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Guidance for forming of structural steels in processing

Hinweise für das Umformen von Baustählen bei der Verarbeitung

Guide pour le formage des aciers de construction lors de leur mise en oeuvre

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This Technical Report was approved by CEN on 13 March 2006. It has been drawn up by the Technical Committee ECISS/TC 10.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This Technical Report (CEN/TR 10347:2006) has been prepared by Technical Committee ECISS/TC 10 "Structural steels – Grades and qualities", the secretariat of which is held by NEN.

In the ECISS/TC 10 meeting of 8 and 9 December 1998 it was decided with Resolution ECISS/TC 10 no 2/1998 to publish ECSC IC 2 as a CEN report. The part on welding in ECSC IC 2 has been revised by CEN/TC 121 and has resulted in EN 1011-2. The part on formability has been revised in this CEN Technical Report.

1 Scope

This CEN Technical Report provides guidance for forming during processing of structural steel products conforming to EN 10025 Parts 2 to 6 and EN 10149 Parts 2 and 3. This Technical Report covers hot and cold forming processes and local hot forming used in flame-straightening operations.

This Technical Report does not cover the special measures necessary for the fabrication of structural components that are subjected predominantly to alternating stresses or that come into contact with aggressive media.

2 Terms and definitions

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

2.1
hot forming
forming at temperatures in the austenite range, generally around 900 °C depending on the chemical composition of the steel grade

2.2
cold forming
forming up to the highest temperature permissible for stress relieving, generally in the range of 530 °C to 580 °C

NOTE See the relevant part of EN 10025 (e.g. 7.3.1.1 of EN 10025-1:2004 and 7.4.1.1 of EN 10149-1:1995).

2.3
flame-straightening
local quick heating of a component with a short holding time (generally less than one minute) at the flame-straightening temperature

2.4
flame-straightening temperature
highest temperature arising in the component during flame-straightening

3 General principles

With rising minimum yield strength values for structural steels and with an increasing wall thickness of structural steel products, extra care needs to be taken during subsequent processing of steel products. Furthermore, the technical delivery conditions of steel products complying with EN 10025 and EN 10149 will depend on the actual process route used by the steel product manufacturer.

In general, suitable steel grades for the special forming situation should be selected. EN 10025 also defines special steel grades for cold forming and additional options for ensuring forming properties which should be preferably used. In cases which are not covered by these order options the steel manufacturer should be consulted. All steel grades of EN 10149 are suitable for cold forming.

In individual cases outside of the specific guidance given here, especially when using structural steels for the first time, forming should be based on prior experience. This may be based on pre-production procedure trials undertaken by the fabricator or on documented trials undertaken by the steel product manufacturer.

If a manufacturer wants to ensure that the hot forming, cold forming or flame-straightening process intended to be applied will not detrimentally influence the mechanical properties of the structure, a process verification should be performed.

NOTE Temperatures referred to in this Technical Report are measured at the steel product surface and not somewhere in the furnace. Allowance should be made for the fact that the temperatures in the product may not be uniform.

4 Hot forming

4.1 General

4.1.1 The following products can generally be subjected to hot forming:

- non alloy structural steels supplied as-rolled for normalizing by the purchaser (see 7.3.1.3 of EN 10025-2:2004) or supplied in the normalized delivery condition conforming to EN 10025-2;
- normalized fine-grain structural steels conforming to EN 10025-3 and EN 10149-3;
- structural steels with improved atmospheric corrosion resistance supplied as-rolled for normalizing by the purchaser (see 7.3.1.3 of EN 10025-5:2004) or supplied in the normalized delivery condition conforming to EN 10025-5.

It is not envisaged that thermomechanical rolled steel grades conforming to EN 10025-2, EN 10025-4 and EN 10149-2 or quenched and tempered steels conforming to EN 10025-6 should require further processing by hot forming. The strength properties of thermomechanical rolled steel grades, the material condition of which is not achievable or reproducible by a heat treatment alone, are impaired by hot forming during further processing.
For quenched and tempered steels the necessary heat treatment after hot forming is very difficult to reproduce.

4.1.2 Where special hot forming operations are performed, e.g. hole flanging or inductive bending, the steel product manufacturer should be consulted. Process verification for induction bending should ensure that both the steel and the process are matched.

4.1.3 Where only local heating to hot forming temperature is involved, other than flame-straightening, attention should be paid to the fact that, apart from the region heated in regular fashion to normalizing temperature, areas appear with temperatures between the lower limiting temperature for normalizing and the upper limiting temperature for stress relieving. In these areas, the material properties can be impaired, depending on the heating technique, temperature, and duration involved.
The area heated into the two phase regime ferrite-austenite is experienced to be particularly critical for both strength and toughness.

