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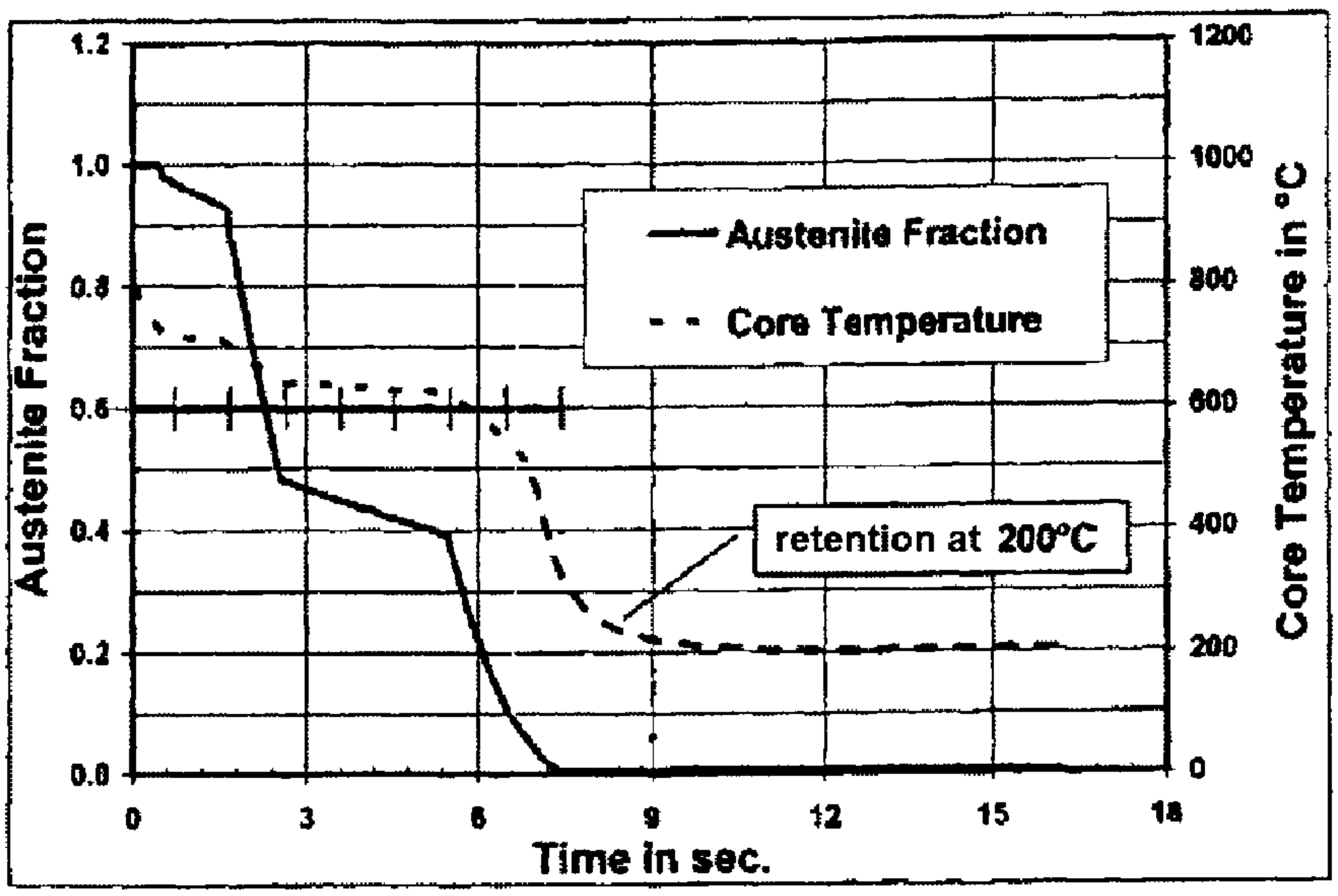
(54) Title: METHOD FOR PRODUCING A STEEL STRIP HAVING A DUAL-PHASE MICROSTRUCTURE

**Example of cooling curve of sheet steel after hot rolling for achieving the DP microstructure (core temperature)**




(57) Abrégé/Abstract:
The invention is directed to a method for producing semi-finished product, particularly steel strip, having a dual-phase microstructure and a tensile strength between 500 and 1000 MPa. The invention is characterized in that elements such as carbon and nitrogen which are interstitially dissolved in the ferritic matrix are bound by alloying elements such as Al, Mo, Nb, Ti and V which form carbide, nitride or carbonitride in order to adjust a microstructure of hard components such as martensite, bainite, carbide with low fractions of residual austenite in a ferritic matrix which is substantially free from interstitially dissolved elements (IF character).

