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Railway applications — Track — Switches and crossings for Vignole rails

Part 2: Requirements for geometric design

bsi.

National foreword

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European foreword

This document (EN 13232-2:2023) 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of an identical text or by endorsement, at the latest by April 2024, and conflicting national standards shall be withdrawn at the latest by April 2024.

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

This document supersedes EN 13232-2:2003+A1:2011.

This series of standards "Railway applications – Track – Switches and crossings for Vignole rails" covers the design and quality of switches and crossings in flat bottomed rail. The list of Parts is as follows:

— *Part 1: Definitions*

— *Part 2: Requirements for geometric design*

— *Part 3: Requirements for wheel/rail interaction*

— *Part 4: Actuation, locking and detection*

— *Part 5: Switches*

— *Part 6: Fixed common and obtuse crossings*

— *Part 7: Crossings with moveable parts*

— *Part 8: Expansion devices*

— *Part 9: Layouts*

Part 1 contains terminology used throughout all parts of this series. Parts 2 to 4 contain basic design guides and are applicable to all switch and crossing assemblies. Parts 5 to 8 deal with particular types of equipment including their tolerances. These use Parts 1 to 4 as a basis. Part 9 defines the geometric and non-geometric acceptance criteria for inspection of layouts.

The changes introduced in this document set the geometric parameters for switch and crossing design in the context of the design process, providing more detail to the user of the standard. A number of figures have been also updated to improve clarity.

This document has been prepared under a Standardization Request given to CEN by the European Commission and the European Free Trade Association.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

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

1 Scope

This document:

— establishes the design process for switches and crossings (S&C), and the use of the other parts of this standard;

— specifies the geometric design principles for wheel guidance;

— establishes the basic limits of supply;

— establishes the applied forces and their adequate support;

— specifies tolerance levels.

These are illustrated herein by application to a turnout. The main switch and crossing components are represented in turnouts and the principles used in turnouts apply equally to more complex layouts.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 13232-1:2023, *Railway applications – Track – Switches and crossings for Vignole rails – Part 1: Definitions*

EN 13232-3:2023, *Railway applications – Track – Switches and crossings for Vignole rails – Part 3: Requirements for wheel/rail interaction*

EN 13232-4:2023, *Railway applications – Track – Switches and crossings for Vignole rails – Part 4: Actuation, locking and detection*

EN 13232-5:2023, *Railway applications – Track – Switches and crossings for Vignole rails – Part 5: Switches*

EN 13232-6:2023, *Railway applications – Track – Switches and crossings for Vignole rails – Part 6: Fixed common and obtuse crossings*

EN 13232-7:2023, *Railway applications – Track – Switches and crossings for Vignole rails – Part 7: Crossings with moveable parts*

EN 13232-9:2023, *Railway applications – Track – Switches and crossings for Vignole rails – Part 9: Layouts*

EN 15273-3:2013+A1:2016, *Railway applications - Gauges - Part 3: Structure gauges*

3 Terms and definitions

For the purpose of this document the terms and definitions given in EN 13232-1:2023 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Design process

4.1 General process

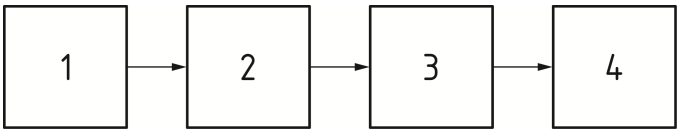
The process for designing switches and crossings is complex owing to the many requirements that apply and the different situations that may occur. Figure 1 gives a schematic representation of the general design process. It separates the whole process into four main steps:

— step 1 contains the general design of the S&C. It consists of the geometrical design, the design of the wheel-rail interaction and the design requirements for compliance with the actuation, locking and detection system. It leads to the definition of the main aspects of the S&C, respecting the main design requirements. Geometric design is defined in this part; other aspects are dealt with in parts 3 and 4;

— step 2 is the main constructional design process, which specifies the main construction of the S&C. It is based on the technology used by the supplier. It is based mainly on the suppliers' experience and expertise;

— step 3 consists of the detailed design of the individual components. It is dealt with in different standards. The design of the main components shall respect the requirements laid down in parts 5 to 8. Other components, such as fastenings, bearers, etc, are dealt with in respective ENs;

— step 4 is the product acceptance, which is described in Part 9.



