

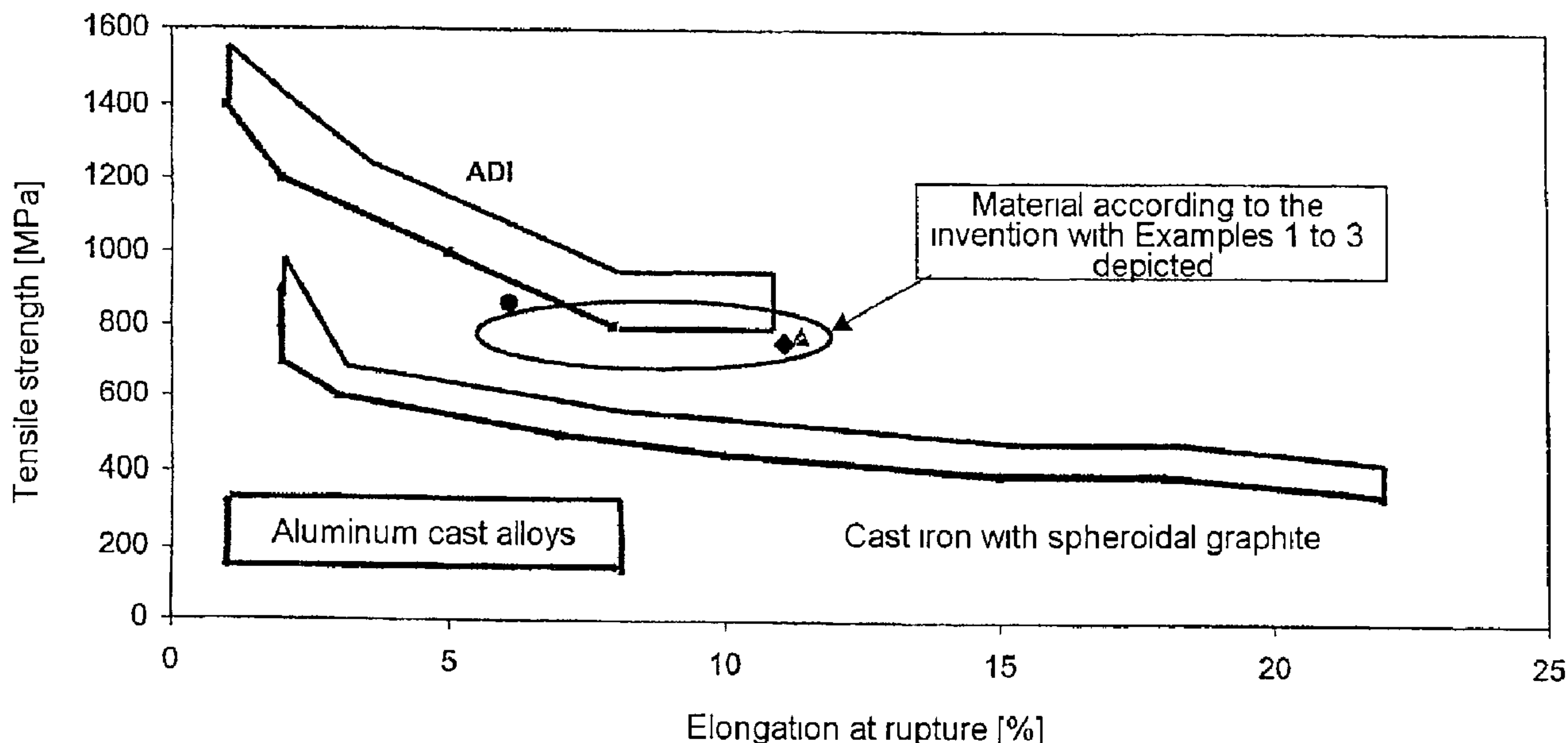


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(54) Title: SPHEROIDAL CAST ALLOY AND METHOD FOR PRODUCING CAST PARTS FROM SAID SPHEROIDAL
CAST ALLOY

Comparison of tensile strength with elongation at rupture



(57) Abrégé/Abstract:

The invention relates to a spheroidal cast alloy for producing cast iron products with great mechanical strength, high wear-resistance and a high degree of ductility. Said alloy comprises the following as non-iron components: between 2.5 and 3.8 wt. % C, between 2.4 and 3.4 wt. % Si, between 0.02 and 0.08 wt. % P, between 0.02 and 0.06 wt. % Mg, between 0.01 and 0.05 wt. % Cr, between 0.002 and 0.02 wt. % Al, between 0.0005 and 0.015 wt. % S, between 0.0002 and 0.002 wt. % B and conventional impurities. According to the invention, the alloy contains between 3.0 and 3.7 wt. % C, between 2.6 and 3.4 wt. % Si, between 0.02 and 0.05 wt. % P, between 0.025 and 0.045 wt. % Mg, between 0.01 and 0.03 wt. % Cr, between 0.003 and 0.017 wt. % Al, between 0.0005 and 0.012 wt. % S and between 0.0004 and 0.002 wt. % B. The alloy is used for example to produce chassis parts or brake discs in the automobile industry.

