BRITISH STANDARD

BS EN 14587-2:2009

Railway applications — Track — Flash butt welding of rails

Part 2: New R220, R260, R260Mn and R350HT grade rails by mobile welding machines at sites other than a fixed plant

ICS 25.160.10; 93.100

British Standards

National foreword

This British Standard is the UK implementation of EN 14587-2:2009.

The UK participation in its preparation was entrusted to Technical Committee RAE/2, Railway track components.

A list of organizations represented on this committee can be obtained on request to its secretary.

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

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Bahnanwendugen - Oberbau - Abbrennstumpfschweißen von Schienen - Teil 2: Abbrennstumpfschweißen neuer Schienen der Stahlsorte R220, R260, R260Mn und R350HT durch mobile Schweißmaschinen an Orten außerhalb eines Schweißwerkes

This European Standard was approved by CEN on 28 February 2009.

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Contents

Page

Foreword

This document (EN 14587-2:2009) has been prepared by Technical Committee CEN/TC 256 "Railway applications", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2009, and conflicting national standards shall be withdrawn at the latest by October 2009.

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

This document is one of a series of three parts of the EN 14587 "Railway applications – Track – Flash butt welding of rails". The list of parts is as follows:

— Part 1: New R220, R260, R260Mn and R350HT grade rails in a fixed plant;

— Part 2: New R220, R260, R260Mn and R350HT grade rails by mobile welding machines at sites other than a fixed plant;

— Part 3: Welding in association with crossing construction.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EC Directive(s).

For relationship with EC Directive(s), see informative Annex ZA, which is an integral part of this document.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This part of EN 14587 has three main topics:

a) approval procedure for a mobile flash butt welding (MFBW) machine;

b) approval of the welding contractor;

c) weld production.

This part of EN 14587 has been occasioned by a European Directive that will permit the freedom of an open European market. To enable this perception to become a reality, it is essential a standard is in place that satisfies the needs of the infrastructure owners or custodians and reflects the production capabilities of the manufacturers in technical and quality terms.

This part of EN 14587 differs from Part 1 significantly due to the peculiarities of a MFBW machine:

— they are used at different places and for different purchasers within a short time;

— they work in various conditions such as weather, rail, track, worksites, power supply, legal regulations;

— they are operated by contractors, but personnel from different companies (including the purchaser) may be on site for the production of the continuous welded track;

— there are technical differences of the equipment used in order to guarantee the required mobility.

Due to the above mentioned special operating conditions of a MFBW machine, the following requirements have been relaxed as a result:

— minimum bend test requirements for production bend tests only;

— maximum permitted trimmed upset.

This part of EN 14587 does not identify any approval of a MFBW machine in terms of electromagnetic compatibility, vehicle braking systems or any requirements regarding load gauge, environment and its attendant issues or infrastructure access pertaining to any railway authority.

1 Scope

This European Standard specifies requirements for the approval of a welding process by a MFBW machine at sites other than fixed plant, as well as the welding contractor together with the requirements for subsequent welding production. Where a MFBW machine is to be used in a static but temporary situation, the requirements of this part of the standard shall apply.

It applies to new Vignole R220, R260, R260Mn and R350HT grade rails of 46 kg/m and above, as contained in EN 13674-1, welded by a MFBW machine at sites other than a fixed plant and intended for use on railway infrastructures.

This European Standard applies to the welding of rails into welded strings.

2 Normative references

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

EN 571-1, *Non destructive testing – Penetrant testing – Part 1: General principles*

EN 1290, *Non-destructive examination of welds – Magnetic particle examination of welds*

EN 13674-1, *Railway applications – Track – Rail – Part 1: Vignole railway rails 46 kg/m and above*

EN 14587-1, *Railway applications – Track – Flash butt welding of rails – Part 1: New R220, R260, R260Mn and R350HT grade rails in a fixed plant*

EN ISO 6507-1, *Metallic materials – Vickers hardness test – Part 1: Test method (ISO 6507-1:2005)*

EN ISO 7500-1, *Metallic materials – Verification of static uniaxial testing machines – Part 1: Tension/compression testing machines – Verification and calibration of the force-measuring system (ISO 7500-1:2004)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
fixed plant
stationary production line for flash butt welding of rails, as specified by EN 14587-1

3.2
welding process
any part of the sequence from the selection of the rail prior to welding through to the finishing of the welded string

3.3
upset
metal extruded around the rail profile as a result of forging

3.4
die burn
damage caused by localised overheating on the surface of the rail caused by poor contact between the rail and the electrode during welding

3.5
trimming
removal of upset

3.6
trimmed upset
metal remaining around the rail profile following trimming

3.7
dressing
removing trimmed upset by grinding or other similar process

3.8
as welded condition
rails that have been welded and trimmed only

3.9
profile finishing
operation by which the rail head or relevant part of the rail head at the weld is returned to rail profile

NOTE The operation can be by grinding, milling, planing or any other suitable means.

3.10
finished condition
welded, trimmed, dressed and profile finished

3.11
flat spot
process driven discontinuity showing as a small lens-like shape in vertical longitudinal section, or a generally circular/elliptical shape having a localised smooth texture when viewed in a vertical transverse section

3.12
lack of bond
area of incomplete fusion between the rails in the joint

NOTE This may appear as crack like or line discontinuity at the interface either on the surface after removal of the upset or in a weld section.

3.13
welded string
long rail comprising a number of shorter rails flash butt welded together

3.14
MFBW machine
abbreviation for a mobile flash butt welding machine

3.15
purchaser
purchaser of the welds

3.16
railway authority (RA)
either the railway regulator or the owner of a railway infrastructure or the custodian with a delegated responsibility for a railway infrastructure

3.17
contractor
company approved by a RA to provide staff and machinery to execute the production of mobile flash butt welds on that particular infrastructure

NOTE This may include staff and machinery from within the RA.

3.18
manufacturer
manufacturer of the welding machine

4 Requirements for the welding process

4.1 General

All welding shall be carried out on a MFBW machine using an automatic, programmed welding sequence.

4.2 Clamping force

Rails shall be secured in the MFBW machine by clamps of such a surface shape or contour, that when a clamping force is exerted on the rails, it shall not damage the rail in such a way that subsequent cracking in the rail in operation is generated.

4.3 Pre-heating – flashing

The fronts of the heated area shall progress uniformly perpendicularly to the running surface during the whole cycle.

There shall be no evidence of overheating on the ends of the rails during pre-heating – flashing. Once initiated, the flashing process shall not be interrupted.

4.4 Progressive flashing

Once initiated, progressive flashing shall be continuous.

4.5 Upsetting

Upsetting shall immediately follow flashing. Sufficient forging pressure shall be applied to ensure that voids are closed and oxides are expelled such that they are kept to a minimum at the weld interface. The weld interface shall extend into the upset.

4.6 Upset current

The upset welding current shall be maintained until the rapid forge has finished and the progressive forging commences.

4.7 Unclamping

In order to maintain the alignment, the time between completion of forging and unclamping shall be a minimum of 4 s.

4.8 Welding program and records

The welding program (settings) shall be determined during procedural trials and, once approval has been granted, shall not be changed.

The welding machine and/or management system equipment shall be capable of displaying the following:

a) welding program identification and setting details;

b) welding current;

c) upset force or pressure;

d) displacement;

e) welding time.

The welding parameters shall be monitored and recorded. These records shall be referenced to the appropriate welds. The welding parameters shall permit the production of welds without any alteration to the program, at rail temperatures of – 10 ºC and above. Alterations of preheating parameters due to various rail temperatures are not considered as alterations to the welding program. A bending test according to 8.10.3 shall be carried out in this case.

NOTE Due to extreme variations in seasonal temperatures, the contractor may request the use of alternative welding programs.

