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(54) **Cold rolled and hardened strip steel product**

(57) The present invention relates to a strip steel product that it consists of a steel alloy in having the following composition in weight-%: C: 0.4-0.8, Si: 0.4-1.2, Mn: 0.2-0.55, Cr: 3.5-4.5, W: 1.5-4.0, and Mo: 1.0-1.8,

balance Fe and normally occurring impurities. The strip steel product is preferably utilised in printing and paper production blades such as coater blades, doctor blades and crepe blades.

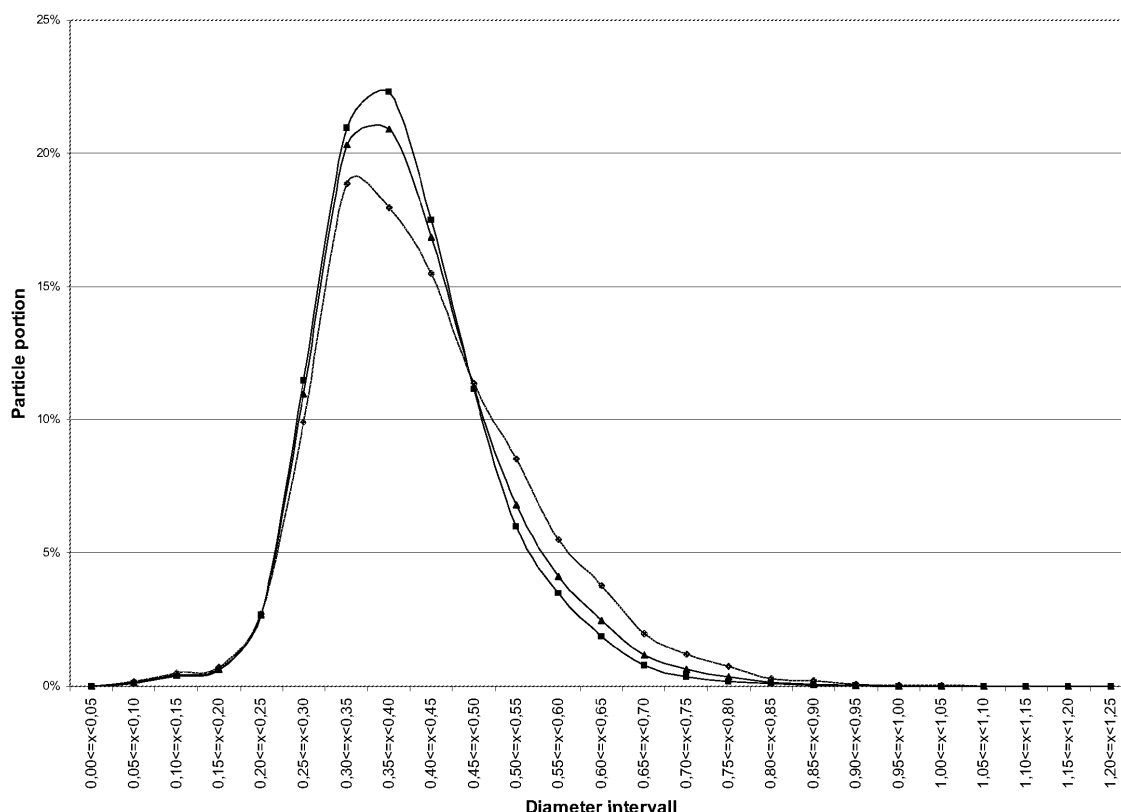


Fig. 3

Description

[0001] The present invention relates to a cold rolled and hardened strip steel product manufactured by conventional metallurgy suitable for manufacturing of coater and doctor blades. In particular the invention relates to a steel strip product made from a steel composition containing alloying additions which forms carbides with carbon in the alloy and therefore increases the strength and wear resistance of the alloy.

BACKGROUND TO THE INVENTION

[0002] Strip steel products are used in the paper and printing industries in the form of coater blades, doctor blades and crepe blades, for example. These blades have in common that they are relatively thin and long and has to endure high demands with regards to straightness, resistance to wear and strength. For example coater blades are used for coating the paper web with a coating slip. These blades are pressed against the moving paper web, usually with back pressure provided by a counter roll, or by a blade, on the opposite side of the paper web, when two-sided coating is performed. To provide even and top quality coating the coater blade must be straight. The normal specification is that the machined edge of the coater blade must not deviate more than 0.3 mm/3,000 mm coater blade length, from complete straightness. Furthermore, any unplanned interruption in the printing process is costly and the coater blades should have a high resistance to wear and have a predictable lifetime. Traditionally carbon steels have been used for the manufacturing of blades for the paper and printing industries, due to their high hardenability.