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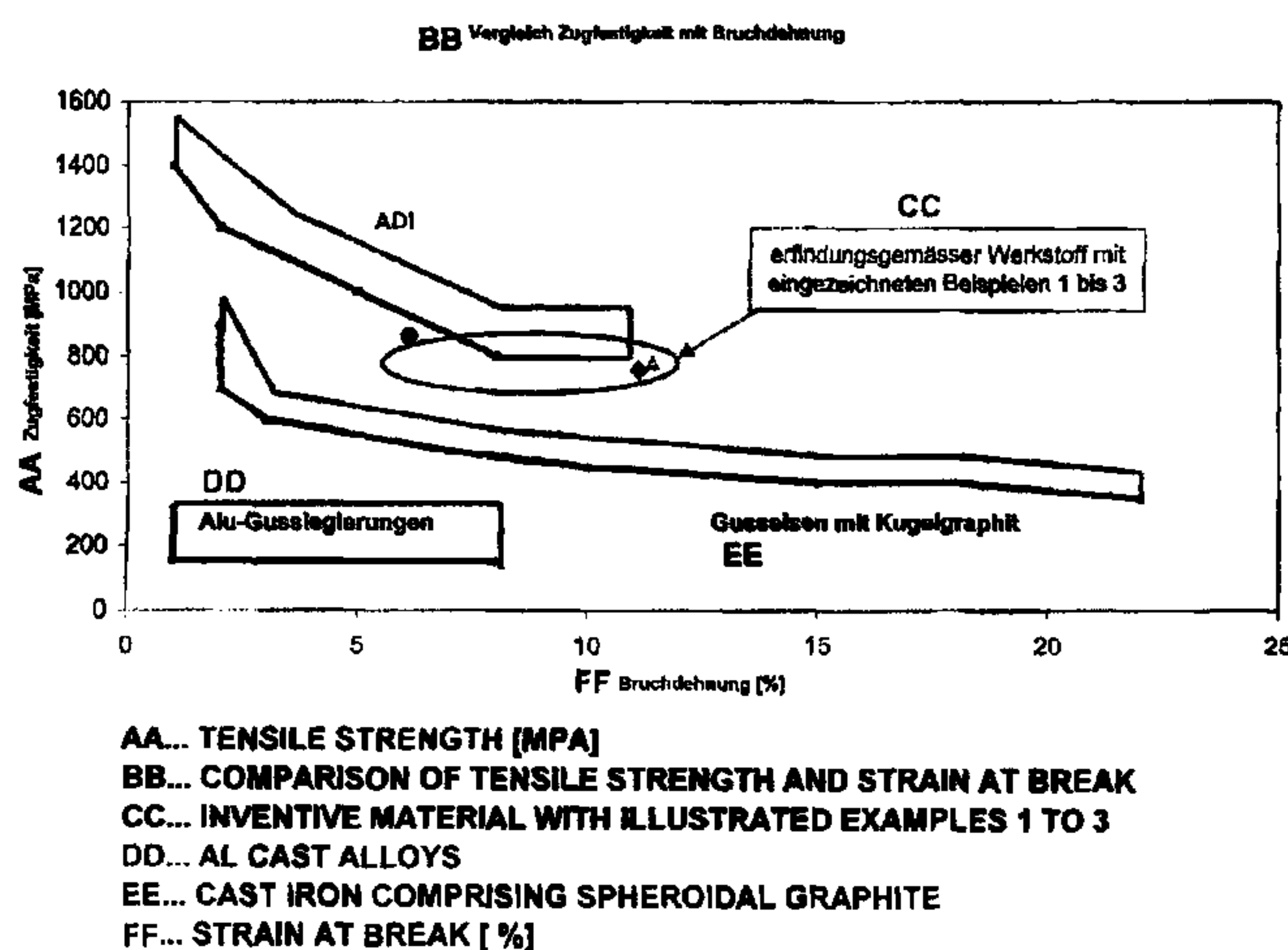
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(54) Title: SPHEROIDAL CAST ALLOY AND METHOD FOR PRODUCING CAST PARTS FROM SAID SPHEROIDAL
CAST ALLOY(54) Bezeichnung: SPHÄROGUSSLEGIERUNG UND VERFAHREN ZUR HERSTELLUNG VON GUSSTEILEN AUS DER
SPHÄROGUSSLEGIERUNG

(57) Abstract: The invention relates to a spheroidal cast alloy for producing cast iron products with great mechanical strength, high wear-resistance and a high degree of ductility. Said alloy comprises the following as non-iron components: between 2.5 and 3.8 wt. % C, between 2.4 and 3.4 wt. % Si, between 0.02 and 0.08 wt. % P, between 0.02 and 0.06 wt. % Mg, between 0.01 and 0.05 wt. % Cr, between 0.002 and 0.02 wt. % Al, between 0.0005 and 0.015 wt. % S, between 0.0002 and 0.002 wt. % B and conventional impurities. According to the invention, the alloy contains between 3.0 and 3.7 wt. % C, between 2.6 and 3.4 wt. % Si, between 0.02 and 0.05 wt. % P, between 0.025 and 0.045 wt. % Mg, between 0.01 and 0.03 wt. % Cr, between 0.003 and 0.017 wt. % Al, between 0.0005 and 0.012 wt. % S and between 0.0004 and 0.002 wt. % B. The alloy is used for example to produce chassis parts or brake discs in the automobile industry.

(57) Zusammenfassung: Es wird eine Sphärogusslegierung vorgeschlagen für Gusseisenprodukte mit einer hohen mechanischen Festigkeit, einer hohen Verschleissfestigkeit und gleichzeitig einer hohen Zähigkeit, umfassend als Nicht-Eisenbestandteile 2,5 bis 3,8 Gew.% C, 2,4 bis 3,4 Gew.% Si, 0,02 bis 0,08 Gew.% P, 0,02 bis 0,06 Gew.% Mg,

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Zur Erklärung der Zweibuchstaben-Codes und der anderen Abkürzungen wird auf die Erklärungen ("Guidance Notes on Codes and Abbreviations") am Anfang jeder regulären Ausgabe der PCT-Gazette verwiesen.

0,01 bis 0,05 Gew.% Cr, 0,002 bis 0,02 Gew.% Al, 0,0005 bis 0,015 Gew.% S, 0,0002 bis 0,002 Gew.% B und den üblichen Verunreinigungen, wobei die Legierung 3,0 bis 3,7 Gew.% C, 2,6 bis 3,4 Gew.% Si, 0,02 bis 0,05 Gew.% P, 0,025 bis 0,045 Gew.% Mg, 0,01 bis 0,03 Gew.% Cr, 0,003 bis 0,017 Gew.% Al, 0,0005 bis 0,012 Gew.% S und 0,0004 bis 0,002 Gew.% B enthält. Die Legierung wird beispielsweise zur Herstellung von Fahrwerksteilen oder Bremscheiben im Automobilbau verwendet.

