conditions, and of an adequate computation.

The new features and the changes in comparison with DIN 120 Part 1 are dealt with in these explanatory notes relating to DIN 15018 Part 1, as far as cranes are concerned.

The specifications of this standard are to be applied in their entirety and neither supplemented nor substituted by parts of DIN 120 Part 1, or by other crane standards. In addition, the "Principles of design and construction" (DIN 15018 Part 2) shall be taken into account for the design of crane structures.

The terminology and nomenclature are in harmony with DIN 1080 (symbols used in structural analysis in civil engineering), for the sake of uniformity and clearer understanding. Thus, for example, all external forces, i.e. forces acting in one direction only, are referred to as loads, whereas all internal forces acting in two directions at the banks of cuts are referred to as stress resultants; it should therefore be borne in mind that the term "load" always represents a comprehensive concept not restricted to describing such things as a useful load, a lifted load or an imposed load, as was formerly the case.

Like all similar recently published design principles, DIN 15018 is not intended as a pocket guide for the design and dimensoning of supporting structures. On the contrary, it contents itself with the enunciation of generally valid rules for the design loads, the load cases and the required analyses and verification. The proper application of the present standard presupposes a clear understanding of the relationships between the mode of operation and the design of cranes, allied with a comprehensive engineering grasp of mechanics and with a very thorough knowledge of the behaviour of materials and of structural steel fabricating methods.

Although this standard applies basically to structures made of steel, its principles are equally applicable to other structural materials, such as light metals, on condition that the influences due to the other material are taken into account fully and correctly as regards quantitative relationship.

Re 1 Field of application

Apart from cranes and crane equipment, the field of application also covers mobile steel structures for continuous conveyors, but not craneways, excavators, waggon tippers and mining machinery.

Re 2 Standards and documents referred to

A list is given of those standards and guidelines which are to be observed in all cases without further individual reference and a further list of standards and guidelines to which reference is made in the text of this standard, involving either the entire standard concerned or extracts thereof.

Re 3 Details to be given for design purposes

The following details shall be provided for design purposes: mode of operation, classification into the relevant lifting classes and loading groups, the assumed static system which reflects actual service conditions as closely as possible, or, where appropriate, a suitably simplified static loadbearing system which nevertheless results in an indisputably safe supporting structure, the steel grades used, the cross-sectional values, the stress analyses and verification of stability of all the loadbearing members and essential connections and joints.

Re 4 Design loads

Under this heading, a new approach has been made with regard to the distinction between individual loads.

Crane structures in service are subjected to repeated loads variable with time, which, for their part, trigger variable stresses in the structural components and connections via the interaction of the static system and of the cross-sectional shape. The purpose of making a distinction between main loads, additional loads and special loads is to clearly define these loads and to avoid the risk of dangerous limiting stress conditions, such as damaging stress (H), attainment of the yield point or of instability states (H, HZ, HS), due to the behaviour of the material.

Consequently, all loads which have an effect on the service strength through their actions shall now be regarded as main loads; these include the self weights which are always present, the lifted loads which act during each operating cycle, including their vertical inertia forces, the inertia forces arising from the motion of cranes, crane components and lifted loads, and also the centrifugal forces during slewing.

All the remaining load effects such as wind loads, forces arising from skewing, thermal effects, snow loads, loads on walkways, etc. shall be regarded as additional loads and shall only be taken into consideration in respect of the general stress analysis and of the verification of stability. The same applies for the special loads, such as the tilting forces on crane trolleys with positive guidance of the lifted load, buffer forces and test loads; they are subject to special rules with regard to their interaction with the other loads. The object of introducing these special loads into the overall picture is to ensure that the crane structure, as an essential component of the production tool "crane", is unlikely to suffer any substantial damage which might adversely affect the production sequence, even in the event of unexpected, rare, but nevertheless unavoidable occurrences.

Re 4.1.4 Vertical inertia forces

A distinction has been made between the causes of the vertical inertia forces, i.e. they have been classified into forces due to the motion (travelling, slewing etc.) of cranes or crane components, and into forces due to the hoisting or lowering of lifted loads; both these causes lead to vibrations of the supporting structure, which is therefore subjected to higher stresses than those which arise from assumed static self weights and lifted loads alone. These increased stresses are allowed for in a simplified manner by the adoption of vibration factors, subdivided into self weight factors

(φ) and nominal load spectrum factors (ψ), by which the vertically acting loads, the stress resultants, or the stresses arising therefrom, are to be multiplied.

The self weight factors (φ) apply exclusively for the self weights of the crane, including its associated equipment, as a function of the travelling speed or of the circumferential velocity v_F, and of the condition of the runway; these factors are situated between 1,1 and 1,2. It may be necessary to select higher values of φ in the case of speeds exceeding 200 m/min and of road travel. In such cases, the reasons for the choice of a higher value are to be substantiated and particularly agreed.

