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(54) Super clean steel

(57) A super clean steel for use in objects subjected to heavy loads in all directions, such as in fuel injection pumps or bearings, comprising, in weight, O max. 7 ppm, Ti max. 15 ppm, and S between about 8 ppm and about 12 ppm, and having a K1(total) value according to DIN 50 602 of below 2.5.

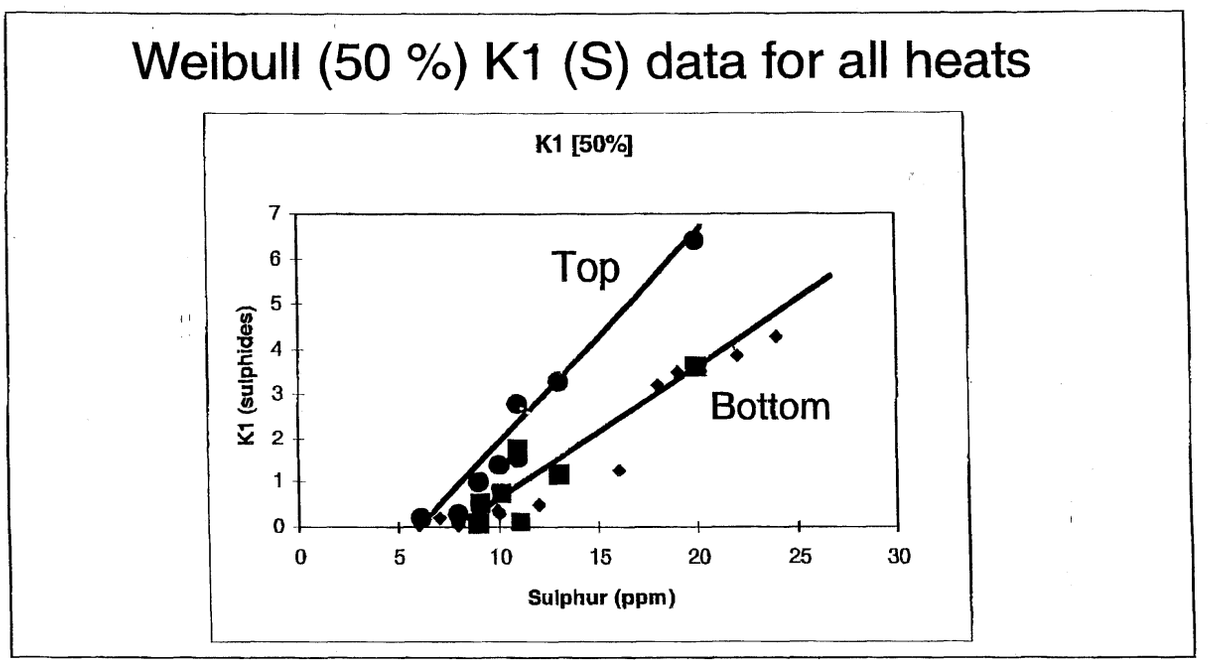

FIG. 1

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Description

Field of Invention

[0001] The present invention relates to super clean steel for use in objects subjected to heavy loads in all directions, such as in fuel injection pumps.

Background

[0002] The development of Diesel engines now demand fuel injection pumps giving a pressure of up to and even above 2,000 bars. In the channels of the pump the surrounding material is exposed to loads acting in all directions. The smallest defect or inclusion in the steel material will result in a failure.

[0003] Often, a bainite hardened bearing steel is used for the manufacture of fuel injection pumps, which up to now have been working with pressures of about 500 - 700 bars.

[0004] A high quality bearing steel contains max. 10-15 ppm O, normally max. 0.015 % S, being steel max. 0.004 % S in premium bearing quality steel, and max 30 ppm Ti. These elements are the most important elements when it comes to the problem of avoiding rupture of fuel injection pumps working at pressures of about 2000 bars.

[0005] Obviously, an isotropic steel material would serve the purposes of taking up loads in every direction. In a bearing steel containing sulfides, the sulfides being elongated, will be oriented, thus making the steel unisotropic. Further, in ingot casting, the sulphides will segregate towards the top of the ingot due to different solidifying rates in different parts of the ingot, and in continuous casting the sulfides will also segregate, preferably towards the centre.