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**Spheroidal cast alloy and method for producing cast
parts from said spheroidal cast alloy**

The invention relates to a spheroidal cast alloy for
5 cast iron products with great mechanical strength, high
wear resistance and at the same time a high degree of
ductility, comprising as non-iron constituents 2.5 to
3.8% by weight C, 2.4 to 3.4% by weight Si, 0.02 to
0.08% by weight P, 0.02 to 0.06% by weight Mg, 0.01 to
10 0.05% by weight Cr, 0.002 to 0.02% by weight Al, 0.0005
to 0.015% by weight S, 0.0002 to 0.002% by weight B and
the conventional impurities.

In motor vehicle construction, cast iron alloys are
15 used for producing cast parts that must have high wear
resistance, for example brake disks, which during the
braking operation have to convert the kinetic energy of
the vehicle into thermal energy. The brake disks can
in this case reach temperatures of up to about 850°C.
20 During the braking operation, not only the brake
linings but also the brake disks are worn. Brake disks
have irregular wear and often have to be replaced while
still under warranty, involving high costs for the
automobile manufacturer. In order that the wear on the
25 surface of the brake disk takes place as evenly as
possible, high demands are made of the crystalline
structure and the homogeneity of the structure. The
homogeneity can be improved by a suitable casting
process.

30 GB 832 666 discloses a cast iron alloy comprising as
non-iron constituents 1.0 to 2.5% by weight C, 1.5 to
3.2% by weight Si, less than 1.15% by weight Mn, less
than 0.5% by weight S and 0.001 to 0.05% by weight B.
35 After casting, the graphite component takes on the
compact form. Because the alloy does not contain any
Mg there is no spheroidal graphite or vermicular
graphite present, but rather a graphite formation that

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resembles temper carbon nodes of malleable cast iron predominates. The alloy contains 5 to 10% carbides in a predominantly pearlitic matrix, which has the consequence that the elongation at rupture becomes relatively low. In order to limit the formation of lamellar graphite, and consequently improve the modulus of elasticity, tellurium and bismuth are admixed as alloying elements. Higher elongation at rupture values are achieved by a subsequent heat treatment.

10

US 2004/0112479-A1 discloses a further cast iron alloy, which preferably contains 3.7% by weight C, 2.5% by weight Si, 1.85% by weight Ni, 0.85% by weight Cu and 0.05% by weight Mo. This material is distinguished by an elongation of 20 to 16% with a tensile strength of 500 to 900 MPa and by a Brinell hardness of 180 to 290 HB. These properties are achieved after a time-consuming heat treatment, which comprises the following successive steps: 10 to 360 minutes of austenitizing at temperatures between 750 and 790°C, rapid cooling in a salt bath at a temperature between 300 and 400°C, 1 to 3 hours of austempering at temperatures between 300 and 400°C and cooling to room temperature. After this treatment, the material has a structure with an austenitic and ferritic microstructure. The material is distinguished by easier machinability than a cast iron that has been subjected to a conventional type of austempering.

30

On the basis of this prior art, the object of the invention is to provide a cast iron alloy which is produced from elements that are as inexpensive as possible, the cast parts having the highest or greatest possible heat resistance and strength, in particular wear resistance, and at the same time a very high degree of ductility, without an additional heat treatment.

35

More specifically, the object of the present invention as broadly disclosed is a spheroidal cast alloy for cast iron products with great mechanical strength, high wear resistance and at the same time a high degree of ductility, comprising as non-iron constituents 2.5 to 3.8% by weight C, 2.4 to 3.4% by weight Si, 0.02 to 0.08% by weight P, 0.02 to 0.06% by weight Mg, 0.01 to 0.05% by weight Cr, 0.002 to 0.02% by weight Al, 0.0005 to 0.015% by weight S, 0.0002 to 0.002% by weight B and the conventional impurities, the alloy containing 3.0 to 3.7% by weight C, 2.6 to 3.4% by weight Si, 0.02 to 0.05% by weight P, 0.025 to 0.045% by weight Mg, 0.01 to 0.03% by weight Cr, 0.003 to 0.017% by weight Al, 0.0005 to 0.012% by weight S and
10 0.0004 to 0.002% by weight B.

The invention as claimed is however more specifically directed to a spheroidal cast alloy for cast iron parts with great mechanical strength, high wear resistance and at the same time a high degree of ductility, characterized in that said alloy contains
3.0 to 3.7% by weight C,
2.6 to 3.4% by weight Si,
0.02 to 0.05% by weight P,
0.025 to 0.045% by weight Mg,
0.01 to 0.03% by weight Cr,
0.003 to 0.017% by weight Al,
20 0.0005 to 0.009% by weight S,
0.0004 to 0.002% by weight B.
0.1 to 1.5% by weight Cu, and
0.1 to 1.0% by weight Mn,
the balance consisting essentially of Fe,
and wherein
the crystalline structure of the cast part is of a pearlitic form in respect of 70 to 90%.

It is of advantage that the alloy has the best possible strength-strain behavior. This is achieved by the spheroidal cast alloy containing 0.1 to 1.5% by weight Cu, preferably 0.5 to 0.8% by weight Cu. This is also achieved by the alloy containing 0.1 to 1.0% by weight Mn, preferably 0.15 to 0.2% by weight Mn.

10 It is also of advantage that the alloy has the best possible wear behavior. This is achieved by the alloy containing 0.1 to 1.5% by weight Cu, preferably 0.5 to 0.8% by weight Cu and 0.1 to 1.0% by weight Mn, preferably 0.15 to 0.2% by weight Mn. This is also achieved by the alloy containing 0.1 to 1.5% by weight Mn, preferably 0.5 to 1.0% by weight Mn, and 0.05 to 1.0% by weight Cu, preferably 0.05 to 0.2% by weight Cu.

