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Steel and a steel manufacturing method.

A steel in which the only alloying additive (besides carbon) is molybdenum and/or tungsten in a total amount of 0,2 - 2,0 %. The steel is manufactured by a method whereby an increased ferrite amount is produced in the steel before pearlite is formed therein by keeping the cooling rate below a critical value, thereby facilitating working of the steel before its final treatment (such as by tempering). The amount of silicon and manganese in the steel is particularly limited, the total content of silicon and manganese being less than 0,30 % and the amount of each of these substances, silicon and manganese, is preferably below 0,15 %. In a certain embodiment, 1 - 2 % of chromium is also added to the steel in order to increase the temperability of the steel.

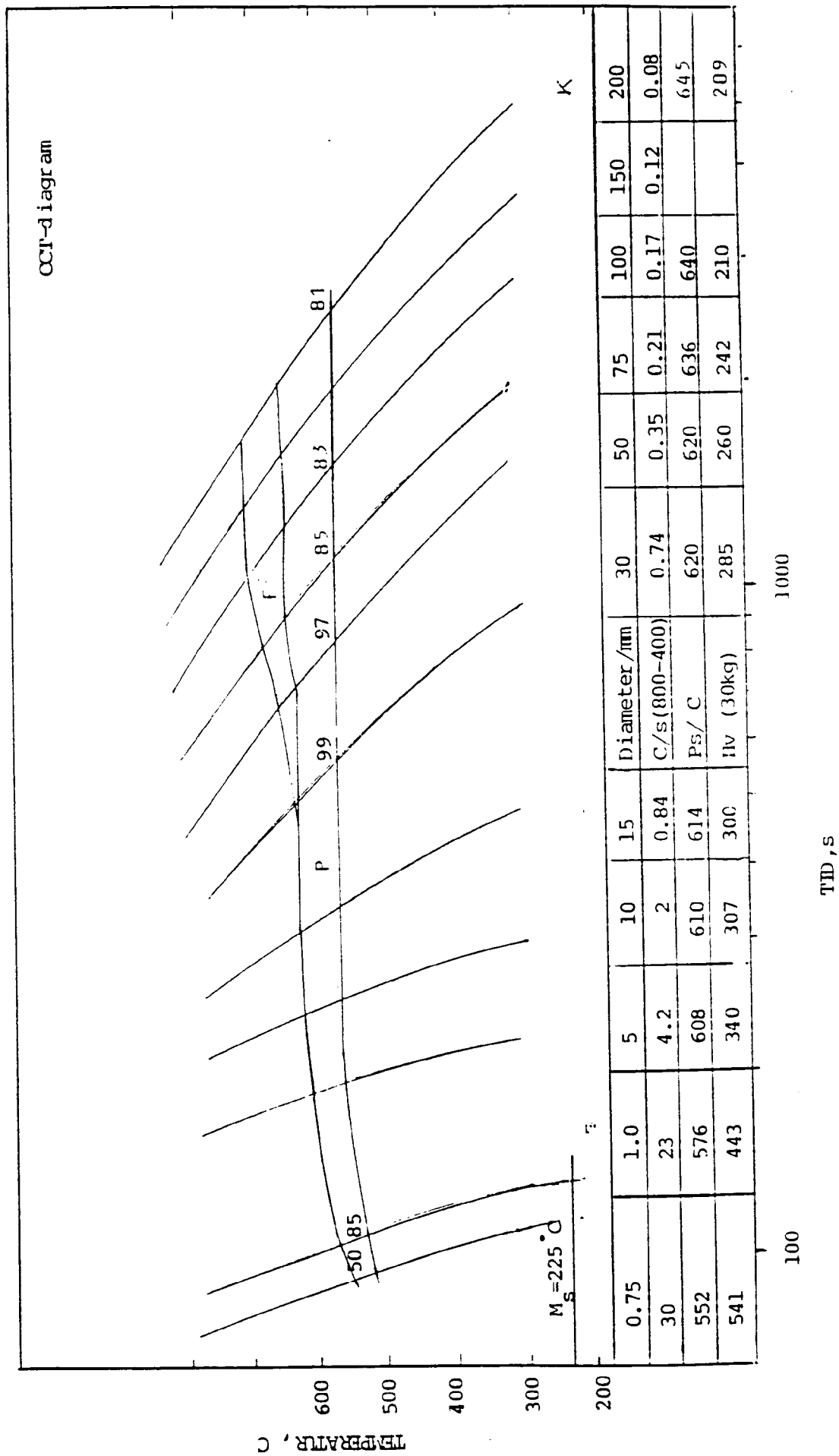


Fig. 1

The present invention relates to a method of treating steel to which, besides iron and carbon, substantially the only intentional alloying element added to the steel is molybdenum or tungsten, so that the steel becomes easier to mold or work before final treatment thereof, e.g. by tempering. The invention also relates to steel treated in accordance with the method of the invention.

The carbon content of steel in accordance with the invention is preferably within the interval 0,10 - 1,20 %, the intervals of 0,10 - 0,35 %, 0,25 - 0,60 %, 0,45 - 0,85 % and 0,70 - 1,15 % being suitable for casehardening steel, toughened steel, induction hardening steel and spring and roller bearing steel, respectively. The only intentional additive (molybdenum and/or tungsten) is preferably present in the steel in an amount within the interval 0,2 - 2,0 %. In certain special situations, such as products requiring high temperability, the steel in accordance with the invention, is also alloyed with chromium, the chromium-content being 1 - 2 %. Other alloying elements normally used in steel, such as silicon, manganese, nickel, vanadium and (with the exception of the special situation discussed above) also chromium, are limited to the lowest possible levels for the industrial manufacturing process used to produce the steel. Such steel is particularly useful for stressed structural members, particularly structural members requiring high ductility and fatigue-resistance. The amount of silicon and manganese in particular must be kept low, the total content of silicon and manganese being less than 0,30 %, and the content of each of the elements silicon and manganese being less than 0,15 %.

