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(54) **Title:** IMPROVED BEARING STEEL

(57) **Abstract:** The present invention relates to a bearing steel comprising at least 0.6 percent by weight of carbon, 0.007 percent by weight or less of phosphorous, and optionally other alloying element(s); the balance being iron, or iron and impurities. The present invention also relates to a bearing consisting of the bearing steel.



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IMPROVED BEARING STEEL

Technical field of the invention

- 5 The present invention relates to a bearing steel. The present invention further relates to bearings made from bearing steel.

Background

- 10 Bearings, such as roller bearings and ball bearings, are subjected to high loads during use. Thus bearings should have high fatigue strength and in addition high hardness.

- Steels with high amounts of carbon are known to have high hardness, but it is
15 a problem that such steels have low fatigue strength.

Summary of the invention

- 20 One purpose of the present invention is to provide bearing steel with improved fatigue strength. It is also a purpose of the present invention to provide bearings produced from the bearing steel according to the present invention.
- 25 According to a first aspect of the present invention the purpose is accomplished by a bearing steel comprising at least 0.6 percent by weight of carbon, 0.007 percent by weight or less of phosphorous, and optionally other alloying element(s), the balance being iron.
- 30 It is understood that the balance may, in addition to iron, consist of impurities. Such impurities may be impurities and trace elements normally being present in iron or steel. Thus, the bearing steel may comprise at least 0.6 percent by weight of carbon, 0.007 percent by weight or less of phosphorous, and

optionally other alloying element(s); the balance being iron, or iron and impurities.

Impurities may be present at levels of 0.5 percent by weight or below, preferably of 0.425 percent by weight or below. Typical impurities may for example be Cu, As, Sn, Sb, Pb, Ti or O, or combinations thereof. Low levels of impurities such as Ti and O result in a low degree of hard non-metallic inclusions, which in combination with low levels of other elements with tendencies to accumulate in austenite grain boundaries result in the bearing steel having high fatigue strength. Particularly, the low amount of phosphorous according to the present invention in combination with the low degree of impurities results in a bearing steel with high fatigue strength.

The iron may be essentially pure iron, essentially without impurities.

The amount of carbon according to the present invention lends the steel a high hardness suitable for steels used for bearings. The amount of phosphorous according to the present invention, results in a bearing steel with high fatigue strength.

The bearing steel may have an amount of phosphorous being below 0.007 percent by weight, preferably in the range of 0.003 to 0.007 percent by weight, such as 0.004 to 0.006 percent by weight. Steel with such amounts of phosphorous may efficiently be produced at steelworks and have high fatigue strength. Phosphorous levels below 0.003 percent by weight may be difficult and costly to produce, and levels above 0.007 percent by weight does not result in the desired high fatigue strengths.

It is a benefit with the present invention that the low amounts of phosphorous combined with the amounts of carbon result in bearing steels with high fatigue strength.

The amount of carbon in the bearing steel may be 0.6 to 1.5 percent by weight, such as 0.7 to 1.3 percent by weight, or 0.7 to 1.1 percent by weight. Preferably the amount of carbon is 0.7 to 1.2 percent by weight, more preferably 0.8 to 1.1 percent by weight. For example the amount may be 0.9
5 to 1.0 percent by weight. Such amounts of carbon lends the bearing steel suitable properties, such as high hardness. Even at such high levels of carbon as for example 0.9 to 1.1 percent by weight, the bearing steels have high fatigue strengths when combined with phosphorous levels at 0.007 percent by weight or below.

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Thus, the bearing steel may be regarded as being a high carbon steel or ultra high carbon steel.

The bearing steel may further comprise sulphur, S, in an amount of 0.02
15 percent by weight or below. The amount of sulphur may be 0.0001 to 0.02 percent by weight, such as 0.0001 to 0.016 percent by weight, or 0.0001 to 0.011 percent by weight. According to one embodiment of the invention, the amount of sulphur is 0.0001 to 0.002 percent by weight, such as 0.0001 to 0.001 percent by weight, for example 0.0001 to 0.0002 percent by weight.
20 Such low amounts of sulphur results in the bearing steel having high fatigue strength. According to an alternative embodiment of the invention the amount of sulphur may be 0.002 to 0.02 percent by weight, such as 0.002 to 0.013 percent by weight, for example 0.003 to 0.012 percent by weight, 0.005 to 0.012 percent by weight, or 0.007 to 0.011 percent by weight. Even at such
25 high amounts of sulphur, and at such high amount of sulphur in combination with the high amount of carbon and the amount of phosphorous according to the present invention, the bearing steel have high fatigue strength.