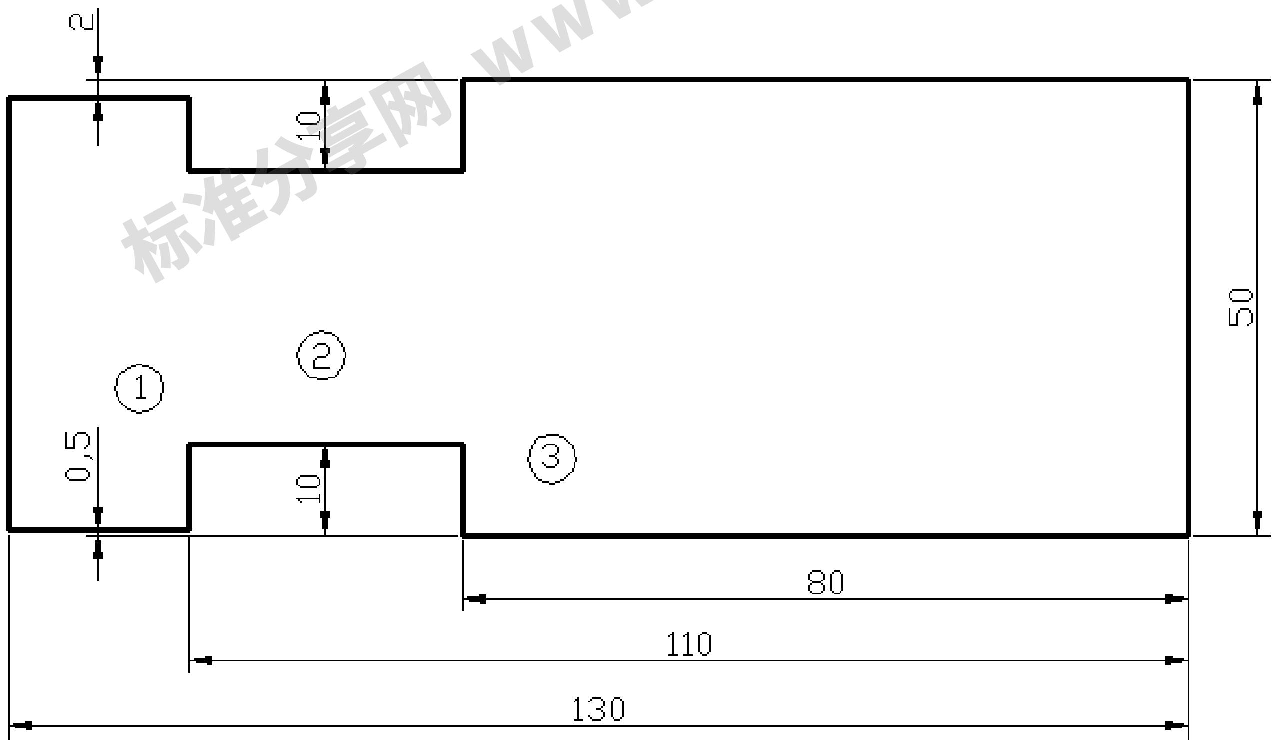
4.9 Step across the weld

Any step between the rails across the weld in the as welded condition (see 3.8) shall not exceed those dimensions shown in Table 1. Checks shall be made using the gauge as shown in Figure 1.

Table 1 — Maximum permitted steps

Position of step on the rail	**Maximum permitted step** mm
Vertically on the longitudinal centreline of the running surface	0,5
Horizontally on the aligned face or edge 14 mm below the running surface	0,5
Horizontally on both edges of the rail foot	2,0

Dimensions in millimetres



Key

① Tip
② Strip recess
③ Stock

Figure 1 — Gauge for measuring the step

4.10 Weld trimming

Weld trimming shall conform to the following requirements:

a) excess upset shall be automatically trimmed;

b) the weld shall be in compression during the removal of excess upset. One side may be released for the shearing operation;

c) removal of the excess upset shall not cause any mechanical or thermal damage to the rails;

d) the surface of the trimmed area shall be free from visible cracking;

e) any dressing of the weld following the removal of upset shall not cause damage to the rail or weld nor reduce either to a dimension below the original rail profile;

f) attention shall be given to the quality of trimming on the underside of the rail foot;

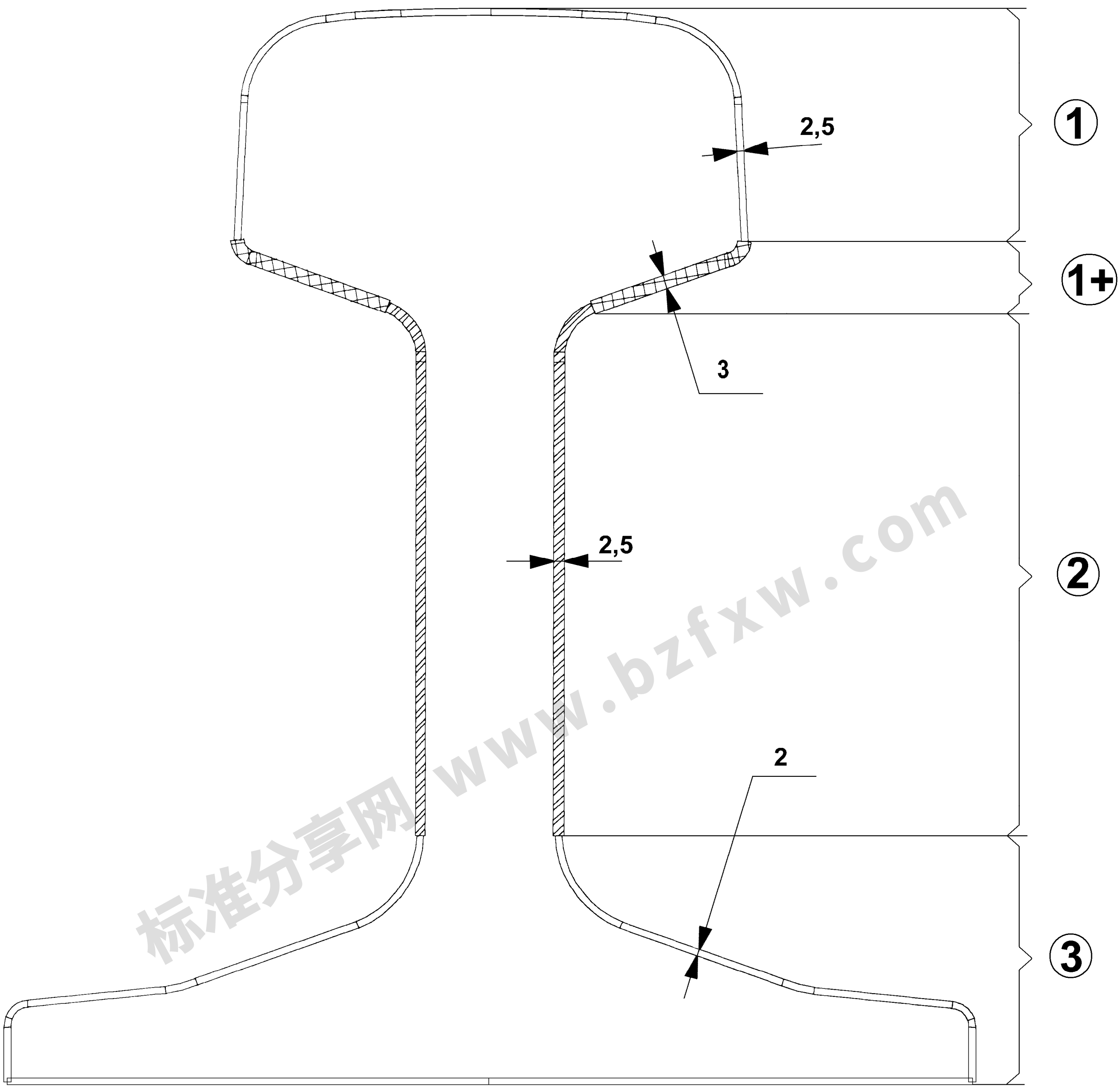
g) the upset shall be free from tearing, notches from the extrusion, cracks, undercut or damage to the adjacent rails;

h) the maximum thickness of the trimmed upset shall be as set out in Table 2 and shown in Figure 2. Where there is a difference in the rail dimensions, the trimmed upset shall be measured in relation to the rail giving the maximum protruding surface. If the values of the trimmed upset are above the maximum values, the trimmed upset shall be dressed locally to the required values without damaging the parent rails.

Table 2 — Maximum permitted trimmed upset

Zone	**Position of trimmed upset about the weld**	**Maximum permitted upset** mm
1	Full head profile from the lower corner on the gauge face to the lower corner on the opposite face	2,5
1+	The fishing surface on the underside of the head	3,0
2	The web, from the end of the top fillet radius and extending down to the start of the bottom fillet radius	2,5
3	The foot, including the start of the bottom fillet radii in the web and extending to the foot tips and completely across the underside of the rail foot	2,0

Dimensions in millimetres



Key

① Zone 1 – rail head
(1+) Zone 1+ – on the underside of the rail head
② Zone 2 – web of the rail
③ Zone 3 – foot of the rail

Figure 2 — Maximum permitted trimmed upset

4.11 Post-weld heat treatment

For the grade R260Mn, a post-weld heat treatment could be required.