[0006] In order to avoid the sulphide problem, it would be obvious to reduce the sulphur content to as close to zero as possible. However, this measure results in that Ca in the melt will enter oxide inclusions in the form of aluminates, forming inclusions being calcium aluminates. While aluminates are hard and brittle and will break during rolling, calcium aluminates are hard but not brittle. They will remain intact during rolling and into the finished product, and when they happen to be at a surface in a channel or anywhere in a heavily loaded zone, this is where a fatigue failure will start.

[0007] In ingot casting these oxide inclusions will be enriched at the bottom of the ingot, and in continuous casting these large oxides will be found towards the centre.

[0008] From the above it is evident that in order to have a super clean steel, where the sulphur content is low, the top of an ingot should be used, while when the sulpher is higher, the bottom of the ingot should be used. This will, however, only be effective in a very small sulphur content range.

[0009] However, having to use different parts of an ingot for different purposes is not very efficient, and will cause a lot of logistic problems and losses.

[0010] There is a need for an alloy giving a super clean steel without the drawbacks of the above discussed prior art technology.

Short summary of the invention

[0011] The object of the invention is to provide a bearing steel having a composition resulting in a super clean steel as cast.

[0012] This and other objects are achieved with the bearing steel according to the invention comprising, in weight:

max. 7 ppm O,
max. 15 ppm Ti,
$8 < S < 12$ ppm.

[0013] By removing practically all oxygen from the steel composition oxide inclusions are avoided.

[0014] Titanium forms nitrides which will give rise to fatigue failures, and therefor the maximum limit of Ti is 15 ppm.

[0015] A sulphur content of 8 ppm or above counteract release of Ca from the slag, and thus the formation of globular oxide inclusions, and a sulphur content below 12 ppm reduces the enrichment of dangerous sulphides in any part of castings.

Brief description of the drawings

[0016] Fig. 1 is a graph showing K1(S) versus the sulphur content in different parts of ingot/casting.

[0017] Fig. 2 is a graph showing K1(OG) versus the sulphur content in different parts of ingot/casting.

[0018] Fig. 3 is a graph showing K1(O) and K1(S) versus the sulphur content of the total ingot/casting.

Detailed description of the invention

[0019] The K-method described in DIN 50602 is used to evaluate the steel regarding inclusions. The result of this method is weighted and depends on the number of inclusions and their size.

[0020] As a reference could be mentioned that the S content in Ovako PBQ quality (premium bearing quality) of 40 ppm max. gives a K1(sulphide) value of 12, and for S being 150 ppm K1 is 100. For a super clean steel the Kl(sulphide) value should be under 2.

[0021] The material solidifies at different rates in different parts of the ingot or strand. Large sulphides will segregate towards the top of an ingot and the centre of a strand. In order to control this segregation the S content has to be suppressed.

[0022] Fig. 1 illustrates graphically what happens when the sulphur content is reduced. From K1(S) values of 6.5 for the top of an ingot and about 3.5 for the bottom

at an S content of about 20 ppm the K1 values are reduced to below 0.5 at sulphur contents of about 9 ppm. From the graph it is also clearly seen that the K1 value increases more for the top part than for the bottom part of an ingot.

[0023] K1 is well below 2 for a sulphur content of about 12 ppm.

[0024] However, reducing the sulphur content has the effect that Ca is released from the slag into the steel, resulting in the formation of calcium aluminates. This is illustrated in Fig. 2 showing K1(O) for top and bottom. From a sulphur content of 9 ppm and down K1(O) increases rapidly in the bottom part of the ingot, while only a small increase can be noticed in the top part.

[0025] In Fig. 3 is illustrated both K1(O) and K1(S) as a function of the S content in the total ingot/casting, from which it can be seen that between 8 ppm S and 12 ppm S K1 is below 2, and accordingly these are the S limits for a super clean steel, i.e. a steel being practically devoid of oxide and sulphide inclusions.

Claims

1. A super clean steel for use in objects subjected to heavy loads in all directions, such as in fuel injection pumps or bearings, comprising, in weight, O max. 7 ppm, Ti max. 15 ppm, and S between about 8 ppm and about 12 ppm, and having a KI(total) value according to DIN 50 602 of below 2.5.