The steel treated in accordance with the invention may, for instance, contain the following elements when based on scrap steel:

Si	Mn	P	S	Ni	Cu	Al
0,10 %	0,20 %	0,015 %	0,015 %	<0,10 %	0,20 %	0,010-0,060 %

Such steel often contains 0,45 % molybdenum and 0,75 % carbon, and higher contents of molybdenum or carbon of course can be added if desired. Other "normal" remainder elements include 0,05 % silicon and 0,10 % manganese.

The method according to the invention comprises selecting a steel within the scope of the composition specified above and subjecting it to cooling, the cooling rate being below a certain value as discussed in more detail below. The invention also comprises a steel with the specified composition and structure obtained through this method. Steel manufactured in accordance with the invention contains an unexpectedly high quantity of ferrite, thus making it less hard to work.

The invention is most easily illustrated with reference to an eutectoid steel. As is known, an eutectoid steel, such as carbon steel containing 0,8 % carbon, has by definition a pearlite content of 100 % and is therefore difficult to mold/work regardless of how it has been allowed to cool. However, by means of the invention, a phenomenon appears which is particularly evident when the steel selected according to the invention has a composition close to eutectoid and is subjected to the cooling described. The phenomenon is that ferrite is surprisingly separated out first and a degenerated pearlite is then formed. The structure as a whole would normally be expected to be pearlite in character since the steel composition has substantially an eutectoid composition. Due to the ferrite having been separated out, the steel becomes less difficult to work/mould.

With an eutectoid steel having the prescribed composition and a molybdenum content of 0,50 %, a structure can be obtained through the invention which is similar to that of a carbon steel with 0,2 % carbon, i.e. a large portion of ferrite is separated from the pearlite. Such a structure is surprising for a steel having an eutectoid composition. In the structure obtained through the invention the pearlite is degenerated. Such degenerated pearlite is known per se and is typical for steel containing molybdenum.

