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## (54) FREE-CUTTING STAINLESS STEEL AND PROCESS FOR PRODUCING THE SAME

NICHTROSTENDER AUTOMATENSTAHL UND HERSTELLUNGSVERFAHREN DAFÜR

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- **SAKURATANI K. ET AL.: 'Ko-Cr Ferrite-kei Tainetsu Haganechu ni Seisei suru BN-kei Kaizaibutsu no Ryukei Bunpu' CURRENT ADVANCES IN MATERIALS AND PROCESSES vol. 17, no. 4, 01 September 2004, page 923, XP003021005**

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## Description

### Technical Field

**[0001]** The present invention relates to free-cutting stainless steel produced by adding a free-cutting additive.

### Background Art

**[0002]** Free-cutting steels by adding free-cutting additives such as S sulfur), Pb (lead) and/or Ca (calcium) for the purpose to improve the machinability of steel are known. As Pb can give rise to earth environmental problems, therefore, the use thereof is being suppressed. S is known as an element that affects the corrosion resistance of steels, so a very little amount of addition of S is not preferable for corrosion resistant steels such as stainless steels. S is only used ignoring improved corrosion resistance where machinability is more significant than corrosion resistance. It is very difficult to add the chemically active elements that have both low melting point and high vapor pressure at the melting point, such as Ca, into molten steel. It is hard to control the content, dispersion and precipitation of Ca containing double oxide additives for improving machinability.

**[0003]** On the other hand, austenitic stainless steels are known as unmachinable steels as these steels have the surface hardening property at cutting. For the purpose to improve machinability, the stainless steels added S itself or S combined with Se (selenium) or Te (tellurium) as free-cutting additives is marketed. As for Japanese Industrial Standards, two kinds of stainless steel, SUS303 and SUS303Se, are standardized as S, Se-added austenitic free-cutting stainless steels. Additionally, SUS430F is standardized as S- or S+Pb-added ferritic free-cutting stainless steels and SUS410F2, 416, 420F, 420F2 and 440F are standardized as martensitic free-cutting stainless steels. Recently, stainless steel to which titanium carbosulfide is added to improve the machinability has been manufactured.

**[0004]** Even a very small addition of chalcogen such as S or its compounds makes the corrosion resistance inferior, which is the most advantageous property of austenitic stainless steels. Therefore, these free-cutting stainless steel are only used under corrosiveless atmospheres or are used for the products for not requiring corrosion resistance. For these reasons, no free-cutting stainless steel that satisfies both excellent machinability and that of corrosion resistance is currently available.

**[0005]** Furthermore, in the case of sulfur free-cutting stainless steel that is currently being manufactured, the added S forms MnS (manganese sulfide), MnS that improves the machinability is plastically deformed easily so that it is elongated to needle shape in accordance with the rolling direction while the hot working of steel rods or sheets. A large amount of needle shape MnS elongated to the rolling direction shows anisotropy of mechanical property of steel and such sulfur free-cutting stainless steels have the defects of manufactured products.

JP-2003-129 191 A discloses a free-cutting stainless steel containing hexagonal boron nitride (R-BN) particles.

### Disclosure of the Invention

### Problem to be Solved by the Invention

**[0006]** In view of the above-mentioned background art, the problem to be solved by the present invention is to provide free-cutting stainless steel that can satisfy not only of excellent machinability but also environment-friendliness, corrosion resistance and excellent mechanical property, and a method of manufacturing free-cutting stainless steel.

### Means for Solving the Problem

**[0007]** The inventors of the present invention found that the above problem is solved by utilizing the properties of h-BN (hexagonal boron nitride) particles having excellent solid-lubricating property and chemically stable characteristic for either acid and alkali.

**[0008]** According to Invention 1, there is provided free-cutting stainless steel that is characterized in that the free-cutting additive is spherical h-BN (hexagonal boron nitride) particles dispersed and precipitated homogeneously in the stainless steel.

**[0009]** According to Invention 2, the free-cutting stainless steel according to Invention 1 is characterized in that the particle diameter of the h-BN particles is 0.2 to 3 $\mu$m.