Abstract

The invention is directed to a method for producing semi-finished product, particularly steel strip, having a dual-phase microstructure and a tensile strength between 500 and 1000 MPa. The invention is characterized in that elements such as carbon and nitrogen which are interstitially dissolved in the ferritic matrix are bound by alloying elements such as Al, Mo, Nb, Ti and V which form carbide, nitride or carbonitride in order to adjust a microstructure of hard components such as martensite, bainite, carbide with low fractions of residual austenite in a ferritic matrix which is substantially free from interstitially dissolved elements (IF character).

# METHOD FOR PRODUCING A STEEL STRIP HAVING A DUAL-PHASE MICROSTRUCTURE

The invention is directed to a method for producing semi-finished product, particularly steel strip, having a dual-phase microstructure, abbreviated as DP steel strip, and a tensile strength between 500 and 1000 MPa.

High-strength steel sheet with good formability, stability of microstructures, and mechanical characteristics up to approximately 600 °C is required in many fields.

One such field is the automotive industry, for example, in which efforts are made to reduce emissions by reducing the weight of structural chassis parts because the consumption of fuel can be reduced by means of reducing weight. On the other hand, there is also a demand for achieving a greater strength of the sheets that are used.

Finally, the sheets should also be suitable for hot-dip galvanization.

However, steels with a dual-phase microstructure that has already been adjusted have the disadvantage that an unwanted, pronounced yield strength generally results when heated above 200 °C as occurs during or in connection with hot-dip galvanization.

Owing to this absence of temperature stability in the materials above approximately 200 °C, semi-finished products such as strip, sheet, pipe and other structural components or workpieces comprising DP steel are not suitable for hot-dip galvanization.

The invention provides a method for the production of a semi-finished product, particularly DP steel strip, which is economical and by which a DP steel strip can be produced which not only has optimal formability properties but also has a temperature stability up to 600 °C and is therefore also suitable for hot-dip galvanization.

According to the invention, there is provided a method for producing semi-finished product, particularly steel strip, having a dual-phase microstructure and a tensile strength between 500 and 1000 MPa, characterized in that elements such as carbon and nitrogen which are interstitially dissolved in the ferritic matrix are bound by alloying elements such as Al, Mo, Nb, Ti and V which form carbide, nitride or carbonitride in order to adjust a microstructure of hard components such as martensite, bainite, carbide with low fractions of residual austenite in a ferritic matrix which is substantially free from interstitially dissolved elements (IF character).

The alloy content of the alloying elements is adapted stoichiometrically to the ferrite content and to the solubility of carbon and nitrogen at the temperature of a subsequent heating or heat treatment of the DP microstructure.

In this way, the semi-finished product or a structural component part manufactured therefrom acquires the properties characteristic of a DP steel with respect to microstructure, strength, minimum elongation, yield strength ratio, and strain hardening exponent also after a subsequent heat treatment or heating, particularly hot-dip galvanization and possibly subsequent dressing.

For the production of hot strip with a DP microstructure, the hot strip is cooled in the two-phase region after exiting the finishing mill train in order to adjust a suitable amount of residual austenite and is subsequently cooled in an accelerated manner to a temperature below the martensite start and finish temperature.

Conversely, for producing cold strip with a DP microstructure, the cold strip is heated in the two-phase region to adjust a suitable amount of residual austenite and is subsequently cooled in an accelerated manner to a temperature below the martensite start and finish temperature. This heat treatment is preferably carried out in a continuous annealing installation.

In one aspect, the invention relates to a method for producing a hot strip, having a dual-phase microstructure and a tensile strength between 500 and 1000 MPa, wherein an element which is interstitially dissolved in a ferritic matrix is bound by an alloying element which forms a carbide, a nitride or a carbonitride in order to adjust a microstructure of a hard component with a fraction of residual austenite in the ferritic matrix which is substantially free from interstitially dissolved elements (IF character), comprising: stoichiometrically adapting the alloy content of the alloying element to the ferrite content and to the solubility of carbon and nitrogen in the ferrite at the temperature of a subsequent heat treatment or heating; cooling the hot strip in the two-phase region after exiting a finishing mill train of a rolling mill in order to adjust an amount of residual austenite for achieving the desired strength class; and subsequently cooling in an accelerated manner to a temperature below the martensite start and finish temperature. Suitably, the subsequent heat treatment or heating is hot-dip galvanization.