20 The essential idea of the invention is to provide a cast iron alloy which has a Brinell hardness of over 220 and which is worn as evenly as possible when used as a brake disk. The graphite in the cast iron alloy may be of a spheroidal or vermicular, but not lamellar form. Although brake disks with lamellar graphite are inexpensive, they have lower resistance to temperature changes. As a result, so-called fire cracks can already occur after a short time in use, rapidly growing and leading to irregularities of the surface. An irregular surface in turn leads to irregular thermal loading, irregular wear and so-called brake juddering.

4a

Further applications of the spheroidal cast alloy according to the invention are axle and chassis parts for trucks and for passenger cars, such as for example wishbones, wheel carriers and pivot bearings, which are exposed to high mechanical and dynamic loads and in the case of a collision of the motor vehicle must plastically deform and must not rupture.

In the accompanying drawings that will be discussed in the Examples below:

10 Figure 1 is a diagram showing the increase in weight caused by oxidation at 700°C in air of a material according to the invention as compared to a conventional cast iron for brake disks;

Figures 2 and 3 are microphotos of a commercially available brake disk and of a brake disk according to the invention, showing different fire cracks;

Figure 4 and 5 are diagrams showing the elongation at ruptures as a function of different strengths; and

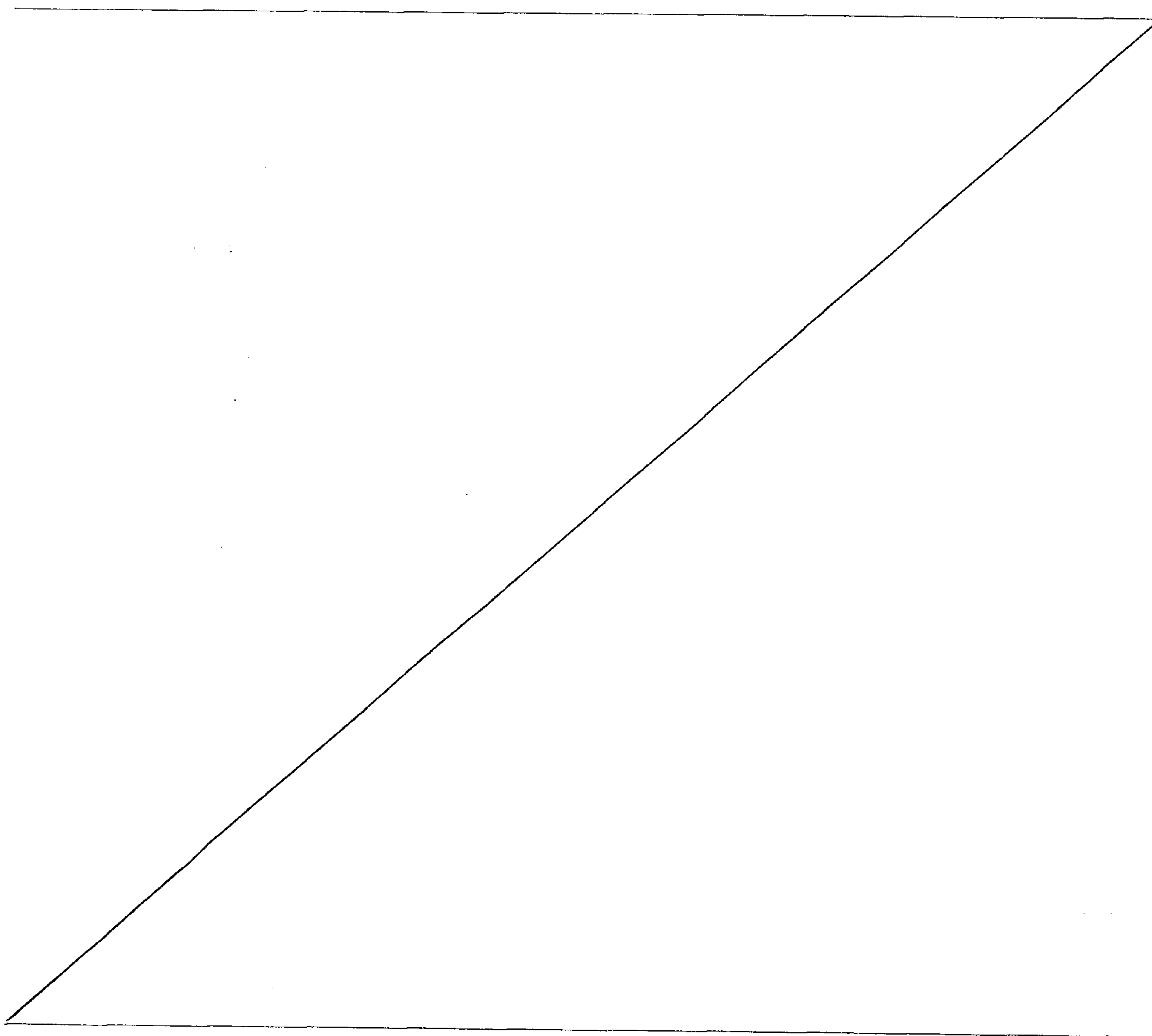
Figure 6 is a diagram comparing the tensile strength with the elongation at rupture of different materials including those of examples 1 to 3.

Example 1

20 A brake disk was produced from the spheroidal cast alloy according to the invention. The chemical composition was 3.34% by weight C, 2.92% by weight Si, 0.62% by weight Cu, 0.17% by weight Mn, 0.038% by weight Mg, 0.025% by weight P, 0.021% by weight Cr, 0.01% by weight Al, 0.001% by weight S and 0.0008% by weight B, the remainder Fe and the conventional impurities. The brake disk was investigated for the number of spherulites, graphite content, graphite form

4b

and graphite size, pearlite content and Brinell hardness. Specimens from the brake disk were subjected to a tensile test in order to establish the strength-strain behavior. The number of spherulites is 384 ± 76 spherulites per mm^2 . The graphite content is $9.7 \pm 0.7\%$. The graphite form in accordance with DIN EN ISO 945 is 97.9% of the form VI. The size distribution in accordance with DIN EN ISO 945 is 45% of size 8, 42% of size 7 and 13% of size 6. The pearlite content is



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84 +/- 1%. The Brinell hardness is 248 +/- 3 HB. In the tensile test, the following values were established: yield strength $R_{p0.2} = 474$ MPa, tensile strength $R_m = 778$ MPa, elongation at rupture $A_5 = 11.4\%$ and modulus of elasticity $E = 165$ to 170 kN/mm².

