

Rules for the design of cranes —

Part 2: Specification for classification, stress calculations and design of mechanisms

ICS 53.020.20

Cooperating organizations

The Mechanical Engineering Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following:

Associated Offices Technical Committee*	Department of the Environment (PSA)
Association of Consulting Engineers	Department of Trade (Marine Division)
Association of Hydraulic Equipment Manufacturers	Department of Transport
Association of Mining Electrical and Mechanical Engineers	Electricity Supply industry in England and Wales
British Compressed Air Society	Engineering Equipment Users' Association
British Electrical and Allied Manufacturers' Association (BEAMA)	Federation of Manufacturers of Construction Equipment and Cranes*
British Gas Corporation	Health and Safety Executive*
British Gear Manufacturers' Association	Institution of Gas Engineers
British Internal Combustion Engine Manufacturers' Association	Institution of Mechanical Engineers*
British Pump Manufacturers' Association	Institution of Plant Engineers
British Steel Corporation	Institution of Production Engineers*
British Steel Industry*	London Transport Executive
British Valve Manufacturers' Association Ltd.	Machine Tool Industry Research Association
Cbmpe	Ministry of Defence*
Chartered Institution of Building Services	National Coal Board
Crown Agents for Oversea Governments and Administrations*	Oil Companies Materials Association*
Department of Industry (Mechanical Engineering)*	Process Plant Association
Department of Industry (National Engineering Laboratory)*	Society of Motor Manufacturers and Traders Limited
	Telecommunication Engineering and Manufacturing Association (TEMA)

The organizations marked with an asterisk in the above list, together with the following, were directly represented on the Technical Committee entrusted with the preparation of this British Standard:

British Ports Association	High Commission of India
British Railways Board	Independent Engineering Insurers' Committee
British Transport Docks Board	Institute of Materials Handling
Bureau of Engineer Surveyors	Institute of Quality Assurance
Contractors' Plant Association	Institution of Structural Engineers
Control and Automation Manufacturers' Association (BEAMA)	National Federation of Building Trades Employers
Department of the Environment (Building Research Establishment)	Port of London Authority
Department of Transport	Welding Institute
Federation of Civil Engineering Contractors	Individual manufacturers
Federation of Wire Rope Manufacturers of Great Britain	

This British Standard, having been prepared under the direction of the Mechanical Engineering Standards Committee, was published under the authority of the Executive Board and comes into effect on 31 December 1980

© BSI 2009

The following BSI references relate to the work on this standard:
Committee reference MEE/41
Draft for comment 78/77677 DC

Amendments issued since publication

Amd. No.	Date of issue	Comments
3952	September 1982	
5013	July 1986	Indicated by a sideline in the margin
C1	November 2009	See foreword

ISBN 978 0 580 68450 0

Contents

	Page
Cooperating organizations	Inside front cover
Foreword	iii
1 Scope	1
2 References	1
3 Service life of a mechanism or component	1
4 Classification of mechanisms	1
4.1 General	1
4.2 Class of utilization	1
4.3 State of loading	1
4.4 Determination of group classification	2
5 Loadings to be considered in the design of mechanisms	2
5.1 General	2
5.2 Loading conditions	3
5.3 Load combinations	3
6 Verification of components	4
7 Working stresses	4
7.1 Checking for strength	4
7.2 Checking for fatigue	4
8 Selection of components	6
8.1 General	6
8.2 Shafts	6
8.3 Bearings	6
8.4 Gearing	6
8.5 Ropes and rope reeving components	7
8.6 Lifting hooks	9
8.7 Rail wheels	9
8.8 Determination of limiting bearing stress, P_L	10
8.9 Determination of the coefficient, c_1	10
8.10 Determination of the coefficient, c_2	10
8.11 Verification of bearing stress	10
8.12 Bolts	10
9 Welding	11
Appendix A Typical classification of crane mechanism	12
Appendix B Assessment of torque loading of crane mechanisms	16
Appendix C Determination of fatigue reference stress	17
Appendix D Gearing	21
Appendix E Derating of hooks	21
Figure 1 — Fatigue reference stress factor, $C_{f, r}$	19
Figure 2 — Size factor, C_2	20
Figure 3 — Surface finish factor, C_3	20
Table 1 — Classes of utilization of mechanisms	1
Table 2 — States of loading of mechanisms	2
Table 3 — Group classification of a mechanism	2
Table 4 — Permissible stress, P_c , for mechanism components	5
Table 5 — Mechanism duty factor, G	5
Table 6 — Minimum coefficient of utilization, Z_p	8
Table 7 — Values of H for rope reeving components	9
Table 8 — Limiting bearing stress, P_L	10