The bearing steel may have a combined amount of sulphur and phosphorous
30 of 0.02 percent by weight or less. Such a combined amount of sulphur and phosphorous may results in a bearing steel with high fatigue strength.

The bearing steel may further comprise aluminium in an amount of 0.01 percent by weight or above, as alloying element. Preferably the amount of aluminium may be 0.015 percent by weight or above, or more preferably 0.02 percent by weight or above. The maximum amount of aluminium may be 0.05 percent by weight. Thus, the amount of aluminium in the bearing steel may be 0.015 to 0.05 percent by weight.

The bearing steel may further comprise molybdenum, Mo, in an amount of 0.1 to 0.7 percent by weight, preferably 0.3 to 0.7 percent by weight, and most preferably above 0.5 and up to 0.7 percent by weight, such as 0.51 and up to 0.6 percent by weight. Such levels of Mo may result in hard bearing steels with high fatigue strength. Further such amounts of Mo may be efficient for production of bearing steels with a bainitic structure.

The bearing steels may have a bainitic structure or be bainite hardened. It is understood that such a bearing steel also may comprise other structures than the bainitic structure. Preferably more than 50 percent of such a bearing steel has a bainitic structure, such as 50 to 90 percent of the bearing steel.

A bainitic structure results in improved mechanical properties, with high toughness and high crack propagation resistance. Thus a bainitic structure is beneficial for bearing steels and bearings due to the high loads such steels and bearings carries during normal and typical use. The combination of relatively high levels of carbon, low levels of phosphorous, relatively high levels of Mo, and/or relatively high levels of sulphur, according to relevant embodiments of the invention, results in bearing steel with high fatigue strength of the bearings.

Bainite hardening of the bearing steel may be obtained according to the following method: Subjecting a steel to austenitization and quenching; subjecting the steel to an initial temperature (T1) above the initial martensite formation temperature (Ms); lowering T1 to a temperature below Ms but

above the actual martensite formation temperature during the bainite transformation.

5 The method for bainite hardening results in that a bainitic structure of the bearing steel may be obtained efficiently with short bainite hardening times and high hardness of the bearing steel.

The hardness of the bearing steel may be above 59 HRC, for example 59 to 62 HRC, or above 62 HRC.

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Thus, the bearing steel or bearing may have a substantially bainitic structure and a hardness of at least 62 HRC.

15 The bearing steel may also have a martensitic structure or be martensite hardened, still with high fatigue strength.

The bearing steel with an amount of Mo of 0.1 to 0.7 percent by weight may be suitable for bearings with a material thickness from above 0 up to 150 mm. The bearing steel may have an amount of Mo of 0.1 to 0.5 percent by weight,
20 which amount of Mo may be suitable for bearings with a material thickness from above 0 up to 150 mm, such as 15 to 100 mm, for example 15 to 45 mm.

The bearing steels with an amount of Mo of 0.5 to 0.7 percent by weight may
25 be particularly suitable for bearings with a material thickness of 45 mm or above, such as a material thickness from 45 to 150 mm, or from 45 to 80 mm. Such bearings may, for example, be roller bearings with a wall thickness from 45 to 80 mm.

30 Bearing steels used for bearings with material thickness below 15 mm may have an amount of Mo of below 0.35 percent by weight, or from above 0 to 0.35 percent by weight. Such bearing steels may have a bainitic structure.

Particularly, the bearing steels comprising Mo in an amount of 0.1 to 0.7 percent by weight may have a bainitic structure.

5 The bearing steel may comprise chromium, Cr, in an amount of 1.0 to 3.0 percent by weight, such 1.3 to 2.0 percent by weight. An amount of Cr of 1.0 to 1.5 percent by weight may be particularly suitable for bearings with a material thickness from above 0 and up to 45 mm, such as from 15 to 45 mm. A Cr content of 1.5 to 3.0 percent by weight, such as 1.5 to 2.0 percent by weight, may be particularly suitable for bearings with a material thickness
10 from 45 mm and above, such as from 45 to 80 mm, or 45 to 150 mm.

The bearing steels comprising Cr in an amount of 1.0 to 3.0 percent by weight may be suitable for a bainitic structure.

15 The optional other alloying element(s) may be selected from the group comprising Si, Mn, S, Cr, Ni, Mo, V, and Al, or combinations thereof.

Such optional other alloying elements may be suitable for giving the steel suitable properties.

20

If present in the bearing steel, suitable levels of said optional other alloying elements may be in the ranges of:

Silicon (Si): 0-2.5, for example 0.0001-2.5, percent by weight.