Key

1 Step 1: General design

2 Step 2: Main constructional design

3 Step 3: Detailed component design

4 Step 4: Acceptance

Figure 1 — General design process

4.2 Design step details

— Each design step requires sufficient **input data** to enable the design to be completed.

— Input data are dealt with by the supplier through the **design rules**. The rules are defined in EN 13232, Parts 2 to 8.

— The results of the different design steps are **outputs**.

All these aspects are schematically represented for each design step in Annex A, with a reference to the different parts and clauses where these aspects are dealt with in detail.

4.3 Practical use of the design process

The previous section deals with the complete design process of S&C. The use of the standard is not limited to this case only.

The customer may choose to request the supplier to perform the whole design process and therefore gives all necessary input data to permit the supplier to perform the design.

The customer may also opt to request the supplier to perform only parts of the design process. In this case the customer shall deliver all inputs of the design steps he has requested the supplier to perform. This means that he has to deliver all outputs of the previous design steps.

EXAMPLE 1 A customer requests the detailed design of an S&C layout based on the geometry of an existing design for use on a main railway line. In this case the supplier receives from the customer the outputs from geometrical requirements as well as the requirements for wheel-rail interaction, in the form of functional and safety dimensions.

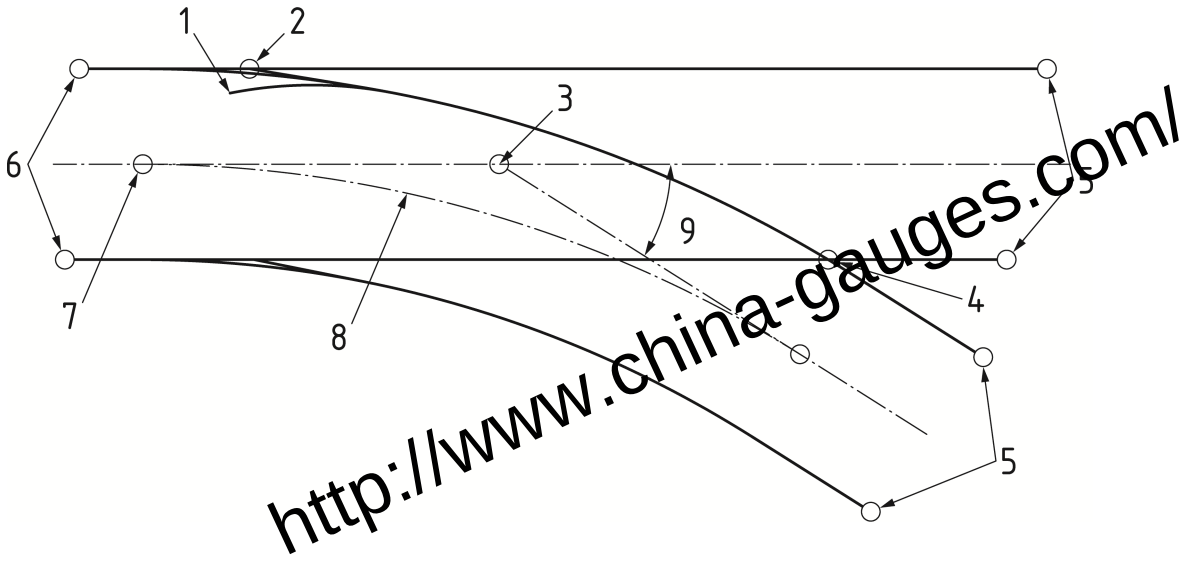
Based on this information and the inputs for both conformity for actuation, locking and detection (ALD) and general requirements, the supplier performs the general and detailed component design.

EXAMPLE 2 A customer requests a supplier to manufacture an S&C layout in accordance with an existing design. The customer delivers a set of detailed drawings to the supplier. The supplier only performs step 4 of the general design process.