For the grade R350HT, a post-weld controlled accelerated cooling could be required.

NOTE The post-weld controlled accelerated cooling is carried out after the removal of excess upset.

5 Procedure approval of a MFBW machine

5.1 General

Procedure approval shall be carried out for each individual machine (no type approval) by testing weld samples produced in accordance with this European Standard.

Procedure approval testing shall be carried out on the rail profile 60E1 or 60E2 and grade R260.

All test results and weld fracture faces shall be made available for inspection.

5.2 Sample preparation

The rail ends shall always be sawn or disc cut to the tolerances as specified in 8.2. The rail brand marks shall be removed from any electrical contact area. Areas of electrical contact on the rails and the machine shall be cleaned to bright metal to give a consistent and good electrical contact at the interface. The rails shall not be damaged by the cleaning operation or through poor electrical contact.

Rails shall be positioned in the welding machine such that the welding interface is central to the contact electrodes as assessed by visual or mechanical means.

Five welds in the as welded condition (see 3.8) shall be manufactured for bend testing (see 5.3.5). No pressing is permitted to correct the geometry of these test welds.

NOTE The contact surface with the stamp of the test press can be prepared by grinding, if necessary.

Depending on the type of fatigue test specified by the purchaser, ten welds in the finished condition (see 3.10) shall be taken for the staircase test method, or three welds in the finished condition (see 3.10) shall be taken for the past the post test method.

5.3 Approval tests

5.3.1 Visual inspection

All of the welds and rails shall be inspected visually for welding, trimming, clamping or profile finishing imperfections, such as tears, cavities, cracks, damage and thermal damage, in particular, in the electrode contact areas.

5.3.2 Weld trimming and upset examination

The upset shall be in accordance with 4.10.

5.3.3 Step across the weld

All the welds submitted in the as welded condition shall be measured to determine the step across the weld, which shall conform to 4.9.

5.3.4 Magnetic particle or dye penetrant inspection

Following visual inspection, all of the welds in the finished condition (see 3.10) shall undergo magnetic particle inspection in accordance with EN 1290 or dye penetrant inspection in accordance with EN 571-1.

The profile finished area and the area of the electrode contacts shall be checked. The inspected area shall be free of cracks. If any defects are revealed the welding process shall be deemed unsuitable.

5.3.5 Bend testing

The five welds in the as welded condition having met the requirements of 5.3.1 to 5.3.4 shall be subject to bend testing in accordance with Annex A.

Each bend test shall be continued until fracture occurs or be terminated when the force limit of the press is reached, provided that the bend test values have reached the values given in Table A.1. For the latter case, the weld shall be notched to ensure that fracture occurs in the welding zone, and the test weld shall be fractured.

If fracture occurs about the weld line the fracture surfaces shall be inspected. The details of any weld imperfection shall be recorded in accordance with Annex B. Lack of bond shall not be permitted. Flat spots shall not be considered to be lack of bond.

If fracture occurs remote from the weld the fracture surfaces shall be checked for the presence of die burn, which if detected shall cause the process to fail approval. If fracture occurs within the rail for reasons other than die burn then another test weld specimen shall be substituted for testing.

The five tested welds shall meet the test requirements for the given rail profile and grade specified in Table A.1

5.3.6 Macro examination

Four welds in the finished condition shall be sectioned for macro examination in accordance with D.1 and shall conform to the following requirements:

a) The visible heat affected zone shall be of a nominally symmetrical shape about the weld line and fall within the widths of 45 mm maximum and 20 mm minimum. The permissible deviation between the maximum and minimum dimension of the visible heat affected zone on any weld shall not exceed 20 mm. This requirement shall apply equally to the vertical axis cuts through the full rail depth and those taken from each rail foot.

b) There shall be no evidence of lack of bond, inclusions, cracks or shrinkage. Imperfections that cannot be positively identified by macro examination shall be inspected by micro examination.

c) In case that flat spots are found, they shall be checked by micro-examination at 100 x magnification. If any cracks are found, the process is rejected.

5.3.7 Micro examination

Following the completion of the macro examination, a micro examination shall be carried out in accordance with D.2. There shall be no evidence of martensite or bainite at 100 x magnification in the visible heat affected zone.

5.3.8 Hardness testing

Two of the four full rail depth longitudinal vertical sections taken for macro and micro examination shall be subjected to hardness testing which shall be carried out in accordance with Annex E.

The minimum and maximum hardness values obtained shall conform to the following requirements:

a) minimum hardness shall not be less than P - 30 HV_{30}

b) maximum hardness shall not exceed P + 60 HV_{30}

where:

P is the average hardness of the unaffected parent rail as measured in the hardness traverse

An isolated hardness value falling outside of the stated minima and maxima above shall be permitted when such a hardness value falls between the two adjacent values that conform to the requirements.

If these requirements are not met, the process is rejected.

5.3.9 Fatigue testing

The fatigue test shall be carried out in accordance with Annex C. Depending on the requirements of the purchaser, this shall be either a staircase test or past the post test. If the results do not meet the requirements in Annex C, the process is rejected.

The number and condition of test pieces required for testing is specified in 5.2.

5.4 Test result report

A report, which contains the results, shall be produced. It shall include a record of:

a) the rail supplier;

b) heat number and chemical analysis of the rail;

c) the parameters and welding settings according to 4.8;

d) results from the tests in 5.3.1 to 5.3.9 including photos of the fracture faces (one per sample) of all broken test welds;

e) results from macro and micro examination;

f) the rail profile grid shown in Annex B.

6 Approval of other rail profiles or grade

6.1 General

Following the initial process approval with a particular rail profile and grade, other rail profiles and the other rail grades as contained in EN 13674-1, shall be undertaken to approval as and when required.

6.2 Approval tests

6.2.1 General

For each grade and profile required, bend testing shall be carried out in accordance with 5.3.5.

Approval given to a particular rail profile and grade shall also permit approval for similar rail profiles and dissimilar grades, provided that a pre-production bend test satisfies the requirements of the lower grade material.

The test result shall be reported in accordance with 5.4.

6.2.2 Grade R220

For the grade R220, there are no additional requirements.

6.2.3 Grade R260Mn

For the grade R260Mn, the micro examination in accordance with 5.3.7 shall be carried out additionally.

6.2.4 Grade R350HT

For the grade R350HT, the hardness test in accordance with Annex E shall be carried out additionally. The results shall be in accordance with the following requirements:

The minimum and maximum hardness values obtained within 10 mm each side from the fusion line shall conform to the following requirements;

a) minimum hardness shall not be less than 325 HV_{30}

b) maximum hardness shall not exceed 410 HV_{30}

An isolated hardness value falling outside of the stated minima and maxima above shall be permitted only when found at the weld centre line.

7 Approval of the Welding Contractor

7.1 General

The approval consists of the Initial Approval (7.2) and the Field Approval (7.3).

7.2 Requirements for initial approval

7.2.1 Welding procedure

The welding contractor shall use welding procedures and MFBWs that are approved in accordance with the requirements of Clause 5 of this European Standard.

7.2.2 Quality systems

The contractor shall operate an independently approved and audited quality management system. Additionally, a product quality plan shall be validated by the purchaser. The quality system shall contain a system of traceability for all welds produced (see 8.5).

NOTE A quality management system conforming to EN ISO 9001 will be deemed to satisfy the requirements.

7.2.3 Information to be provided by the contractor

The following information shall be provided as relevant by the contractor:

a) maximum track gradient capability;

b) maximum length of free rail welding capability which shall include:

   1) support on or by frictionless rollers or similar, to enable free longitudinal or lateral movement

7.2.4 Operators

The welding contractor shall maintain a system that ensures the competence of their welding operators by appropriate training and assessment.

7.2.5 Supervision

The welding contractor shall maintain a management and supervision system of flash butt welding that complies with the requirements of the purchaser.

7.2.6 Weld Inspection

The welding contractor shall maintain a system of weld inspection according to the purchaser requirements. Non-conformances found during these inspections shall be recorded in the traceability system.

7.2.7 Equipment

Equipment shall comply with the operating manual. Inspection and calibration equipment shall comply with those requirements as agreed between the contractor and the purchaser.

7.3 Field approval of the welding contractor

The approval shall be granted after execution of 30 welds on track (carried out in 2 shifts) if they satisfied the weld acceptance criteria defined by the purchaser in accordance with 8.

