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1392269

PATENT SPECIFICATION

(11) 1392 269

- v(21) Application No. 50528/73 (22) Filed 31 Oct. 1973
(31) Convention Application No. 790867 (32) Filed 31 Oct. 1972 in
(33) Belgium (BE)
(44) Complete Specification published 30 April 1975
(51) INT CL² C21D 1/00
(52) Index at acceptance

C7N 2A 3 4F 8

C7A 748 770 772 773 780 782 A249 A279 A28X A28Y A329
A339 A349 A369 A389 A409 A439 A459 A509 A529
A53Y A54X A579 A589 A58Y A609 A629 A671
A673 A675 A677 A679 A67X A681 A683 A685 A687
A689 A68X A693 A695 A697 A699 A69X A70X



(54) ROLLED STEEL ROD OR BAR

(71) We, CENTRE DE RECHERCHES METALLURGIQUES—CENTRUM VOOR RESEARCH IN DE METALLURGIE, of 47, Rue Montoyer, Brussels, Belgium, a Belgian Body Corporate, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a treatment for improving the quality of rolled steel rod or bar especially concrete-reinforcing rod or bar.

The process can be applied to both killed and semi-killed steels and rimming steels.

The main qualities looked for in steel rod or bar, *inter alia*, as high as possible a 'yield point' for the grade of steel used, as well as weldability, fatigue resistance, and sufficient ductility for the intended use.

To improve the weldability and ductility of steel it is necessary to reduce its carbon and manganese contents, which, however, causes a reduction in its tensile strength. In order to remedy this disadvantage, the steel can be subjected to a suitable cooling treatment, preferably applied directly at the exit of the rolling mill, which enables the 'yield point' of the rod or bar to be raised to some extent.

When rod or bar (such as concrete-reinforcing rod or bar) is cooled by convection or radiation, the law of cooling almost only depends on its diameter, which has the result that, for a bar of a specific diameter, it is necessary in order to modify its elastic limit, to use other means in order to complement the pure and simple act of cooling.

Of these means, it is particularly worth mentioning the addition of dispersoidal elements (e.g. Nb and V) which cause grain refinement and precipitation hardening of the ferrite. This is indeed efficacious but has the

disadvantage that the cost increases as the 'yield point' is raised. 45

Thus what is desired is a process which avoids the aforesaid disadvantage without the carbon and manganese contents in the steel having to be increased in a way which is unacceptable from the point of view of weldability. 50

In one aspect the present invention provides a process for the production of steel rod or bar in a hot rolling mill, including superficially quenching the rod or bar at the exit of the finishing stand, the core of the rod or bar having a temperature of approximately 850°C at the end of the quenching step; and subsequently cooling the rod or bar at such a rate that the austenitic core transforms to ferrite and carbides, while the surface layer is tempered by the heat transferred from the core. 55 60

In another aspect the invention provides a process for the production of steel rod or bar in a hot rolling mill, including superficially quenching the rod or bar at the exit of the finishing stand, to give the surface layer of the rod or bar a bainitic or martensitic structure, the core of the rod or bar remaining austenitic; and subsequently cooling the rod or bar at such a rate that the austenitic core transforms to ferrite and carbides, while the surface layer is tempered by the heat transferred from the core. 65 70 75

In the preferred process, at the exit of the finishing stand of the hot rolling mill, the rod or bar is subjected to superficial quenching by means of a suitable cooling liquid, and the conditions of quenching are selected so that at the outlet of the liquid-cooling zone the core of the rod or bar has a temperature of about 850°C (e.g. 800–860°C). The rod or bar stays on the cooler (air cooling), so that it is possible for the quenched surface layer to become tempered and for the austenitic 80 85

core of the rod or bar to transform to ferrite and carbides (e.g. to transform to pearlite).

According to the conditions used, the quenched surface layer is either of martensite or bainite.