5 General design requirements

5.1 Reference points

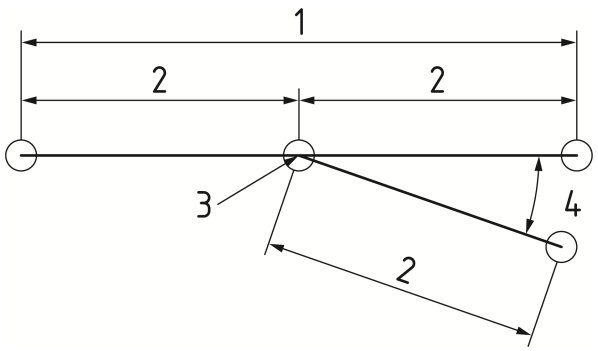
Key reference points relating to turnout geometry and the limits of supply of a turnout are illustrated in Figures 2 and 3.



Key

1 Real point of switch
2 Mathematical point of switch
3 Tumout intersection
4 Theoretical intersection
5 Limits of supply (heel joints)
6 Limits of supply (front joints)
7 Origin of switch curve
8 Centreline radius
9 Turnout angle

Figure 2 — Key reference points



Key

1 Overall length
2 Tangent length
3 Turnout intersection
4 Turnout angle

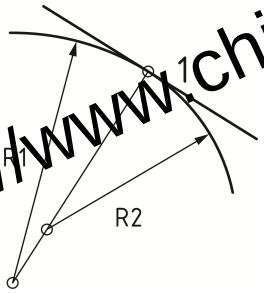
Figure 3 — Setting out diagram

5.2 General tangency rules

At any change in radius the two radii shall be mutually tangential at the running edges. To achieve this, the centres of adjacent curves shall lie on the same radial line (see Figure 4).

Exceptions to the mutual tangency rule may occur. Examples include switch entry angle for intersecting switches or to allow for gauge widening.

Details are given in EN 13232-3:2023 and EN 13232-5:2023.



Key

1 Tangent

Figure 4 — Mutual tangency

5.3 Inputs

For a concise definition of the geometry of an assembly of switches and crossings, a minimum amount of basic quantitative information is required. The following items are both necessary and sufficient for such a definition of a turnout.

The following shall be defined by the customer and numerical values provided to the supplier. Note that some values may be different from those for plain line:

— track gauge;

— speed;

— maximum lateral acceleration or cant deficiency;

— maximum rate of change of lateral acceleration or cant deficiency;

— turnout intersection point and angle (see Figure 3);

— limits of supply (front joints, heel joints);

— gauge widening (if any);

— abrupt change of cant deficiency;

— vehicle length.

For a crossover or junction, in addition, the following shall be defined by the customer and provided to the supplier:

— distance between main line track centrelines.

For switches and crossings on a curved main line, the following shall be defined and provided by the customer:

— main line curvature;

— main line and branch line cant through turnout.

The key points whose location shall be agreed between customer and supplier are as follows:

— origin of switch curve;

— real point of switch (RP) (see EN 13232-3:2023);

— theoretical intersection (of crossing).

Radii of main and branch lines and the positions at which they change shall be agreed, together with:

— centreline radii;

— origin of switch curve to positions of changes of radii;

— tangent offset (if any).

where such changes of radii shall be bounded either by included angle, or by longitudinal distance or by lateral offset, or in the case of a transition section, by such data as is necessary to uniquely define its shape.

Some examples are illustrated in EN 13803.

6 Geometry design rules (step 1)

6.1 Introduction

Geometry is represented in the running plane by the running edges. For the purpose of determination of permissible speeds and for definition of the turnout, curvature is defined by the radius of the track centreline.

In order to maintain safe and continuous support and guidance of wheels, certain rules of tangency are imposed. Speed and radius are then related to lateral acceleration. Cant deficiency is derived from this. Switches and crossings are characterized by changes in lateral acceleration, so rules for both steady and sudden changes between radii are included in this section.

Calculations and rules relate to vehicles with two axles or vehicles with two-axle bogies. Vehicles with other than two axles may require special consideration and as such their configuration shall be provided by the customer.

These rules are defined for steady-state design, i.e. without acceleration. Requirements of a dynamic nature shall be stated by the customer.

6.2 Speed relationships

Fundamental rules of circular motion determine the relationship between radius and speed around a curve.

