



SUOMI – FINLAND

(FI)

PATENTTI- JA REKISTERIHALLITUS  
PATENT- OCH REGISTERSTYRELSEN



FI000124995B

(12) PATENTTIJULKAISU  
PATENTSKRIFT

(10) FI 124995 B

(45) Patentti myönnetty - Patent beviljats

15.04.2015

(51) Kv.lk. - Int.kl.

**C22C 38/50** (2006.01)

**C22C 38/48** (2006.01)

**C22C 38/46** (2006.01)

**C22C 38/44** (2006.01)

**C22C 38/42** (2006.01)

(21) Patentihakemus - Patentansökning

20126212

(22) Saapumispäivä - Ankomstdag

20.11.2012

(24) Tekemispäivä - Ingivningsdag

20.11.2012

(41) Tullut julkiseksi - Blivit offentlig

21.05.2014

(73) Haltija - Innehavare

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(54) Keksinnön nimitys - Uppfinningens benämning

**Ferriittinen ruostumaton teräs**

**Ferritiskt rostfritt stål**

(56) Viitejulkaisut - Anförda publikationer

WO 2012046879 A1, EP 2100983 A1

(57) Tiivistelmä - Sammandrag

The invention relates to a ferritic stainless steel having excellent corrosion and sheet forming properties. The steel consists of in weight percentages 0,001 - 0,035 % carbon, 0,05 - 1,0 % silicon, 0,1 - 0,8 % manganese, 20 - 24 % chromium, 0,05 - 0,8 % nickel, less than 0,2 % molybdenum, 0,2 - 0,8 % copper, 0,001 - 0,05 % nitrogen, 0,05 - 0,8 % titanium, 0,05 - 0,8 % niobium, 0,03 - 0,5 % vanadium, less than 0,04 % aluminium, and the sum C+N less than 0,06 %, the remainder being iron and inevitable impurities in such conditions, that the ratio  $(Ti+Nb)/(C+N)$  is higher or equal to 8, and the ratio  $Ti_{eq}/C_{eq} = (Ti + 0,515*Nb + 0,940*V)/(C+0,858*N)$  is higher or equal to 6.

Keksintö kohdistuu ferriittiseen ruostumattomaan teräkseen, jolla on erinomaiset korroosiokestävyys- ja levymuokkausominaisuudet. Teräs koostuu paino-%:na 0,001 - 0,035 % hiiltä, 0,05 - 1,0 % piitä, 0,1 - 0,8 % mangaania, 20 - 24 % kromia, 0,05 - 0,8 % nikkeliä, vähemmän kuin 0,2 % molybdeeniä, 0,2 - 0,8 % kuparia, 0,001 - 0,05 % typpeä, 0,05 - 0,8 % titaania, 0,05 - 0,8 % niobia, 0,03 - 0,5 % vanadiinia, vähemmän kuin 0,04 % alumiinia, ja summa C+N vähemmän kuin 0,06 %, lopun ollessa rautaa (Fe) ja väistämättömiä epäpuhtauksia sellaisin ehdoin, että suhde  $(Ti+Nb)/(C+N)$  on korkeampi tai yhtä kuin 8, ja suhde  $Ti_{eq}/C_{eq} = (Ti + 0,515*Nb + 0,940*V)/(C+0,858*N)$  on korkeampi tai yhtä kuin 6.

## FERRITIC STAINLESS STEEL

This invention relates to a stabilized ferritic stainless steel having good corrosion resistance and good sheet forming properties.

5

The most critical point in developing ferritic stainless steel is how to take care of carbon and nitrogen elements. These elements have to be bound to carbides, nitrides or carbonitrides. The elements used in this type of binding are called stabilizing elements. The common stabilizing elements are niobium and  
10 titanium. The requirements for stabilization of carbon and nitrogen can be diminished for ferritic stainless steels where for instance the carbon content is very low, less than 0,01 weight %. However, this low carbon content causes requirements for the manufacturing process. The common AOD (Argon-Oxygen-Decarburization) producing technology for stainless steels is not any  
15 more practical and, therefore, more expensive producing methods shall be used, such as the VOD (Vacuum-Oxygen-Decarburization) producing technology.