In cases where several motions take place simultaneously, it is permitted to use several different self weight factors in order to achieve a closer approximation of true working conditions for the individual groups of components concerned, according to their partial self weights and their partial conditions. The vertical inertia forces due to self weights alone are to be entered in the calculation in the same way as before, in accordance with DIN 120 Part 1.

The inertia forces due to the sudden picking up of lifted loads, which is the condition normally considered here, and which forces in this standard are still assumed to act exclusively in the vertical direction, depend on the one hand on the springing of the system, i.e. on the elasticity of the hoisting ropes and of the crane structure, and on the other hand on the instantaneous hoisting speed at the start of the hoisting operation, which depends on the nominal hoisting speed v_H and on the crane driver's mode of driving. Based on measurement results and on experimental data, the conventional cranes have been classified into lifting classes H 1 to H 4 (table 2) with the nominal load spectrum factors ψ ranging from 1,1 to 1,3 in the case of H 1, and from 1,4 to 2,2 in the case of H 4, in accordance with table 2 and figure 1. The lifted loads, the stress resultants or the stresses deriving therefrom are to be multiplied by these factors. These factors are also intended to make allowance for various uncertainties in the determination of other influences. As in the case of the self weight factors φ, it is permitted, when selecting the nominal load spectrum factors ψ, to approximate the true conditions more closely in individual cases by correlating certain individual structural assemblies which are clearly separated from one another into different lifting classes, if the hoisting conditions are accurately known.

The above comments make it clear that the nominal load spectrum factor ψ has been defined more precisely than was the former compensation factor ψ specified in DIN 120 Part 1; these former compensation factors were designed to allow both for the increased stresses resulting from inertia forces due to hoisting motions and for the reduced service strengths of the materials when subjected to frequently repeated variable stressing. This mixing of two phenomena and characteristics which are entirely unrelated to one another has now been eliminated (see clause 7.4).

Re 4.1.5 Inertia forces arising from driving mechanisms

The inertia forces which arise during the acceleration and deceleration of crane motions depend for their origin on the approximately equal driving and braking torques generated during every operating cycle. As a general rule, the quasi-static inertia forces shall be calculated for both processes (acceleration and deceleration) taking into consideration the mechanical system (distribution of masses, velocity conditions), as well as the efficiencies and the other resistances to motion. In the case of mechanisms, such as travelling gear units, where the transmissibility of the driving forces is restricted by frictional contact, e.g. between a track wheel and a rail, the calculation may be based on an upper limiting value, which depends on the coefficient of frictional contact ($f = 0,20$) and on the minimum wheel loads to be considered for the transmissibility of the largest possible driving force. This applies because the forces must be capable of being frictionally transmitted even under unfavourable conditions, such as the minimum wheel load or the minimum wheel loads, because the proper functioning of the mechanism demands it.

To allow for unavoidable transient oscillation phenomena set up during sudden changes in the drive forces, it is permitted to multiply the difference of the quasi-static force before and after the sudden action of the drive forces by an oscillation coefficient of 1,50 instead of carrying out a more accurate calculation of the dynamic forces. The inertia force effects determined in this way shall be supported in complete harmony with the loadbearing structure and driving mechanism; rules are given in the standard, by way of example, for the distribution of the reactions on the individual track wheels, and for the lateral forces arising therefrom. Subsequent changes of the driving mechanism will involve a change in the design loads of the structure and will always require renewed calculation.

In cases of wide-span cranes equipped with mechanically independent travelling bogies fitted with an electrical straight-line running control and/or an anti-skewing safety device, the necessary allowance shall be made in the calculation for the dynamic effect of the operational error, or (in emergencies) the maximum permissible control error (see DIN 19226) (elastic forward motion).

Re 4.1.6 Centrifugal forces

From now on, centrifugal forces are to be taken into consideration in slewing cranes.

Re 4.1.7 Impact from bulk material

The transient forces generated by the impact of bulk material, which are of very short duration, need only be taken into account as local loads whose action is limited to the loadbearing members immediately affected, and this action need not be followed down to the bearings and track wheels.

Re 4.2 Additional loads

Apart from the additional loads already mentioned, such as the wind loads specified in DIN 1055 Part 4, the thermal effects, the snow loads specified in DIN 1055 Part 5 and the loads on walkways, stairways etc. an important new factor has been added, viz. the forces arising from skewing.

Re 4.2.1 Wind loads

The design dynamic pressure for cranes in service, $q = 250\ \text{N/m}^2$, and the design dynamic pressures for cranes out of service, which are to be entered in the calculation as specified in DIN 1055 Part 4, include the dynamic pressure peaks (wind gusts) and their dynamic effects on the supporting structure. The mean dynamic pressure corresponding to these wind conditions is considerably smaller.

