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11 Publication number: **0 572 246 A1**

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EUROPEAN PATENT APPLICATION

21 Application number: **93304100.6**

51 Int. Cl.⁵: **C22C 38/12, C22C 38/02**

22 Date of filing: **26.05.93**

30 Priority: **29.05.92 FI 922461**

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43 Date of publication of application:
01.12.93 Bulletin 93/48

SF-55100 Imatra(FI)

84 Designated Contracting States:
AT CH DE ES FR GB IT LI SE

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54 **Forging and a method for its manufacture.**

57 For producing a forging with good fatigue strength the billet for the desired forging is made of a material which, in addition to iron, contains the following elements:

C from 0.2 to 0.6 percent by weight

Si from 1.25 to 2.0 percent by weight

Mn from 0.5 to 1.5 percent by weight

V from 0.04 to 0.2 percent by weight

S from 0 to 0.2 percent by weight

Cr from 0 to 0.5 percent by weight

Al from 0 to 0.1 percent by weight

N from 0 to 0.04 percent by weight

Nb from 0 to 0.1 percent by weight

Ti from 0 to 0.05 percent by weight.

The billet is forged at a temperature of more than 800 °C. Subsequently, the billet, which has now become a forging, is cooled in air or gas substantially uniformly acting on the forging.

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This invention relates to a method for producing a forging with good fatigue strength and to a forging having good fatigue strength.

For machine elements, produced by hot forging, which become exposed to fatigue load, the fatigue strength S_v is most often a critical feature which determines the dimensions of the element. The problem is that the static strength of the element in question, for example its tensile strength R_m , has an affect on the machinability of the material. With regard to the total production cost of an element the optimum static tensile strength is about 1000 MPa. If the element has a static tensile strength essentially exceeding this value, the machinability of the material is poor in many cases causing, in particular, high speed steel tools to wear rapidly when machining the material resulting in unreasonably high tool costs. If the fatigue strength of an element can be increased without increasing its static strength, the element can be made more slender and high cutting costs can be avoided. Then the element will be lighter and the production costs will be lower, resulting in a rise in the value of the element and/or lower total production costs.

The cold cropping of bars to produce forging billets, which precedes the forging of modern microalloyed steels, often causes a problem, in particular when the tensile strength in the rolling phase exceeds 900 MPa. In particular the cropping usually creates cracks on the shear surface of the cropped billet. If the fatigue strength of the final forging can be raised without raising the tensile strength of the bar blank, the alloying of the steel can be reduced, *inter alia* with regard to manganese. Then the tensile strength is reduced and at the same time the cold cropping properties are improved without any reduction of the fatigue strength of the final forged product. In this way the cold cutting difficulties can be eliminated and the alloying costs can be reduced.

Forgings made of known microalloyed steels, in particular connecting rods, crankshafts, drive shafts and the like, must often be surface finished, generally by working the surface (particle blasting, rolling, etc.), or by surface hardening, in order to improve the fatigue strength. The combination of the steel composition according to the invention and the treatment according to the invention essentially reduces the necessity of surface treatment for the type of products referred to, thereby reducing their production costs.

The object of the invention is to produce a forging with a high fatigue strength without the above-described technical drawbacks. At the same time the advantages mentioned above are achieved. The object of the invention is obtained by the method of claim 1 and the forging of claims 6 and 7.

Alloyed steels resembling the alloyed steel of the forging according to the invention have been used before, *inter alia* as raw material for steel springs and different fastening elements, as described in the Finnish *laid open* publication FI 48204. The main difference between the forging according to the invention and the known springs and fastening elements is that, according to the invention, the microstructure will be mostly (typically to more than 90 percent) ferritic-perlitic, which is obtained by air cooling, while the microstructure of the elements described in FI 48204 is martensite or bainite for the greatest part, which is obtained by quenching and tempering or austempering.

According to the method of the invention the billets are hot forged at a temperature of more than 800 °C and after that they are allowed to cool in air. This treatment is known *per se* as a treatment method for microalloyed steels for the purpose of eliminating a separate quench and temper treatment in order to reduce the production costs. In the case of the invention the treatment result is different. The high silicon content provides an improved fatigue strength. It is assumed that this is caused by the fact that small amounts of residual austenite are formed which, under fatigue stress, turn into martensite. Thereby a so-called cyclic work hardening takes place, which increases the fatigue strength.

Novel in the invention is the combination of a steel according to the invention, containing a high degree of silicon, and a working method generally used in the production of other microalloyed steel forgings. This results, for the reasons explained above, in a product with a fatigue strength that is essentially better than in previously known microalloyed steel products.

A silicon content higher than normal in air-cooled microalloyed steels is known from DE-A-3009443. The invention differs from this, firstly in that the silicon content is higher, and secondly, in that the object is to improve the fatigue strength, whereas the object of the known technique is to improve the notch toughness, not the fatigue strength.

It is of advantage for an element according to the invention that its production process includes, before hot forging, heating to such a high temperature that the vanadium carbonitrides of the element dissolve. This improves the strength of the element so that it is usually near the optimum value mentioned on the first page of this specification, which also is of advantage with respect to the fatigue strength.

By reducing the nitrogen content of the material to at the most 0.012 percent by weight, or the titanium content to at the most 0.01 percent by weight, the advantage is achieved that large nitride particles harmful for the fatigue strength, will not be formed. This is ensured, in particular, if the continuous casting method is used in the manufacturing process of the material.

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In order to obtain better mechanical features the cooling of the forging can be effected by using flowing air as coolant, preferably air moistened, for instance by water spray. It is of advantage to use this kind of forced cooling when the temperature of the element is above 600 ° C. The forced cooling causes the forging to obtain a sufficient strength without any negative influence on its toughness. This is because forced cooling results in a finer micro structure of the element. The grain size becomes smaller and the interlamellar spacing of the perlite remains small, whereby the strength is improved but the toughness remains unaltered.