In a further aspect, the invention relates to a method for producing a cold strip, having a dual-phase microstructure and a tensile strength between 500 and 1000 MPa, wherein an element which is interstitially dissolved in a ferritic matrix is bound by an alloying element which forms a carbide, a nitride or a carbonitride in order to adjust a microstructure of a hard component with a fraction of residual austenite in the ferritic matrix which is substantially free from interstitially dissolved elements (IF character), comprising: stoichiometrically adapting the alloy content of the alloying element to the ferrite content and to the solubility of carbon and nitrogen in the ferrite at the temperature of a subsequent heat treatment or heating; and heating the cold strip in the two-phase region to adjust an amount of residual austenite and subsequently cooling in an accelerated manner to a temperature below the martensite start and finish temperature. Suitably, the heat treatment for adjusting the DP microstructure in the cold strip is carried out in a continuous annealing installation.

In the above defined methods, suitably: the elements which are interstitially dissolved are carbon and nitrogen; the alloying elements are Al, Mo, Nb, Ti and V; the hard

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component is martensite, bainite and carbide; and the heat treatment is carried out between 400°C and $A_3$.

Example

In order to exclude the influence of dissolved N on the aging behavior, the N content should be fixated as low as possible and by adding Al and possibly Ti. A correspondingly increased V content can also be used for nitrogen fixation.

Table 1 contains some possible chemical compositions:

| No. | Concept | C | Si | Mn | P | S | Al | Mo | Ti | Nb | V | Cr | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | reference | 0.06 | 0.35 | 1.1 | 0.02 | 0.004 | 0.025 | - | - | - | - | 0.65 | min. |
| 2 | Mo | | | | | | | 0.2 | | | - | | |
| 3 | MoV | 0.06 | 0.35 | 1.1 | 0.02 | 0.004 | 0.025 | 0.1 | - | - | 0.05 | 0.65 | min. |
| 4 | V | | | | | | | - | | | 0.1 | | |

Table 1: Chemical composition concept IF-DP in percent by mass

The accompanying diagrams show:

Fig. 1 by way of example, the cooling curve of steel sheet after hot rolling for adjusting a dual-phase microstructure; and

Fig. 2 a typical stress-strain diagram for a DP steel with low yield strength ratio (≤ 75%) and without a pronounced yield strength.

In Figure 1, the austenite fraction is plotted over the time axis on the left-hand side and the core temperature is plotted over the time axis on the right-hand side.

The cooling curve of a steel sheet after hot rolling for adjusting a dual-phase microstructure is shown by way of example.

In so doing, the ferrite region is cooled initially, and most of the austenite is transformed to ferrite within a very short time period. This first cooling stage can be followed by a holding period, or further cooling to temperatures below the martensite start temperature is carried out directly. In so doing, any remaining residual austenite transforms to martensite and generates the second, hard phase. A coiling temperature of about 200 °C is aimed for.

The solid line shows the austenite dissociation as cooling time increases. The curve in dashes shows the lowering of the core temperature, also over the cooling time. It can be seen that cooling is accelerated between approximately 600 °C and the holding temperature of 200 °C.

CLAIMS:

1. A method for producing a hot strip, having a dual-phase microstructure and a tensile strength between 500 and 1000 MPa, wherein an element which is interstitially dissolved in a ferritic matrix is bound by an alloying element which forms a carbide, a nitride or a carbonitride in order to adjust a microstructure of a hard component with a fraction of residual austenite in the ferritic matrix which is substantially free from interstitially dissolved elements (IF character), comprising:

stoichiometrically adapting the alloy content of the alloying element to the ferrite content and to the solubility of carbon and nitrogen in the ferrite at the temperature of a subsequent heat treatment or heating;

cooling the hot strip in the two-phase region after exiting a finishing mill train of a rolling mill in order to adjust an amount of residual austenite for achieving the desired strength class; and

subsequently cooling in an accelerated manner to a temperature below the martensite start and finish temperature.

2. The method according to claim 1, wherein the subsequent heat treatment or heating is hot-dip galvanization.

3. A method for producing a cold strip, having a dual-phase microstructure and a tensile strength between 500 and 1000 MPa, wherein an element which is interstitially dissolved in a ferritic matrix is bound by an alloying element which forms a carbide, a nitride or a carbonitride in order to adjust a microstructure of a hard component with a fraction of residual austenite in the ferritic matrix which is substantially free from interstitially dissolved elements (IF character), comprising:

stoichiometrically adapting the alloy content of the alloying element to the ferrite content and to the solubility of carbon and nitrogen in the ferrite at the temperature of a subsequent heat treatment or heating; and heating the cold strip in the two-phase region to adjust an amount of residual austenite and subsequently cooling in an accelerated manner to a temperature below the martensite start and finish temperature.