The design dynamic pressure for cranes in service corresponds to a wind condition under which the moving of loads with the aid of the crane remains barely just possible in normal cases. Consequently, there may well be instances where it would be reasonable to specify a higher or a lower design dynamic pressure for cranes in service. Steps shall however always be taken to ensure that crane operation is immediately discontinued when the wind condition approaches a state corresponding to the selected design dynamic pressure for the crane in service.

The adoption of different design dynamic pressures within the context described above may, for example, be considered appropriate in the case of coastal cranes, in order to delay the moment in time when such cranes must be shut down because of the "normal case" wind conditions which occur more frequently along the coast; they may also be considered appropriate in the case of truck-mounted

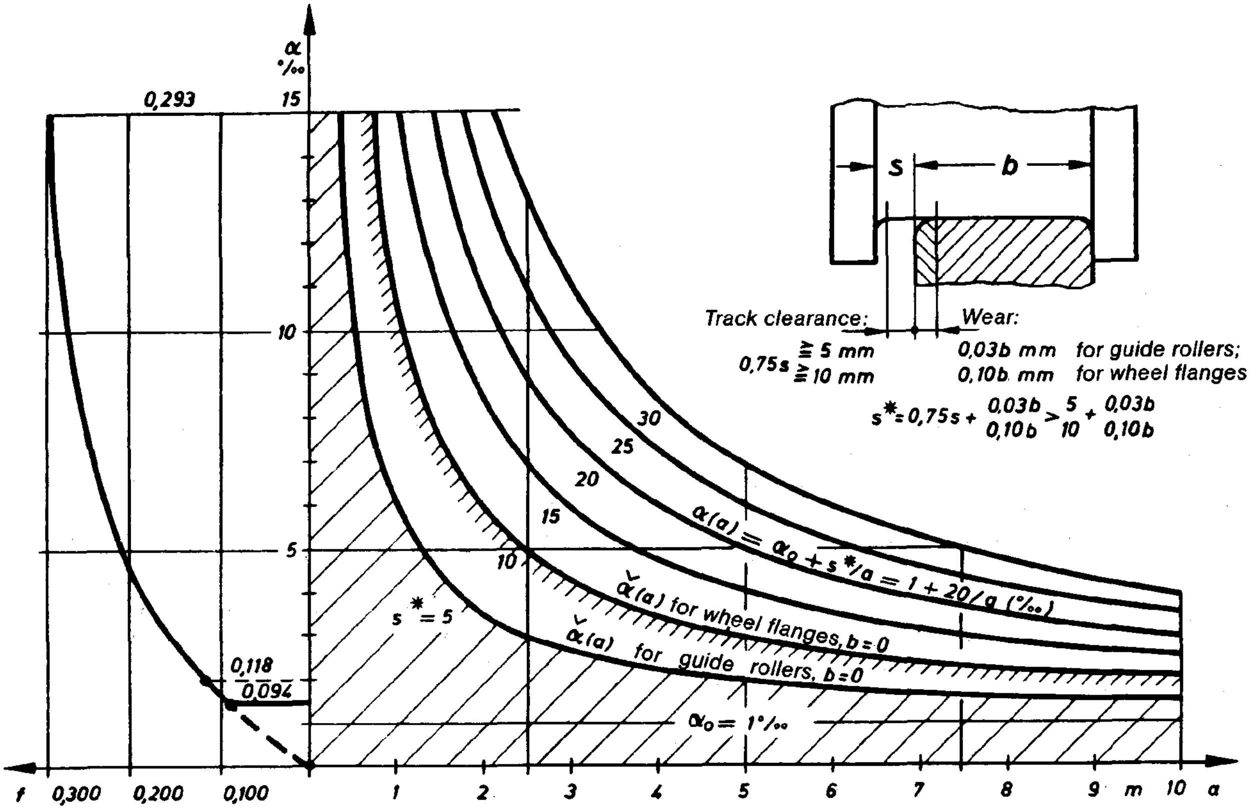


Figure 13.

In the above illustration,

s is the track clearance between rail and guiding means;
b is the width of rail;
a is the centreline distance of wheels or guiding means (see figure 4 in this connection);
α is the skew angle;
f is the coefficient of frictional contact.

mobile cranes and of tower slewing cranes in order to enable the lifting capacity of such cranes to be exploited more fully in wind conditions below the "standard case". This flexible approach to the specification of the design dynamic pressure for cranes in service is in harmony with the views expressed by ISO/TC 96/SC 1, who recommended 125 N/m^2 and 500 N/m^2 as the lower and upper limits respectively for the design dynamic pressure for cranes in service for the calculation of the steel structures. Naturally, where a dynamic pressure deviating from the standard is selected, this pressure is to be taken into account both in the calculation (as described in DIN 15 018 Part 1) and in the verification of stability (as described in DIN 15 019 Part 1 and Part 2).