The EP patent 936280 relates to a titanium and niobium stabilized ferritic  
20 stainless steel having the composition in weight % less than 0,025 % carbon, 0,2-0,7 % silicon, 0,1-1,0 % manganese, 17-21 % chromium, 0,07-0,4 % nickel, 1,0-1,25 % molybdenum, less than 0,025 % nitrogen, 0,1-0,2 % titanium, 0,2-0,35 % niobium, 0,045-0,060 % boron, 0,02-0,04 % (REM+hafnium), the rest being iron and inevitable impurities. According to this EP patent 936280 copper  
25 and molybdenum have a beneficial effect on the resistance to general and localised corrosion and the rare earth metals (REM) globulise the sulphides, thus improving ductility and formability. However, molybdenum and REM are expensive elements that make the manufacturing of the steel expensive.

30 The EP patent 1818422 describes a niobium stabilized ferritic stainless steel having among others less than 0,03 weight % carbon, 18 - 22 weight % chromium, less than 0,03 weight % nitrogen and 0,2 - 1,0 weight % niobium. In

accordance with this EP patent the stabilization of carbon and nitrogen is carried out using only niobium.

The US patent 7056398 describes a ultra-low-carbon-based ferritic stainless steel including in weight % less than 0,01 % carbon, less than 1,0 % silicon, less than 1,5 % manganese, 11 – 23 % chromium, less than 1,0 % aluminium, less than 0,04 % nitrogen, 0,0005 – 0,01 % boron, less than 0,3 % vanadium, less than 0,8 % niobium, less than 1,0 % titanium, wherein  $18 \leq \text{Nb}/(\text{C}+\text{N}) + 2(\text{Ti}/(\text{C}+\text{N})) \leq 60$ . During the steel making process carbon is removed as much as possible and the solid-solution carbon is fixed as carbides by titanium and niobium. In the steel of the US patent 7056398 a portion of titanium is replaced with vanadium and vanadium is added in combination with boron to improve toughness. Further, boron forms boron nitride (BN) which prevents the precipitation of titanium nitride further deteriorating the toughness of the steel. The steel of this US patent 7056398 is concentrated on improving brittle resistance at the expense of corrosion resistance and recommends the use a protective over coating.

The EP patent application 2163658 describes a ferritic stainless steel with sulfate corrosion resistance containing less than 0,02 % carbon, 0,05-0,8 % silicon, less than 0,5 % manganese, 20-24 % chromium, less than 0,5 % nickel, 0,3-0,8 % copper, less than 0,02 % nitrogen, 0,20-0,55 % niobium, less than 0,1 % aluminium and the balance being iron and inevitable impurities. In this ferritic stainless only niobium is used in the stabilization of carbon and nitrogen.

The EP patent application 2182085 relates to a ferritic stainless steel having a superior punching workability without generating burrs. The steel contains in weight % 0,003 – 0,012 % carbon, less than 0,13 % silicon, less than 0,25 % manganese 20,5 – 23,5 % chromium, less than 0,5 % nickel, 0,3 – 0,6 % copper, 0,003 – 0,012 % nitrogen, 0,3 – 0,5 % niobium, 0,05 – 0,15 % titanium, less than 0,06 % aluminium, the rest being iron and inevitable impurities. Further, the ratio Nb/Ti contained in a NbTi complex carbonitride present in

ferrite crystal grain boundaries is in the range of 1 to 10. In addition, the ferritic stainless steel of this EP patent application 2182085 comprises less than 0,001 % boron, less than 0,1 % molybdenum, less than 0,05 % vanadium and less than 0,01 % calcium. It is also said that when the carbon content is more than 5 0,012 % the generation of chromium carbide cannot be suppressed and the corrosion resistance is degraded, and that when more than 0,05 % vanadium is added steel is hardened and, as a result, workability is degraded.