4.2 Temperature during hot forming

To carry out hot forming, the work piece should be heated above 900 °C, but not above 1050 °C, preferably not above 1020 °C. After reaching the planned temperature for the work piece, holding at that temperature to ensure a uniform temperature in the work piece is only necessary if stipulated in the relevant steel product standard.

NOTE 1 The temperature of 900 °C relates to the lower temperatures for normalizing.

NOTE 2 For quenched and tempered steels see 4.1.1.

Heating rates should be as fast as possible and holding times should be as short as possible. For this reason, work pieces should not be heated in a pile.

During hot forming, the temperature should not drop below the lower limit of admissible temperatures as given in Table 1. In particular, when the product thickness is small (less than 15 mm) the heat flow from the work piece to the forming devices should be taken into account during hot forming.

After hot forming, the work piece should generally be cooled in air, in order to ensure a minimum of deformation due to internal stresses. The cooling rate should be kept as similar as possible to the one applied to the original product.

In general, the cooling rate after hot forming depends on the shape and wall thickness of the component. In particular, the cooling rate of products with a small thickness is significantly higher when the work piece is cooled in contact with the forming devices than in contact with air. For this reason, retarded cooling or tempering may be necessary in special cases for normalized steel grades with minimum yield strength values equal to or greater than 420 MPa and small wall thickness (less than 15 mm). Details should be obtained from the steel product manufacturer.

The temperature should be monitored in all hot forming operations in order to ensure that, during the forming operation, the highest allowable temperature is not exceeded (see 4.3.2). This is of particular importance where the heat treatment of the work piece is not intended to be repeated after forming.

4.3 Heat treatment after hot forming

4.3.1 Heating to a temperature greater than about 50 K above the transformation temperature Ac_3, at which austenitization is completed, in particular if combined with a long holding time, leads to grain growth and thereby impairs the toughness properties and the yield strength. For this reason, after hot forming the finished component should be heat treated generally in accordance with the advice of the steel product manufacturer or the relevant steel product standard.

It is essential that normalized steel grades are renormalized. This is of particular importance where fabrication processes require the normalizing of the component after hot forming. Under these circumstances, a normalized steel product could be ordered in the 'as-rolled' delivery condition. The steel product manufacturer should be consulted for advice.

4.3.2 With normalized steel grades, normalizing after hot forming may be omitted in the following cases:

a) After single-step hot forming, normalizing of the finished component may be omitted if the process has been undertaken within the limits given in Table 1.

Table 1 — Criteria for omitting renewed heat treatment after single-step hot forming

Test temperature for verification of Charpy impact energy	Steel grade	Maximum temperature before hot forming	Lowest temperature at the end of hot forming with the degree of hot forming[a]	
			> 5 %	≤ 5 %
°C		°C	°C	°C
≥ - 20	S235-S355	980	750	700
	S420-S460	940		
< - 20	S235-S355	940		
	S420-S460	925		

[a] Degree of hot forming is related to the highest local strength.

b) After multi-step hot forming, renewed heat treatment of the component may be omitted provided the work piece has been cooled, prior to the last step, to a temperature below 500 °C for steel grades S235 to S355, or below 300 °C for steel grades S420 to S460, and that in the last step, the process has been undertaken within the limits given in Table 1.

4.3.3 In the course of selecting the steel product, the purchaser should ensure that the required heat treatment can be applied to the finished component, taking into account the influence of the shape and the thickness of the component on the heat flow.

4.4 Practical hints regarding hot forming

The envisaged effects of the fabricating process on the mechanical properties of the components should be taken into account, particularly where special toughness requirements are involved.

If, after hot forming, heat treatment of the component is to be undertaken, the cooling rate of the component when cooled from the normalizing temperature, should be planned such that it is similar to that applied to the original normalized product.

For air cooling, a component should be taken out of the furnace after heating for normalizing and cooled in free air. Some forced air circulation might be advantageous in order to avoid heat accumulation as a result of local stack heat flow.

5 Cold forming

5.1 General

In general, the steel grades conforming to EN 10025, Parts 2–6 can be subjected to cold forming. All steel grades of EN 10149 Parts 2 and 3 can be subjected to cold forming. When cold forming above room temperature is planned, it should be checked whether the material is suitable for the envisaged temperatures. Forming in the range 200 °C to 380 °C should be avoided. Preferably steel grades suitable for cold forming should be used. EN 10025 defines special steel grades and/or order options for which recommended bending radii are given in the standard.