In comparison with the known materials for brake disks, it was possible to establish a much better oxidation behavior (see **Figure 1**) and a greatly reduced tendency to fire cracking (see **Figures 2 and 3**). The oxidation behavior, and consequently also the wear behavior, is greatly improved by the addition of a mixture of copper and/or manganese to the spheroidal cast alloy.

In Figure 1, the weight increase in grams per square meter and per day caused by oxidation at 700°C in air is represented. The material according to the invention shows a weight increase of about 9 g/m².d, in comparison with a cast iron material for conventional brake disks with a weight increase of about 21 g/m².d.

The tests to test for fire cracking were carried out as follows: a sample with the dimensions 40 x 20 x 7 mm is subjected to at least 100 cycles comprising 7 seconds of heating up to 700°C and 6 seconds of quenching in water. Subsequently, transverse sections are produced and examined under a microscope and photographed.

Figure 2 shows a microphoto of a commercially available brake disk with a fire crack 0.4 mm deep. Figure 3 shows a further microphoto of the brake disk according to the invention, to the same magnification, with a fire crack 0.14 mm deep.

Example 2

A wishbone for passenger cars was produced from the spheroidal cast alloy according to the invention. The

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chemical composition was 3.5% by weight C, 2.85% by weight Si, 0.63% by weight Cu, 0.18% by weight Mn, 0.038% by weight Mg, 0.026% by weight P, 0.029% by weight Cr, 0.004% by weight Al, 0.001% by weight S and 5 0.0007% by weight B, the remainder Fe and the conventional impurities. In the tensile test, the following values were established: yield strength $R_{p0.2}$ = 465 MPa, tensile strength R_m = 757 MPa, elongation at rupture A_5 = 11.1% and modulus of elasticity E = 165 to 10 170 kN/mm². The Brinell hardness is 258 +/- 3 HB.

Example 3

A wheel carrier for passenger cars was produced from 15 the spheroidal cast alloy according to the invention. The chemical composition was 3.43% by weight C, 3.38% by weight Si, 0.71% by weight Cu, 0.2% by weight Mn, 0.037% by weight Mg, 0.047% by weight P, 0.043% by weight Cr, 0.012% by weight Al, 0.004% by weight S and 20 0.0008% by weight B, the remainder Fe and the conventional impurities. In the tensile test, the following values were established: yield strength $R_{p0.2}$ = 558 MPa, tensile strength R_m = 862 MPa and elongation at rupture A_5 = 6.1%. The Brinell hardness is 288 HB. 25 The number of spherulites in the microstructure was determined as 455 spherulites per mm².

Figure 4 shows the elongation at rupture A_5 as a function of the tensile strength R_m . The solid line 30 indicates the minimum values in accordance with the standard EN 1563 for cast iron with spheroidal graphite of types produced in the cast state. The measurements of the material according to the invention are entered in accordance with Examples 1 to 3 presented above.

35

Figure 5 shows the elongation at rupture A_5 as a function of the yield strength $R_{p0.2}$. The solid line indicates the minimum values in accordance with the

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standard EN 1563 for cast iron with spheroidal graphite of types produced in the cast state. The measurements of the material according to the invention are entered in accordance with Examples 1 to 3 presented above.

5

The material properties of the spheroidal cast iron according to the invention are consequently far above the European standard EN 1563 for cast iron with spheroidal graphite and even reach the values of ADI (= Austempered Ductile Iron), a cast iron material standardized in Europe under EN 1564 which is produced by a very complex heat treatment in relatively great wall thicknesses that can only be obtained by alloying the expensive elements nickel and/or molybdenum, and is consequently correspondingly expensive.

15

Figure 6 shows the strength ranges against the elongation at rupture of the materials aluminum cast alloys, cast iron with spheroidal graphite, ADI and the material according to the invention with Examples 1 to 3 entered.

20

The uniformity of the structure is also achieved by a novel casting process. The casting mold is divided horizontally instead of vertically, the brake disks being arranged horizontally and the filling of the casting mold being carried out from the middle toward the edge of the brake disk. This has the consequence that the casting mold is filled rotationally symmetrically and that the brake disk is uniformly cooled from the inside to the outside after casting. As a result, a uniform, homogeneous structure is created over the entire circumference of the brake disk. A subsequent heat treatment, which is time-consuming and incurs costs, is no longer required.

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WHAT IS CLAIMED IS:

1. A spheroidal cast alloy for cast iron parts with great mechanical strength, high wear resistance and at the same time a high degree of ductility, characterized in that said alloy contains:
3.0 to 3.7% by weight C,
2.6 to 3.4% by weight Si,
0.02 to 0.05% by weight P,
0.025 to 0.045% by weight Mg,
0.01 to 0.03% by weight Cr,
10 0.003 to 0.017% by weight Al,
0.0005 to 0.009% by weight S,
0.0004 to 0.002% by weight B.
0.1 to 1.5% by weight Cu, and
0.1 to 1.0% by weight Mn,
the balance consisting essentially of Fe,
and wherein
the crystalline structure of the cast part is of a pearlitic form in respect of 70 to 90%.
2. The spheroidal cast alloy as claimed in claim 1, characterized in that said alloy contains 0.5 to 0.8% by weight Cu.
- 20 3. The spheroidal cast alloy as claimed in claim 1 or 2, characterized in that said alloy contains 0.15 to 0.2% by weight Mn.
4. The spheroidal cast alloy as claimed in any one of claims 1 to 3, characterized in that, immediately after casting and cooling, the graphite component is of a spheroidal and/or vermicular form in respect of over 90% of the graphite present.