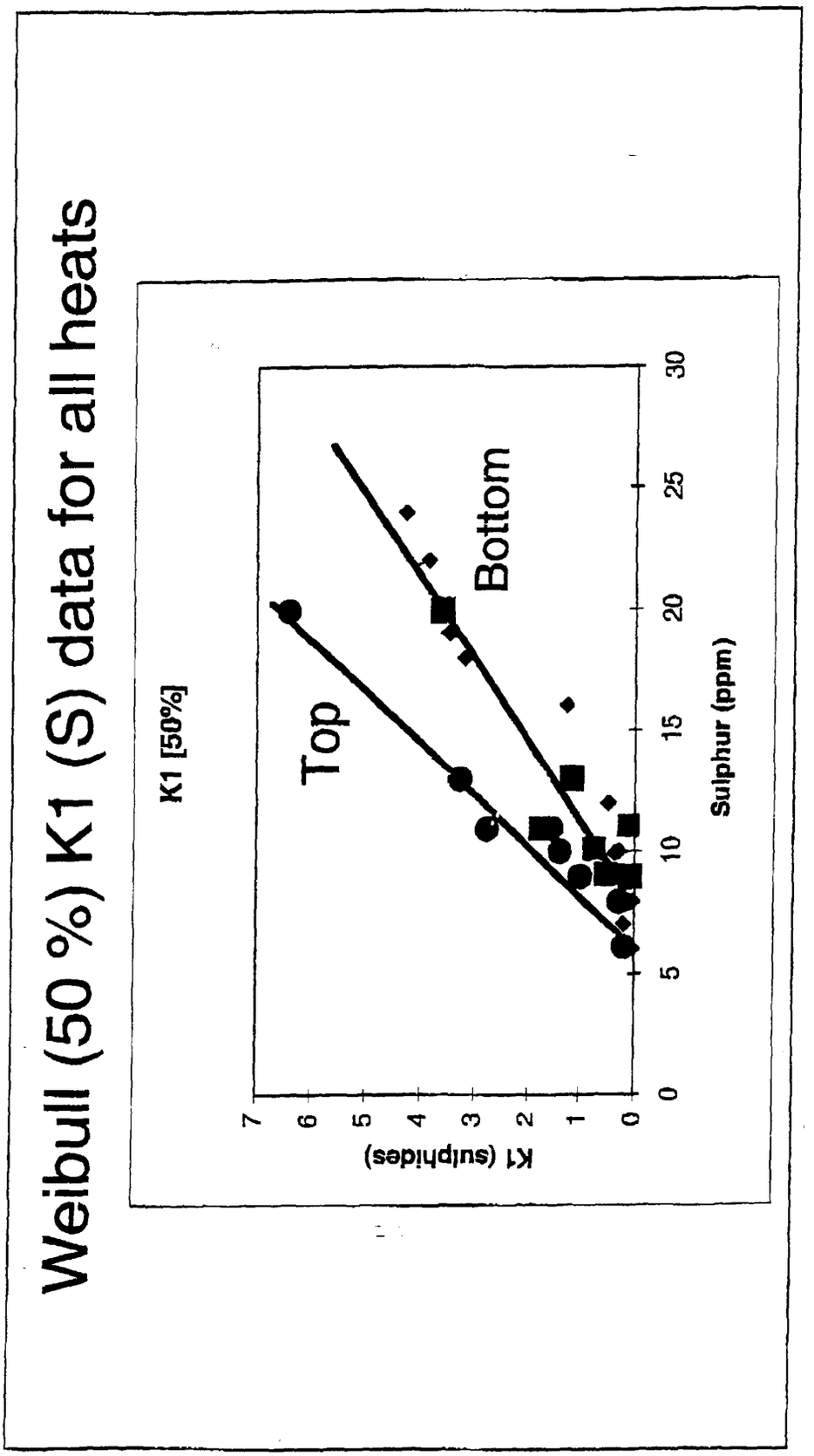
Weibull (50 %) K1 (S) data for all heats
K1 [50%]
K1 (sulphides)
Sulphur (ppm)
Top
Bottom
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30