From the practical point of view, the desired quenching of the bar is obtained by selecting the cooling devices and suitably adjusting the length and arrangement of these devices, for example cooling sprays.

Although, whatever conditions of quenching are applied to the rod or bar, the mechanical properties of the rod or bar are improved compared with bars which have not been subjected to this treatment, it has nevertheless been found that the improvement increases as the heat transfer coefficient of the quenching installation increases. Thus for a treatment lasting 0.55 seconds, the steel may have a yield point of 45 kg/mm² when the installation has a low heat transfer coefficient, and may have a yield point of 65 kg/mm² if this coefficient is raised, if for example a short cooling spray is used but where very intense cooling of the rod or bar has taken place (e.g. if the water contains a mineral salt or a surface-active agent in suspension or solution).

The example just given allows the improvement in the quality of the rod or bar obtained by implementing the process of the invention to be appreciated. The rolled test-pieces examined were concrete-reinforcing bars 12 mm in diameter and of steel having the following composition:

carbon	: 0.24%
manganese	: 1.38%
silicon	: 0.08
aluminium	: 0.002%
sulphur	: 0.020%

In the as-rolled state, the bars in question had the following properties:

Yield Point (Re)	: 35 ± 1 kg/mm ²
Tensile strength (Rr)	: 58 ± 2 kg/mm ²
Elongation (A)	: 33 ± 2 %

Treated according to the process of the invention, by passing through a water spray with a high heat transfer coefficient, the bars had the following properties:

Time in water spray	Re kg/mm ²	A %	Re/Rr
0.45 seconds	50	27	0.75
0.65 seconds	75	19	0.85

The process according to the invention enables rod and bar of a particular type to be

obtained, namely having a bainitic or martensitic surface layer and a core composed of ferrite and carbides.

In the accompanying drawings:

Figure 1 is graph of hardness against depth, for a round bar;

Figure 2a is a photograph of the cross-section of a round bar;

Figure 2b is a photomicrograph of the surface layer of the bar; and

Figure 2c is a photomicrograph of the core of the bar.

Figure 1 shows the variation of the hardness of the steel along a radius of a cross-section of a concrete-reinforcing bar as treated according to the invention. The hardness (DHP) is shown along the ordinate whilst the abscissa indicates the distance (d) from the surface of the bar.

Figure 2a illustrates a cross-section of a concrete-reinforcing bar treated according to the invention; the surface layer and core can be distinctly seen. Figure 2b shows the martensitic surface layer, and Figure 2c shows the ferrite and carbides which constitute the core of the bar (magnification: 500×).

WHAT WE CLAIM IS:—

1. A process for the production of steel rod or bar in a hot rolling mill, including superficially quenching the rod or bar at the exit of the finishing stand, the core of the rod or bar having a temperature of approximately 850°C at the end of the quenching step; and subsequently cooling the rod or bar at such a rate that the austenitic core transforms to ferrite and carbides, while the surface layer is tempered by the heat transferred from the core.

2. A process for the production of steel rod or bar in a hot rolling mill, including superficially quenching the rod or bar at the exit of the finishing stand, to give the surface layer of the rod or bar a bainitic or martensitic structure, the core of the rod or bar remaining austenitic; and subsequently cooling the rod or bar at such a rate that the austenitic core transforms to ferrite and carbides, while the surface layer is tempered by the heat transferred from the core.

3. A process as claimed in claim 1 or 2, in which the rod or bar is superficially quenched with water.

4. A process as claimed in claim 3, in which the water contains a mineral salt or a surface-active agent, in suspension or solution.

5. A process as claimed in claim 1, 2, or 4, in which the rate of removal of heat from the rod or bar during superficial quenching is higher than that obtained in a water quench.

6. A process as claimed in claim 1, substan-



core of the rod or bar to transform to ferrite and carbides (e.g. to transform to pearlite).

According to the conditions used, the quenched surface layer is either of martensite or bainite.