For railway specific applications the following formula applies:

$$v_{max} = \sqrt{(a_{max} R_C)} \quad (1)$$

where:

R_C is the local centreline radius of the curve in m;

a_{max} is the maximum lateral acceleration in m/s²;

V_{max} is the maximum local velocity in m/s.

Alternatively with V_{max} in km/h:

$$V_{max} = 3{,}6 \sqrt{(a_{max} R_C)} \quad (2)$$

Often it is convenient to express maximum speed in terms of more physical measures, using the variables cant deficiency and wheel contact gauge (see Figure 5). Firstly, wheel contact gauge is expressed conventionally as:

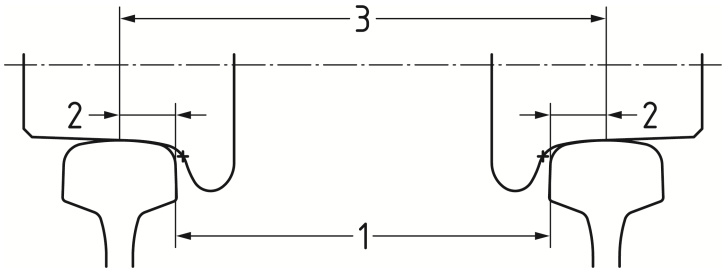
$$s_w = G + W_r \quad (3)$$

where:

s_W is the wheel contact gauge, or distance between the two upper wheel/rail contacts, in mm;

G is the track gauge in mm;

Wr is the rail head width in mm.



Key

1 track gauge G
2 half of rail head width W_r
3 wheel contact gauge s_w

Figure 5 — Wheel contact gauge

If s_r is not specified, for standard gauge (1 435 mm), a value of 1 500 mm may be assumed for s_w. The speed relationship is then given by:

$$V_{\max} = 3{,}6 \sqrt{(h_d\, g\, R_c / s_w)} \quad (4)$$

where:

h_d is the maximum permitted cant deficiency in mm;

g is the acceleration due to gravity, normally taken as 9,81 m/s²

6.3 Effects of changes in curvature

6.3.1 Introduction

Most real situations yield a step change in curvature, since a smooth curvature change only occurs in transition curves. The effects of step changes are mitigated by the vehicle's suspension system, but an approximate rule is necessary to enable the switch and crossing supplier to match the vehicle's requirements. The rules for steady transitions are covered first, then the rules for step changes in curvature.

NOTE See EN 13803 for examples of alternative arrangements of transitions within turnouts.

6.3.2 Change of lateral acceleration

The steady change of curvature is quantified by the rate of change of lateral acceleration. Alternatively, it may be termed a rate of change of cant deficiency which is related to a rate of change of lateral acceleration. See EN 13803:2017, 6.5.

6.3.3 Types and locations of transitions

Transition curves are used to eliminate the effects of step changes by employing a suitable rate of change of lateral acceleration. An example of a steady transition is the clothoid, which employs a constant rate of change of lateral acceleration or cant deficiency.

6.3.4 Rules for steady changes in curvature

In the case of steady changes in curvature, as occur in turnouts and crossovers, the changes in lateral acceleration or cant deficiency should be dealt with according to EN 13803:2017, 6.5.2 and 6.5.3

6.3.5 Rules for step changes in curvature (virtual transitions)

In the case of step changes in curvature, as occur in turnouts and crossovers, the changes in lateral acceleration or cant deficiency may be dealt with according to the procedure in EN 13803:2017, Annex M.

6.3.6 Rules for special cases

Where the length of the transition is less than *t*he length between bogie centres, an alternative method shall be used. An equivalent radius should be determined between the customer and supplier. This may be established in accordance with EN 13803.

6.3.7 Switches and crossings on curves

Basic S&C design has straight main line (except for equal split turnouts). Curved S&C is based on basic designs with equivalent radius. Equivalent radius may be calculated in accordance with EN 13803.

6.4 Output

The result of the geometry design process is the geometry plan, containing the following information:

— track gauge throughout the S&C;

— cant throughout the S&C;

— origin of switch curve;

— real point of switch;

— theoretical intersection (crossing);

— centreline radii;

— tangent offset;

— limits of supply.