	Page
Table 9 — Coefficient, c_1 , for rail wheels	11
Table 10 — Coefficient, c_2 , for rail wheels	11
Table 12 — Hours per day for gear design	21
Table 13 — Derating of hooks (Table 2 of BS 2903:1970)	21
Table 14 — Derating of hooks (Table 1 of BS 2903:1970)	21
Publications referred to	Inside back cover

Foreword

The preparation of a British Standard dealing with design stress levels in the mechanisms of cranes was begun in response to demand from the user industries and particularly the public sector. Whilst British Standards have existed, for many years, concerned with specific mechanical items that are used in cranes, such as steel wire ropes, hooks and antifriction bearings, the process of design of crane mechanisms has received only limited attention in the British Standards for particular types of crane. Following the successful introduction of BS 2573-1 to regulate and rationalize design stress levels in crane structures of all types, and its recent revision to align more closely with international policy in the International Organization for Standardization (ISO), it became increasingly urgent to produce a corresponding standard for crane mechanisms, and developments in ISO Technical Committee 96, Cranes, Lifting Appliances and Related Excavator Equipment, indicated the sort of approach that might be adopted.

Whereas in the case of crane structures there was considerable affinity with the fields of steel girder bridges and the use of structural steel in building which, to some extent, determined the analytical treatment, crane mechanisms involve specialized empirical design and problems can arise in the selection of proprietary components for which there is little precedent in other British Standards. As in the case of BS 2573-1, the “Rules for the design of hoisting appliances Section 1: heavy lifting equipment” of the Fédération Européenne de la Manutention (F.E.M.) were available for the technical committee to consider together with such work of ISO/TC 96 as had reached a definitive form.

A difficult decision had to be taken on the method of classification to adopt because the needs of specially designed cranes and series built standard cranes were to some extent in conflict. An approach, based on ISO work, was finally adopted which enables each mechanism of a crane to be classified in respect of the duty it performs, independently of the design classification of the whole crane. Whilst, to some users, the unfamiliarity of this concept may initially raise doubts, it is considered to give the best possible scope for precise definition of the purchaser’s requirements on the one hand and for rational mechanism design and economic production on the other.

A concept of service life has been defined with the object of providing a basis for compatibility of mechanical components in a mechanism, whether selected proprietary items or purpose designed, in respect of the time during which each component is in motion. In practical terms this should ensure, for example, that the couplings, shafts, gears, bearings, etc., in a particular train all have a comparable basis of durability.

It was essential to recognize in the standard that experience of crane mechanisms under known service conditions is the most valuable and reliable basis for design, and that absolute stress computations are the exception rather than the rule. The content has also been generally confined to the permissible stress and design rule aspects, since any attempt to provide design guidance beyond this level would involve a very extensive practical design manual, which is not the intent of the standard. Mention is made of practical design details only to the extent that they are inseparably associated with the basis for the permissible stresses.

The committee found its scope limited in certain areas where the revision of some British Standards has been held back in order to take advantage of work which is being carried out in ISO. Hooks and the capacity of gears are particular instances in which it should be possible to enlarge the treatment when ISO progress permits.