[0003] In order to increase strength and wear resistance it has been suggested to use additions in the composition that would result in the formation of carbides. Examples thereof is disclosed in EP 0 672 761 and US 6 547 846. EP 0 672 761 describes a steel alloy comprising 2.6 % Cr, 2.3 % Mo, 2 % V, 0.55% C, 1.0% Si and 0.8 % Mn. US 6 547 846 discloses a steel alloy containing 4.0 % Cr, 2.0 % Mo, 2.0 % W, 1.0-1.8 % V, 0.32-0.35 Mn, 0.46-1.0 Si and 0.48-0.75% C. Furthermore, US 6 632 301 B2 discloses various steel alloys having up to 2.6 % Cr, up to 2.3 % Mo, up to 0.56 % W and up to 0.9 % V.

[0004] The introduction of carbide formers and hence a distribution of hard carbides in the final steel product has increased the hardness and wear resistance of the material. The hardness alone does not make the material optimal for the intended use as blades in the paper and printing industries. The part of the blades contacting the other surface is typically a thin edge. The wear should be small, but also well controlled and even along the contacting surface. The introduction of carbides has the drawback of increasing the risk for chipping at the edge of the blade, if the carbides are too big, as the thickness of the blade at the edge can be in the same order as the size of the carbides.

[0005] Hence, there still is a need for a steel composition that is wear resistant, have high strength and that is relatively easy to manufacture and process through melting, casting, forging, hot and cold rolling and finally heat treatment.

SUMMARY OF THE INVENTION

[0006] It is an object of the present disclosure to present a strip steel product which is suitable for high wear applications, such as coater blades, doctor blades and crepe blades.

[0007] The object of the present invention is achieved by means of a strip steel product e as defined in claim 1.

[0008] The present invention relates to a strip steel product that it consists of a steel alloy in having the following composition in weight-%: C: 0.4-0.8, Si: 0.4-1.2, Mn: 0.2-0.55, Cr: 3.5-4.5, W: 1.5-4.0, and Mo: 1.0-1.8, balance Fe and normally occurring impurities. The strip steel product is preferably utilised in printing and paper production blades such as coater blades, doctor blades and crepe blades.

[0009] The strip steel product according to the invention has a hardness in the order of 670 HV and has been shown to have excellent wear resistance in wear measurements and test production.

[0010] Thanks to the inventive strip steel product it is possible to produce for example coater blades, with a significantly increased lifetime, and thereby reducing the downtime in a paper or printing production line. The possibility to control the size distribution of the carbides in the strip steel product makes it possible to provide blades with a thin edge, but with a significantly reduced tendency to chipping.

[0011] Further features and advantages of the present invention will be presented in the following detailed description and in the independent patent claims.

BRIEF DESCRIPTION OF THE FIGURES**[0012]**

Figures 1 a-d Graphs illustrating the result of a Thermo-Calc evaluation, with regard to phases and amount of different phases.

Figures 2a-c Graphs illustrating the result of a wear measurements of the steel strip product according to the present invention in comparison with commercially available products in different media, a) with process water, b) de-ionized water and c) average result; and

5 Figures 3 Graph showing the carbide size distribution of the hardened strip steel.

DETAILED DESCRIPTION

10 **[0013]** The steel according to the present disclosure is preferably produced by conventional methods, such as melting, casting, forging, hot and cold rolling. The thin dimensions of the final products make other methods such as powder metallurgy less suitable as the size and distribution of the carbides need to be carefully controlled. Also the difficulties in controlling the oxygen content in the powder, and hence the oxide in the final product makes powder technology less attractive.

15 **[0014]** The effect and the content of the different alloying elements of the steel composition will now be explained in more detail.

Carbon

20 **[0015]** The content of carbon affects the hardenability of the material and also the hardness thereof. In order to harden the material the content of C needs to be at least approximately 0.4 % by weight. When present in higher amounts carbon also forms carbides, which in turn increases the hardness of the alloy further. However, a too high content of C makes it difficult to process. Therefore, the content of C should be limited to maximally 0.8 % by weight. For the alloy according to the present invention a carbon content of 0.4-0.8 wt% is selected in order to achieve an appropriate amount of carbides and a good hardenability. According to an embodiment of the invention, the carbon content is 0.45-0.7 wt%.

25 The range of the carbon content is verified by ThermoCalc-calculations as illustrated in Figure 1a-d, with a carbon content of 0.5 (a), 0.55 (b) 0.6 (c) and 0.65 (d) wt%. The other constituents are as in sample A, Table 1.

Silicon

30 **[0016]** Silicon is always present as a result of the manufacturing process, desoxidation for example. Also, it facilitates the hardening process wherein a through hardening is favoured. Furthermore, it improves the high temperature strength. However, too high levels of silicon will stabilise the ferrite which is not desired for a high strength material. According to the present alloy composition, the content of silicon is 0.4-1.2 wt%. According to an embodiment the content is max 0.4-0.9 wt%.