The invention can be generalized as follows, with respect to an eutectoid steel composition. The following is required in order to obtain pro-eutectoid ferrite in steel with nominally eutectoid composition:

- 1) The steel must contain a considerable proportion of a substance strongly prone to forming carbides. Examples of such substances are molybdenum and tungsten. The effect of adding a substance strongly prone to forming carbides is that the forming of pearlite is greatly delayed.
- 2) The steel must be substantially free from substances facilitating the formation of pearlite. Particularly, the amounts of silicon and manganese must be kept low.
- 3) Cooling must take place below a certain critical cooling rate if pro-eutectoid ferrite is to be separated out.

The critical cooling rate is determined by the composition of the steel, particularly by the amount of substance strongly prone to forming carbides. The quantity of ferrite separated out increases the lower the cooling rate. The quantity of ferrite separated out increases with increasing amounts of molybdenum or tungsten, and decreases with increasing amounts of silicon and manganese. The ferrite formed contains a considerable amount of submicroscopic particles of MC type. For a steel alloyed with only molybdenum, the carbides are

molybdenum carbides. These carbide separations are typically 1 nanometer in size.

Although the invention most easily is described with reference to steel of eutectoid character, it will be understood that it can be applied with advantage to non-eutectoid steels suitable for use as e.g. case-hardening steel, toughened steel, induction hardening steel and spring and roller bearing steel.

The sulfur content in the steel may be adjusted depending upon the field of application of the steel. The sulfur content is suitably less than or equal to 0,015 % for steel which is intended for plastic molding as the primary molding operation. The sulfur content may be within the interval 0,010 - 0,025 % for steel which will primarily be subjected to cutting. If the demands on cuttability of the steel are high, the sulfur content should suitably lie within the interval 0,010 - 0,080 %.

The titanium content in the steel is suitable less than 55 ppm, and the oxygen content is suitable less than or equal to 20 ppm.

Other features and advantages of the present invention will become apparent from the following description of the invention which refers to the accompanying drawings.

Figure 1 shows a CCT diagram illustrating the invention.

Figure 2, 3 and 4 show, on three different scales of enlargement, the structure of a steel having a composition according to the invention after cooling.

Figures 5, 6 and 7 show, on the same enlargement scales as in figures 2 - 4, the structure of a carbon steel containing 0,2 % carbon cooled at the same cooling rate.

Figure 8 shows the structure of a steel produced according to the invention, but having a high molybdenum content and low silicon and manganese contents.

Figures 9 and 10 show the structure of steel cooled at the same rate as the steel according to figure 8, but having low molybdenum and manganese contents and a high silicon content (fig. 9); and a low molybdenum content and high silicon and manganese contents (fig. 10).

Numbers are shown for each cooling curve at the bottom of figure 1, which relate to the magnitudes of parameters stated in the middle of the rows in the table. Figure 1 refers to a eutectoid steel containing 0,5 % molybdenum and remainder contents below the limits specified above.

"Diameter/mm" refers to a comparison dimension for the cooling, i.e., the cooling rate for the curve in question is that obtained when air cooling a steel rod with the stated diameter in millimeters. "C/s (800-400)" refers to the cooling rate in °C per second in the temperature interval 800 - 400°C. "Ps/C" refers to the temperature in °C at which pearlite starts to form. "Hv (30 kg)" refers to the result of a Vickers hardness test with a load of 30 kg.

Figure 1 shows the area in which pearlite develops, marked with "P", between two generally horizontal lines defining the commencement and termination of the pearlite development. The pearlite amount of the structure is stated as a percentage close to the lower horizontal line for each cooling rate.