The following test results show the improvement of the fatigue strength achieved by the combination of the method and the steel composition according to the invention.

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TABLE I

MATERIAL	C	Si	Mn	V	S	Cr	Al	N	Nb	Ti
Reference 1	0.44	0.52	1.06	0.12	0.044	0.58	0.013	0.012	0.00	0.00
Reference 2	0.46	0.51	0.98	0.13	0.053	0.45	0.015	0.009	0.00	0.00
Reference 3	0.42	0.53	1.00	0.14	0.084	0.36	0.017	0.012	0.00	0.00
Reference 4	0.37	0.56	1.38	0.15	0.063	0.22	0.016	0.010	0.00	0.00
Test material 1	0.34	1.40	0.88	0.14	0.060	0.19	0.035	0.015	0.00	0.00
Test material 2	0.43	1.26	1.08	0.18	0.030	0.33	0.014	0.013	0.00	0.00

The compositions of the test materials and the reference materials are given in percent by weight.

TABLE II

MATERIAL	DIMENSION EFFECTIVE (mm)	TREATMENT	Sv (10 ⁷) N/mm ²	Rm N/mm ²	Sv/Rm	TEST MATERIAL SUPERIORITY %
Test material 1	Ø50	forged	429	852	0.503	-
Reference material 2	Ø50	forged	431	952	0.453	11
Reference material 3	Ø50	forged	396	868	0.456	10
Reference material 4	Ø50	forged	430	932	0.461	9
Test material 2	Ø60	rolled	543	1024	0.530	-
Reference material 1	Ø42	rolled	373	916	0.407	30
Reference material 2	Ø35	rolled	375	891	0.421	26
Reference material 3	Ø45	rolled	404	875	0.462	15

Fatigue strength of test materials and reference materials measured in endurance test by rotating bending. The elements have been cooled in air from the forming heat.

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The fatigue strength Sv was determined in a rotating bending test, load alternations 10 million
55 revolutions. The ultimate tensile strength Rm influences the fatigue strength, which means that the ratio of fatigue strength and tensile strength must be observed. Compared to modern reference steels the improvement in the fatigue strength to tensile strength ratio for steels produced according to the invention is from about 10 to 30%.

The invention is not limited to the disclosed examples and modifications are feasible within the scope of the appended claims.

Claims

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1. A method for producing a forging with good fatigue strength, **characterised by** the combination that the billet for the desired forging is made of a material which, in addition to iron, contains the following elements:

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C from 0.2 to 0.6 percent by weight

Si from 1.25 to 2.0 percent by weight

Mn from 0.5 to 1.5 percent by weight

V from 0.04 to 0.2 percent by weight

S from 0 to 0.2 percent by weight

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Cr from 0 to 0.5 percent by weight

Al from 0 to 0.1 percent by weight

N from 0 to 0.04 percent by weight

Nb from 0 to 0.1 percent by weight

Ti from 0 to 0.05 percent by weight,

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that the billet is forged at a temperature of more than 800°C and that the forging so formed is subsequently cooled in air or gas substantially uniformly acting on the forging.

2. A method according to claim 1, **characterised in that** the billet before the hot forging is heated to a temperature, where its vanadium carbonitrides dissolve.

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3. A method according to claim 1 or 2, **characterised in that** the nitrogen content of the material is no more than 0.012 percent by weight.

4. A method according to claim 1, 2 or 3, **characterised in that** the titanium content of the material is no more than 0.01 per cent by weight.

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5. A method according to any of the preceding claims, **characterised in that** in the cooling of the forging, at least when its temperature is above 600°C, dry or humid flowing air or gas is used as a coolant.

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6. A forging made by the method of any one of claims 1 to 5.

7. A forging with good fatigue strength, **characterised in that** it is made of a material which, in addition to iron, contains the following elements:

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C from 0.2 to 0.6 percent by weight

Si from 1.25 to 2.0 percent by weight

Mn from 0.5 to 1.5 percent by weight

V from 0.04 to 0.2 percent by weight

S from 0 to 0.2 percent by weight

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Cr from 0 to 0.5 percent by weight

Al from 0 to 0.1 percent by weight

N from 0 to 0.04 percent by weight

Nb from 0 to 0.1 percent by weight

Ti from 0 to 0.05 percent by weight,

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and in that the microstructure of the forging is mostly ferritic-perlitic.

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EUROPEAN SEARCH REPORT

Application Number

EP 93 30 4100

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	EP-A-0 035 681 (THYSSEN EDELSTAHLWERKE) *Claims 1-4*	1-7	C22C38/12 C22C38/02
A,D	& DE-A-3 009 443 ---	1-7	
Y	DE-A-3 124 977 (K.K.KOBE SEIKO SHO) *Claims 1-6*	1	
Y	SU-A-301 371 (V.ROUNOV ET AL.) * the whole document *	1	
Y	SU-A-522 264 (BREJNEVA ET AL.) * the whole document *	1	
A	AU-A-483 965 (AMSTED INDUSTRIES INCORPORATED) * the whole document *	1-7	
A	GB-A-1 441 695 (TOWMOTOR CORPORATION) * the whole document *	1-7	
A	DE-A-2 210 915 (HOESCH WERKE AG) *Claims 1-5*	1-7	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	US-A-3 173 782 (MELLOY ET AL.) *Claims 1-6*	1-7	C22C

The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 06 SEPTEMBER 1993	Examiner LIPPENS M.H.
<p>CATEGORY OF CITED DOCUMENTS</p> <p>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</p> <p>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</p>			

EPO FORM 1503 01.82 (P/9001)