A ferritic stainless steel with good corrosion resistance is also described in the 10 US patent application 2009056838 with the composition containing less than 0,03 % carbon, less than 1,0 % silicon, less than 0,5 % manganese, 20,5 -22,5 % chromium, less than 1,0 % nickel, 0,3 - 0,8 % copper, less than 0,03 % nitrogen, less than 0,1 % aluminium, less than 0,01 % niobium,  $(4 \times (C+N)) \% <$  titanium  $< 0,35 \%$ ),  $(C+N)$  less than 0,05 % and the balance being iron and 15 inevitable impurities. In accordance with this US patent application 2009056838 niobium is not used, because niobium increases the recrystallization temperature, causing insufficient annealing in the high speed annealing line of a cold-rolled sheet. On the contrary, titanium is an essential element to be added for increasing pitting potential and thus improving corrosion resistance. 20 Vanadium has an effect of preventing occurrence of intergranular corrosion in welding area. Therefore, vanadium is optionally added at the range of 0,01 - 0,5 %.

The WO publication 2010016014 describes a ferritic stainless steel having 25 excellent resistance to hydrogen embrittlement and stress corrosion cracking. The steel contains less than 0,015 % carbon, less than 1,0 % silicon, less than 1,0 % manganese, 20 – 25 % chromium, less than 0,5 % nickel, less than 0,5 % molybdenum, less than 0,5 % copper, less than 0,015 % nitrogen, less than 0,05 % aluminium, less than 0,25 % niobium, less than 0,25 % titanium, and 30 further less than 0,20 % expensive element, tantalum, the balance being iron and inevitable impurities. The addition of high contents of niobium and/or tantalum causes strengthening of the crystalline structure and, therefore, the

sum (Ti+Nb+Ta) is comprised in the range 0,2 – 0,5 %. Further, for preventing hydrogen embrittlement the ratio  $(\text{Nb} + \frac{1}{2}\text{Ta})/\text{Ti}$  is necessary to be at the range of 1 – 2.

- 5 The object of the present invention is to eliminate some drawbacks of the prior art and to achieve a ferritic stainless steel having good corrosion resistance and good sheet forming properties, which steel is stabilized by niobium, titanium and vanadium and is produced using AOD (Argon-Oxygen-Decarburization) technology. The essential features of the present invention are enlisted in the  
10 appended claims.

The chemical composition of the ferritic stainless steel according to the invention consists of in weight % less than 0,035 % carbon (C), less than 1,0 % silicon (Si), less than 0,8 % manganese (Mn), 20 – 24 % chromium (Cr), less  
15 than 0,8 % nickel (Ni), less than 0,5 % molybdenum (Mo), less than 0,8 % copper (Cu), less than 0,05 % nitrogen (N), less than 0,8 % titanium (Ti), less than 0,8 % niobium (Nb), less than 0,5 % vanadium (V), aluminium less than 0,04 % the rest being iron and evitable impurities occupying in stainless steels, in such conditions that the sum of (C+N) is less than 0,06 % and the ratio  
20  $(\text{Ti} + \text{Nb})/(\text{C} + \text{N})$  is higher or equal to 8, and the ratio  $(\text{Ti} + 0,515 \cdot \text{Nb} + 0,940 \cdot \text{V})/(\text{C} + 0,858 \cdot \text{N})$  is higher or equal to 6.

The effects and the content in weight %, if nothing else mentioned, of each alloying element are discussed in the following:

25

Carbon (C) decreases elongation and r-value and, preferably, carbon is removed as much as possible during the steel making process. The solid-solution carbon is fixed as carbides by titanium, niobium and vanadium as described below. The carbon content is limited to 0,035 %, preferably to 0,03  
30 %, but having at least of 0,001 % carbon.

Silicon (Si) is used to reduce chromium from slag back to melt. Some silicon remainders in steel are necessary to make sure that reduction is done well. Therefore, the silicon content is less than 1,0 %, preferably 0,05 - 0,7 %.

5 Manganese (Mn) degrades the corrosion resistance of ferritic stainless steel by forming manganese sulphides. With low sulphur (S) content the manganese content is less than 0,8 %, preferable less than 0,65 %. The more preferable range is 0,10 – 0,65 % manganese.