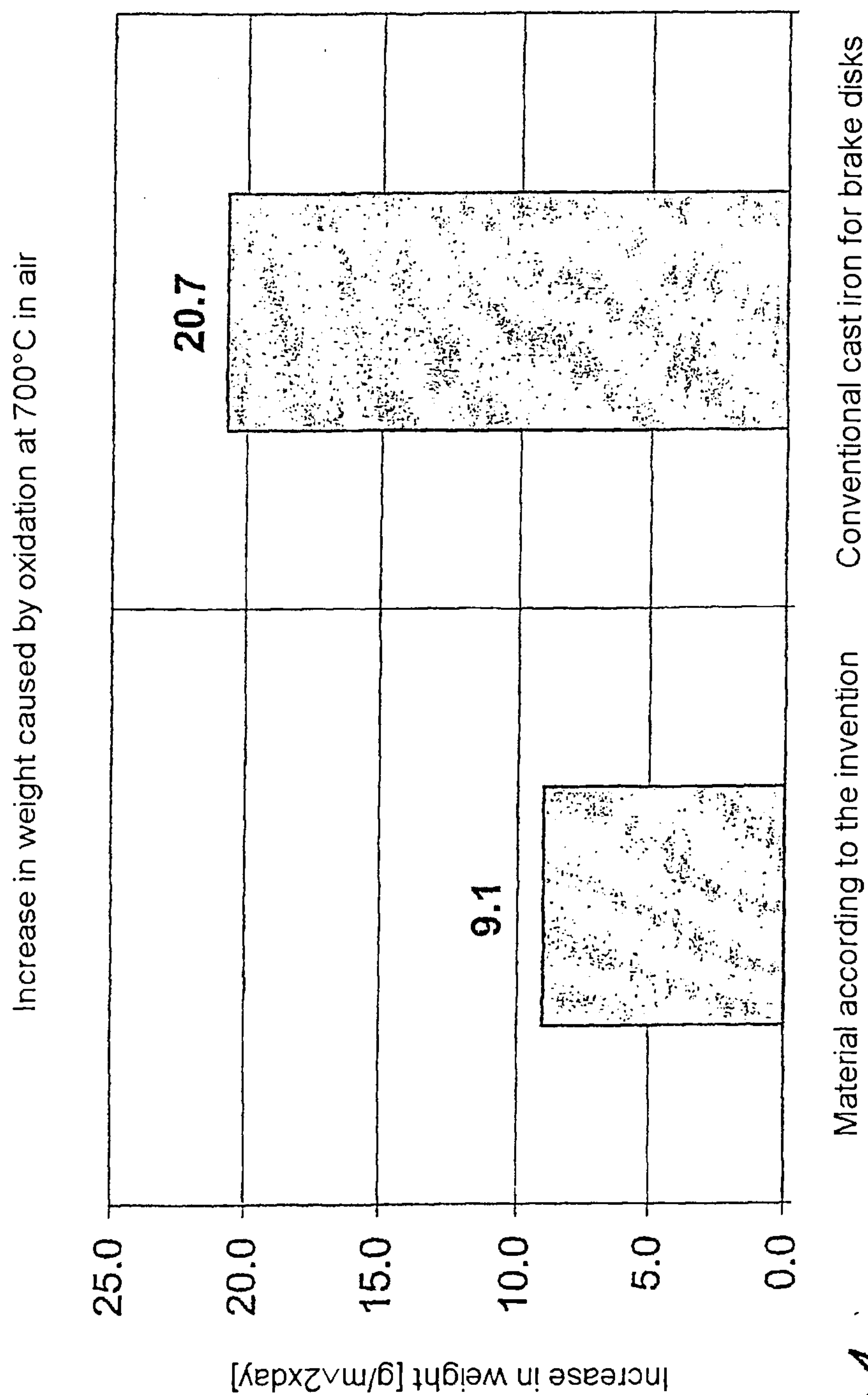
5. The spheroidal cast alloy as claimed in any one of claims 1 to 4, characterized in that, immediately after casting and cooling, the crystalline structure of the cast part has 200 to 700 spherulites per mm².
6. The spheroidal cast alloy as claimed in any one of claims 1 to 5, characterized in that the cast part has a Brinell hardness of over 220.
7. The spheroidal cast alloy as claimed in any one of claims 1 to 6, characterized in that the graphite particles have a size distribution of at least 30% of size 8, 10% to 70% of size 7 and at most 20% of size 6 in accordance with DIN EN ISO 945.
8. The spheroidal cast alloy as claimed in any one of claims 1 to 7, characterized
10 in that the cast part has an elongation at rupture A₅ of 5 to 14% with a tensile strength R_m of 900 to 600 MPa.
9. The spheroidal cast alloy as claimed in any one of claims 1 to 8, characterized in that the cast part has an elongation at rupture A₅ of 5 to 14% with a yield strength R_{p0.2} of 600 to 400 MPa.
10. Use of a spheroidal cast alloy as claimed in any one of claims 1 to 9, for chassis parts in motor vehicles.
11. Use of a spheroidal cast alloy as claimed in any one of claims 1 to 9, for wishbones in motor vehicles.
12. Use of a spheroidal cast alloy as claimed in any one of claims 1 to 9, for wheel
20 carriers in motor vehicles.
13. Use of a spheroidal cast alloy as claimed in any one of claims 1 to 9, for pivot bearings in motor vehicles.

14. Use of a spheroidal cast alloy as claimed in any one of claims 1 to 9, for brake disks in motor vehicles.

15. A method for producing a cast part from a spheroidal cast alloy as claimed in any one of claims 1 to 9, characterized in that, after the casting and cooling of the cast part, no heat treatment of the cast part is performed.

16. A method as claimed in claim 15, characterized in that use is made of a casting mold that is divided horizontally and in which the cast part is arranged horizontally.