4. The method according to claim 3, wherein the heat treatment for adjusting the DP microstructure in the cold strip is carried out in a continuous annealing installation.

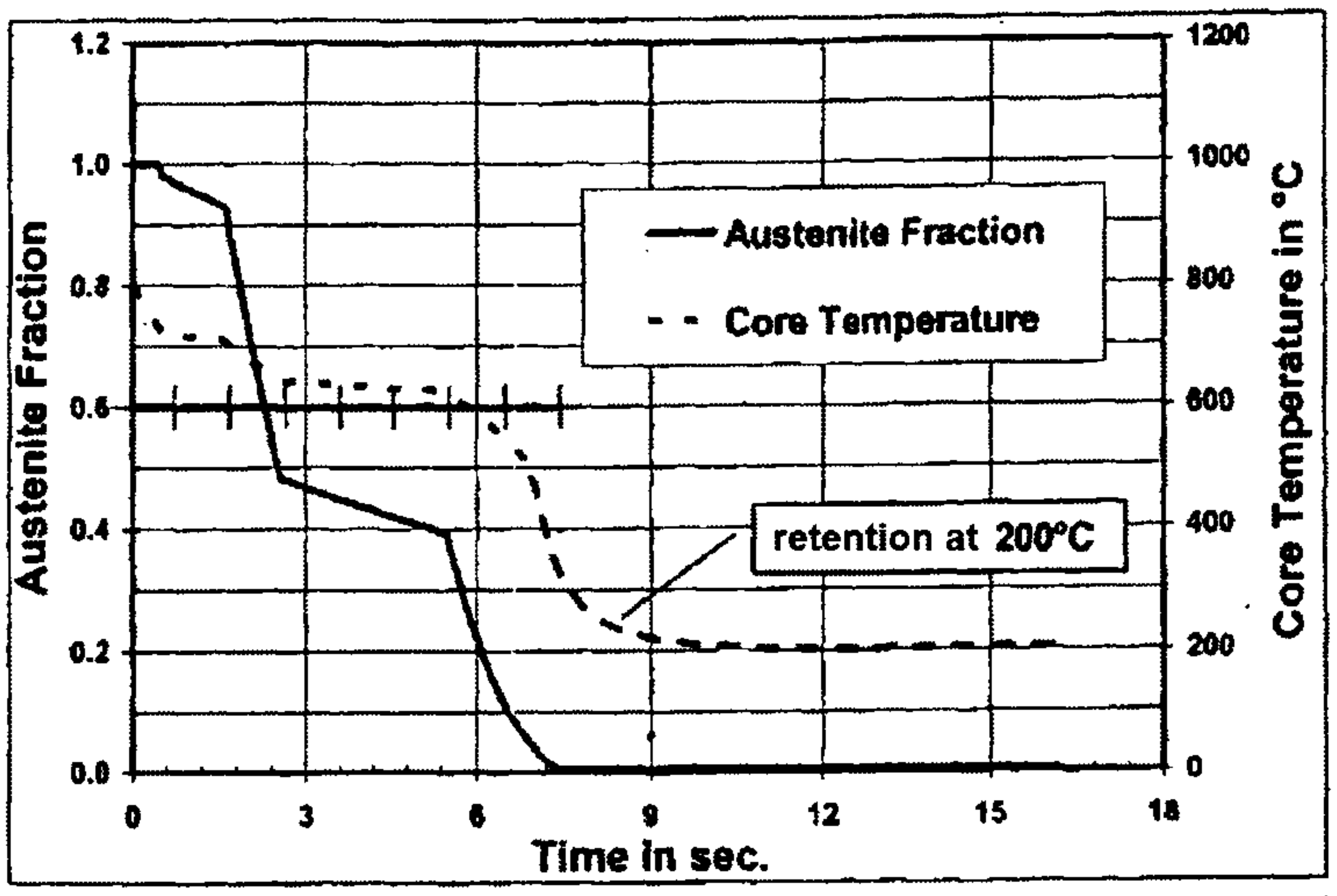
5. The method according to any one of claims 1 to 4, wherein the elements which are interstitially dissolved are carbon and nitrogen.