FIG. 1

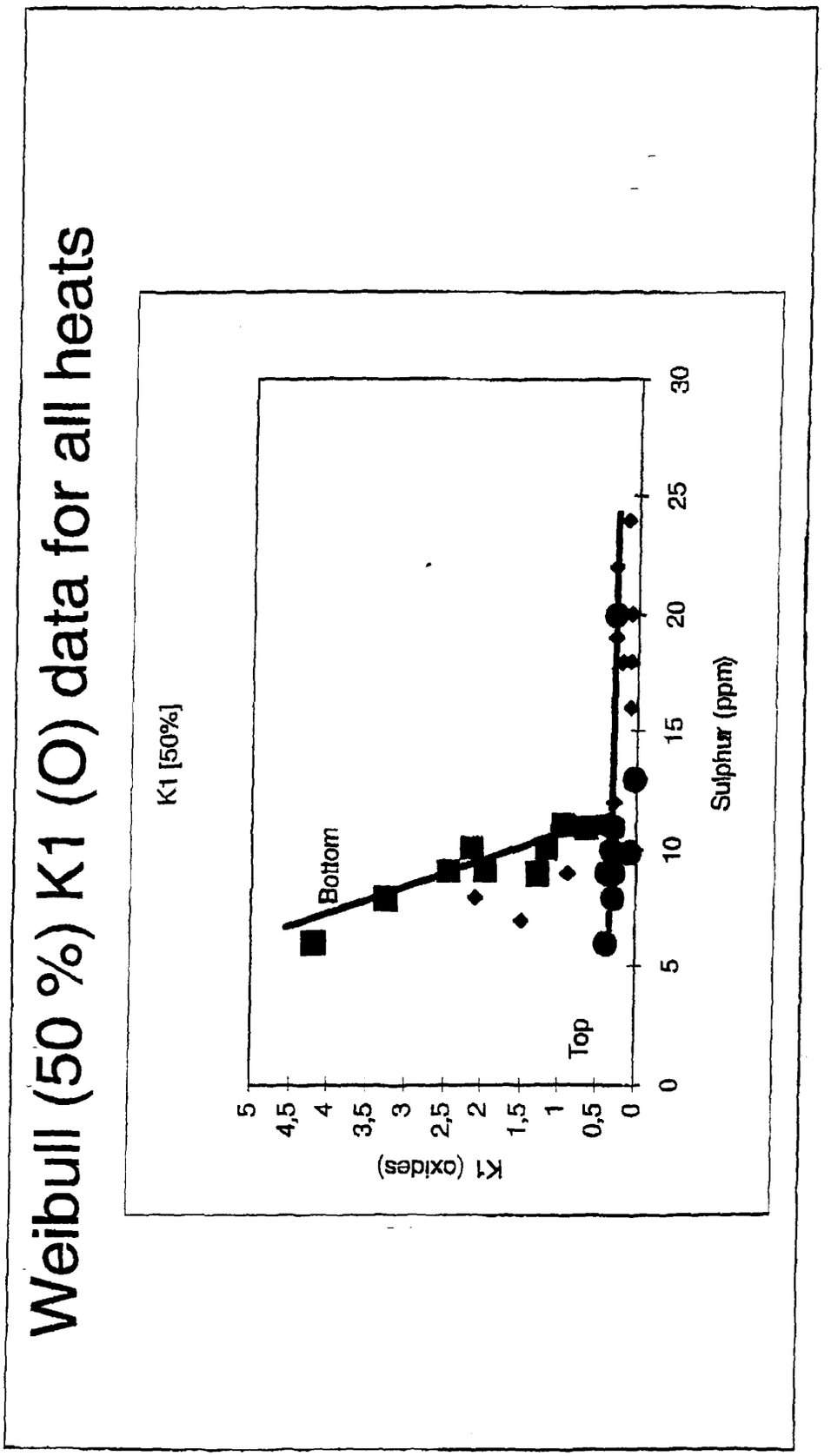
Weibull (50 %) K1 (O) data for all heats
K1 [50%]
Bottom
Top
K1 (oxides)
Sulphur (ppm)
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
0
5
10
15
20
25
30