From the practical point of view, the desired quenching of the bar is obtained by selecting the cooling devices and suitably adjusting the length and arrangement of these devices, for example cooling sprays.

Although, whatever conditions of quenching are applied to the rod or bar, the mechanical properties of the rod or bar are improved compared with bars which have not been subjected to this treatment, it has nevertheless been found that the improvement increases as the heat transfer coefficient of the quenching installation increases. Thus for a treatment lasting 0.55 seconds, the steel may have a yield point of 45 kg/mm² when the installation has a low heat transfer coefficient, and may have a yield point of 65 kg/mm² if this coefficient is raised, if for example a short cooling spray is used but where very intense cooling of the rod or bar has taken place (e.g. if the water contains a mineral salt or a surface-active agent in suspension or solution).

The example just given allows the improvement in the quality of the rod or bar obtained by implementing the process of the invention to be appreciated. The rolled test-pieces examined were concrete-reinforcing bars 12 mm in diameter and of steel having the following composition:

carbon	: 0.24%
manganese	: 1.38%
silicon	: 0.08
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sulphur	: 0.020%

In the as-rolled state, the bars in question had the following properties:

Yield Point (Re)	: 35 ± 1 kg/mm ²
Tensile strength (Rr)	: 58 ± 2 kg/mm ²
Elongation (A)	: 33 ± 2 %

Treated according to the process of the invention, by passing through a water spray with a high heat transfer coefficient, the bars had the following properties:

Time in water spray	Re kg/mm ²	A %	Re/Rr
0.45 seconds	50	27	0.75
0.65 seconds	75	19	0.85

The process according to the invention enables rod and bar of a particular type to be

obtained, namely having a bainitic or martensitic surface layer and a core composed of ferrite and carbides.

In the accompanying drawings:

Figure 1 is graph of hardness against depth, for a round bar;

Figure 2a is a photograph of the cross-section of a round bar;

Figure 2b is a photomicrograph of the surface layer of the bar; and

Figure 2c is a photomicrograph of the core of the bar.

Figure 1 shows the variation of the hardness of the steel along a radius of a cross-section of a concrete-reinforcing bar as treated according to the invention. The hardness (DHP) is shown along the ordinate whilst the abscissa indicates the distance (d) from the surface of the bar.

Figure 2a illustrates a cross-section of a concrete-reinforcing bar treated according to the invention; the surface layer and core can be distinctly seen. Figure 2b shows the martensitic surface layer, and Figure 2c shows the ferrite and carbides which constitute the core of the bar (magnification: 500×).

WHAT WE CLAIM IS:—

1. A process for the production of steel rod or bar in a hot rolling mill, including superficially quenching the rod or bar at the exit of the finishing stand, the core of the rod or bar having a temperature of approximately 850°C at the end of the quenching step; and subsequently cooling the rod or bar at such a rate that the austenitic core transforms to ferrite and carbides, while the surface layer is tempered by the heat transferred from the core.

2. A process for the production of steel rod or bar in a hot rolling mill, including superficially quenching the rod or bar at the exit of the finishing stand, to give the surface layer of the rod or bar a bainitic or martensitic structure, the core of the rod or bar remaining austenitic; and subsequently cooling the rod or bar at such a rate that the austenitic core transforms to ferrite and carbides, while the surface layer is tempered by the heat transferred from the core.

3. A process as claimed in claim 1 or 2, in which the rod or bar is superficially quenched with water.

4. A process as claimed in claim 3, in which the water contains a mineral salt or a surface-active agent, in suspension or solution.

5. A process as claimed in claim 1, 2, or 4, in which the rate of removal of heat from the rod or bar during superficial quenching is higher than that obtained in a water quench.

6. A process as claimed in claim 1, substan-



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tially as described herein with reference to the accompanying drawings.

7. Rolled steel rod or bar produced by a process as claimed in any preceding claim.

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Agents for the Applicant(s).

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1975.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.