25 Manganese (Mn): 0-2, for example 0.0001-2, percent by weight.

Sulphur (S): 0-0.02, for example 0.0001-0.02, percent by weight.

Chromium (Cr): 0-3 percent by weight.

Nickel (Ni): 0-1, for example 0.0001-1, percent by weight.

Molybdenum (Mo): 0-1 percent by weight.

30 Vanadium (V): 0-1, for example 0.0001-1, percent by weight.

Aluminium (Al): 0.01-0.050 percent by weight.

Such levels of alloying elements may result in low degree of hard non-metallic inclusions and in a bearing steel with high fatigue strength

5 According to a second aspect of the invention, there is provided a bearing comprising or consisting of bearing steel comprising at least 0.6 percent by weight of carbon, 0.007 percent by weight or less of phosphorous, and optionally other alloying element(s); the balance being iron, or iron and impurities.

10 It may be preferred that the bearing consists of or essentially consists of at least 0.6 percent by weight of carbon, 0.007 percent by weight or less of phosphorous, and optionally other alloying element(s).

15 Thus, bearings may be provided with the properties of the bearing steel as discussed above. Thus, bearings may be provided having high fatigue strength.

20 The bearings may be selected from the group comprising ball bearings and roller bearings; wherein the ball bearings may be selected from the group comprising deep groove ball bearings, angular contact ball bearings, thrust ball bearings, angular contact thrust ball bearings and self-aligning ball bearings, or combinations thereof; and wherein the roller bearings may be selected from the group comprising cylindrical roller bearings, spherical roller bearings, cylindrical roller thrust bearings, needle roller bearings, toroidal roller bearings, CARB® toroidal roller bearings, combined needle roller bearings, tapered roller bearings, tapered roller thrust bearings, needle roller thrust bearings, spherical roller thrust bearings, combined cylindrical roller/taper roller bearings, track runner bearings, and indexing roller units, or combinations thereof. At least one component of the bearing, such as a
25 30 rolling element or a bearing ring of the bearing may comprise the bearing steel according to the invention.

The bearings may be a combination of ball bearings and roller bearings selected from the groups above.

The bearing may have a material thickness of above 0 and up to 150 mm, such as above 0 and up to 80 mm. Thus, the bearing may have a material thickness of above 0 and up to 45 mm, such as 15 to 45 mm, or the bearing may have a material thickness of 45 mm or above, such as 45 to 80 mm, or
5 45 to 150 mm.

The discussions above concerning the bearing steels related to the first aspect of the present invention may also be relevant for the bearings of the second aspect of the invention concerning bearings. References to these
10 discussions are hereby made with regards to the bearings.

Example

15 In the following comparative example benefits with the present invention will be appreciated and understood. It is understood that the example is included to improve the understanding of the present invention and that the example not in any way may be understood as being limiting concerning the scope of the present invention.

20

Two steel heats A and B were used to cast ingots A and B. The ingots A and B were forged to 350 mm round billets. The billets A and B were cut and machined into rotating beam samples A and B. The samples A and B were bainite hardened using a conventional bainite transformation cycle with a salt
25 bath transformation at 235°C. The samples A and B were finished by hard turning, grinding and polishing. Chemical compositions of the samples A and B obtained from the heats A and B are disclosed in Table 1. Samples A are comparative.

30 Table 1. Chemical compositions of bearing steels obtained from heats A (comparative) and B.

	Percent by weight of elements in steel	p.p.m. in steel
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Sample	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Al	As	Sn	Ti	O
A	0.95	0.47	0.93	0.014	0.004	1.85	0.16	0.54	0.18	0.006	0.029	0.008	0.009	13	4.6
B	0.95	0.43	0.95	0.005	0.010	1.93	0.19	0.58	0.24	0.006	0.034	0.008	0.009	13	5.0

As illustrated by table 1, samples A and B differs in that the amount of phosphorous is considerably lower in samples B compared to samples A; samples A have a phosphorous content being 2.8 times higher than that of samples B. It can also be noted from table 1 that the sulphur content in

5 samples B is 2.5 times higher than the sulphur content of samples A. Further, the amount of Al in sample B is 17% higher than in comparative sample A. The contents of the other elements are identical or similar when samples A and B are compared.

10 Rotating beam fatigue tests and stair case tests:

Several samples A and B were tested at a constant stress level of 1060 MPa and stair-cases were produced. The results from the tests are illustrated by Figures 1 and 2. From the tests and the results it is concluded that the median life at the constant stress tests is at least five times higher for the

15 samples B according to the invention compared to the comparative samples A.