Re 4.2.2 Forces arising from skewing

Forces arising from skewing are generated when the resultant direction of rolling movement of the travelling crane no longer coincides with the direction of the craneway rail, and when the front positive guiding means come into contact with the rail. As is well known, this unavoidable abnormality is caused by tolerances and inaccuracies which arise in the manufacture of the crane (bores of track wheels) and of the craneway (bends, kinks). The values and distribution of these forces depend chiefly on the clearances of wheel flanges or rollers, also on the number, arrangement, bearing arrangement and rotational speed synchronization of the track wheels and on the location of the guide rollers (if any), or in other words on the systems of the travel mechanism and of the supporting structure. Depending on the possible skew angle *α*, which consists of several components as a result of the causes mentioned, on the centreline distance of the wheels relative to the front guiding means, on the location of the centre of mass of the entire system depending on the position of the crane trolley, and on the location of the slip pole, a positive contact force *S* is generated at the front guiding element (wheel flange or horizontal guide roller) and a group of frictionally transmitted forces is also generated at the contact faces of the track wheels.

Guideline values have been specified for the standard case, on the basis of which the possible skew angle determining the skewing forces can be calculated as a function of the type of guiding means, the track clearance, the wear, and the tolerances of the crane and craneway; only a 75 % track clearance has been taken into consideration, because the skewing crane normally straightens out again before attaining the maximum skew position.

Just as it is permissible, subject to agreement, to deviate from these guideline values and to use a different, well-founded (smaller or larger) value for the skew angle in the calculation, so is it equally permissible to take into account the influence of the overall and local yieldings of the crane and craneway on the forces arising from skewing.

Figure 13 illustrates the relationship between the guideline values, the skew angle and the corresponding coefficient of frictional contact *f*.

The method of calculation described here has been derived from the tracking technique of railborne vehicles, and from the results of detailed investigations carried out by the Braunschweig Technical University, using an experimental crane amongst other things, under the sponsorship of the *Verein Deutscher Maschinenbau-Anstalten* (Association of German Mechanical Engineering Plants) and of the *Verein*

Deutscher Eisenhüttenleute (Society of German Ferrous Metallurgy Engineers).

Re 4.3 Special loads

The following special loads have been introduced into the standard for the first time: the tilting force acting on crane trolleys with positive guidance of the lifted load, on impact against an obstacle, the buffer forces generated when the crane hits stops or buffers, and the test loads applied during loading tests.

The buffer forces are to be determined from the kinetic energy of the colliding crane, assuming certain given travelling speeds, and from the energy diagram of the buffers. The distribution of the buffer forces depends on the location of the centre of mass, on the freedom of movement of the crane on the craneway and on the buffer characteristics; this distribution is to be determined in agreement with the structure and driving mechanism.

The purpose of taking into account "small" and "large" test loads and the associated special load cases is to ensure that the steel structures of those cranes which are subjected to a test loading for inspection tests or at some later inspection date exhibit adequate safety margins in the general stress analysis and in the verification of stability. This special load case may prove to be of significance for the dimensioning of steel structures or members which exhibit a non-linear transmission pattern (loads – stress resultants – stresses); this applies, for example, to all supporting structures or components which are prestressed or which have a variable structural configuration.

The specification of the test loads and details relating to the necessity for, and the actual performance of load tests on cranes in respect of which no verification of stability need be carried out, are dealt with elsewhere.

Re 5 Load cases

All the above-mentioned main loads and additional loads, including the related coefficients, are summarized in table 7 under the heading of "normal load cases" and the special loads are listed under the heading of "special load cases", and the determining interaction of the individual loads can be gathered from this table for each type of crane. All the loads listed in the same column represent a separate load case, and in addition a distinction is made in the case of the normal load cases between H load cases (framed by a thick line) and HZ load cases.

Re 6 Calculation

In addition to the conventional computational stress analysis, the results of strain measurements may also be included in the evaluation if the required safety margins are observed.

As compared with DIN 120 Part 1, the crane manufacturer may now also proceed on the assumption that the craneway is correctly laid, and if that is not the case, the plant operator is under obligation to supply the relevant details.

In addition to structural steel of the conventional steel grades St 37 and St 52, and to tube steel St 35 specified in table 8, other steel grades may also be used on condition that their mechanical and chemical properties and their weldability are adequately guaranteed. In these cases, the permissible stresses are to be derived from the guaranteed yield stress and are to be substantiated from the service strengths at 90% survival probability by tests closely approximating actual service conditions. The stresses shall be determined separately for the individual load cases with the usual cross-sectional values, and as a general rule it is recommended to calculate the stresses for the individual loads and finally to superimpose them as specified in table 7.