10 Chromium (Cr) enhances oxidation resistance and corrosion resistance. In order to achieve corrosion resistance comparable to steel grade EN 1.4301 chromium content must be 20 – 24 %, preferably 20 – 21,5 %.

Nickel (Ni) is an element favourably contributing to the improvement of  
15 toughness, but nickel has sensitivity to stress corrosion cracking (SCC). In order to consider these effects the nickel content is less than 0,8 %, preferably less than 0,5 % so that the nickel content is preferably at least 0,05 %.

Molybdenum (Mo) enhances corrosion resistance but reduces elongation to  
20 fracture. The molybdenum content is less than 0,5 %, preferably less than 0,2 %.

Copper (Cu) improves corrosion resistance in acidic solutions, but high copper content can be harmful. The copper content is thus less than 0,8 %, preferably  
25 less than 0,5 %, but preferably at least 0,2 %.

Nitrogen (N) reduces elongation to fracture. The nitrogen content is less than 0,05 %, preferably less than 0,03 %, but preferably at least 0,001 %.

30 Aluminium (Al) is used to remove oxygen from melt. The aluminium content is less than 0,04 %.

Titanium (Ti) is very useful because it forms titanium nitrides with nitrogen at very high temperatures. Titanium nitrides prevent grain growth during annealing and welding. The titanium content is less than 0,8 %, preferably 0,05 – 0,40 %.

- 5 Niobium (Nb) is used to some extent to bind carbon to niobium carbides. With niobium the recrystallization temperature can be controlled. Niobium is most expensive elements of chosen stabilization elements titanium, vanadium and niobium. The niobium content is less than 0,8 %, preferably 0,05 – 0,40 %.
- 10 Vanadium (V) forms carbides and nitrides at lower temperatures. These precipitations are small and major part of them is usually inside grains. Amount of vanadium needed to carbon stabilization is only about half of amount of niobium needed to same carbon stabilization. This is because vanadium atomic weight is only about a half of niobium atomic weight. Because vanadium is  
15 cheaper than niobium then vanadium is an economic choice. Vanadium also improves toughness of steel. The vanadium content is less than 0,5 %, preferably 0,03 - 0,20 %.

With all these three stabilization elements, titanium, niobium and vanadium, it is  
20 possible to achieve atomic lattice, which is practically interstitially free. That means that essentially all carbon and nitrogen atoms are bound with stabilization elements.

Several stainless steel alloys were prepared for testing the ferritic stainless  
25 steel of the invention. During the preparation every alloy was melted, cast and hot-rolled. The hot-rolled plate was further annealed and pickled before cold-rolling. Then the cold-rolled sheet at the final thickness was again annealed and pickled. The table 1 further contains the chemical compositions of the reference materials EN 1.4301 and 1.4404.

Alloy	C	Si	Mn	P	S	Cr	Ni	Mo	Ti	Nb	Cu	V	Al	N
A	0,014	0,31	0,34	0,006	0,004	21,0	0,21	<0,01	0,26	0,22	0,41	0,01	0,010	0,019
B	0,021	0,46	0,29	0,005	0,003	20,9	0,20	<0,01	0,21	0,23	0,41	0,01	0,011	0,023
C	0,022	0,46	0,51	0,006	0,004	21,1	0,20	<0,01	0,32	0,12	0,42	0,01	0,016	0,019
D	0,021	0,47	0,31	0,006	0,003	20,9	0,20	<0,01	0,11	0,34	0,42	0,01	0,010	0,024
E	0,035	0,48	0,31	0,005	0,004	21,0	0,20	<0,01	0,20	<0,01	0,42	0,13	0,010	0,023
F	0,021	0,45	0,31	0,005	0,003	21,0	0,20	<0,01	0,16	<0,01	0,42	0,12	0,011	0,024
G	0,024	0,48	0,52	0,006	0,004	21,0	0,20	<0,01	0,02	0,11	0,41	0,15	0,040	0,024
H	0,019	0,60	0,35	0,040	0,003	20,8	0,21	0,02	0,15	0,25	0,33	0,07	0,012	0,024
EN 1.4301	0,04	0,4	1,4	0,03	0,001	18,2	8,1	0,2	0,01	0	0,4	0	0,002	0,04
EN 1.4404	0,02	0,5	1,7	0,03	0,001	17,0	10,1	2,0	0,01	0	0,4	0	0,002	0,04