7.4 Audits

The purchaser reserves the right to audit the welding contractor at any time.

8 Weld production and acceptance requirements

8.1 Information from the purchaser

The following information as a minimum shall be supplied by the purchaser:

a) the rail profile;

b) the rail grade;

c) the profile class as in EN 13674-1;

d) the straightness class as in EN 13674-1;

e) geometrical acceptance criteria class/classes, see 8.9;

f) weld identification, duration and type of records, see 8.5 and 8.11;

g) production bend test frequency.

8.2 Site preparation of rail ends

Rail ends shall always be sawn or disc cut and the end squareness shall be within the tolerances as specified in Figure 3.

Dimensions in millimetres

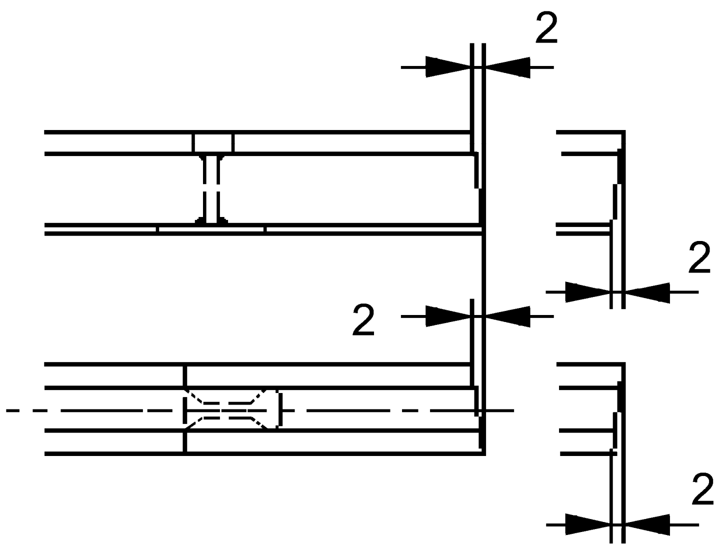


Figure 3 — Measurement of the rail end squareness

8.3 Rail alignment

For reasons of asymmetry all rails shall be welded with the brand marks at the same side. If this cannot be achieved, the contractor shall inform the purchaser accordingly.

8.4 Weld parameter monitoring

The welding programme and parameters shall be as those for which approval was granted.

Automatic monitoring and recording of the weld parameters shall be required for all production welds.

Alterations of preheating parameters due to various rail temperatures are not considered as alterations to the welding program. A bending test according to 8.10.3 shall be carried out in this case.

8.5 Weld identification

The weld shall be marked at the time of production by such a means that it can be identified in track as specified by the purchaser in 8.1 f).

The means of weld identification shall permit traceability to the records and information obtained at the time of production.

8.6 Visual inspection

All of the welds and rails shall be inspected visually for welding, trimming, clamping or profile finishing imperfections, such as tears, cavities, cracks, damage, geometrical non-conformities and thermal damage, in particular, in the electrode contact areas.

8.7 Steps across the weld

A weld with a step exceeding the maximum dimension as specified in 4.9 shall be removed from the welded string. The weld shall be removed by cutting at a minimum distance of 100 mm on each side of the weld.

Where the step exceeds the limits owing to differences in the rail dimensions, the contractor shall inform the purchaser accordingly.

8.8 Profile finishing of the rail head

8.8.1 Initial grinding

If the remaining upset at the rail head is larger than 0,50 mm, the upset at the rail head of all welds produced shall be rough ground, leaving a maximum of 0,50 mm above the running surface and the running edge of the rail. If required by the RA, the field side of the rail head shall be ground to profile.

8.8.2 Final grinding

Final grinding shall be carried out in-track with the rail fastened in position over a minimum distance of three sleepers each side of the weld. Profile finishing of the rail head shall be carried out and contained in the shortest possible length, but shall not exceed the limits in Table 3.

The correction of the weld alignment, if required, shall be carried out by pressing.

Any pressing operation shall be carried out when the rail temperature is less than 200 ºC.

The profile finishing shall not cause any thermal or mechanical damage to the weld or rail.

The contour of the rail head shall be retained during profile finishing.

If required by the RA, the field side of the rail head shall be ground to profile.

8.9 Geometrical acceptance criteria

The straightness of the welded joint after pressing and profile finishing shall be measured vertically and horizontally within a 1 m span.

The horizontal straightness of the head shall apply to running edges only.

Any deviation from straight shall be in accordance with Table 3, at ambient temperature.

Straightness and flatness shall be measured when the weld is at ambient temperature and secured in its final position. The weld shall conform to the requirements of Table 3.

Table 3 — Tolerances for straightness and flatness of flash-butt welds at ambient temperature

Dimensions in millimetres

Weld alignment	Class 1	Class 2	Class 3	Class 4	Class 5
Vertically on the running surface	+ 0,3 + 0,1	+ 0,4 0	+ 0,3 - 0,20	+ 0,3 - 0,15	+ 0,2 - 0,10
Grinding length	max. 400 mm each side		max. 600 mm		
Horizontally on the head	+ 0,3 0	± 0,4	± 0,5	± 0,5	± 0,5
Grinding length	max. 400 mm each side		max. 300 mm		
Running surface flatness, measured over the length of the ground area	0,15	0,20	0,20[a]	0,15 [a]	0,10 [a]
NOTE 1 For horizontal alignment, positive tolerances will widen gauge. NOTE 2 The purchaser may select from the classes 1 or 2 above, different classes for vertical and horizontal straightness and flatness					
[a] to be checked for peaked weld only					

Straightness and flatness across the weld shall be measured as follows:

a) the vertical straightness across the running surface shall be measured along the longitudinal centre line of the rail with the weld centrally between and referenced to datum points on the rail 500 mm either side of the weld.

b) the horizontal straightness of the weld across the rail head shall be measured on the gauge face at a point approx. 14 mm below the running surface and referenced to datum points on the rail 500 mm either side of the weld centreline.

c) the running surface flatness at the level of the weld shall be measured by means of a 1 m straight edge positioned over the ground area. The maximum gap between the straight edge and the ground running table of the rail shall be in the class of Table 3 as specified by the purchaser in 8.1 e).

d) the means of measuring the weld straightness and flatness as described in 8.9 shall be the choice of the contractor but in the case of any dispute a calibrated straight edge and feeler shims shall be used.

8.10 Weld production testing

8.10.1 General

A test weld shall be produced or selected at a frequency of at least one per week whilst the MFBW machine is in production but regardless of production rate, and subjected to bend testing in accordance with 8.10.3. All test welds shall be in the as welded condition. The contact surface with the stamp of the test press can be prepared by grinding, if necessary.

All test welds shall be at ambient temperature when tested. If enhanced cooling is applied other than as part of normal production, the cooling method shall be recorded on the test data sheet.

Test welds shall either be selected from the production line or be made using short test pieces.

8.10.2 Additional test requirements

In addition to the routine requirements for bend tests, the following occurrences will require a mandatory bend test:

a) immediately following rectification of a welding machine malfunction;

b) immediately following machine overhaul or work other than normal maintenance;

c) any change to another approved procedure, if the procedure has not been used in the previous 4 weeks.

8.10.3 Bend test

When using a MFBW machine in track, welds can be made between rails supplied by more than one manufacturer and the differences in rail composition and rolling tolerances that can occur, may result in the bend tests giving spurious results. For this reason, a separate Table A.2 has been introduced for minimum bend test loads for production welds.

The bend test shall be carried out in accordance with Annex A. The load need be applied only until the minimum production test load limit is reached, after which the test can be terminated.

The requirements for minimum bend test load for weld production tests shall be in accordance with Table A.2.

A record shall be retained of the applied load and deflection and shall include the rail profile and grade, date of welding and reason for the test.

Upon completion of the bend test, should the weld have fractured, the fracture surfaces shall be examined and weld features as described in this European Standard shall be recorded. Such defects shall be investigated in accordance with 5.3.5.

8.10.4 Interpretation of results

Upon completion of the test the results shall be interpreted as follows:

If the weld has not fractured at the specified minimum production test load and the minimum deflection value, it shall be deemed to have met the required standard.

If the weld fails to meet the specified minimum production test load or the minimum deflection value, then the following actions shall be taken:

a) the contractor shall carry out an investigation;

NOTE Production may commence or continue, as decided by the purchaser.

b) the contractor shall report the findings of 1) and the proposed corrective action to the purchaser;

c) the problem shall be resolved by the contractor taking appropriate corrective actions;

d) if the problem cannot be resolved to the satisfaction of the purchaser, the following action shall be taken:

   1) in case that the failed bend test was at the beginning of a sequence, the weld manufactured immediately following the failed bend test shall be removed from track for further bend testing. Failure of this weld shall require further bend testing until a satisfactory result is achieved.