Stair case tests of samples A and B, as illustrated in figure 2, show a significant improvement in the fatigue limit when samples B according to the

20 invention are compared to comparative samples A.

It is evident from the tests that the a bearing steel with the chemical composition according to samples B in table 1 results in considerably improved properties including improved fatigue strength. For example it was

25 concluded that the low amounts of phosphorous had a beneficial effect on the improved fatigue strength.

According to one embodiment of the invention, the bearing steel may comprise 0.9 to 1.1 percent by weight of carbon, 0.004-0.007 percent by

30 weight of phosphorous, 0.5 to 0.7 percent by weight of molybdenum, and

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optionally other alloying element(s); the balance being iron, or iron and impurities. Such a bearing steel results in high fatigue strength.

5 According to another embodiment of the invention, the bearing steel may comprise 0.9 to 1.1 percent by weight of carbon, 0.004-0.007 percent by weight of phosphorous, 0.5 to 0.7 percent by weight of molybdenum, 0.002 to 0.016 percent by weight of S, and optionally other alloying element(s); the balance being iron, or iron and impurities. Such a bearing steel results in high fatigue strength.

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CLAIMS

1. A bearing steel comprising at least 0.6 percent by weight of carbon, 0.007 percent by weight or less of phosphorous, and optionally other alloying element(s); the balance being iron, or iron and impurities.
2. The bearing steel according to claim 1 wherein the amount of phosphorous is below 0.007 percent by weight, preferably in the range of 0.004 to 0.007 percent by weight.
3. The bearing steel according to claim 1 or 2, wherein the amount of carbon is 0.6 to 1.5 percent by weight.
4. The bearing steel according to claim 3, wherein the amount of carbon is 0.8 to 1.1 percent by weight.
5. The bearing steel according to anyone of the previous claims, further comprising sulphur in an amount of 0.02 percent by weight or below, preferably 0.002 to 0.016 percent by weight, as alloying element.
6. The bearing steel according to anyone of the previous claims further comprising aluminium in an amount of 0.015 percent by weight or above, as alloying element.
7. The bearing steel according to anyone of the previous claims, further comprising molybdenum in an amount of 0.1 to 0.7 percent by weight, preferably 0.4 to 0.7 percent by weight, and most preferably above 0.5 and up to 0.6 percent by weight, as alloying element.
8. The bearing steel according to anyone of the previous claims, comprising 0.9 to 1.1 percent by weight of carbon, 0.003 to 0.007 percent by weight of

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phosphorous, 0.5 to 0.7 percent by weight of molybdenum, 0.002 to 0.016 percent by weight of sulphur.

5 9. The bearing steel according to anyone of the previous claims wherein the bearing steel has a bainitic structure.

10 10. The bearing steel according to anyone of the previous claims wherein the optional other alloying element(s) is/are selected from the group consisting of Si, Mn, S, Cr, Ni, Mo, V, and Al, or combinations thereof.

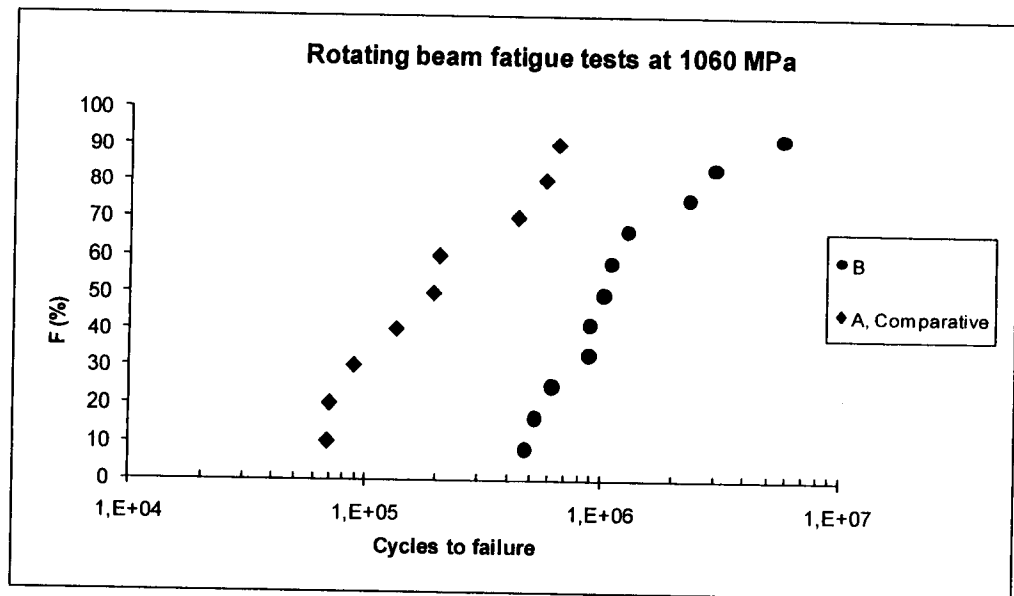
11. A bearing comprising bearing steel according to claim 1.