**[0010]** According to Invention 3, there is provided a method of manufacturing free-cutting stainless steel produced by adding a free-cutting additive, characterized in that free-cutting stainless steel where h-BN particles are precipitated is heated to dissolve the h-BN particles into steel matrix, quenched and subsequently tempered to disperse and precipitate h-BN particles homogeneously again as free-cutting additive.

**[0011]** According to Invention 4, there is provided a method of manufacturing free-cutting stainless steel produced by adding a free-cutting additive, characterized in that free-cutting stainless steel where h-BN particles are precipitated is heated to dissolve the h-BN particles into steel matrix and subsequently subjected to slow cooling to disperse and precipitate h-BN particles homogeneously again as free-cutting additive.

**[0012]** According to Invention 5, the method of manufacturing free-cutting stainless steel according to Invention 3 or 4 is characterized in that the addition of B (boron) is not less than $3 \times 10^{-3}$ mass% and less than $2 \times 10^{-1}$ mass% and the content of N (nitrogen) is not less than $1.5 \times 10^{-2}$ mass%, while the relation between the content of B and that of N satisfies the formula 1 shown below:

(formula 1)

$$N \geq \frac{14}{10.8} B \qquad (1)$$

**[0013]** According to Invention 6, the method of manufacturing free-cutting stainless steel according to Invention 5 is characterized in that the relation between the content of B and that of N satisfies the formula 2 below:

(formula 2)

$$N \geq 2B \qquad (2)$$

**[0014]** According to Invention 7, the method of manufacturing free-cutting stainless steel according to Invention 5 or 6 is characterized in that the addition of B (boron) is less than $1 \times 10^{-1}$ mass%.

**[0015]** According to Invention 8, the method of manufacturing free-cutting stainless steel according to any of Inventions 3 through 7 is characterized in that B is added by adding ferroboron or metallic boron and N is added by atmospheric (argon + nitrogen) or by reduced atmospheric nitrogen, to molten stainless steel.

**[0016]** According to Invention 9, the method of manufacturing free-cutting stainless steel according to any of Inventions 3 through 7 is characterized in that B is added by adding ferroboron or metallic boron and N is added by adding nitrogen-containing compounds, to molten stainless steel.

## Advantages of the Invention

**[0017]** The present invention provides free-cutting stainless steel and its manufacturing method by adding h-BN particles which have acid and alkali resistant and excellent solid-lubricating properties by dispersing and precipitating h-BN particles homogeneously into steel matrix without deterioration of corrosion resistance and mechanical anisotropy.

**[0018]** Invention 1 satisfies not only the excellent machinability but also environment-friendliness and corrosion resistance.

**[0019]** As h-BN particles have higher heat resistant property compared to lead, the stainless steel which has both free-cutting and heat resistant properties can be obtained.

**[0020]** Furthermore, h-BN particles are sherical, thereby enables not to give mechanical anisotropy property to this steel.

**[0021]** These advantages are performed by utilizing h-BN particles which have solid-lubricant property, therefore, stainless steel with excellent machinability and environment-friendliness are manufactured without deterioration of corrosion resistance and mechanical anisotropy which are shown in available sulfur free-cutting stainless steel.

**[0022]** Although another way to manufacture free-cutting stainless steel by powder metallurgy process by dispersing h-BN particles is to be thought, there is the worst disadvantage of this process that a large number of voids remain in steel and large size structural material can never manufacture.

**[0023]** On the contrary, Inventions 3 and 4 make it possible to manufacture free-cutting stainless steel without using powder metallurgy process and manufacture large size structural material not having pores remain.

## Brief Description of the Drawings

**[0024]**

FIG. 1 is a picture of fractured surface of a sample taken through SEM, showing the precipitation and dispersion behavior of particles in the sample and identifying the kind of particles by means of EDS analysis.

FIG. 2 is a graph illustrating the relationship between the cutting speed and the combined cutting force of each of the samples of varying the addition of B.

FIG. 3 is a graph illustrating the results of a corrosion test on each of the samples of varying the addition of B conducted by the method of sulfuric acid test (JIS G 0591).