7 Main constructional design (step 2)

7.1 Introduction

Design of switches and crossings involves aspects other than geometry. The component parts of switches and crossings are dealt with in Parts 5 to 8 (see Foreword) but some non-geometric design issues are of a more general nature:

— rail section and inclination;

— ability to withstand thermal forces;

— ability to support axle loading;

— performance under rail creep conditions (e.g. braking);

— influence of bearer cross-section and spacing;

— safety in operation;

— condition and loading of rolling stock;

— ability to function under the prevailing environmental conditions.

These issues are influenced by the axle spacing and frequency, temperature changes, ballast and subgrade quality, etc. They will be affected by maintenance practices and in turn will affect the economic service life. These items also possess interfaces to other items outside the supplier's scope. The customer shall define in verifiable terms the characteristics required at these interfaces.

7.2 Inputs

The customer shall give sufficient information to permit the supplier to perform the detailed design. Following information shall always be delivered, characterizing the use of the S&C:

— axle load;

— gross tonnage;

— train speed;

— use in continuously welded track;

— use and positions of insulated joints or other signalling system;

— standard track subgrade conditions.

— wheel and wheel set data (new and worn condition) as requested in EN 13232-3:2023.

Based on this information several technical choices will have to be made defining:

— rail section;

— switch rail section;

— rail inclination;

— bearer type;

— bearer spacing (minimum, nominal and maximum value);

— rail fastening system.

In addition several options are open for the customer:

— main switch design;

— crossing type;

— baseplate type;

— insulation;

— switch heating system (if required).

7.3 General requirements

The track system shall be designed to ensure the stability of the track whilst under traffic.

The track system shall be capable of sustaining the horizontal and vertical vehicle loads and of transferring them to the subgrade without over-stressing it.

The track system shall be capable of sustaining any thermal forces, including those from adjacent track sections, without over-stressing of the track support.

Infrastructure gauge and flangeway depth shall be in accordance with EN 15273-3:2013+A1:2016.

7.4 Specific requirements

The following specific requirements shall be respected during design:

— distance between rail foot and bearer end (nominal; minimum and maximum);

— the minimum distance between screw axis and bearer end and side;

— minimum distance between abutting bearer ends;

— bearer length (maximum and minimum);

— nominal bearer spacing at joints;

— minimum distance between joints and/or welds;