In the case of system-dependent non-linear relationships between loads and stresses, the procedure described in DIN 4114 Part 2, February 1953x edition, Ri 10.2, shall be followed as appropriate.

Re 7 Verification and analyses

Re 7.1 General

In the verification and analyses it shall be demonstrated separately for each individual load case as per table 7 that the permissible stresses and/or the required safety factors depending on the load case, type of crane and verification are in fact adhered to in the members and principal connections and joints. Only in certain exceptional cases, involving minor deviations from the design loads, unintentional changes in the support conditions, and conditions prevailing during construction work on site, may the permissible stresses relating to load case HZ specified in table 9 be exceeded, and the maintenance of the required factors of safety relating to load case HZ be no longer compulsory.

Re 7.2 General stress analysis

The general stress analysis is intended to demonstrate by calculation the safety against attainment of the yield point, separately for the H and HZ load cases. The permissible stresses listed in tables 10 to 12 have been adjusted to the values normally used today in structural engineering; the 1,1 times the values specified for load case HZ shall apply for special load case HS as described in table 7. In cases where several stresses act simultaneously, comparison stresses are to be calculated in addition with the stresses assigned to one another in each case.

Re 7.3 Verification of stability

Verification of stability in respect of safety against buckling, collapsing and bulging shall be carried out as described in DIN 4114. As a departure from DIN 4114, different factors of safety against bulging have been specified for full panels and partial panels of flat plates for all load cases (H, HZ, HS). The higher factors of safety specified for full panels now correspond, for $\psi = 1$, to those applying to the permissible compressive stresses in the general stress analysis. These factors are readily and economically achievable in stiffened full panels by appropriately sizing the stiffeners, which are to be designed as continuous members and/or be rigidly supported laterally at the ends. The factors of safety for the partial panels have been adjusted, for $\psi = 1$, to the relative smaller factors of safety to be considered for the permissible tensile stresses in the general stress analysis. Hence the required factors of safety against bulging harmonize with those which are generally required in DIN 4114 Part 1 for web plates, for $\psi = -1$.

The different types of verification of safety against bulging, applicable to "web plates" and to "rectangular plates which are components of a member in compression" (flange plates) as given in DIN 4114 are designed to take into account the differing loadbearing capacity of the plates as a function of the stress distribution. Since the steel structures of cranes normally consist of members subjected to three-dimensional loading, it becomes impossible to make a clear-cut distinction between "web plates" and "flange plates", with the typical stress distributions associated with these terms. In order therefore to take adequate account of the differing loadbearing behaviour of the plates as a function of the stress distribution, differing factors of safety against bulging have been established as a function of ψ; if a plate is subjected to stresses acting on all its edges (web plate subjected to wheel load, web plate at one corner of a frame) then the larger, i.e. the more unfavourable value of ψ shall be used to determine the required factor of safety against bulging.

Furthermore, if in the case of stiffened plates the stiffeners have been designed for the minimum stiffness specified in DIN 4114 Part 2, subclause 18.1 (February 1953x edition), and if only the partial panels have been calculated in respect of bulging, then the factors of safety against bulging applying to the full panel shall also be adhered to for the partial panels.

Complementing DIN 4114, factors of safety against bulging have also been specified for all load cases in respect of circular cylindrical shells, and a formula has been included for the determination of the bulging stresses.

Re 7.4 Verification of service strength

The verification of service strength has been modified in comparison with DIN 120 Part 1, as a result of recent experiments and fresh knowledge. Both the somewhat dubious "compensating factors", ψ, formerly used for this and other unrelated purposes, and the coefficients γ of DIN 120 Part 1 have been discarded. The specifications relating to welded railway bridges have been drawn upon as a useful aid when establishing the more elaborate differentiating system of permissible stresses.

The verification of service strength relating to safety against failure as a result of frequently repeated stresses variable with time need only be carried out for load cases H as described in table 7, for all cranes subjected to more than 20000 stress cycles.

The permissible stresses in this case had to be specified in a different way, according to the following characteristics: according to loading groups, which comprise combinations of differently distributed specific stress collectives with different absolute number of stress cycles, which are likely to cause approximately an equal degree of damage to the members or to the connections, also according to steel grades, types of stress, notch cases and limiting stress ratios.

Since the service strength decreases with increasing stress cycle numbers, N 1 to N 4, and with increasing fullness ratios of the stress collectives, S_0 to S_3 (see figure 8), six loading groups, B 1 to B 6, are listed in table 14 in accordance with the correlations of these two parameters to one another; thus, for example, loading group B 5 applies for the correlations S_1/N 4 and S_2/N 3 and S_3/N 2. The usual types of crane have been classified in table 23 into six loading groups in accordance with the aspects described above, depending on their stressing during operation throughout their intended life.