Table 1: Chemical compositions



From the table 1 it is seen that the alloys A, B, C and D are double stabilized with titanium and niobium. The alloys A and B have essentially equal amount of titanium and niobium. The alloy C has more titanium than niobium, while the alloy D has more niobium than titanium. The alloys E, F, G and H contain also  
5 vanadium in addition to titanium and niobium, the alloys E and F having only a small amount of niobium and the alloy G having only a small content of titanium. The triple stabilized with titanium, niobium and vanadium in accordance with the invention is the alloy H.

10 As corrosion resistance is the most important property of stainless steel, the pitting corrosion potential of all the alloys listed in the table 1 was determined potentiodynamically. The alloys were wet ground with 320 mesh and allowed to repassivate in air at ambient temperature for at least 24 hours. The pitting potential measurements were done in naturally aerated aqueous 1.2 wt-%  
15 NaCl-solution (0.7 wt-% Cl<sup>-</sup>, 0.2 M NaCl) at room temperature of about 22°C. The polarization curves were recorded at 20 mV/min using crevice-free flushed-port cells (Avesta cells as described in ASTM G150) with an electrochemically active area of about 1 cm<sup>2</sup>. Platinum foils served as counter electrodes. KCl saturated calomel electrodes (SCE) were used as reference electrodes. The  
20 average value of six breakthrough pitting potential measurements for each alloy was calculated and is listed in table 2.

In order to verify that the stabilization against intergranular corrosion was successful, the alloys were submitted to a Strauss test according to EN ISO  
25 3651-2:1998-08: Determination of resistance to intergranular corrosion of stainless steels - Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels - Corrosion test in media containing sulfuric acid. The results of these tests are presented in the table 2.

30 The table 2 also contains the respective results for the reference materials EN 1.4301 and 1.4404.

Alloy	Corrosion potential, mV	Sensitization
A	480	no
B	476	no
C	487	no
D	459	no
E	576	no
F	620	no
G	223	yes
H	645	no
Ref. EN 1.4301	451	no
Ref. EN 1.4404	550	no

Table 2 Pitting potential and sensitization

The results for the corrosion potential in the table 2 show that the ferritic stainless steel of the invention has a better pitting corrosion resistance than the reference steels EN 1.4301 and EN 1.4404. Further, there is no sensitization for the alloys in accordance with the invention. The alloy G is outside of this invention, because the alloy G does not fulfil corrosion requirements of this invention. The alloy G is understabilized.

10

The yield strength  $R_{p0.2}$ , the tensile strength  $R_m$  as well as the elongation to fracture were determined for the ferritic stainless steel of the invention in the mechanical tests for the alloys of the table 1. The results are presented in the table 3:

15

Alloy	$R_{p0.2}$ , N/mm <sup>2</sup>	$R_m$ , N/mm <sup>2</sup>	Elongation, %
A	352	490	27
B	313	475	28
C	319	473	30
D	316	485	28
E	358	488	28
F	365	481	30
H	350	515	31
Ref. EN 1.4301	240	540	>45

Table 3 Results for mechanical tests

The results in the table 3 show that the alloy H having the stabilization with niobium, titanium and vanadium has the best values within the tested alloys for

these tested mechanical properties; the highest tensile strength combined with the longest elongation to fracture. Further, the test results of the table 3 show, that the tensile strength and the elongation to fracture of the reference material EN 1.4301 are higher than the representative values for the ferritic stainless steel. The reason is based on different atomic lattice type. The reference steel lattice is called face centred cubic (FCC) lattice and ferritic stainless lattice is called body centred cubic (BCC). FCC lattice has “always” better elongation than BCC lattice.