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Manganese

40 **[0017]** Mn is i.a. present as a result of the manufacturing process, wherein it improves desoxidation and neutralises the detrimental effect of sulphur. It also improves the yield and tensile strength as well as facilitates the through hardening. Too high levels of Mn may cause high levels of residual austenite, wherein the suitable content of Mn with regard to the risk of residual austenite depends on the other alloying elements. According to the present composition the content of Mn is 0.2-0.55 wt%. According to an embodiment, the content of Mn is 0.20-0.40 wt%.

Chromium

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[0018] Chromium improves the strength of the alloy as well as the wear resistance. It forms carbides with carbon. Cr also gives the steel sufficient hardenability by allowing enough martensite to be formed during quenching in air, oil or water. However, a too high content of Cr renders desired carbides of for example V less stable. The composition according to the present invention contains 3.5-4.5 wt% Cr.

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Tungsten

55 **[0019]** Tungsten forms carbides with carbon. As a result thereof, it increases the wear resistance. Furthermore, a through hardening is facilitated since W suppresses the formation of bainite. W also improves the high temperature strength. It also renders a good edge sharpness of the material. According to the present invention a tungsten content of 1.5 wt% is required in order to achieve the positive effects. However, a too high content of tungsten in combination with a high content of carbon generates too much carbide in an early production stage, i.e. primary carbides, and therefore results in difficulties to process the material, for example by hot rolling. The maximum content of W of the present alloy

composition is therefore limited to 4 wt%, preferably max 2.5 wt%. According to an embodiment the W content is 1.5-2.5 wt%.

Molybdenum

[0020] Mo increases the high temperature strength of the alloy. As some of the other elements of the alloy, Mo also forms carbides with carbon. It also increases the yield strength and facilitates through hardening. A too high content of Mo makes the steel more disposed to oxidise during processing which can make the manufacturing process more difficult. The present alloy composition therefore contains 1-1.8 wt% Mo.

Impurities

[0021] In addition to the elements above, some impurities are always present due to the composition of the scrap used. Examples of such impurities are Ni and Cu, which two elements should be limited to max 0.2 wt% of each. Furthermore, impurities are also present due to normally occurring steelmaking alloying additions for e.g. desoxidation or hot ductility.

[0022] A number of samples with nominal compositions within the range of the steel composition according to the present invention were manufactured by conventional metallurgy processing in a melting furnace, re-melting, cast, forged and hot-rolled. An average of the samples are denoted sample A in table 1 and hereinafter. Table 1 also presents commercially available comparison samples, wherein sample B is a steel composition corresponding to the alloy disclosed in EP 0 672 761, C is a traditional carbon steel, and D is a high Cr alloy. The contents are given in % by weight.

Table 1

Sample	C	Si	Mn	Cr	W	V	Mo
A	0,50	0,80	0,30	4,0	2,0	-	1,5
B	0,5	1	0,75	2,5	-	0,9	2,3
C	1,0	0,3	0,3	1,4	-	-	-
D	0,68	0,4	0,7	13	-	-	-

[0023] Figure 2 illustrate the result of wear measurement. The wear measurements were designed to closely mimic realistic conditions. Blades of the materials according to table 1 were worn against a 175 cm anilox cylinder at a pressure of 2 bar, at 200 m/min in 16 hours. a) is with process water as the medium, b) de-ionized water and c) the average result. As illustrated in figure 2a-c the sample A, with a composition according to the present invention exhibited a superior resistance to wear as compared to samples B, C and D. In the case with process water an approximate improvement of 25% were observed. Similar results have been observed in actual production testing.

[0024] As described above the strip steel product has to have a high hardness in order to be suitable for the listed applications. The strip steel product according to the invention exhibits a hardness of approximately 670 HV and a tensile strength of 2200 MPa. If required, the hardness can be further increased by edge hardening.

[0025] It is believed that the size distribution of the carbides, i.e. the chromium and tungsten carbide particles, is of importance for the mechanical properties of the strip steel product. The size distribution of carbides in the steel strip product according to the present invention is illustrated in Figure 3: chromium carbides (squares), tungsten carbides (diamonds) and combined (triangles). The carbide size distribution has been extracted from SEM-micrographs by image processing. For printing doctor blades, and other applications requiring a thin blade, i.e. a thickness up to 0.3 mm, the diameter of the carbides should be below 1 μ m and preferably the majority of the carbides have a diameter below 0.6 μ m.

[0026] The strip steel product according to the invention has been illustratively described with references to applications such as coater blades, doctor blades and crepe blades. Also other applications wherein a hard and wear resistant strip steel is utilised for example knife and saw applications, valve applications and dies for example label dies.