The classification of a crane is governed by the part of the crane subjected to the most unfavourable stressing; just as in the case of the adoption of self weight factors and nominal load spectrum factors, it is permitted to classify certain individual structural assemblies or members which are clearly separated from one another into different loading groups as specified in table 23, on condition that the service conditions described in table 14 are well known.

In comparison with DIN 120 Part 1, the differentiation in accordance with notch effects of the individual members and connections within each loading group has been included in the present standard for the first time. By analogy with the stress lines dealt with in the specifications for welded railway bridges, the present standard establishes the experimentally verified relationship between permissible stresses, structural shape, type of connection and design of the member concerned and of the connection. Accordingly, a distinction has to be made between eight notch cases for each loading group, viz. W 0, W 1 and W 2 for non-welded components, riveted and bolted connections and K 0 to K 4 for welded components and their joints. Tables 25 to 32 give examples and details for the classification of frequently used structural shapes and connections or joints into these notch cases, including symbols for the welds and test methods in accordance with table 24. All these notch cases are given code numbers to facilitate comparison.

Extensive tests at various limiting stress ratios made it possible to develop, for each steel grade, the values of permissible stress in the verification of service strength for the eight notch cases assigned to each of the six loading

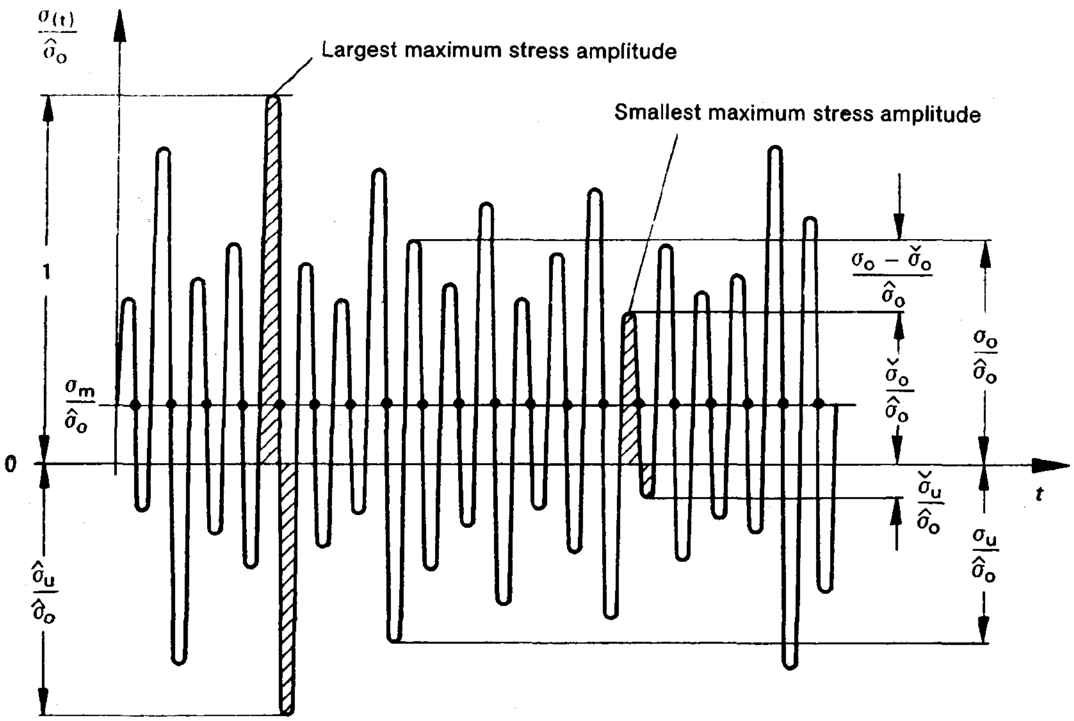


Figure 14 a).

Portion of a stress/time pattern related to the largest maximum stress, with $N = 20$ stress cycles, showing the largest and smallest maximum stress amplitudes and characterized by:

$$\sigma_m = \frac{1}{2}(\min\sigma + \max\sigma) = \text{constant and } x = \min\sigma/\max\sigma,$$

with $\min\sigma \triangleq \hat{\sigma}_u$, $\max\sigma \triangleq \hat{\sigma}_o$ and $|\hat{\sigma}_o| > |\hat{\sigma}_u|$.