15 12. The bearing according to claim 11, wherein the bearing has a material thickness of 45 mm or below, preferably 15 to 45 mm.

13. The bearing according to claim 11, wherein the bearing has a material thickness of 45 mm or above, preferably from 45 to 80 mm.

Figures

1/2



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Fig. 1

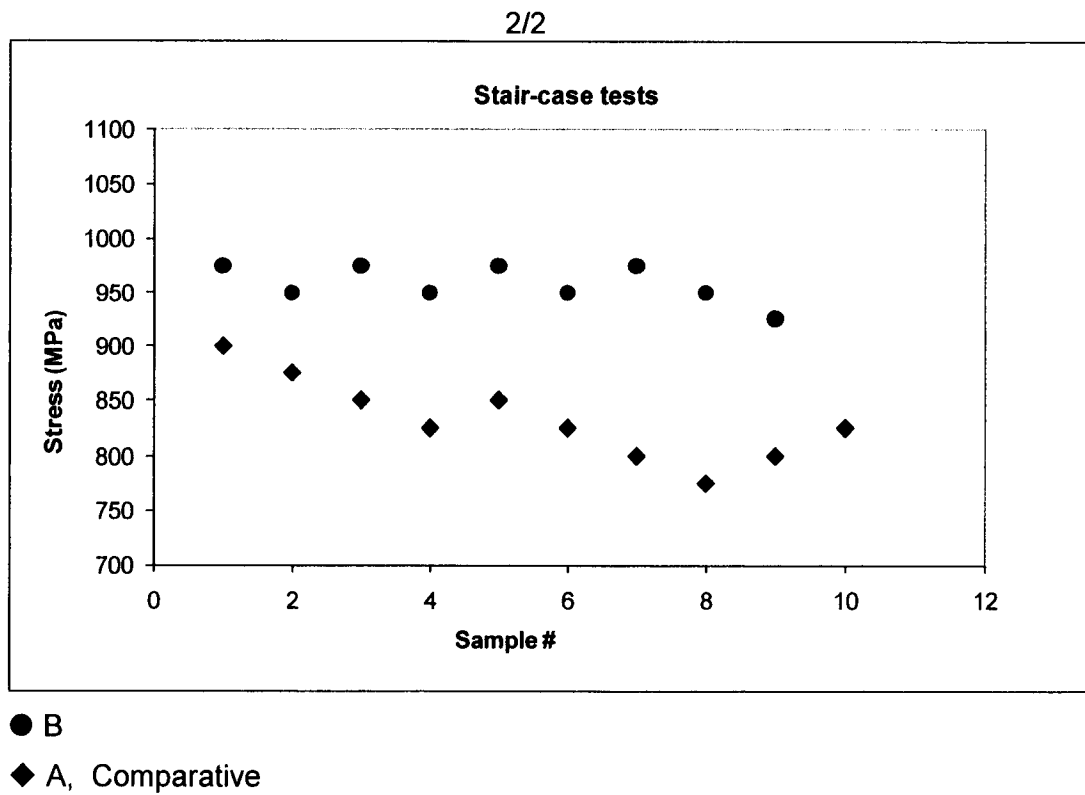


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2012/000075

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C22C, F16C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, Alloys

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7393420 B2 (DAITO YOSHIHIRO ET AL), 22 December 2005 (2005-12-22); abstract; claim 1; Table 1-2, especially example L --	1-13
X	JP 11080896 A (SUMITOMO METAL IND), 26 March 1999 (1999-03-26); (abstract) Retrieved from: WPI database; Original document: table 1-2; abstract; Table 1-2 --	1-13
X	JP 11335773 A (NIPPON KOSHUHA STEEL CO LTD), 7 December 1999 (1999-12-07); (abstract) Retrieved from: WPI database; Original document: table 1-2; abstract; Table 1, especially example 16 --	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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Name and mailing address of the ISA/SE

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2012/000075

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001049388 A (SUMITOMO METAL IND), 20 February 2001 (2001-02-20); (abstract) Retrieved from: PAJ database; Original document: table 1-2; abstract; Table 1, especially example P -- -----	1-13

Continuation of: second sheet

International Patent Classification (IPC)

C22C 38/44 (2006.01)

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F16C 33/00 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2012/000075

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