A wedge-shaped area exists in the upper part of Figure 1, above the upper pearlite limit curve. This wedge-shaped area is provided with the marking "F" and illustrates the ferrite development according to the invention. Figure 1 clearly shows that ferrite F starts to develop when the cooling rate is below 0,74 °C/s. Ferrite development can in fact be traced even at a cooling rate of 0,84°C/s, but the quantity of ferrite is slight. In practice, therefore, the cooling rate should be less than 0,80°C/s for the steel referred to in figure 1, i.e., a eutectoid steel which, besides iron and carbon, consists of 0,5 % molybdenum, 0,10 % silicon and 0,20 % manganese, whereas the remaining substances have the remainder contents stated above, as acceptable for ball bearing steel based on scrap.

It will be apparent that molybdenum may be replaced by tungsten or that tungsten may be added, in which case the range 0,2 - 1,0 % represents the total amount of molybdenum and tungsten, and the other alloying materials, particularly silicon and manganese are limited in the manner specified above and to the extent suitable for the manufacturing process used to make the steel. Similarly, more chromium may be added to increase the temperability of the steel.

Figures 2 - 4 illustrate that the steel described in connection with figure 1, cooled at a rate of approximately 0,21°C per second, acquires a structure fully comparable with the structure of pure carbon steel with 0,2 % carbon which has been cooled at the same rate and is illustrated in figures 5 - 7, respectively.

This comparison shows that a molybdenum or tungsten steel with a eutectoid composition, selected and treated according to the invention, will acquire a structure with a pronounced quantity of free ferrite, the ferrite quantity corresponding to that occurring in carbon steel with 0,2 % carbon, and the eutectoid steel produced according to the invention will therefore have a moldability/workability comparable to that of a carbon steel with 0,2 % carbon. However, it should be clear that the same effect is obtained, at least to a certain extent, for other steels and cooling rates within the prescribed limits.

Figure 8 shows the structure of a steel with 0,5 % molybdenum, approximately 0,30 % silicon, and less than 0,15 % manganese, obtained according to the invention.

Figure 9 shows the structure of a steel with 0,2 % molybdenum, approximately 0,30 % silicon, and less than 0,15 % manganese, said structure having been obtained at a cooling rate corresponding to that for the steel according to figure 8.

Figure 10 shows the resultant structure when the molybdenum content is low, i.e. 0,2 %, the manganese content is high, i.e. 0,30 % and the silicon is high, i.e. 0,30 %.

Figures 8 - 10 indicate that the desired favorable structure (figure 8) with a relatively large amount of free ferrite is primarily obtained when the steel composition has a molybdenum content within the interval 0,2 - 1,0 % and low contents of silicon and manganese (the other remainder contents being low as described above,) and when the steel is cooled at a rate lower than the critical value described in conjunction with figure 1.

It will be understood with reference to figure 1 that if a lower molybdenum content is chosen for the steel, a lower cooling rate is required if the ferrite development indicated in figure 1 is to be maintained. The greater the amounts of remainder substances, particularly silicon and manganese, contained in the steel selected, the less ferrite will be formed.

The ferrite developed in the structure is relatively "pure" since all elements which become deposited in ferrite are suppressed in the steel selected. The magnitude and purity of the ferrite phase thus offers good workability for the steel. The elements which give the final product its desired final properties, appear in the form of carbides and are released only when required, i.e., when the steel is tempered.

The submicroscopic particles separated out during the formation of ferrite are relatively uniformly distributed in the steel. Their distribution and their extremely minute size are not detrimental to the moldability of the steel and the carbon and carbide-builders (e.g. Mo) bonded in the submicroscopic carbides facilitate tempering of the steel due to quicker homogenization at austenitizing.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