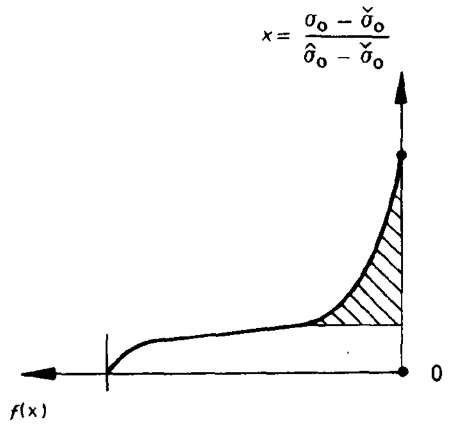


Figure 14b).

Probability density $f(x)$ corresponding to all the stress amplitudes $\sigma_o - \check{\sigma}_o$[7]), related to the greatest difference of the maximum stress amplitudes $\hat{\sigma}_o - \check{\sigma}_o$.

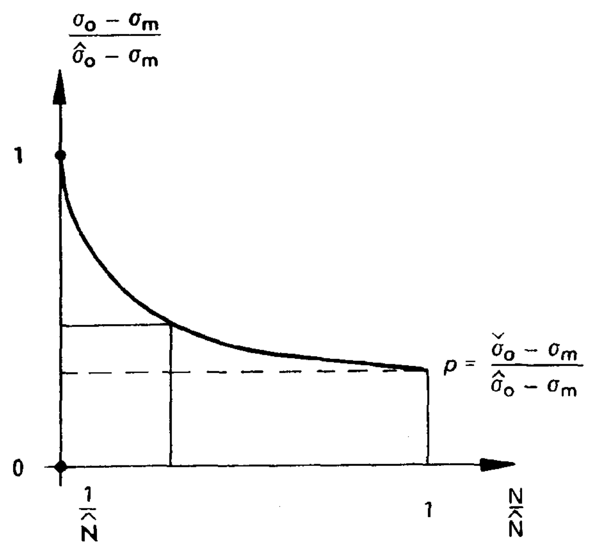


Figure 14c).

Distribution function/relative cumulative frequency stress collective related to the largest stress amplitude

$$N/\hat{N} = 2 \int_x^\infty f(x)\,dx$$

groups using a uniform and simple scheme involving approximately equal factors of safety. As regards the five notch cases for welded components made of St 37 and St 52 steels, the tests indicated that the bearable stresses were approximately equal, and these five cases could therefore be handled in the same way. The values of the stress scheme given in table 17 are based on the alternating stresses with limiting stresses of equal magnitude but opposite sign ($\varkappa = -1{,}0$). Between these basic values there exist constant step ratios depending on the steel grade, the loading group and the notch case. The remaining values for any optional limiting stress ratios between $\varkappa = -1{,}0$ and $+1{,}0$ can be derived with the aid of the established Smith diagram shown in figure 9. The equations for this are given in tables 18 and 19 as a function of the limiting stress ratios. In addition, all the figures are specified in tabular and diagrammatic form in a Supplement to the present standard. If electronic data processing facilities are employed, such tables become superfluous, because the mathematical notations for the permissible stresses in tables 18 and 19 can be incorporated in the computer programmes.

In explanation of figure 8 (idealized related stress collectives) and of table 15 (related stresses $\sigma_o - \sigma_m / \hat{\sigma}_o - \sigma_m$ of the idealized stress collectives), the relationship between a related stress/time pattern $\sigma_{(t)}/\hat{\sigma}_o$ with σ_m = constant, the frequency $f(x)$ and the cumulative frequency

$$N/\hat{N} = 2 \int_{\sigma_o}^\infty f(x)\,dx$$

is illustrated in figures 14a) to 14c). The multistage tests for the determination of the bearable working stresses carried out by the *LBF* in Darmstadt[6]), were based on such stress/time patterns and on a Gaussian normal distribution of the stress amplitudes $\sigma_o - \check{\sigma}_o / \hat{\sigma}_o - \check{\sigma}_o$. The frequency for the purposes of the test was standardized and specified as follows:

$$f(x) = \frac{1}{\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\,\frac{[(\sigma_o - \check{\sigma}_o)/(\hat{\sigma}_o - \check{\sigma}_o)]^2}{0{,}217}\right\}$$

Re 8 Holding ropes and guy ropes

The rules for the calculation of holding ropes and guy ropes are also different from those given in DIN 120 Part 1. The values of permissible stress had to be derived from relatively few experimental values.

Re 9 Tension on prestressed bolts

The data on this subject are new and are based on scientific investigations and on industrial data. Reference is made in this connection to the further work being carried out by *VDI* on the *Systematische Berechnung hochbeanspruchter Schraubenverbindungen* (Systematic calculation of highly stressed bolted connections), (*VDI-Richtlinie* 2230).