10 The ferritic stainless steel in accordance with the invention was also tested for the determination of values in sheet forming properties which are very important in many thin sheet applications. For those sheet forming properties there were done sheet forming simulation test for a uniform elongation and r-value. The uniform elongation correlates with the sheet stretching capabilities, and the r-value correlates with the deep drawing capabilities. Uniform elongation and r-values were measured with tensile test. The results of the tests are presented in the table 4:

Alloy	uniform elongation, %	r-value
A	18,9	1,82
B	19,0	1,75
C	18,5	1,75
D	18,6	2,05
E	18,4	2,09
F	18,6	1,91
H	19,1	2,44
Ref. EN 1.4301	>40	1,1

Table 4: Sheet forming properties

20

The results in the table 4 show, that the alloy H has the longest uniform elongation and the highest r-value, when these alloys are compared with the other test alloys. Even though the reference material EN 1.4301 has a better uniform elongation than the tested alloys, EN 1.4301 has a much weaker r-value than all the tested alloys.

25

When using niobium, titanium and vanadium in the stabilization of the interstitial elements carbon and nitrogen in the ferritic stainless steel of the invention, the compounds which are generated during the stabilization, are such as titanium carbide (TiC), titanium nitride (TiN), niobium carbide (NbC), niobium nitride  
 5 (NbN), vanadium carbide (VC) and vanadium nitride (VN). In this stabilization it is used a simple formula to evaluate the amount and the effect of stabilization as well as the role of the different stabilization elements.

The connection between the stabilization elements titanium, niobium and  
 10 vanadium is defined by a formula (1) for a stabilization equivalent ( $Ti_{eq}$ ) where the content of each element is in weight %:

$$Ti_{eq} = Ti + 0,515 \cdot Nb + 0,940 \cdot V \quad (1).$$

15 Respectively, the connection between of the interstitial elements carbon and nitrogen is defined by a formula (2) for an interstitial equivalent ( $C_{eq}$ ) where the contents of carbon and nitrogen are in weight %:

$$C_{eq} = C + 0,858 \cdot N \quad (2).$$

20

The ratio  $Ti_{eq}/C_{eq}$  is used as one factor for determining the disposition for sensitization, and the ratio  $Ti_{eq}/C_{eq}$  is higher or equal to 6 and the ratio  $(Ti+Nb)/(C+N)$  higher or equal to 8 for the ferritic stainless steel of the invention in order to avoid the sensitization.

25

The values for the ratio  $Ti_{eq}/C_{eq}$  for the alloys A to H as well as for the ratio  $(Ti+Nb)/(C+N)$  are calculated in the table 5.

30

Alloy	$Ti_{eq}/C_{eq}$	$(Ti+Nb)/(C+N)$
A	12,8	14,5
B	8,4	10,0
C	10,3	10,7
D	7,0	10,0
E	6,0	3,6
F	6,8	3,8
G	4,9	2,7
H	8,8	9,3

Table 5 Values for  $Ti_{eq}/C_{eq}$  and  $(Ti+Nb)/(C+N)$

The values of the table 5 show that the alloy H, the triple stabilized with niobium, titanium and vanadium in accordance with the invention, has 5 favourable values for both the ratios  $Ti_{eq}/C_{eq}$  and  $(Ti+Nb)/(C+N)$ . Instead, for instance the alloy G, which was sensitized according to the table 2, has unfavourable values for both the ratios  $Ti_{eq}/C_{eq}$  and  $(Ti+Nb)/(C+N)$ .