Claims

1. A method for increasing the moldability of steel prior to final treatment thereof, **comprising** the step of cooling a steel containing iron, carbon and an alloying additive selected from the group consisting essentially of molybdenum, tungsten, mixtures of molybdenum and tungsten, mixtures of molybdenum and chromium, mixtures of tungsten and chromium and mixtures of molybdenum, tungsten and chromium at a rate whereat ferrite separates out in said steel before pearlite formation therein.
2. The method of claim 1, **where** in said alloying additive is selected from the group consisting essentially of molybdenum, tungsten or mixtures thereof.
3. The method of claim 2, **wherein** said alloying additive is present in said steel in an amount between 0,2 and 2,0 %.
4. The method of claim 1, **wherein** said alloying additive is selected from the group consisting essentially of mixtures of molybdenum and chromium, mixtures of tungsten and chromium and mixtures of molybdenum, tungsten and chromium.
5. The method of claim 4, **wherein** said molybdenum, tungsten, or molybdenum and tungsten are present in said steel in an amount between 0,2 to 2,0 %.
6. The method of claim 5, **wherein** said chromium is present in said steel in an amount between 1,0 to 2,0 %.
7. The method of claim 1, **wherein** said cooling rate is less than 0,80°C/s.
8. The method of claim 1, **wherein** said carbon is present in said steel in an amount between 0,1 to 0,35 %.
9. The method of claim 1, **wherein** said carbon is present in said steel in an amount between 0,25 to 0,60 %.

10. The method of claim 1, **wherein** said carbon is present in said steel in an amount between 0,45 to , 0,85 %.

5 11. The method of claim 1, **wherein** said carbon is present in said steel in an amount between 0,70 to 1,15 %.

12. Steel prepared in accordance with the method of claim 1.

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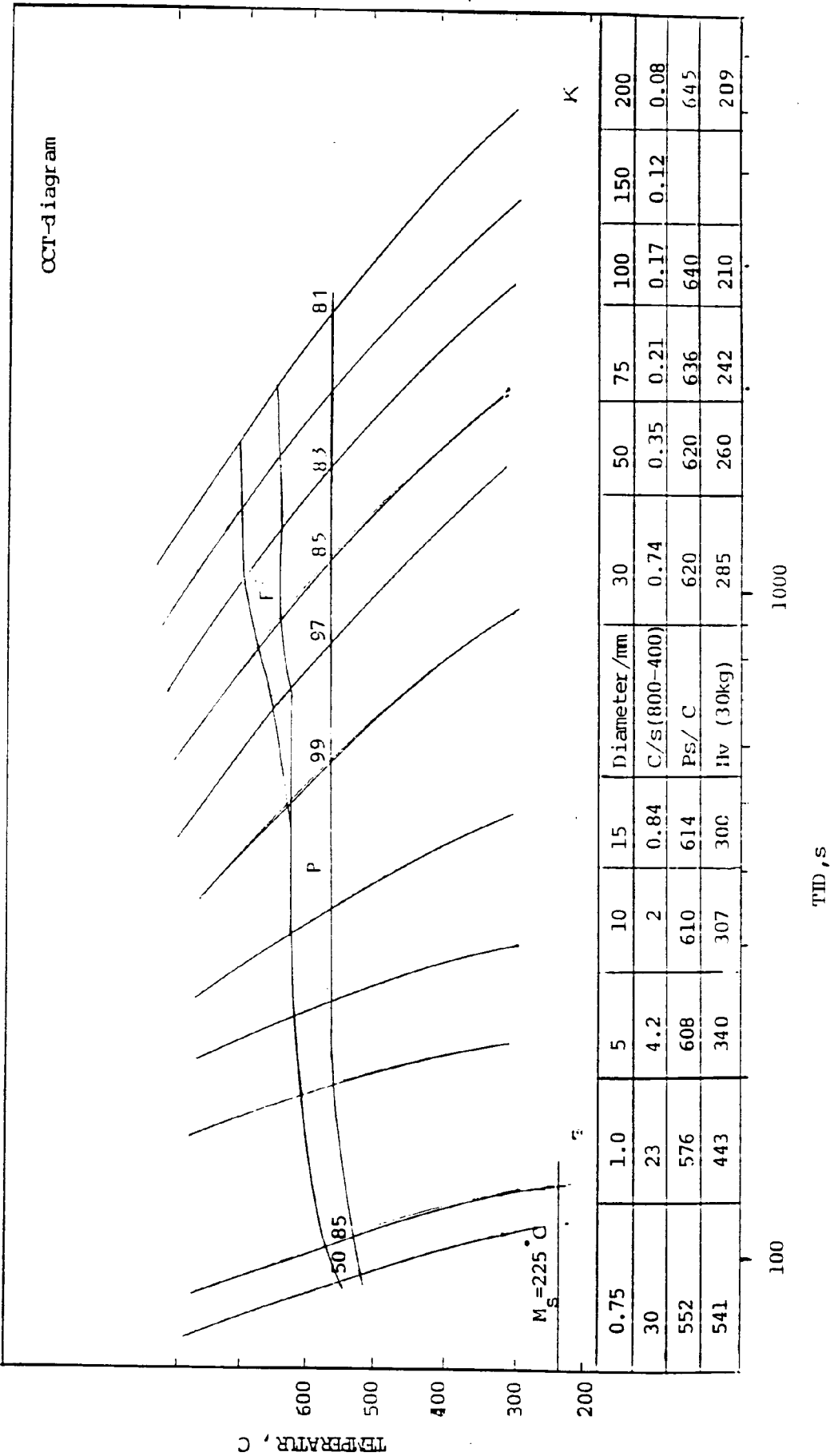