6. The method according to any one of claims 1 to 5, wherein the alloying elements are Al, Mo, Nb, Ti and V.

7. The method according to any one of claims 1 to 6, wherein the hard component is martensite, bainite and carbide.

8. The method according to any one of claims 1 to 7, wherein the heat treatment is carried out between 400°C and $A_3$.

Figure 1: Example of cooling curve of sheet steel after hot rolling for achieving the DP microstructure (core temperature)



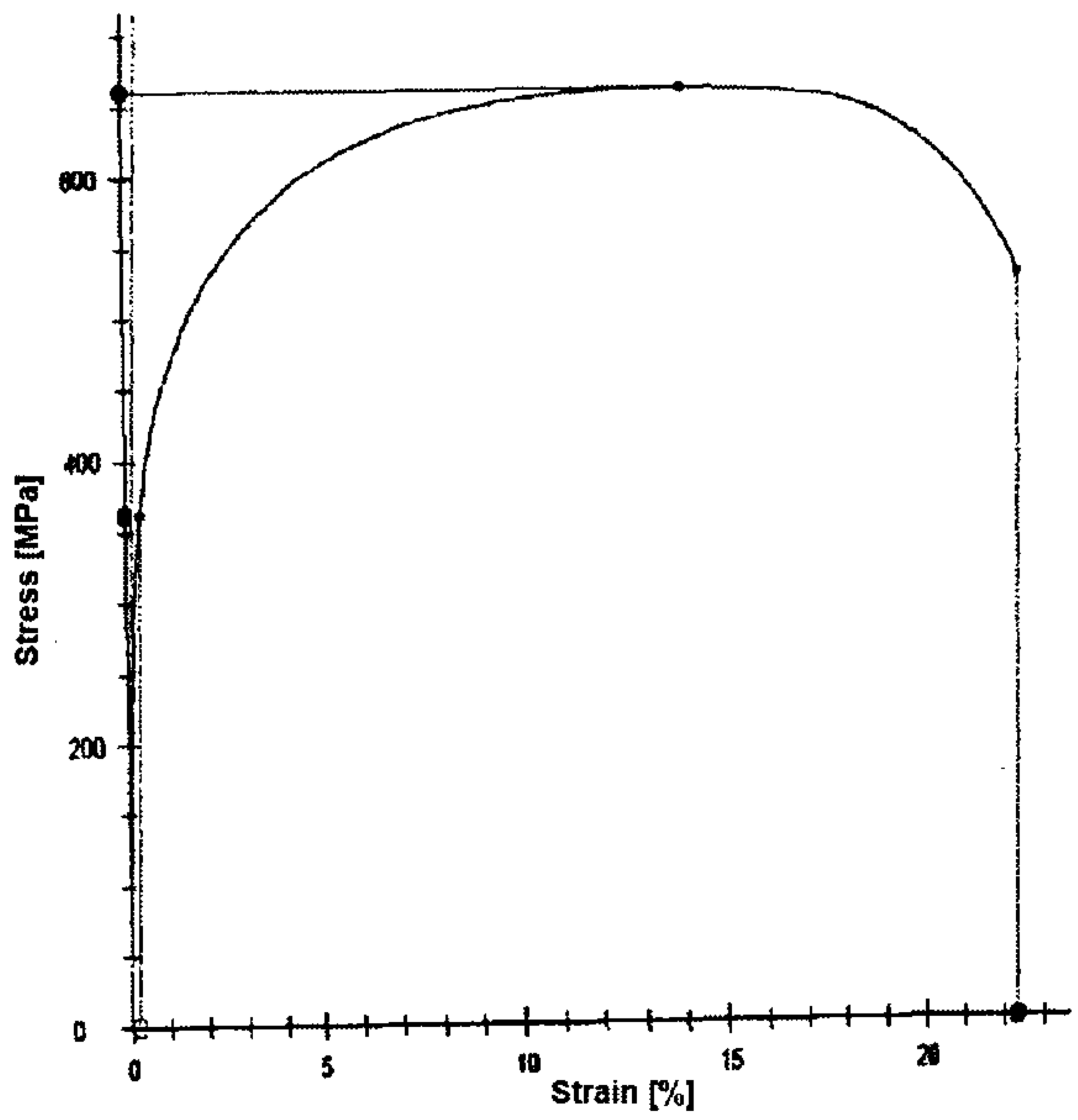



**Figure 2: Typical stress-strain diagram for a DP steel (alloy 4 from Table 1)**

**Example of cooling curve of sheet steel after hot rolling for achieving the DP microstructure (core temperature)**