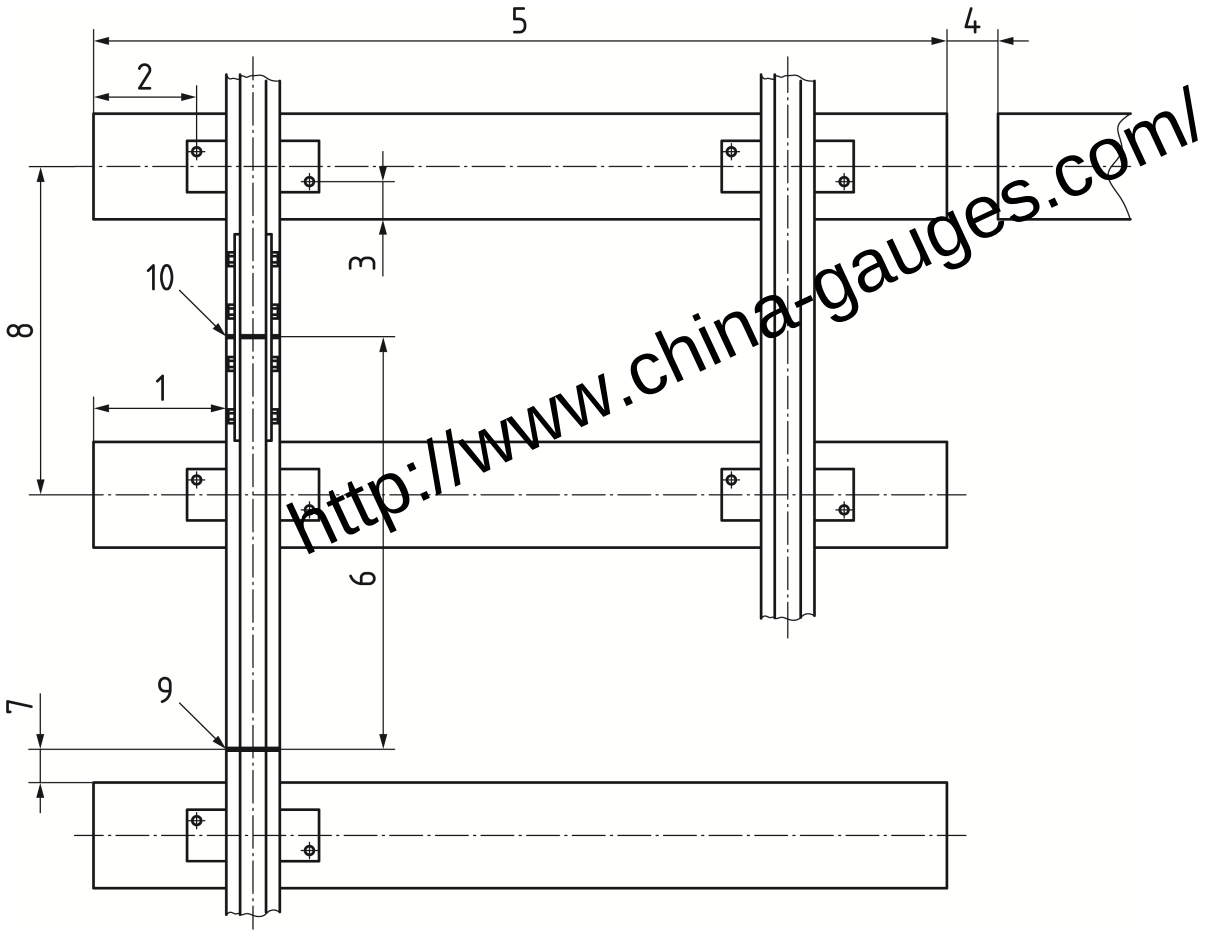
— maximum distance between joints and/or welds;

— minimum number of fastenings between unfastened rail section (i.e. switch) and weld or joint;

— minimum distance between weld position and bearer;

— gauge clearances necessary for access with tools and equipment.

Several of these dimensions are represented on Figure 6.



Key

1 Distance between rail foot and bearer end
2 Minimum distance between screw axis and bearer end
3 Minimum distance between screw axis and bearer side
4 Minimum distance between abutting bearer ends
5 Bearer length
6 Minimum distance between joints and/or weldings
7 Minimum distance between weld position and bearer
8 Bearer spacing
9 Weld
10 Joint

Figure 6 — Specific requirements

7.5 Structural requirements

The complexity of the system does not permit the setting of general rules for this aspect of the design.

For existing designs, the supplier shall demonstrate compliance with the customer's requirements through similar applications and/or relevant references.

For new designs, the supplier shall demonstrate compliance with the customer's requirements through calculations, laboratory and/or track testing.

7.6 Other requirements

Additional requirements may be given by the customer taking into account transport, handling and maintenance of the S&C or its components. In this case, the customer shall provide the supplier with all necessary information on the installation and maintenance machinery used in conjunction with the S&C.

In the case of special prevailing environmental conditions, the customer shall give all necessary information to permit the supplier to adapt his design.

7.7 Actuation, locking and detection design

The design of the actuation, locking and detection (ALD) system is not dealt with by this standard. As ALD systems have to work in close conjunction with the S&C, the design shall be performed in parallel. EN 13232-4:2023 defines the requirements for the conformity checking of the ALD system.

The necessary inputs from the S&C are determined in EN 13232-4:2023.

The geometrical design process is schematically given in Figure A.1.

The tests for conformity checking are given in EN 13232-4:2023.

The conceptual ALD design shall result in an ALD layout plan.

7.8 Output – Main construction documents

7.8.1 General

The detailed design shall result in a set of construction plans and/or documents. These shall contain the following details:

7.8.2 Geometry

— setting out diagram;

— track gauge;

— geometry (curvature);

— entry angle (defined in EN 13232-3:2023);

— type of geometrical form;

— detailed switch geometry (at the switch toe);

— detailed crossing geometry;

— detailed check rail geometry (entry angle, parallel length, etc.).