The selection of steel wire ropes as specified in 8.5, is based on ISO work which is known to have wide acceptance and, in some cases, permits lower factors of safety than have been used in the past. It should be noted that there will often be overriding regulations or other limitations on factors of safety for crane ropes, and also that the provisions in this standard presuppose regular inspection and discard criteria in accordance with established recommendations.

An outline procedure for fatigue verifications has been included, which defines recommended principles, but it is not possible, in the present state of the art, to include a comprehensive treatment, and reference to specialized text books may be necessary.

The rules included for determining rail wheel sizes have been based on F.E.M. and German work which is known to have given satisfactory results in service over a considerable period.

Because cranes lift and transport heavy loads, there is a major safety aspect in their design which has, to some extent, to be related to the level of design stresses permitted. Nevertheless, it has been the general experience of users, manufacturers and the safety authorities that, where design was found to contribute to an accident, it was nearly always caused by bad detail design or failure to appreciate the loadings involved rather than the selection of too high a permissible stress. Whilst, therefore, the present standard has a significant contribution to make to improved standards of industrial safety, it should be emphasized that the main responsibility for safe design will always remain with the manufacturer and designer making proper use of their specialist experience.

In line with current policy, the values in this Part of this British Standard have been expressed in SI units.

The start and end of text introduced or altered by Corrigendum No. 1 is indicated in the text by tags [C1] <C1>.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 22, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 2573 provides the basis for calculating stresses in components of crane mechanisms and specifies the way in which permissible stresses shall be determined. It also gives rules for the selection of proprietary items where these are used as mechanism components.

2 References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3 Service life of a mechanism or component

The service life of a mechanism or component is defined as “the total number of hours during which the mechanism or component is in motion”.

Mechanisms and components shall be designed or selected for a particular intended service life and one of the nominal values specified in Table 1 shall be used.

NOTE 1 In many cases it is desirable that separate components forming part of a mechanism (e.g. the couplings, shafts, gears, bearings, etc., in a particular train) should be designed or selected for the same service life. Where components of a mechanism are brought into use for only part of the time that the mechanism as a whole is in motion, the components can be designed for a shorter service life to take this into account.

NOTE 2 In some cases, economic considerations or technical limitations dictate that a component should be designed or selected for a shorter life than the remainder of the mechanism, so that renewal of the component will be necessary during the life of the mechanism: for example a rope with a service life shorter than that of the remainder of the hoist mechanism can be used.

The service life for which a mechanism or component is designed is a figure used only as a design parameter and shall not be taken as implying a guaranteed life.

4 Classification of mechanisms

4.1 General. For the purpose of applying this Part of this British Standard, mechanisms shall be classified into groups according to their desired service life and the conditions of loading to which they are subjected. The purposes of such classification is to provide a rational and uniform basis for the design of mechanisms and their components that takes account of these considerations. It also provides a framework of reference between the purchaser and the manufacturer. The classification system adopted follows that specified by ISO in ISO 4301.¹⁾

The two factors considered in determining the group to which a mechanism belongs shall be its class of utilization and its state of loading.

4.2 Class of utilization. The class of utilization of a mechanism shall be determined from its assumed service life in hours. This is the total number of hours for which the mechanism will be in motion. Where the appliance of which the mechanism is part has known duties, such as would be the case where it performed part of a continuous, repetitive process, the service life shall be calculated from the actual daily utilization time for the mechanism, the number of working days per year and the number of years of expected service. In the absence of such information regarding the duty of the appliance, an assumed daily utilization time shall be used.

The class of utilization shall be selected according to the value of service life given in Table 1 that is nearest to, but not less than, the assumed service life determined by the procedure outlined in the previous paragraph.