Re 10 Tables

Re 10.2 Welds

Simultaneously with the conclusion of the consultations on the present standard, DIN 8563 Part 3 was published; it deals with the evaluation groups for the quality assessment of welded joints. DIN 8563 Part 3 incorporates a new kind of specification of the evaluation groups for welded joints. The previously used designations "Quality 1", "Quality 2" and "special quality" specified in the previous edition of DIN 8563 Part 1 will no longer be used in future.

Attention is also drawn to the fact that the details relating to the symbolic representation of welds are being revised.

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6) *Laboratorium für Betriebsfestigkeit* (Laboratory for service strength), Darmstadt, Technical Bulletin No. 15/65; *Verwendung eines Einheitskollektivs bei Betriebsfestigkeits-Versuchen* (Use of a standard collective for service strength tests).

7) R. Zurmühl. *Praktische Mathematik für Ingenieure und Physiker* (Practical mathematics for engineers and physicists).

Standards and documents referred to

See clause 2.

Previous editions

DIN 120 Part 1: 11.36xxxx

DIN 15018 Part 1: 04.74

Amendments

The following amendments have been made in comparison with the April 1974 edition:

the corrections mentioned in the *DIN-Mitteilungen* 61, 1982, No. 8, pages 496 to 498 have been incorporated.

Clause 2 Standards and documents referred to

The standards and documents to be observed, and in particular those to which reference is made in the text of the present standard, have been brought up to date. This applies to the following standards and documents in particular:

DIN 1080 Part 1, Part 2 and Part 4;
DIN 1055 Part 4 and Part 5;
DIN 8563 Part 3;
DIN 15019 Part 1;
DASt-Richtlinie 010;
DIN 267 Part 3;
DIN 2310 Part 1 and Part 3;
DIN 6917;
DIN 6918;
DIN 17100;
DIN 17111;
DIN 18800 Part 1.

The references to Standards DIN 741, DIN 1050 and DIN 4100 have been dropped, as these standards have been withdrawn.

DIN 18800 Part 1 has been included for the first time, because reference is made to subclauses 3.4, 7.3.1.1 and 7.3.1.2 of the above-mentioned standard in the text of the present standard. (This replaces the references to DIN 4100 in subclause 6.5 of the April 1974 edition of DIN 15018 Part 1.)

Subclause 7.2.1 Load cases and permissible stresses

The USt 36-1 material for rivets has been altered to USt 36 in agreement with DIN 17111.

(The RSt 44-2 material for rivets is no longer included in DIN 17111. For the sake of completeness, it is still specified in the present standard.)

Subclause 7.4.4 Permissible stresses

In table 19 reference is made to the reduced shear stresses in welded joints specified in DIN 4132, February 1981 edition, subclause 4.4.5.

Subclause 10.3 Examples of classification of commonly used structural shapes into notch cases

The qualities of flame-cut surfaces have been designated by symbols '11' and '22' in accordance with DIN 2310 Part 1 and Part 3, in respect of components with the code numbers W 01 and W 11.

Explanatory notes relating to the November 1984 revised edition

The present standard has been revised following an abridged procedure, as already notified in the *DIN-Mitteilungen* 61, 1982, No. 8, pages 496 to 498, and brought in line as far as possible with the most recent state of the relevant standards concerned. In this context, certain references and printing errors have been corrected, and certain editorial changes have been made.

Various comments and more far-reaching suggestions for amendments have been discussed and taken into consideration in so far as it was possible to do so within the framework of the abridged procedure.

Those suggestions which could not be incorporated here have been duly noted and their inclusion has, by common consent, been postponed until such time as the content of the standard will be under review.

A short summary of the most important amendments to the text is given below.

The *Vorläufige Richtlinien für Berechnung, Ausführung und bauliche Durchbildung von gleitfesten Schraubenverbindungen* (Provisional guidelines for the calculation, design and construction of friction grip bolted connections) have temporarily been superseded by *DASt-Richtlinie* 010 *Anwendung hochfester Schrauben im Stahlbau*, because in the current edition of DIN 18800 Part 1 specifications are included relating to loadbearing members subjected to loadings which are not predominantly static, such specifications being of vital importance to crane structures.

The normal load case consisting of main loads and additional loads as described in table 7, column 4, has been specified to conform to anticipated international specifications. Accordingly, it must be assumed that the crane is travelling in steady state condition, and that skewing forces and possibly also wind forces are acting. Consequently, the lifted load shall also be multiplied by the self weight factor φ.

On the basis of recent tests which are not yet completely concluded, it would appear advisable to reduce the values of permissible shear stress in the verification of service strength relative to fillet welds. As a result, an appropriate reference has been made in table 19 to take into consideration in a suitable fashion the reduced shear stresses specified in DIN 4132, February 1981 edition, subclause 4.4.5, in respect of fillet welds and of welds with root notches.

International Patent Classification

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