   2) in case that the failed bend test was within a sequence, the weld manufactured immediately prior to and following the failed bend test shall be removed from track for further bend testing. Failure of one or both of these welds shall require further bend testing in the direction of the failed weld(s) until a satisfactory result is achieved.

8.11 Documentation

For each weld, the following records shall be retained for a period of not less than five years and be made available to the purchaser as and when requested:

a) weld identification and location;

b) weld parameter monitoring;

c) production bend test results;

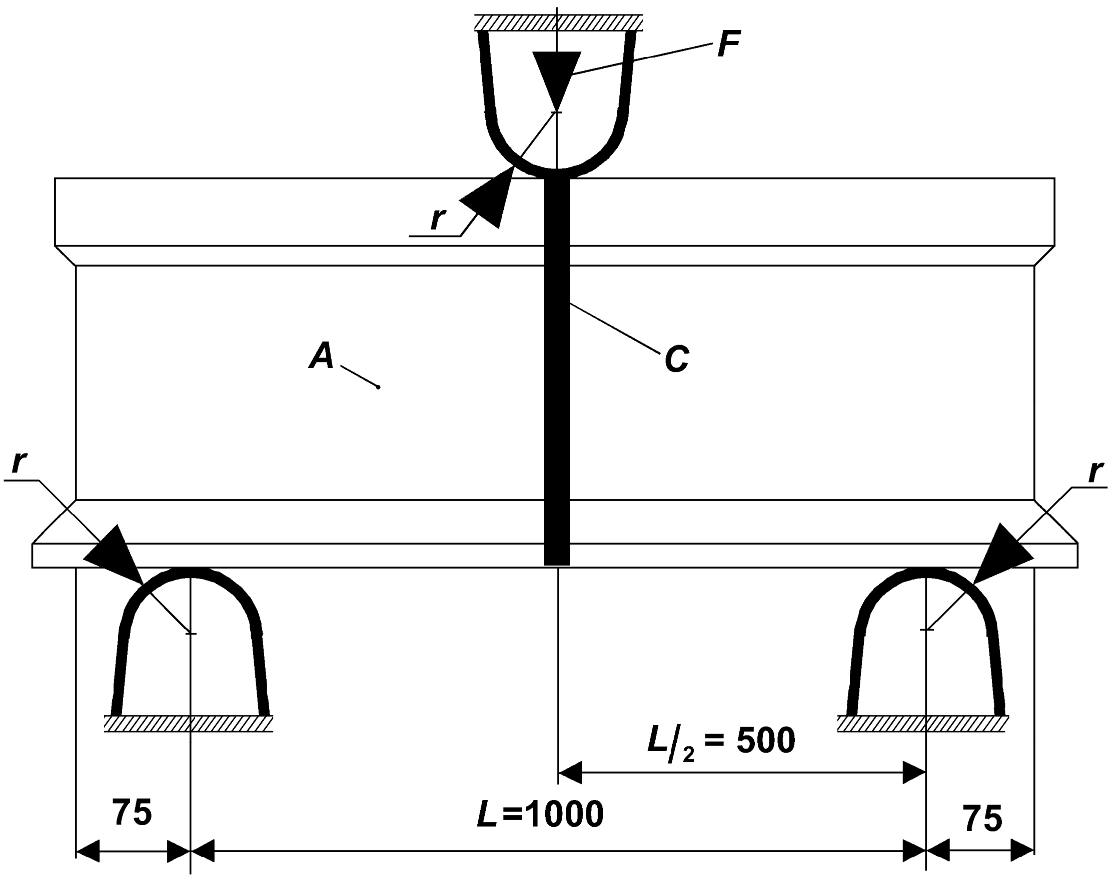
d) weld alignment data, if required.

Annex A
(normative)

Bend test requirements

An example of a bend test arrangement is given in Figure A.1.

Dimensions in millimetres



Key

F force

A rail

C weld

NOTE 1 r: 25 mm to 70 mm

NOTE 2 loading rate: 40 kN/s to 120 kN/s

Figure A.1 — Bend test arrangement

Table A.1 — Minimum bend test requirements for approval

Rail Profile	Minimum bend test deflection mm	Minimum bend test force kN	
	R220, R260, R260Mn and R350HT Grades	R220 Grade	R260, R260Mn and R350HT Grades
60E1	20	1500	1600
60E2		1500	1600
56E1		1230	1330
55E1		1200	1300
54E1	25	1230	1330
54E2		1170	1270
54E3		1080	1180
52E1		1100	1200
50E6		1070	1170
50E3		1060	1160
49E1	30	950	1050
46E1		910	1010
46E2		930	1030

Table A.2 — Minimum bend test requirements for production

Rail Profile	Minimum bend test deflection mm	Minimum bend test force kN	
	R220, R260, R260Mn and R350HT Grades	R220 Grade	R260, R260Mn and R350HT Grades
60E1	20	1425	1520
60E2		1425	1520
56E1		1170	1265
55E1		1140	1235
54E1	25	1170	1265
54E2		1110	1205
54E3		1025	1120
52E1		1045	1140
50E6		965	1110
50E3		1005	1100
49E1	30	900	995
46E1		865	960
46E2		885	980

Annex B
(normative)

Test weld fracture faces – Recording of defects

All weld fracture faces from the approval tests referred to in 5.3.5 and 6.2, and all weld fracture faces from production tests referred to in 8.10 shall be inspected and the details of any weld defects recorded on the rail profile grid shown in Figure B.1. The record shall show the following details relative to each defect:

a) size: x and y dimensions;

b) shape;

c) location;

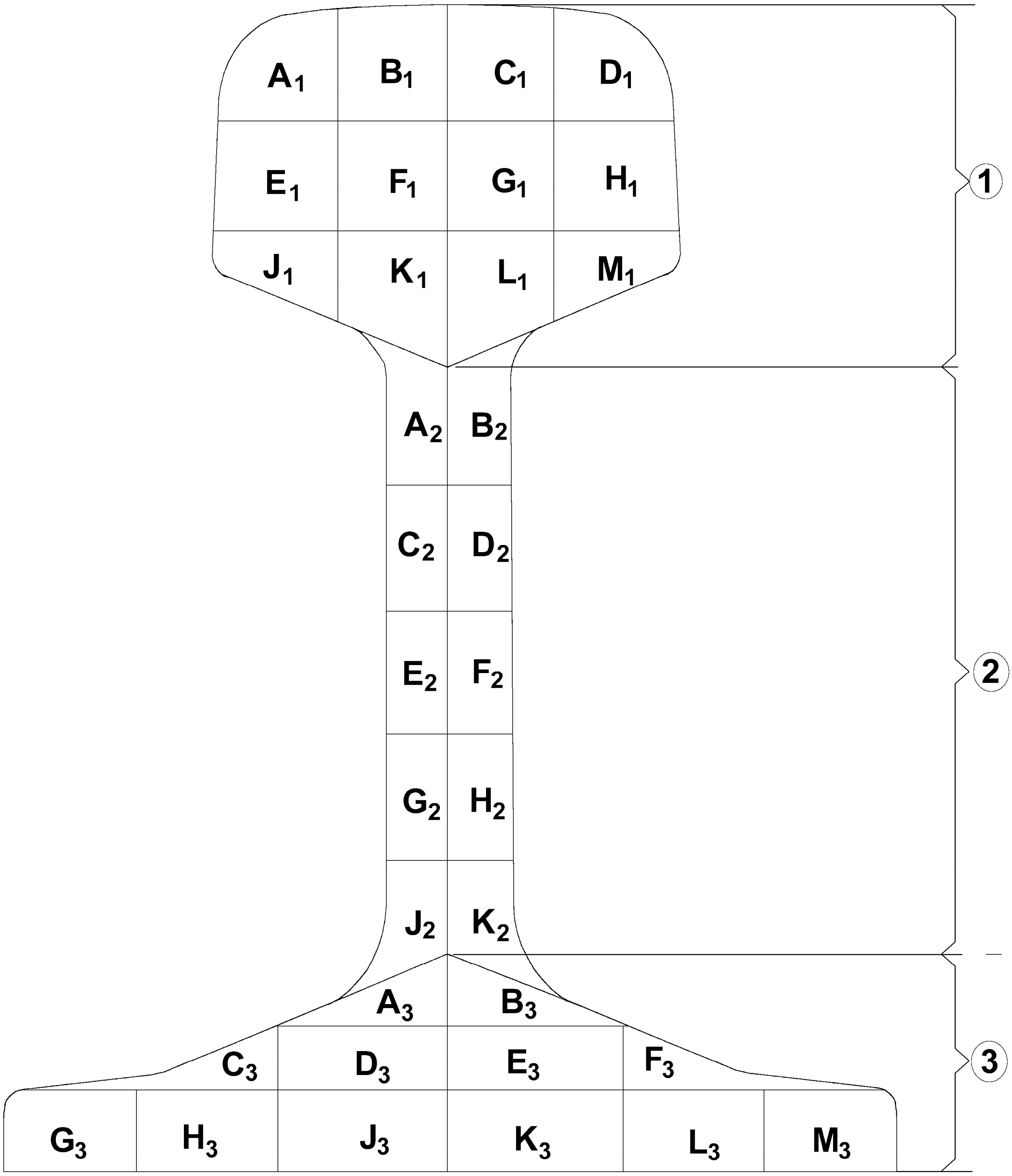
d) orientation;

e) origin of fracture;

f) type of defect.