Table 1 — Classes of utilization of mechanisms

Class of utilization	Service life hours	Remarks
T1	400	Irregular use
T2	800	
T3	1 600	
T4	3 200	Regular light use
T5	6 300	Regular intermittent use
T6	12 000	Regular intensive use
T7	25 000	Continuous intensive use
T8	50 000	
T9	> 50 000	

4.3 State of loading

4.3.1 The state of loading characterizes the extent to which a mechanism is subjected to its maximum loading and to smaller loadings.

¹⁾ In course of preparation.

4.3.2 Where details are available of the loading that the mechanism will experience, the nominal load spectrum factor, K_m , and corresponding state of loading shall be determined as follows:

let

P_i be the individual load magnitudes (loading levels) characteristic of the duty of the mechanism (that is $P_1, P_2, P_3, \dots, P_n$);

$P_{\max}$ be the maximum loading applied to the mechanism;

t_i be the individual durations of use of a mechanism at the individual loading levels P_1, P_2, P_3 , etc., (that is $t_1, t_2, t_3, \dots, t_n$);

T be the total duration of use at all loading levels = $(t_1 + t_2 + t_3, \dots, t_n)$;

then the spectrum factor, K'_m , is given by the formula

$$K'_m = \sqrt[3]{\frac{t_1}{T} \left(\frac{P_1}{P_{\max}} \right)^3 + \frac{t_2}{T} \left(\frac{P_2}{P_{\max}} \right)^3 + \dots + \frac{t_n}{T} \left(\frac{P_n}{P_{\max}} \right)^3}$$

The nominal load spectrum factor and the corresponding state of loading are obtained from Table 2 by selecting the value of K_m that is nearest to, but not less than, the calculated value of, K'_m .

4.3.3 When details of the loading to which the mechanism will be subjected are not known, an appropriate nominal state of loading shall be selected and the descriptive remarks in Table 2 used to assist in such cases.

NOTE For purpose-built cranes, the selection of an appropriate nominal state of loading for each mechanism may be agreed between the purchaser and manufacturer.

4.4 Determination of group classification.

When the class of utilization and the state of loading has been determined, the group classification of a mechanism shall be determined from Table 3.

The manufacturer shall in every case specify to the purchaser, and clearly and permanently mark on the crane, the group in which each mechanism of a crane has been classified for design purposes.

Appendix A gives examples of group classification ranges for the mechanisms of various types of crane in particular applications.

Table 2 — States of loading of mechanisms

States of loading	Nominal load spectrum factor, K_m	Remarks
L1 Light	0.50	Mechanisms subjected very rarely to their maximum load and, normally, to very light loads
L2 Moderate	0.63	Mechanisms occasionally subjected to their maximum load but, normally, to rather light loads
L3 Heavy	0.80	Mechanisms frequently subjected to their maximum load and, normally, to loads of medium magnitude
L4 Very heavy	1.00	Mechanisms regularly subjected to their maximum loads

Table 3 — Group classification of a mechanism

State of loading	Classes of utilization								
	T1	T2	T3	T4	T5	T6	T7	T8	T9
L1	M3	M3	M3	M3	M4	M5	M6	M7	M8
L2	M3	M3	M3	M4	M5	M6	M7	M8	M8
L3	M3	M3	M4	M5	M6	M7	M8	M8	M8
L4	M3	M4	M5	M6	M7	M8	M8	M8	M8

5 Loadings to be considered in the design of mechanisms

5.1 General. The following loadings shall be taken into account when designing a mechanism and its components.

R_1 Loads due to the dead weight of the mechanism or component.

R_2 Loads due to the dead weight of those parts of the crane acting on the mechanism or component under consideration.

R_3 Loads due to the weight of the hook load.

R_4 Loads due to the weight of the hook load augmented by the impact factor given in 5.3 of Part 1:1977 of this British Standard.