## CLAIMS

1. Ferritic stainless steel having excellent corrosion and sheet forming properties, **characterized** in that the steel consists of in weight percentages
- 5 0,001 - 0,035 % carbon, 0,05 - 1,0 % silicon, 0,1 - 0,8 % manganese, 20 - 24 % chromium, 0,05 - 0,8 % nickel, less than 0,2 % molybdenum, 0,2 - 0,8 % copper, 0,001 - 0,05 % nitrogen, 0,05 - 0,8 % titanium, 0,05 - 0,8 % niobium, 0,03 - 0,5 % vanadium, less than 0,04 % aluminium, and the sum C+N less than 0,06 %, the remainder being iron and inevitable impurities in such
- 10 conditions, that the ratio  
(Ti+Nb)/(C+N) is higher or equal to 8,  
and the ratio  
 $Ti_{eq}/C_{eq} = (Ti + 0,515*Nb + 0,940*V)/(C+0,858*N)$  is higher or equal to 6.
- 15 2. Ferritic stainless according to the claim 1, **characterized** in that the carbon content is less than 0,03 weight %, but at least 0,001 %.
3. Ferritic stainless according to the claim 1 or 2, **characterized** in that the silicon content is 0,05 - 0,7 weight %.
- 20 4. Ferritic stainless steel, according to any of the preceding claims, **characterized** in that the manganese content is less than 0,65 weight %, preferably 0,10 – 0,65 %.
- 25 5. Ferritic stainless steel, according to any of the preceding claims, **characterized** in that the nickel content is less than 0,5 weight %, but at least 0,05 %.
- 30 6. Ferritic stainless steel, according to any of the preceding claims, **characterized** in that the copper content is less than 0,5 weight %, but at least 0,2%.

7. Ferritic stainless steel, according to any of the preceding claims, **characterized** in that the nitrogen content is less than 0,03 weight %, but at least 0,001 %.

5

8. Ferritic stainless steel, according to any of the preceding claims, **characterized** in that the titanium content is 0,05 – 0,40 weight %.

9. Ferritic stainless steel, according to any of the preceding claims,  
10 **characterized** in that the niobium content is 0,05 – 0,40 weight %.

10. Ferritic stainless steel, according to any of the preceding claims, **characterized** in that the vanadium content is 0,03 – 0,20 weight %.

15 11. Ferritic stainless steel, according to any of the preceding claims, **characterized** in that the chromium content is 20 – 21,5 weight %.

## PATENTTIVAATIMUKSET

1. Ferriittinen ruostumaton teräs, jolla on erinomaiset korroosiokestävyys- ja levymuokkausominaisuudet, **tunnettu** siitä, että teräs koostuu paino-%:na
- 5 0,001 - 0,035 % hiiltä, 0,05 - 1,0 % piitä, 0,1 - 0,8 % mangaania, 20 – 24 % kromia, 0,05 - 0,8 % nikkeliä, vähemmän kuin 0,2 % molybdeeniä, 0,2 - 0,8 % kuparia, 0,001 - 0,05 % typpeä, 0,05 - 0,8 % titaania, 0,05 - 0,8 niobia, 0,03 - 0,5 % vanadiinia, vähemmän kuin 0,04 % alumiinia, ja summa C+N vähemmän
- 10 sellaisin ehdoin, että suhde  
 $(Ti+Nb)/(C+N)$  on korkeampi tai yhtä kuin 8,  
 ja suhde  
 $Ti_{eq}/C_{eq} = (Ti + 0,515*Nb + 0,940*V)/(C+0,858*N)$  on korkeampi tai yhtä kuin 6.
- 15 2. Patenttivaatimuksen 1 mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että hiilipitoisuus on vähemmän kuin 0,03 paino-%, mutta ainakin 0,001 %.
3. Patenttivaatimuksen 1 mukainen ferriittinen ruostumaton teräs, **tunnettu**
- 20 siitä, että piipitoisuus on 0,05 – 0,7 paino-%.
4. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että mangaanipitoisuus on vähemmän kuin 0,65 paino-% mieluummin 0,10 – 0,65 %.
- 25 5. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että nikkelpitoisuus on vähemmän kuin 0,5 paino-%, mutta ainakin 0,05 %.



6. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että kuparipitoisuus on vähemmän kuin 0,5 paino-%, mutta ainakin 0,2 %.
- 5 7. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että typpipitoisuus on vähemmän kuin 0,03 paino-%, mutta ainakin 0,001 %.
8. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton
- 10 teräs, **tunnettu** siitä, että titaanipitoisuus on 0,05 - 0,40 paino-%.
9. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että niobipitoisuus on 0,05 - 0,40 paino-%.
- 15 10. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että vanadiinipitoisuus on 0,03 - 0,20 paino-%.
11. Jonkin edellä olevan patenttivaatimuksen mukainen ferriittinen ruostumaton teräs, **tunnettu** siitä, että kromipitoisuus on 20 – 21,5 paino-%.

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