Claims

1. Strip steel product **characterised in that** it consists of a steel alloy in having the following composition in weight-%:

C 0.4-0.8
Si 0.4-1.2

Mn 0.2-0.55

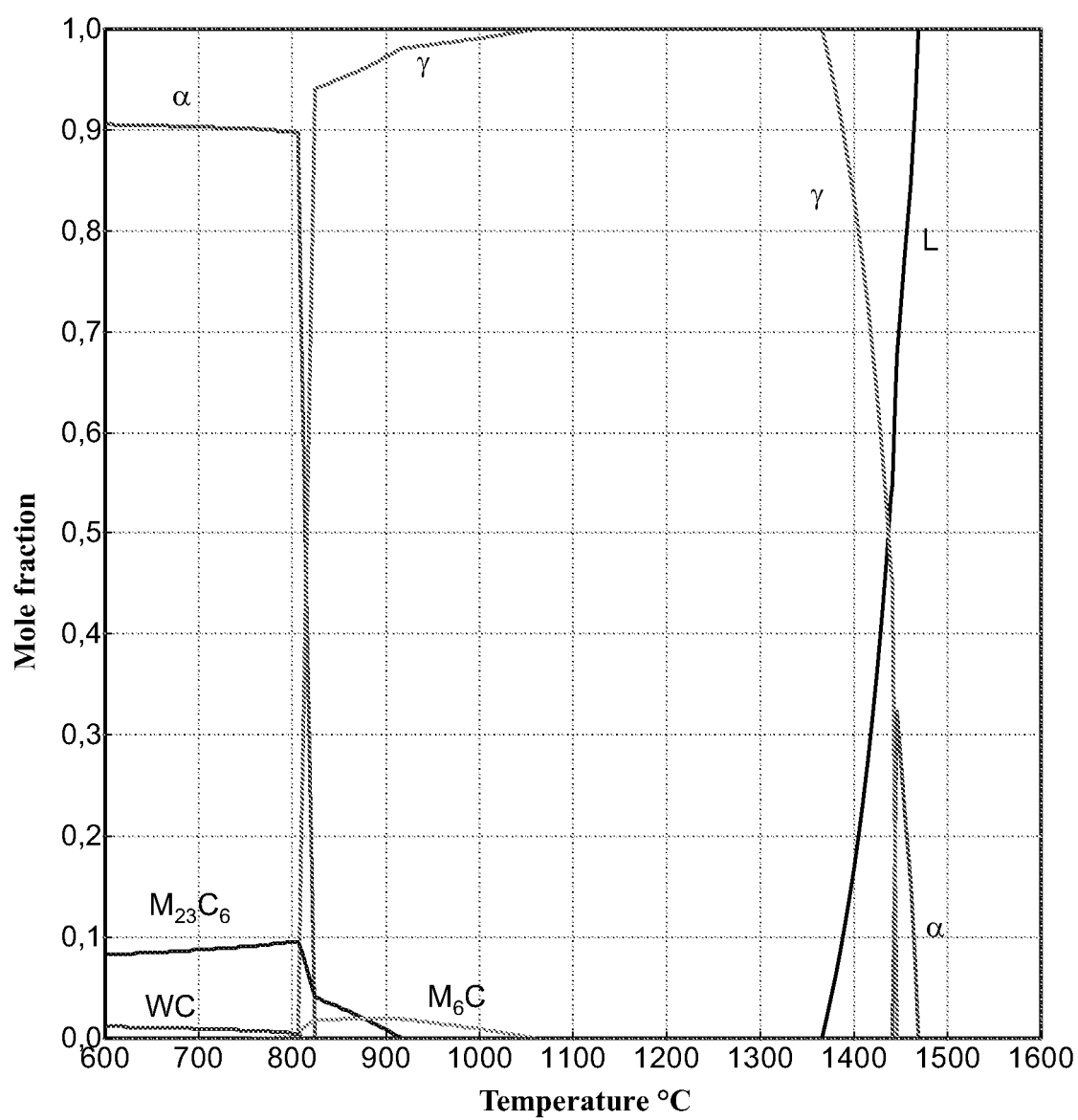
Cr 3.5-4.5

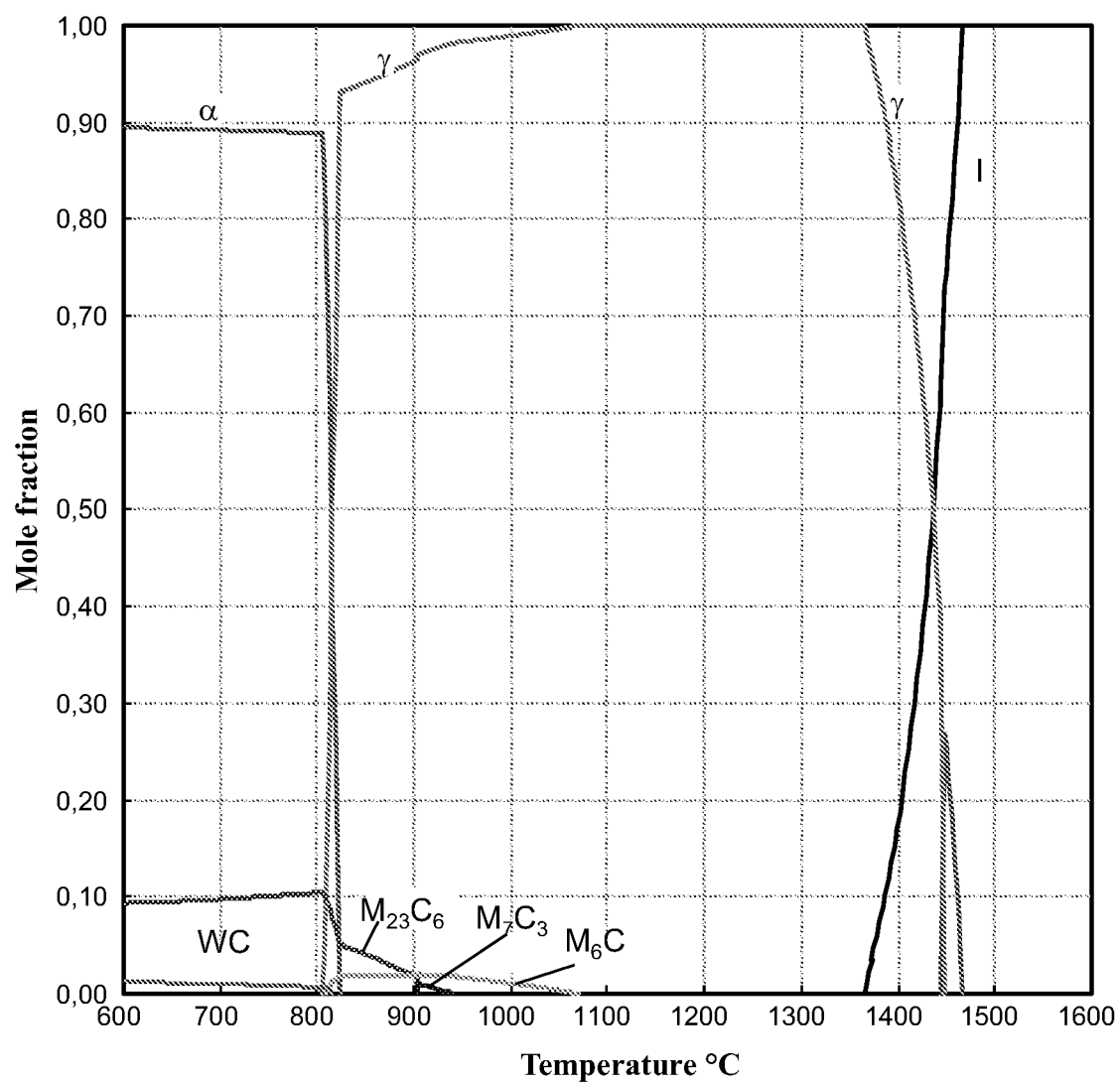
W 1.5-4.0