10 17. A method as claimed in claim 15, characterized in that use is made of a casting mold that is filled rotationally symmetrically from a middle point of the cast part.

*Fig. 1*

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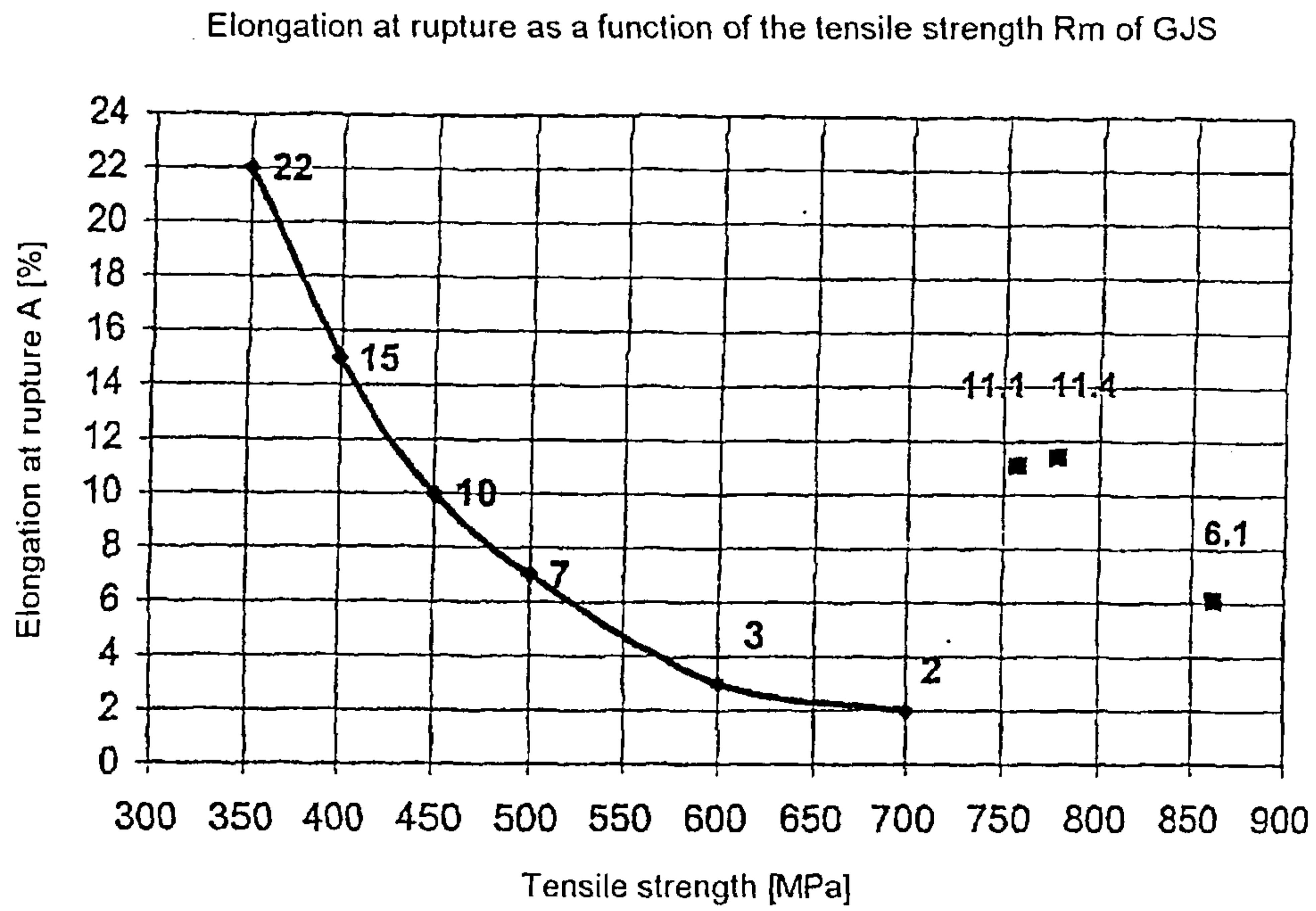