7.8.3 Guidance

— crossing nose protection;

— flangeway;

— switch free wheel passage.

7.8.4 Actuation

— toe opening at drive position;

— ALD layout.

7.8.5 Constructional

— overall length;

— construction length of switch/stock rail;

— construction length of crossing;

— construction length of check rail (including entry flares);

— bearer positions.

7.8.6 Information lists

In addition the following information shall be supplied:

— rail section;

— rail inclination;

— fastenings;

— speeds;

— axle loads;

— gross tonnage (annual or daily).

8 Detailed component design (step 3)

8.1 Switches

The inputs and rules for the design of half sets of switches are given in EN 13232-5:2023. The supplier shall take into account all rules given in EN 13232-5:2023, and the functional and safety dimensions determined according to EN 13232-3:2023 and EN 13232-4:2023.

8.2 Crossings

The inputs and rules for the design of crossings are given in EN 13232-6:2023 for fixed crossings and EN 13232-7:2023 for crossings with moveable parts. The supplier shall take into account all rules given in these parts, and the functional and safety dimensions determined according to EN 13232-3:2023 and EN 13232-4:2023.

8.3 Expansion devices

The inputs and rules for the design of expansion devices are given in EN 13232-8:2023.

8.4 Other components

The customer shall refer to the technical specifications that apply for the following components, as far as applicable:

— rails;

— rail fastenings;

— bearers;

— welds;

— screws;

— studs;

— sliding chairs;

— baseplates;

— insulating joints.

8.5 Output – Assembly documents

8.5.1 Main assembly documents

At the conclusion of the detailed design of the S&C layout, the supplier shall supply the following information:

— the assembly documents;

— the parts list for the layout.

The assembly documents shall include the following minimum information:

— rail profile;

— materials and grades including heat treatments;

— setting out diagram;

— geometry (curvature);

— offsets at given dimensions;

— running edge openings at switches and crossings;

— track gauge;

— functional and safety dimensions;

— tangent points;

— rail lengths;

— position of change of rail inclination;

— check rail lengths;

— position of parallel check rail length;

— position and type of joints and welds;

— joint gaps;

— position and type of anti-creep devices;

— bearer type;

— bearer position and number;

— bearer length;

— nominal bearer end position;

— baseplate type and position;

— type of baseplate fixings;

— rail fastenings;

— type and location of rail pads and baseplate pads;

— crossing type;

— actuation; locking and detection positions.

All positions shall be referenced to a datum defined by the supplier.

The parts list shall include the following minimum information:

— part number;

— part name;

— drawing number (if required);

— number of parts.

8.5.2 Optional documents

Only when clearly requested in the tender documents, the supplier shall deliver the following additional information:

— maintenance documents;

— handling documents;

— detailed component drawings;

— parts lists for component drawings.

9 Tolerances

9.1 Individual tolerances

For individual manufacturing tolerances for switches refer to EN 13232-5:2023, for crossings refer to EN 13232-6:2023 and EN 13232-7:2023, for expansion devices refer to EN 13232-8:2023.

9.2 Accumulation of tolerances

For the build-up of manufacturing tolerances on switches and crossings within a layout, refer to EN 13232-9:2023.

9.3 Acceptance basis

Radii and angles are considered to be nominal, that is, effectively exact. Acceptance criteria shall be based on longitudinal or lateral measurements or those obtained from versine calculations. Sufficient longitudinal, lateral and versine dimensions shall be verified by measurement to prove that the nominal radii and angles are correct.

In addition the following as-manufactured dimensions shall be verified by measurement in accordance with the tolerances specified by the customer or agreed with him:

— track gauge;

— distances to limits of supply (front joints, heel joints);

— width and depth of wheel flangeway gaps in switches, crossings and checks;

— lengths of rails including check rails and crossings, together with their position relative to the crossing nose;

— height of check rail above running rail;

— switch toe opening;

— minimum flangeway opening for free passage in switches.

Other as-manufactured dimensions requiring verification by measurement shall be agreed at the design stage.

Annex A
(informative)

Design process

Figure A.1 summarizes the design process in schematic form, showing the contribution of each part of EN 13232, the relationship between the parts, and the information flow.