Test weld identification and the relevant bend test or fatigue test information shall be endorsed and appended to the rail profile grid.

A weld fracture face containing no imperfections shall be similarly recorded with an entry being made on the rail profile grid to show clearly the wording "No visible imperfections".



Key

① head
② web
③ foot

Figure B.1 — Rail profile grid

Annex C
(normative)

Fatigue test method for flash butt welds

C.1 Scope

This Annex describes the staircase test method (see C.4.2) to establish the fatigue strength distribution of a weld at an endurance of 5 million cycles. The fatigue strength is determined in terms of the nominal outer fibre stress range in the foot of the weld, which is the stress range that would exist in the parent rail at the weld location in the absence of the weld.

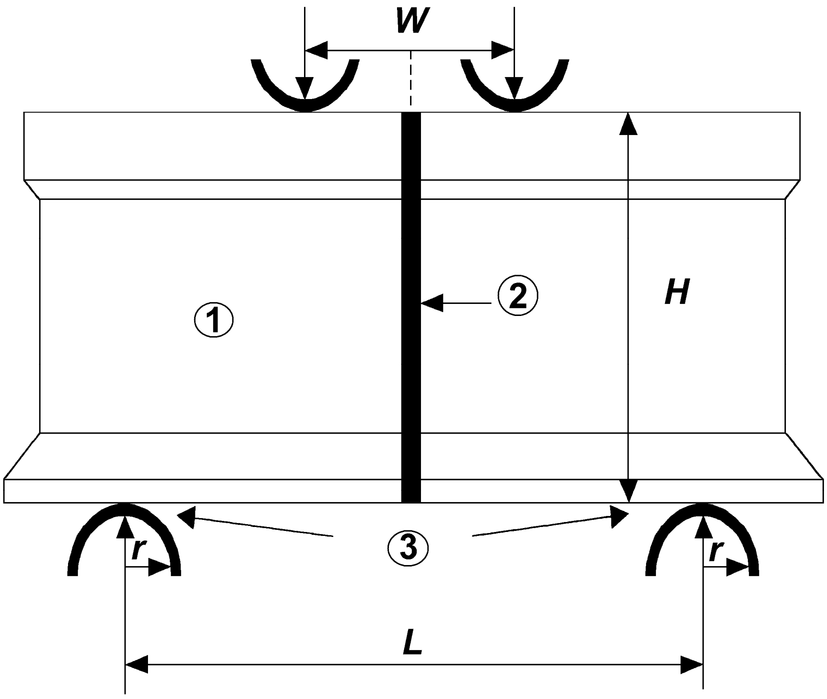
The past-the-post method (see C.4.4) is also described. Three welds shall be tested and none of them shall break below or at a defined cyclic stress level.

The relationship of the applied load to the nominal outer fibre stress is established using a length of plain rail, strain-gauged and load-cycled at the frequency of the test.

C.2 Test equipment

C.2.1 Tests shall be conducted in four points bending with the rail foot in tension.

The inner span (*W*) shall be a minimum 150 mm. The outer span (*L*) shall exceed the inner span by at least twice the rail height *(H)* and shall be symmetrical about the inner span.



Key

1. rail
2. weld
3. bearer

NOTE 1 r: 25 mm to 70 mm

NOTE 2 Loading rate: 40 kN/s to 120 kN/s

Figure C.1 — Fatigue test arrangement

C.2.2 The inner and outer spans shall be measured and recorded.

C.2.3 The distances from the centre line of the actuator to the loading points shall be measured and recorded. Corresponding dimensions on either side of the actuator centre line should not differ by more than 3 mm.

C.2.4 The radius of curvature of the loading points shall not be less than 40 mm. The loading point contact surfaces shall be free to translate or rotate so that friction between the loading points and the specimen is minimised.

NOTE High contact stresses may result in cracks developing at the loading points. The use of arrangements that minimize contact stresses at the loading points is therefore advised. Contact stresses may be further reduced by increasing the outer span and so reducing the force required to achieve a given applied bending moment.

C.2.5 The applied force shall be measured using a fatigue rated load cell verified to EN ISO 7500-1, Grade 1.0.

NOTE Depending on the outer span, a 500 kN or 1 000 kN actuator is likely to be suitable for most applications.

C.3 Calibration procedure

C.3.1 General

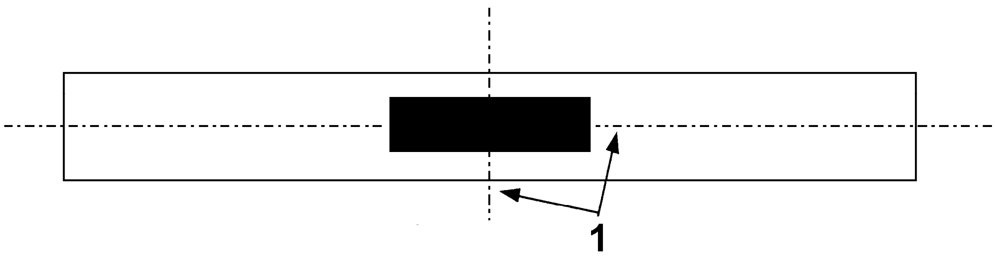
This subclause describes the determination of the relationship between the nominal outer fibre stress and the applied load.

C.3.2 Test piece

The test piece should be a section of new rail of the profile under consideration with a length exceeding that of the outer span of the test rig by no more than 100 mm.

C.3.3 Test piece preparation

Attach a strain gauge to the foot of the rail as shown in Figure C.2. Use a gauge of a nominally 350 Ω resistance and a gauge length of 6 mm. The gauge factor shall be known to an accuracy of 1 %. Attach three similar gauges to an independent block of the same steel.



Key

1 centre lines of gauge and rail to coincide

Figure C.2 — Location of gauge

NOTE For more detailed instructions on the fitment and use of strain gauges, refer to specialist manuals.

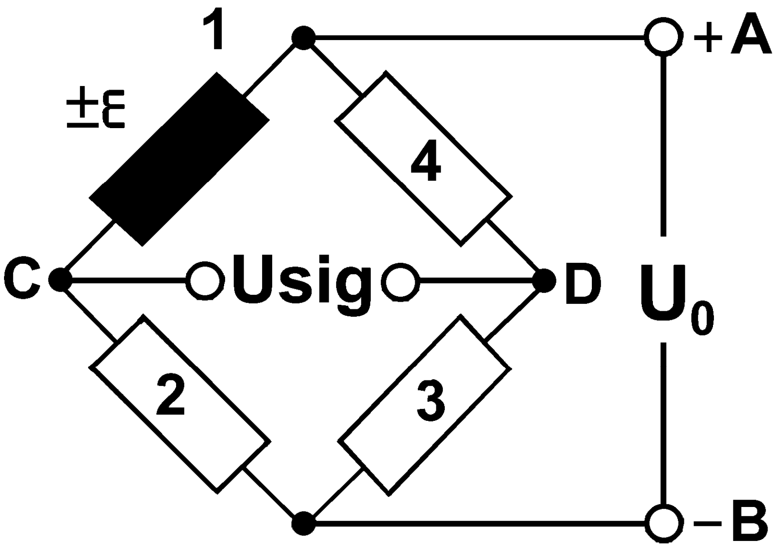
C.3.4 Instrumentation

A digital voltmeter, with peak reading circuits accurate to 1 part in 1, 000 at the test frequency, shall be used.