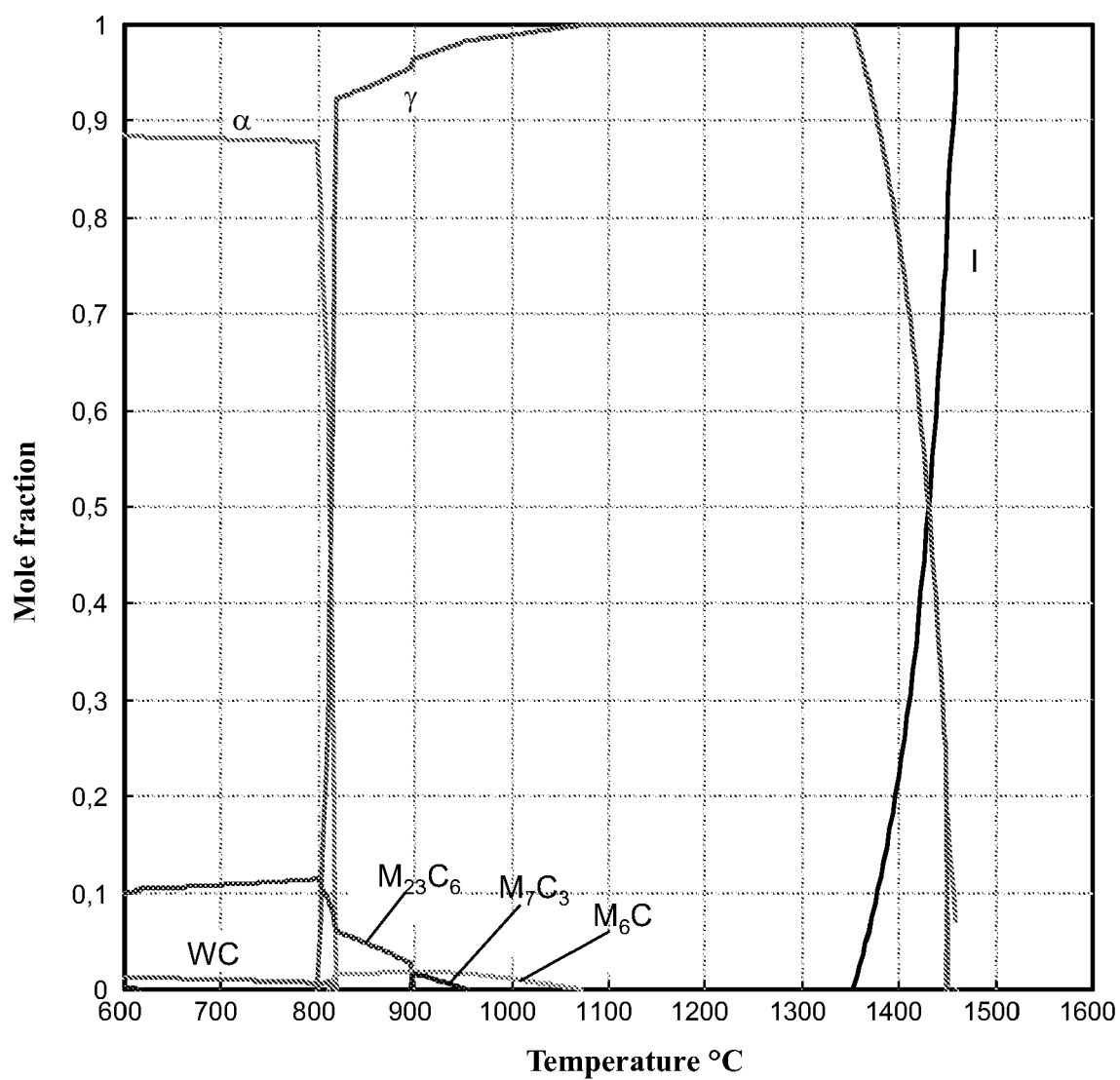
Mo 1.0-1.8

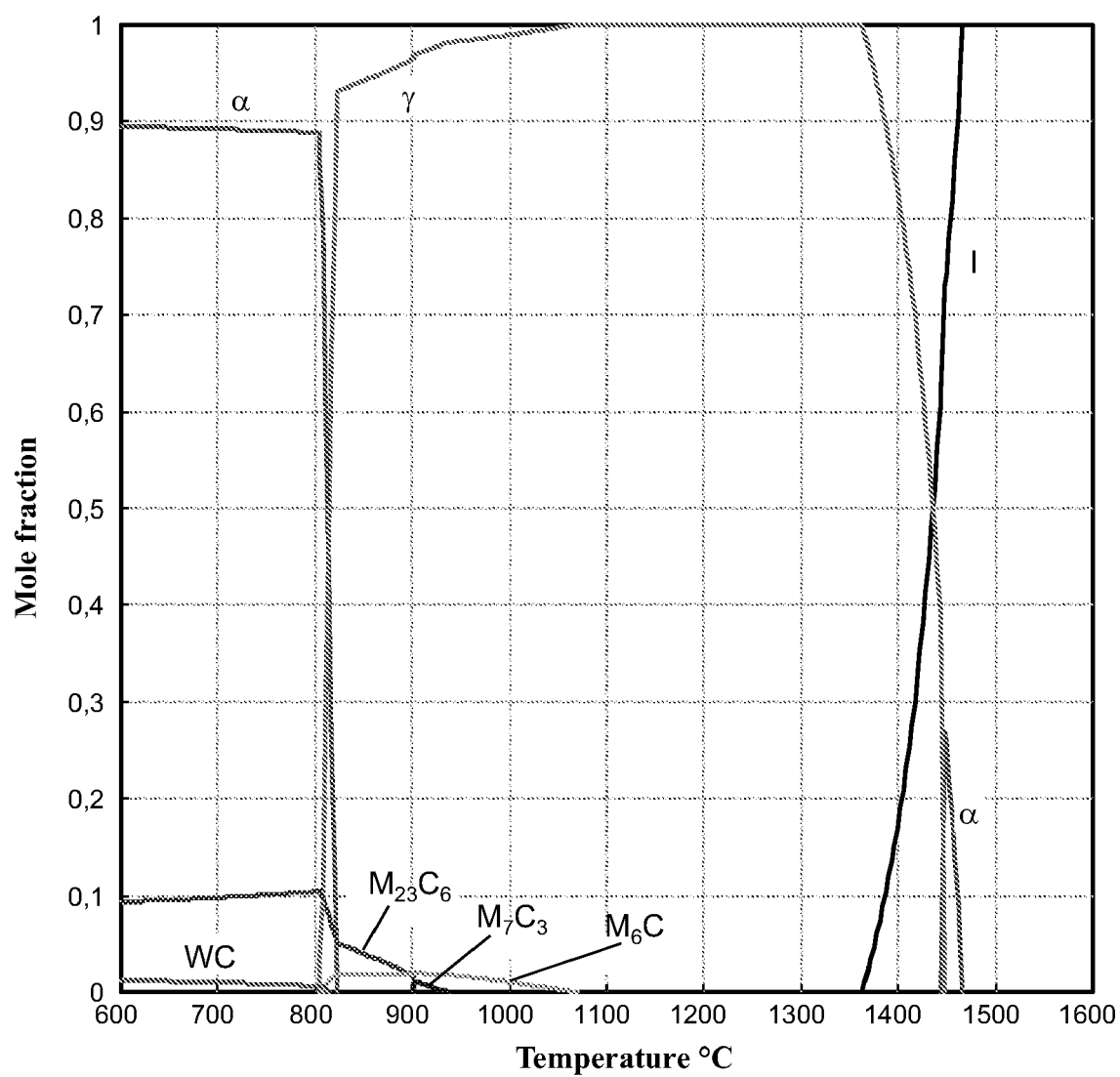
balance Fe and normally occurring impurities.