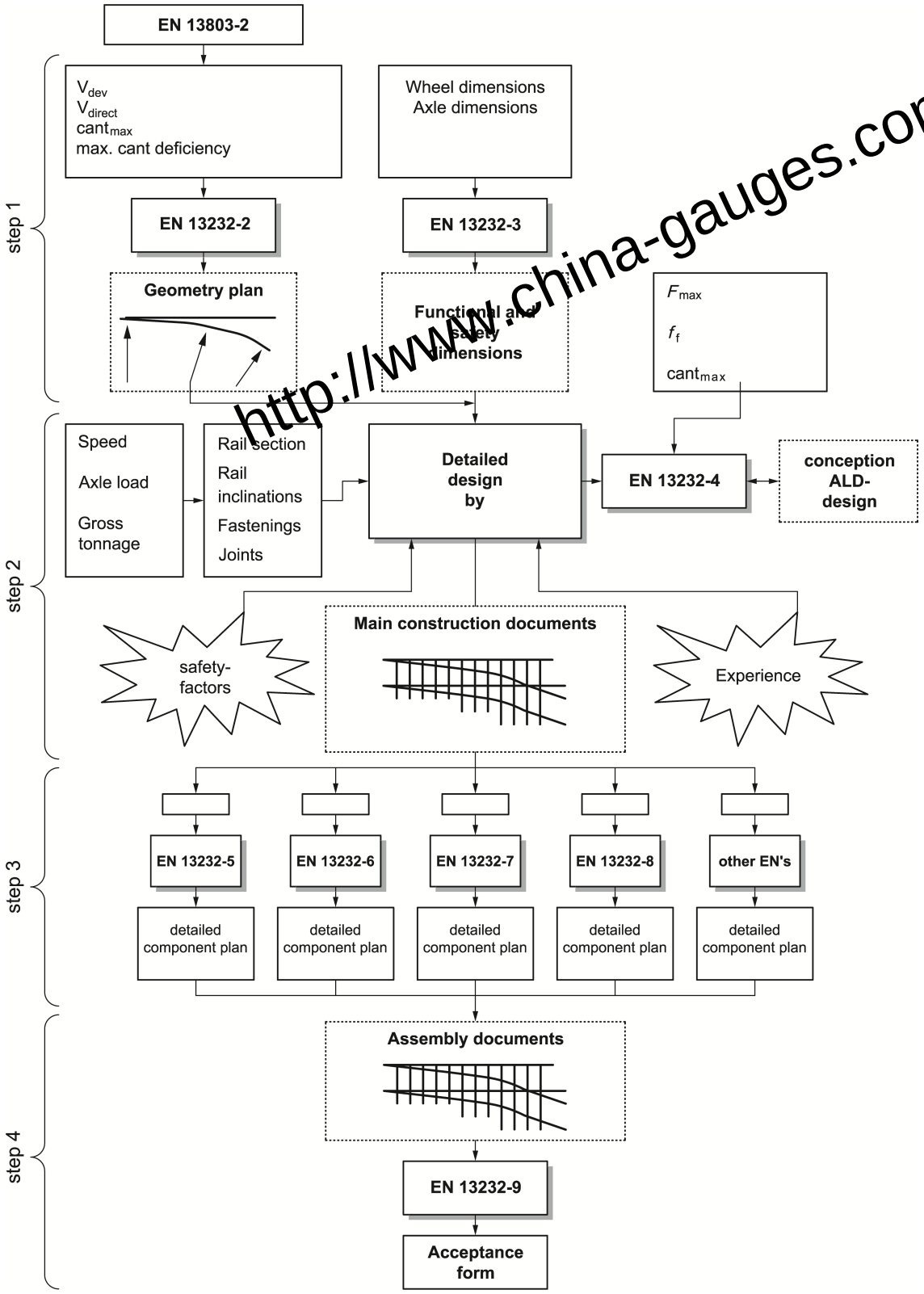


Figure A.1 — Design process

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[2] EN 13232-7:2023, Railway applications – Track – Switches and crossings for Vignole rails - *Part 7: Crossings with moveable parts*

[3] EN 13232-8:2023, Railway applications – Track – Switches and crossings for Vignole rails - *Part 8: Expansion devices*

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