C.3.5 Procedure

C.3.5.1 Mount the rail in the test rig with the strain gauge positioned directly beneath the actuator. The rail should be mounted so that the application of compressive loads by the actuator places the foot of the rail in tension. Position the independent block adjacent to the test piece. Wire the gauges to form a Wheatstone bridge circuit as shown schematically in Figure C.3. Apply a constant voltage of approximately 9 V DC between points A and B with A positive with respect to B.

Allow the system to stabilise for one hour before taking measurements. Measure and record the value of this voltage as U_0.



Key

1 strain gauge on the test piece

2, 3, 4 unstrained gauges on the independent block

Figure C.3 — Circuit diagram (schematic)

NOTE The wires connecting the active gauge to the remainder of the bridge should be of equal length and twisted together.

C.3.5.2 Let the nominal outer fibre stress = σ. For the range of values of σ_i given in Table C.1, calculate U_{sig} using the following equation:

$$U_{sig} = \frac{\sigma_i \cdot gf \cdot U_0}{4 \cdot E} \quad \text{(C.1)}$$

where

U_{sig} is the voltage increase between C and D when σ is increased from 0 to σ_i;

gf is the gauge factor of the strain gauge on the rail;

U_0 is the voltage applied to the bridge;

E is the Young's modulus, to be taken as 210 GPa.

C.3.5.3 Apply a cyclic force to the rail with a sinusoidal waveform and a frequency equal to that to be used for fatigue testing. For k = 1 to 8 (see Table C.1) vary the applied minimum and maximum force until the maximum and minimum vales of U_{sig} associated with the paired values of σ_i are achieved. Record the associated forces indicated by the load cell. Repeat three times, going through the full range of stresses on each occasion.

Table C.1 — Values of σ_i (MPa) for which U_{sig} is to be determined

k	σ_i MPa	σ_i MPa
1	15	150
2	17	170
3	19	190
4	21	210
5	23	230
6	25	250
7	27	270
8	29	290

C.3.5.4 Ignoring the first group of tests, tabulate the results as shown in Table C.2.

C.3.5.5 Using the data given in Table C.2, create dynamic calibration curves showing the maximum cyclic stress, and the stress range as a function of forces measured by the load cell, at the test frequency to be used.

Table C.2 — Calibration results

k	σ_i MPa	U_{sig} V	**Associated force** kN	**Average force** $F_{k\,min}$ kN	σ_i MPa	U_{sig} V	**Associated force** kN	**Average force** $F_{k\,max}$ kN	ΔF_k kN [a]
1	15				150				
2	17				170				
3	19				190				
4	21				210				
5	23				230				
6	25				250				
7	27				270				
8	29				290				

[a] $\Delta F_k = F_{k\,max} - F_{k\,min}$

C.4 Fatigue test method

C.4.1 General

The purchaser has the option according to 5.3.9 to select either a staircase (see C.4.2) or a past-the-post test (see C.4.4). Table C.3 defines the requirements for both types of test.

Table C.3 — Fatigue test requirements for the profile 60E1

	Staircase test method (C.4.2) Minimum requirements		**Past-the-post test method (C.4.4)**
Rail grade	Mean fatigue strength (MPa)	Standard deviation (MPa)	Maximum stress applied (MPa)
R220	230	27	180
R260	245	27	190
R260Mn	245	27	190
R350HT	245	27	190

C.4.2 Staircase testing method

C.4.2.1 Test pieces

Ten test pieces are required. The weld shall be positioned at the centre of the weld of the test piece to within ± 10 mm. The test piece length shall not exceed the outer test span by more than 100 mm.

C.4.2.2 Procedure

C.4.2.2.1 Position a test piece in the test rig so that the centre line of the weld is aligned with the centre line of the actuator to within 3 mm.

C.4.2.2.2 Determine the maximum stress associated with the mean fatigue strength at 5 million cycles required by the purchaser.

EXAMPLE If the mean fatigue strength is to be not less than a stress range of 230 MPa when the ratio of the minimum to maximum applied stress (R) is 0,1, then the maximum stress will be $230/(1 - R)$ = 256 MPa.

From the calibration curves created in C.3.5.5, determine the maximum force and the force range corresponding to these values of maximum stress and stress range.

C.4.2.2.3 Cyclically load the weld using a sinusoidal waveform, so that the maximum value of force and the range derived in C.4.2.2.2 are achieved. The indicated maximum load and load range shall both be maintained to within 2 % of the nominal value required. Continue cycling until either the test piece breaks or 5 million cycles have been applied.

C.4.2.2.4 If the test piece breaks, the test result shall be recorded as a 'failure'. If it survives, it shall be recorded as a 'run-out'. The cyclic force range and nominal outer fibre stress range shall also be recorded.

C.4.2.2.5 Where the test results in a run-out, repeat the test on another test piece but increase the cyclic force range by an amount corresponding to an increase in the nominal outer fibre stress range in the foot of 10 MPa. Where the test result is a failure, repeat the test on another test piece with the maximum foot stress range reduced by 10 MPa. In both cases the minimum force applied shall be 10 % of the maximum.

C.4.2.2.6 Where any failure is due to die-burn, the result shall be disregarded and an additional test piece made and tested.

C.4.2.2.7 Continue as above until ten test pieces have been tested.

C.4.2.3 Data analysis

C.4.2.3.1 Results are all failures or all run-outs

No data analysis is required.

C.4.2.3.2 Both failures and run-outs obtained

Estimate the mean value and standard deviation of the fatigue strength as follows.

Determine first of all whether failures or run-outs are the less frequent events. Then calculate the mean fatigue strength σ_m using the following equation:

$$\sigma_m = \sigma_0 + d \cdot \left(\frac{A}{N} \pm 0{,}5\right) \tag{C.2}$$

where

σ_0 is the lowest stress range at which tests with the less frequent result were conducted (MPa);

d = 10 MPa;

$A = \Sigma\, i \cdot n_i$ where i ranges from 0 to z;

$N = \Sigma\, n_i$ where i ranges from 0 to z

where

n_i is the number of less frequent events at the i-th stress level above σ_0;

i is the coded stress level (i = 0 for σ_0) ;

z is the number of stress levels above σ_0 at which testing has been undertaken.

In the equation use (*A*/*N* + 0,5) if the less frequent event is a run-out and (*A*/*N* - 0,5) if the less frequent event is a failure.

Calculate the standard deviation using the following equation:

$$s = 1{,}62 \cdot d \cdot \left(\frac{B \cdot N - A^2}{N^2} + 0{,}029\right) \tag{C.3}$$

where

$B = \Sigma i^2 \cdot n_i$

C.4.2.3.3 Information to be reported

a) for each test series the following shall be reported:

1) the inner and outer spans of the test rig (C.2.2);

2) the distances from the centre line of the actuator to the loading points (C.2.3);

3) dynamic calibration results (C.3.5.4);

4) the mean and standard deviation of the fatigue strength at 5 million cycles if calculated according to the procedure given in C.4.2.3.2.

b) for each test, report:

1) the maximum force range applied;

2) the nominal outer fibre stress range applied;

3) whether the test resulted in a failure or a run-out;

4) in the case of failure, the crack initiation location.

C.4.2.4 Acceptance criteria

C.4.2.4.1 All results are failures

The process is not acceptable.

C.4.2.4.2 All results are run-outs

The process is acceptable.

C.4.2.4.3 Both run-outs and failures occur

The mean fatigue strength shall exceed the value specified by the purchaser and the standard deviation shall be less than the value specified by the purchaser.

If the calculated value of $s \leq 5,3$ MPa, the standard deviation is small and shall be deemed acceptable. However the value given by Equation C.3 will be spurious.