Fig. 4

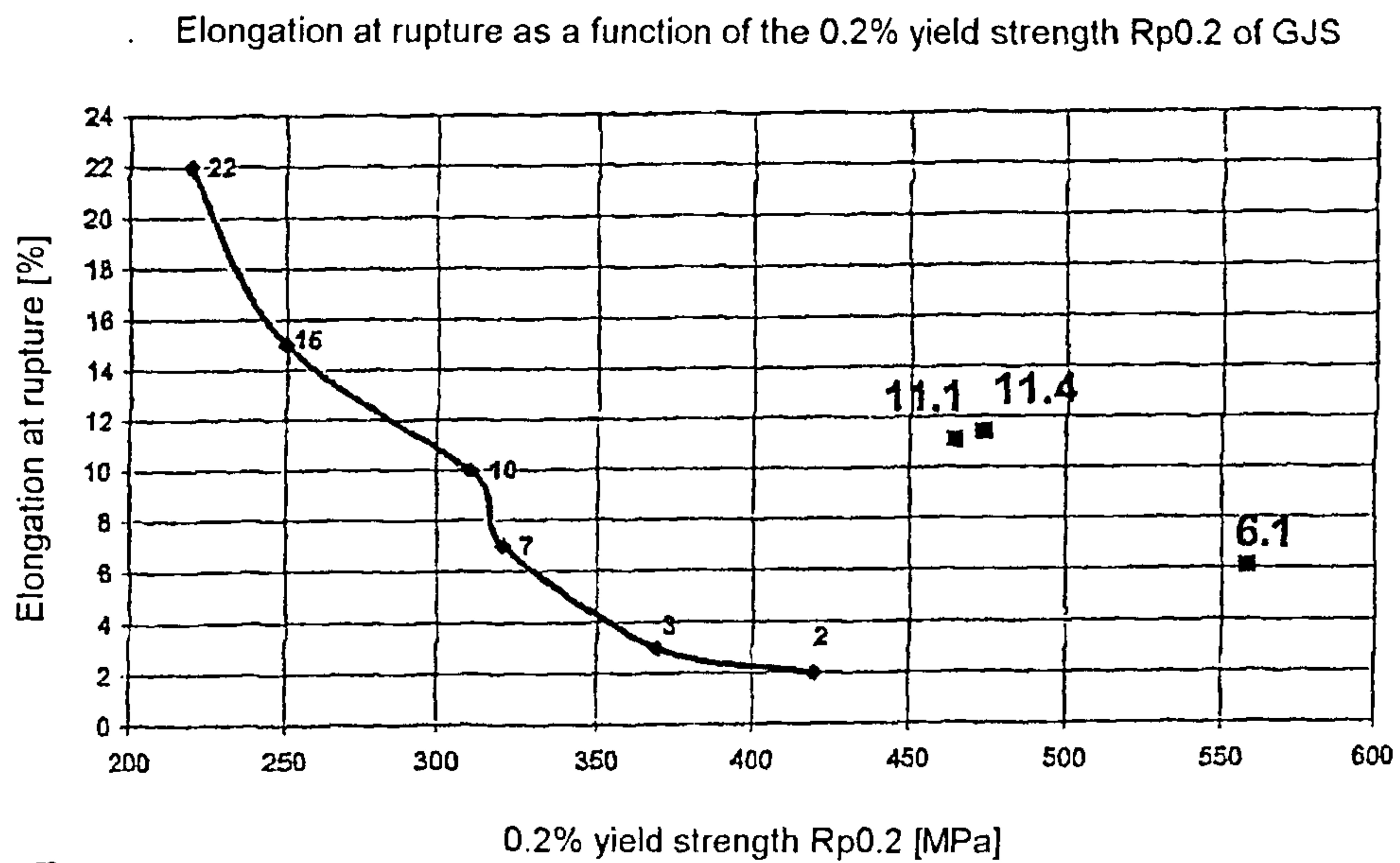


Fig. 5

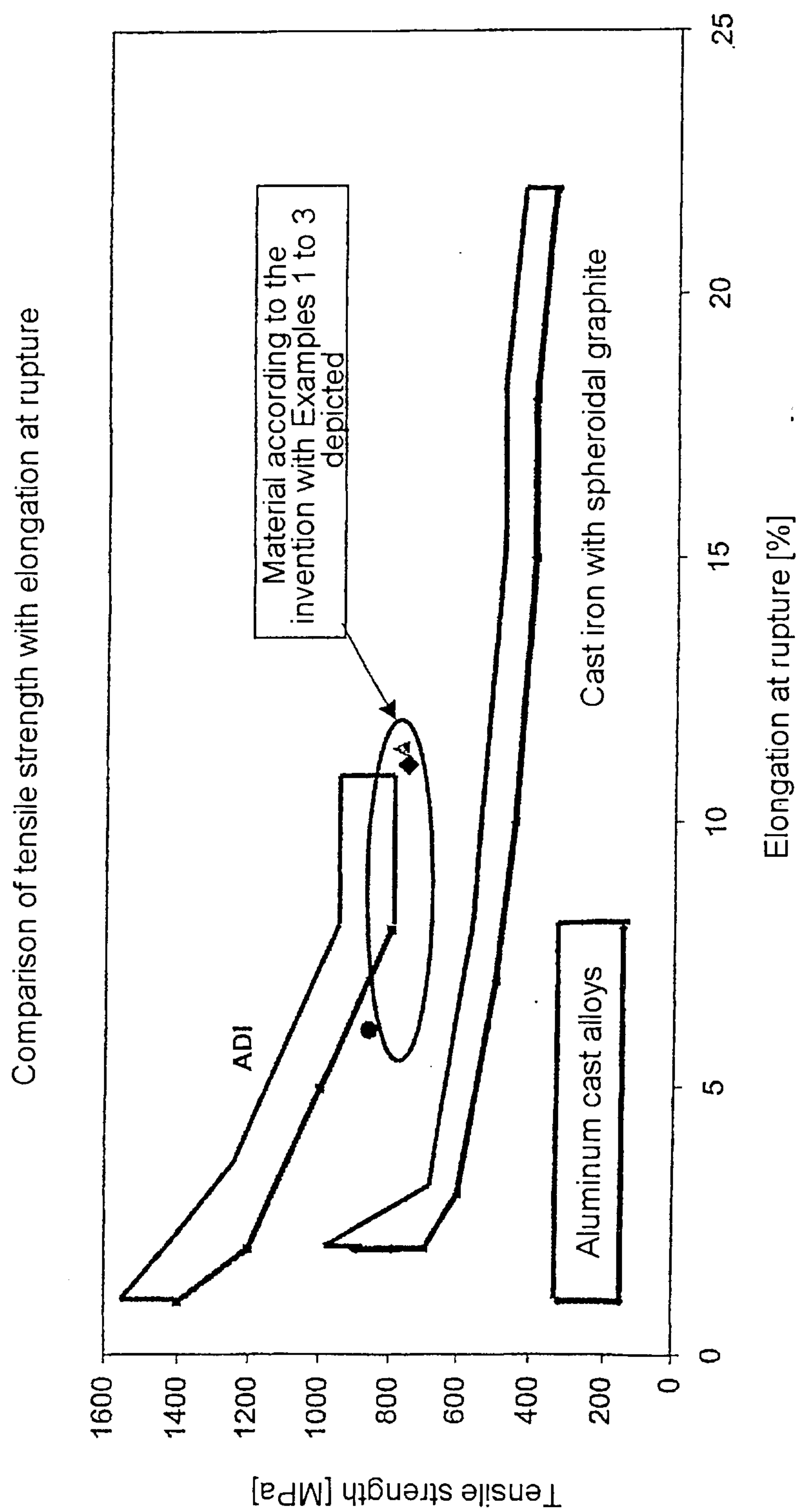


Fig. 6

Comparison of tensile strength with elongation at rupture