Fig. 1

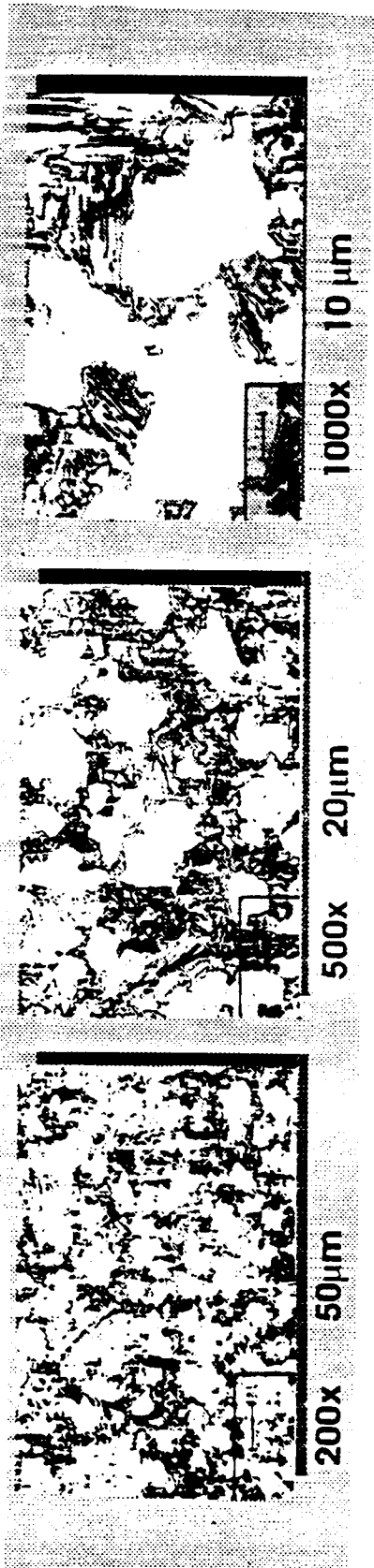


Fig. 2

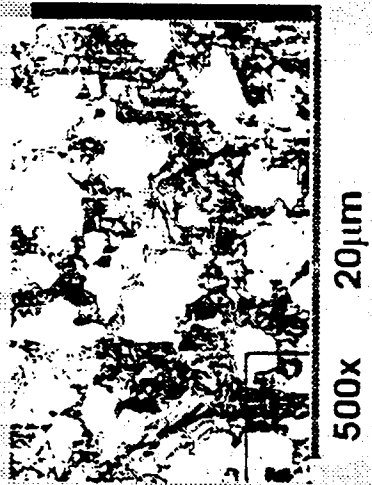


Fig. 3



Fig. 4

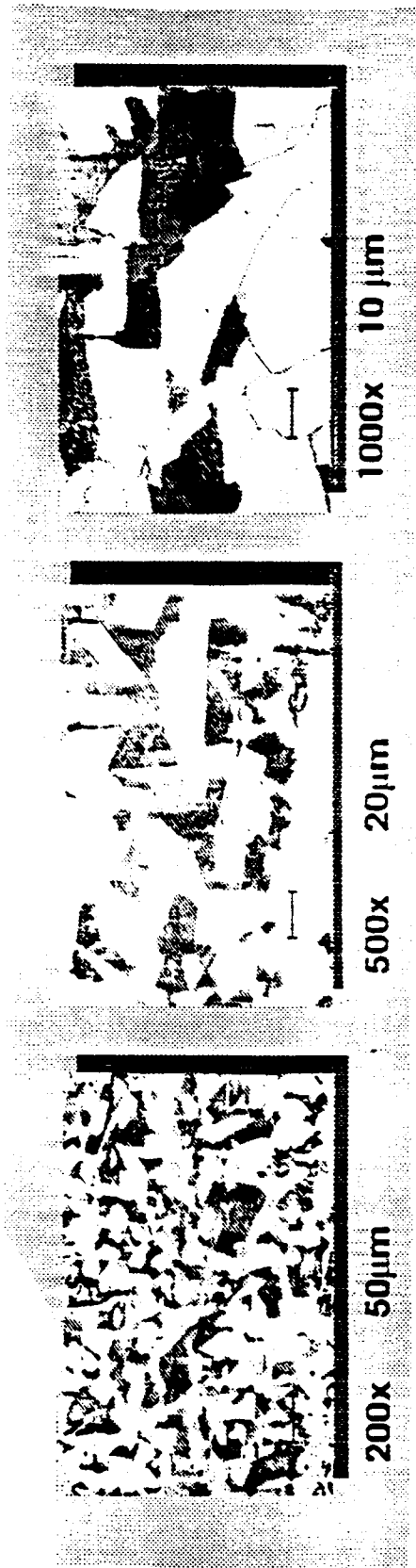


Fig. 5

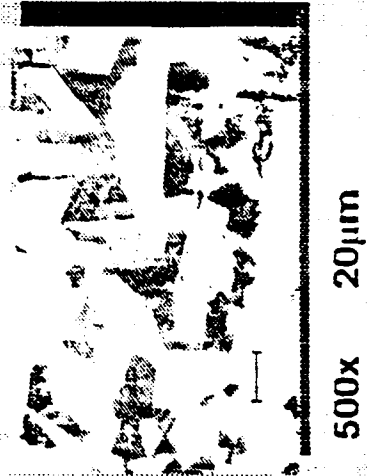


Fig. 6

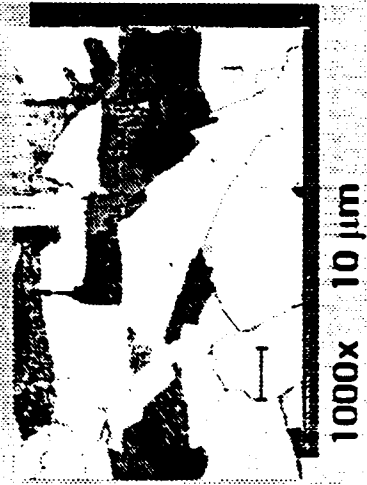


Fig. 7

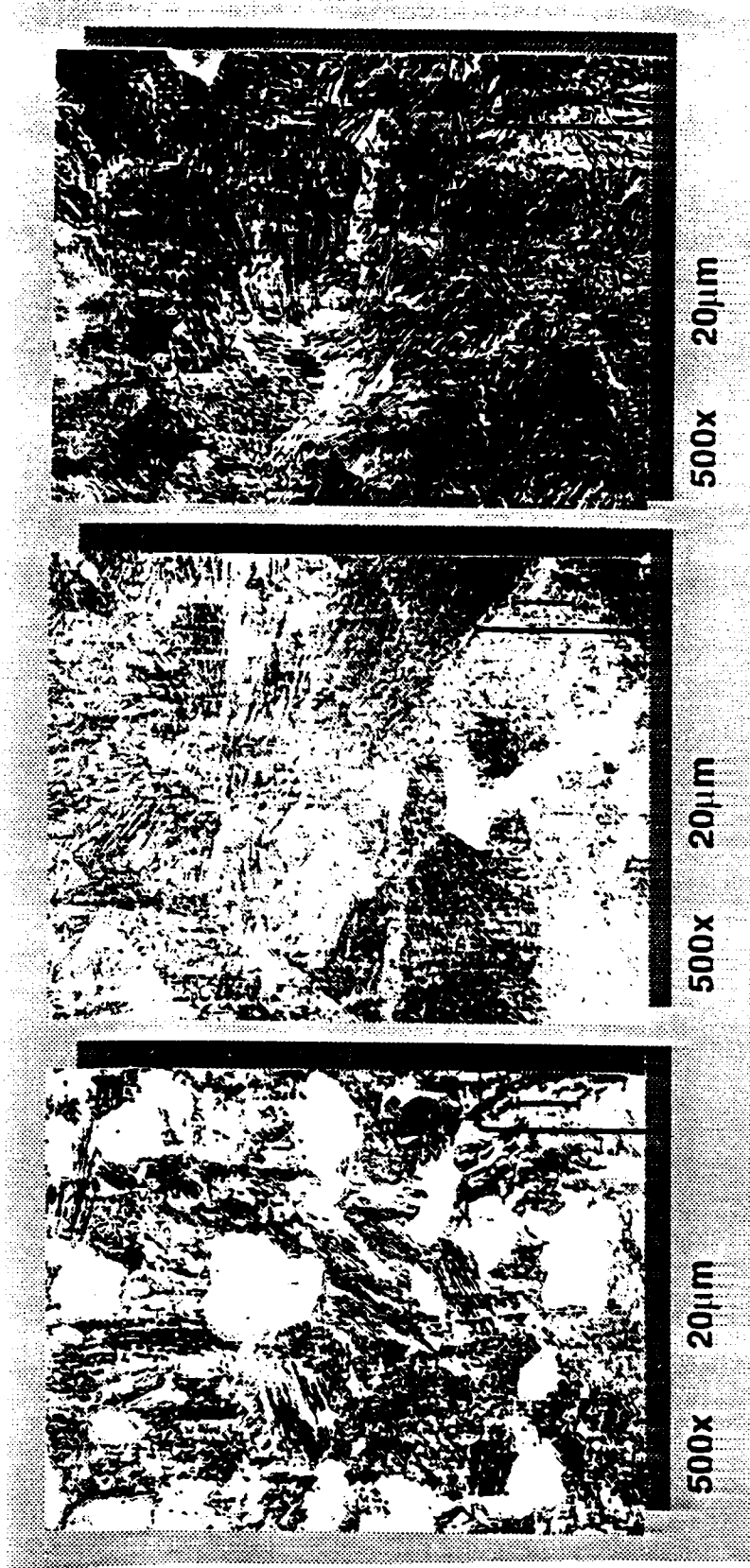


Fig. 8

Fig. 9

Fig. 10



European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 91 85 0164

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 5)
A	US-A-2 778 755 (BROWN et al.) * Complete document * ---	1	C 21 D 1/84 C 22 C 38/12
A	EP-A-0 349 023 (SKF INDUSTRIAL TRADING & DEVELOPMENT) * Claims 1,2 * ---	4,5,11	
A	CH-A- 267 753 (SCHOELLER-BLECKMANN STAHLWERKE) * Complete document * & FR-A-970 899 ---	4-6,10,11	
A	US-A-2 158 036 (PAVITT) * Complete document * -----	4,5,11	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 5)
			C 21 D C 22 C
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25-09-1991	Examiner LIPPENS M.H.
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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