FIG. 2

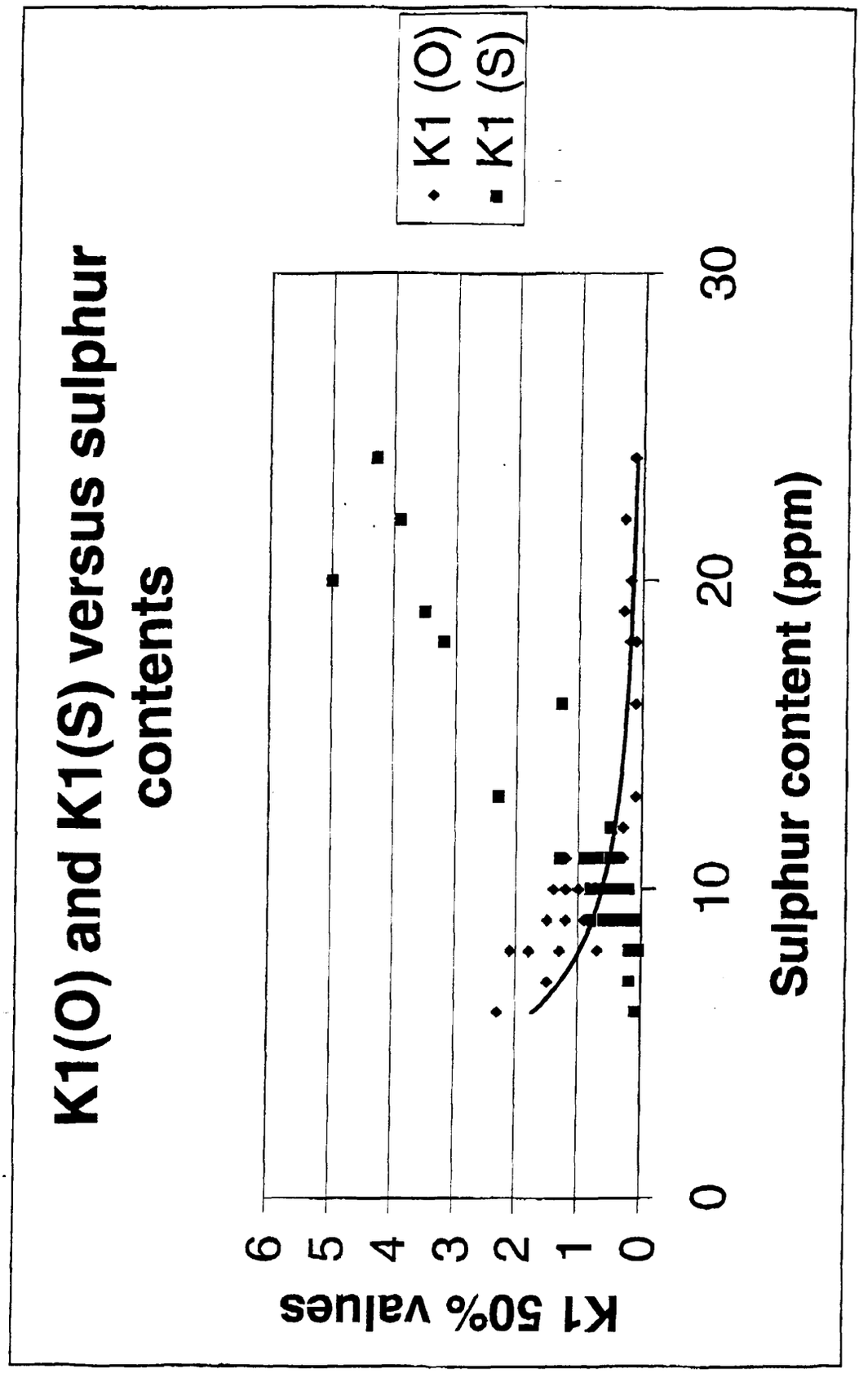
K1(O) and K1(S) versus sulphur contents
K1 (O)
K1 (S)
K1 50% values
0
1
2
3
4
5
6
0
10
20
30
Sulphur content (ppm)

FIG. 3