- R_5 Dynamic loadings arising from the acceleration or braking of the motion and from skewing interaction between crane and track. These loads include those due to the inertia of the mechanism itself, its prime mover, brakes, the associated crane parts, the hook load, the concurrent operation of other motions, etc., as applicable.
- R_6 Loads arising from frictional forces.
- V_1 Loads due to the service wind acting horizontally in any direction, where applicable. (See 5.7 of Part 1:1977 of this British Standard.)
- V_2 Loads due to the out of service wind acting horizontally in any direction where applicable. (See 5.7 of Part 1:1977 of this British Standard.)
- B Loads due to collision with resilient buffers.

Loads shall be quantified by the designer having regard to the part played by the mechanism in the service and environment for which the crane is designed. Appendix B gives guidance on the assessment of torque loading of crane mechanisms.

5.2 Loading conditions. Each mechanism of the crane shall be designed to operate satisfactorily under the most unfavourable combination of loadings that can occur under the following conditions.

Case 1 Normal service without wind.

Case 2 Normal service with wind.

In addition to meeting the in-service requirements under cases 1 and 2, the crane mechanism shall, where appropriate, be designed to withstand the loadings to which they may be subjected under cases 3 and 4.

Case 3 Crane out of service.

Case 4 Exceptional loading conditions appropriate to the type of crane and its application that occur infrequently during its life (e.g. during erection of the crane).

5.3 Load combinations

5.3.1 General. In determining the loading used as the basis for design under each of the loading conditions given in 5.2, the value taken shall be that resulting from the most unfavourable combination of the loads specified in this clause that could actually occur in practice.

NOTE It should be noted that this will not necessarily correspond to the combination of the maximum values of each of the individual loads.

5.3.2 Case 1: normal service without wind

a) Vertical motion: hoisting or lowering

$$1) R_1 + R_2 + R_3 + R_5 + R_6$$

$$2) R_1 + R_2 + R_4$$

b) Horizontal motion: traverse or travel

$$R_1 + R_2 + R_3 + R_5 + R_6$$

c) Horizontal motion: slewing

$$R_1 + R_2 + R_3 + R_5 + R_6$$

d) Horizontal/vertical motion (see note in 5.3.5)

$$R_1 + R_2 + R_3 + R_5 + R_6$$

5.3.3 Case 2: normal service with wind

a) Vertical motion: hoisting or lowering

$$1) R_1 + R_2 + R_3 + R_5 + R_6 + V_1$$

$$2) R_1 + R_2 + R_4 + V_1$$

b) Horizontal motion: traverse or travel

$$R_1 + R_2 + R_3 + R_5 + R_6 + V_1$$

c) Horizontal motion: slewing

$$R_1 + R_2 + R_3 + R_5 + R_6 + V_1$$

d) Horizontal/vertical motion (see note in 5.3.5)

$$R_1 + R_2 + R_3 + R_5 + R_6 + V_1$$

NOTE In computing the acceleration forces, R_5 , it should be remembered that the accelerations achieved can be influenced by the presence of wind forces. In particular, a wind force that opposes a motion can significantly reduce the acceleration, with consequent reduction of the acceleration force.

5.3.4 Case 3: crane out of service

a) Vertical motion: hoisting or lowering

Not applicable

b) Horizontal motion: traverse or travel

$$R_1 + R_2 + V_2$$

c) Horizontal motion: slewing

$$R_1 + R_2 + V_2$$

d) Horizontal/vertical motion (see note in 5.3.5)

$$R_1 + R_2 + V_2$$

5.3.5 Case 4: exceptional loading conditions. The combinations of loads to be considered for this case of loading will depend upon the type of crane, the application and the crane motion. Account shall be taken of any loading conditions that are known to apply but which are not covered under the other three cases of loading.

A specific case is buffer load B , which is covered by 5.6 of Part 1:1977 of this British Standard.

During erection or dismantling operations it should be noted that, unless the operation can be completed during a period when the wind does not exceed V_1 conditions, the parts being erected or dismantled should be so secured that they will withstand a wind of V_2 conditions.