2. Strip steel product according to claim 1 **characterised in that** the content of C is 0.45-0.7 % by weight.
3. Strip steel product according to claim 1 **characterised in that** the content of Mn is 0.20-0.40 % by weight.
4. Strip steel product according to claim 1 **characterised in that** the content of W is 1.5-2.5 % by weight.
5. Strip steel product according to claim 1 **characterised in that** the steel alloy comprises carbides of tungsten and chromium, the carbides having a diameter less than 1 μm .
6. Strip steel product according to any of the preceding claims **characterised in that** it is produced by conventional metallurgy.
7. Doctor blade for printing applications made of a strip steel product according to any of the preceding claims.
8. Coater blade for pulp and paper industry made of a strip steel product according to any of the preceding claims.
9. Crepe blade for pulp and paper industry made of a strip steel product according to any of the preceding claims.
10. Label die for printing applications made of a strip steel product according to any of the preceding claims.

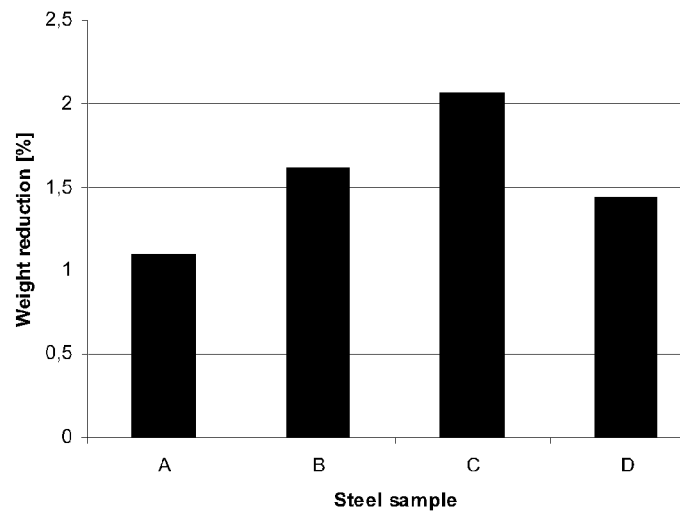
*Fig. 1a*

*Fig. 1b*

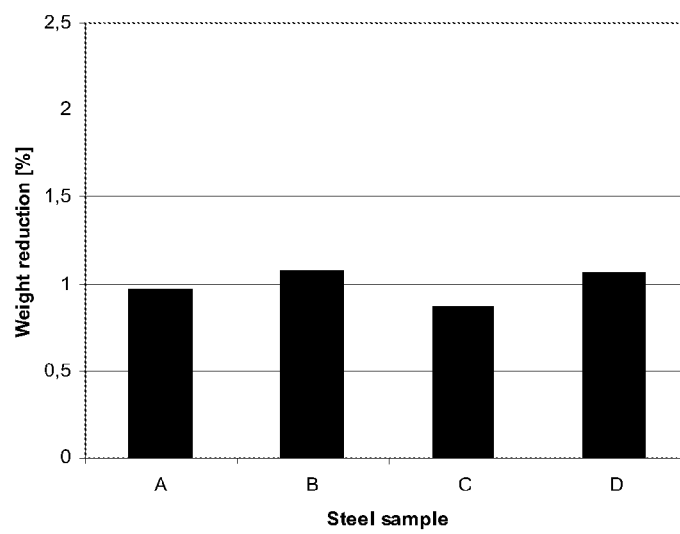
*Fig. 1c*

*Fig. 1d*

a)



b)



c)