C.4.3 Example of the data analysis of a fatigue strength determination by the staircase method

Table C.4 — Experimental results

σ	1	2	3	4	5	6	7	8	9	10	i	n_i	$i \cdot n_i$	$i^2 \cdot n_i$
230			x								2	1	2	4
220		0		x				x		0	1	2	2	2
210	0				x		0		0		0	1	0	0
200						0								
											N	4		
											A		4	
											B			6

Number of failures (x): 4 less frequent event – anticipated

Number of run-outs (0): 6

The lowest stress range at which a failure occurs (σ_o) is 210 MPa. As failure is the less frequent event, the form of the Equation C.2 that shall be used is:

$$\sigma_{\text{m}} = \sigma_0 + d \cdot \left(\frac{A}{N} - 0{,}5 \right) = 210\text{MPa} + 10 \cdot \left(\frac{4}{4} - 0{,}5 \right) \text{MPa} = 215 \text{ MPa} \quad \text{(C.4)}$$

The standard deviation according to Equation C.3 is:

$$s = 1{,}62 \cdot d \cdot \left(\frac{B \cdot N - A^2}{N^2} + 0{,}029 \right) = 1{,}62 \cdot 10 \cdot \left(\frac{6 \cdot 4 - 4^2}{4^2} + 0{,}029 \right) \text{MPa} = 8{,}6 \text{ MPa} \quad \text{(C.5)}$$

C.4.4 Past-the-post testing method

C.4.4.1 Test pieces

Three test pieces are required. The weld shall be positioned at the centre of the test piece to within ± 10 mm. The test piece length shall not exceed the outer test span by more than 100 mm.

C.4.4.2 Procedure

C.4.4.2.1 Position a test piece in the test rig so that the centre line of the weld is aligned with the centre line of the actuator to within 3 mm.

C.4.4.2.2 The maximum applied stress is shown in Table C.3. The minimum stress applied shall be 10 % of the maximum stress. No failures are acceptable at an endurance of less than 5 million cycles.

EXAMPLE If the specified stress range is 180 MPa when the ratio of the minimum to maximum applied stress (*R*) is 0,1, then the maximum stress will be 180/(1 – *R*) = 200 MPa.

From the calibration curves created in C.3.5.5, determine the maximum force and the force range corresponding to these values of maximum stress and stress range.

C.4.4.2.3 Cyclically load the weld using a sinusoidal waveform so that the maximum and minimum stress values are achieved. The indicated values shall both be maintained to within 2 % of the nominal value required. Continue cycling until either the test piece breaks or 5 million cycles have been applied. If the test piece breaks, the test result shall be recorded as a 'failure'. If it survives, it shall be recorded as a 'run-out'.

C.4.4.3 Information to be reported

a) for each test series the following shall be reported:

   1) the inner and outer spans of the test rig (C.2.2);

   2) the distances from the centre line of the actuator to the loading points (C.2.3);

   3) the dynamic calibration results (C.3.5.4);

   4) the outer fibre stresses applied (C.4.2.3.3).

b) for each test, report:

   1) whether the test resulted in a failure or a run-out;

   2) in the case of failures, the crack initiation location.

C.4.4.4 Acceptance criterion

If any test piece breaks at less than 5 million cycles, the process shall be rejected.

Annex D
(normative)

Macro examination and micro examination

D.1 Macro examination

A longitudinal vertical section shall be taken centrally down the vertical axis of the full rail and extend 60 mm each side of the fusion line. Similar sections shall be taken from both sides of the foot, 10 mm inboard of the foot tips. The sections shall be polished to a suitable finish using a minimum 220 grit paper. One full depth rail sample and the associated rail foot samples from each of the two welds shall be etched to show the weld boundary lines. In case of dispute, the FRY etching method shall be used.

The etching agent shall have the following chemical composition per 10 l:

a) 1,875 kg cupric chloride ($CuCl_2 – 2H_20$);

b) 5 l hydrochloric acid (HCl 1,18 ml – 35 %);

c) 4,2 l distilled water.

Etching at room temperature shall be for sufficient time, 30 min minimum, in order to show the boundary lines clearly when examined.

D.2 Micro examination

Microscopic examination shall be carried out on samples from the cut sections taken from the head (one sample 20 mm x 20 mm) and foot (two samples 10 mm high x 20 mm) of two of the four welds. The samples shall be etched in 4 % Nital.

Annex E
(normative)

Hardness testing

Two welds in the finished condition shall be sectioned for hardness testing. A vertical longitudinal section shall be taken down the vertical axis of the rail head and extend approximately 100 mm each side of the weld.

The variation in hardness across the heat affected zone of each of the two welds shall be measured using the Vickers hardness test in accordance with EN ISO 6507-1 and the following parameters:

a) HV 30;

b) impressions to be on a line between 3 mm and 5 mm below the running surface on the vertical longitudinal axis of the rail. Spacing shall be at 2 mm centres;

c) the hardness traverse shall extend from the weld to points on each side of the weld at least 20 mm into unaffected parent rail.

The measurements obtained shall be recorded in graph and numeric form.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC

This European Standard has been prepared under mandates given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the Directive 2008/57/EC.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in table ZA 1 for High Speed Rail Infrastructure and table ZA 2 for Conventional Rail confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA 1 — Correspondence between this European Standard, the Infrastructure TSI for the trans-European high speed rail system dated 20 December 2007 (published in the Official Journal L77, 19.03.2008, p.1),and Directive 2008/57/EC

Clause(s)/ sub-clause(s) of this European Standard	Chapter/ § of the TSI	Essential Requirements of Directive 2008/57/EC	Comments
Clause 8 Weld production and acceptance requirements Sub-clause 8.3 Rail alignment Sub-clause 8.6. Visual inspection Sub-clause 8.7 Steps across the welds. Sub-clause 8.8 profile finishing of the rail head Sub-clause 8.9 Geometrical acceptance requirements Sub-clause 8.10 Weld production testing Annex A Bend test requirements Table A 2 – minimum bend test requirements during production	4.2.9 Description of the infrastructure domain – Functional and technical specifications of the domain – equivalent conicity 4.2.10 Description of the infrastructure domain – Functional and technical specifications of the domain – track geometrical quality and limits on isolated defects 4.2.11 Description of the infrastructure domain – Functional and technical specifications of the domain – rail inclination 4.2.13 Description of the infrastructure domain – Functional and technical specifications of the domain – track resistance 5.3.1.1. Interoperability constituents – Constituents performances and specifications – The rail – Railhead profile	Annex III, Essential Requirements, General Requirements – Clauses 1.1.1, 1.1.2, 1.1.3, Safety	EN 14587-2 does not identify any approval of a mobile flash butt welding machine in terms of electromagnetic compatibility, vehicle braking systems or any requirements regarding load gauge, environment and its attendant issues or infrastructure access pertaining to any railway authority.

Table ZA 2 — Correspondence between this European Standard, the ERA draft of Conventional Rail System TSI Infrastructure (version 2.6 dated 28/07/2008) and Directive 2008/57/EC

Clause(s)/ sub-clause(s) of this European Standard	**Chapter/ § of the TSI**	**Essential Requirements of Directive 2008/57/EC**	**Comments**
Clause 8 Weld production and acceptance requirements Sub-clause 8.3 Rail alignment Sub-clause 8.6. Visual inspection Sub-clause 8.7 Steps across the welds. Sub-clause 8.8 profile finishing of the rail head Sub-clause 8.9 Geometrical acceptance requirements Sub-clause 8.10 Weld production testing Annex A Bend test requirements Table A 2 – minimum bend test requirements during production	4.2.5.5. Description of the infrastructure subsystem – Functional and technical specifications of the subsystem – Track parameters - Equivalent conicity 4.2.5.6. Description of the infrastructure subsystem – Functional and technical specifications of the subsystem – Track parameters – Railhead profile foe plain line 4.2.5.7. Description of the infrastructure subsystem – Functional and technical specifications of the subsystem – Track parameters – Rail inclination 4.2.7.1. Description of the infrastructure subsystem – Functional and technical specifications of the subsystem – Track resistance to applied loads – Track resistance to vertical loads. 4.2.7.2. Description of the infrastructure subsystem – Functional and technical specifications of the subsystem – Track resistance to applied loads – Longitudinal track resistance. 4.2.7.3. Description of the infrastructure subsystem – Functional and technical specifications of the subsystem – Track resistance to applied loads – Lateral track resistance 4.2.9. Description of the infrastructure	Annex III, Essential Requirements, General Requirements – Clauses 1.1.1, 1.1.2, 1.1.3, Safety	The CR TSI INF is still a draft subject to change without notice EN 14587-2 does not identify any approval of a mobile flash butt welding machine in terms of electromagnetic compatibility, vehicle braking systems or any requirements regarding load gauge, environment and its attendant issues or infrastructure access pertaining to any railway authority. Annex F of the draft ERA TSI Requirements for controlling equivalent conicity in service remains an open point

	subsystem – Functional and technical specifications of the subsystem – Track geometrical quality and limits on isolated defects 5.3.1. Interoperability constituents – Constituents performances and specifications – The rail.		

Warning – Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard

Bibliography

[1] EN ISO 9001:2008, *Quality management systems – Requirements (ISO 9001:2008)*

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