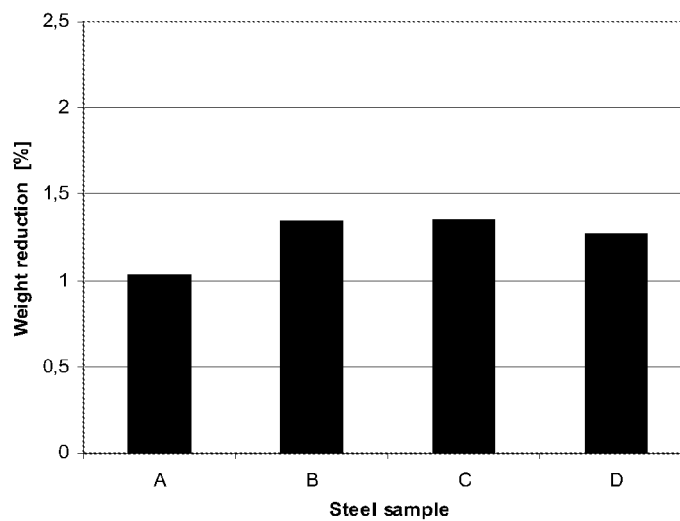
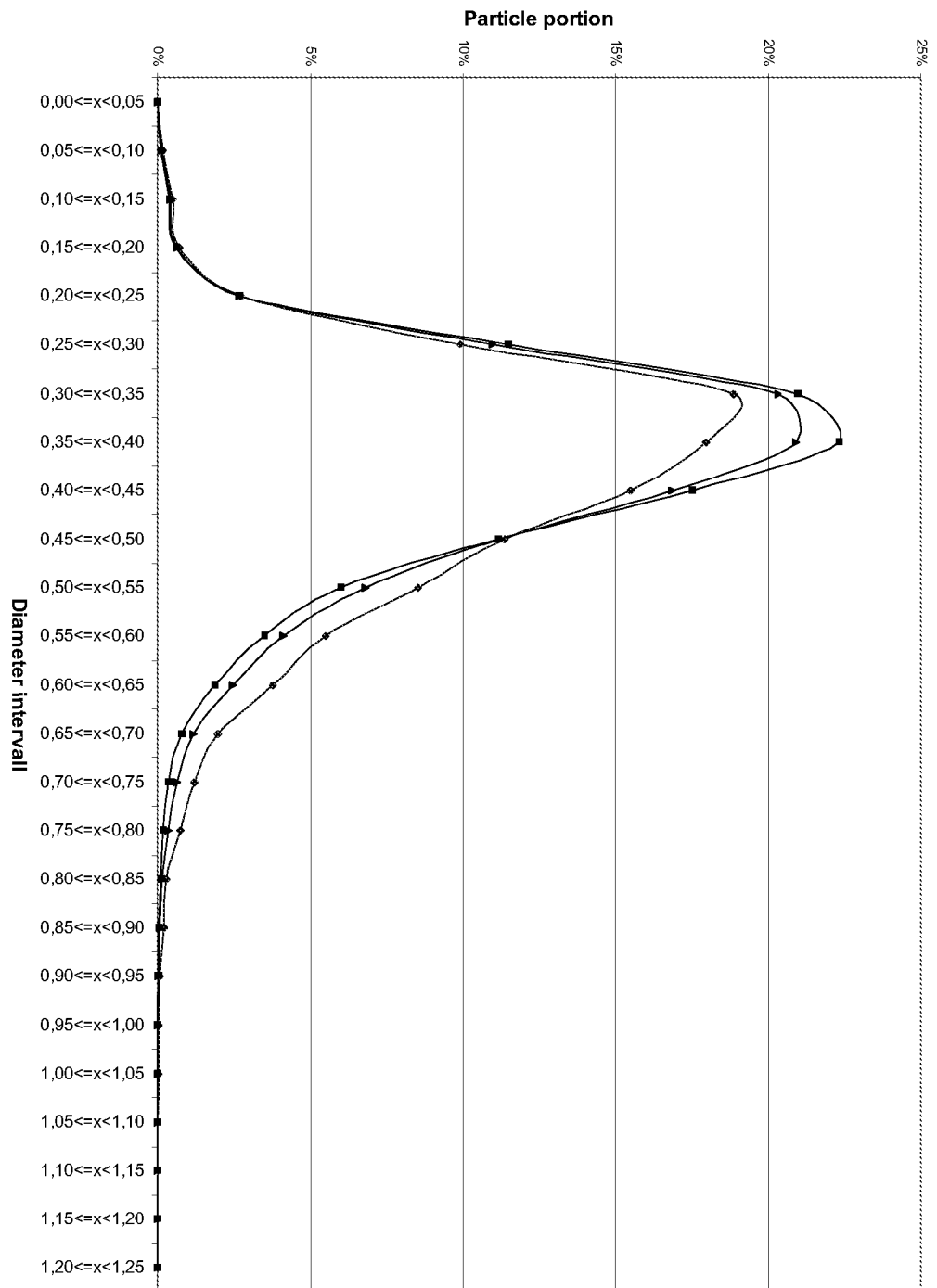


Fig. 2a-c

*Fig. 3*



EUROPEAN SEARCH REPORT

Application Number
EP 11 17 0995

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Place of search Munich		Date of completion of the search 9 November 2011	Examiner Catana, Cosmin
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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