FIG. 4 is a picture of a sample taken through SEM (scanning electron microscope), showing the dispersion behavior of precipitated particles in the sample held at 1,250°C for 1/2 hours and subsequently cooled to the room temperature at a cooling rate of 100°C/hour.

## Best Mode for Carrying Out the Invention.

**[0025]** The present invention, which is characterized as described above, will now be described below by way of embodiments.

**[0026]** A manufacturing method according to the present invention employs a conventional melting furnace that can control the melting atmosphere for conventional stainless steel making. In the melting process, ferroboron or metallic boron is used as B source material. The use of ferroboron for the source of melting charge is technically advantageous for its low melting point as source material to be molten and also economic because the cost per unit weight of B is lower than metallic B.

**[0027]** Standard B concentration in stainless steel is not less than $3 \times 10^{-3}$ mass% and less than $2 \times 10^{-1}$ mass%, preferably not less than 0.003 mass% and less than 0.1 mass%, more preferably not less than 0.003 mass% and less than 0.05 mass%. As N source material, N in the melting atmosphere may be absorbed or N-containing compounds such as chromium nitride may be added.

**[0028]** Note that, when N is adsorbed from the melting atmosphere, the N concentration in the molten stainless steel at 1,600°C in accordance with Sievert's low is proportional to the 1/2-th power of the N partial pressure in the atmosphere and is about 0.25 mass% in N atmosphere at the atmospheric pressure for SUS304 that is a typical austenitic stainless steel.

**[0029]** Standard N concentration in stainless steel is not less than $1.5 \times 10^{-2}$ mass%, preferably not less than $5 \times 10^{-2}$ mass%. When the concentration ratio of N to B (N/B) in stainless steel is low, solid-soluted B in stainless steel increases and precipitated h-BN particles that are effective for machinability decrease. Therefore, the value of N/B is preferably as large as possible.

**[0030]** The above relationship can be expressed by formula 1 shown below:

(formula 1)

$$N \geq \frac{14}{10.8} B \qquad (1)$$

and preferably expressed by formula 2 shown below:
(formula 2)

$$N \geq 2B \qquad (2)$$

**[0031]** Molten stainless steel manufactured in a process as described above so as to contain B and N is poured into molds to become ingots or is made into billets or slabs in the case of a continuous molding facility. The cast products are then heated to the forging temperature in an ordinary soaking furnace and then subjected to an ordinary forging/rolling process so as to produce rods, pipes and/or sheets. The forging temperature is 1,200 to 1,250°C for ordinary stainless steel.

**[0032]** While 0.2 to 3 μm h-BN particles are preferable to be precipitated homogeneously in the stainless steel products, h-BN particles coarsely grown to about 20 to 30 μm can be dispersed irregularly in part of the product depending on the cooling rate after the forging/rolling process in the case of stainless steel rods, pipes and/or sheets. It is desirable to execute a heat treatment process as described below to avoid such a problem.

**[0033]** The h-BN particles precipitated in stainless steel are decomposed to B and N in the stainless steel in a relatively short time (e.g., from 0.5 to 1 hour at 1,250°C) and dissolved in the matrix of stainless steel at temperature not lower than 1,250°C.

**[0034]** Such a process is not feasible when stainless steel is molted. Therefore, the process needs to be executed at the temperature lower than the melting temperature of the stainless steel.

**[0035]** The above-described condition can be obtained by quenching the stainless steel that contains supersaturated B and N. When the stainless steel containing supersaturated B and N, is tempered at 800°C to 1,150°C, h-BN is precipitated again. When the stainless steel is tempered at or around 800°C, very fine h-BN particles are precipitated and dispersed homogeneously throughout the stainless steel product because the difference between the equilibrium solubility of B and N at this temperature and the supersaturated solubility thereof is large, the diffusion rate of B and N is low and the diffusion distance of these elements is so short, the precipitation of h-BN nuclei takes place prior to the growth of h-BN nuclei for these two reasons. Contrarily, when the stainless steel is tempered at or around 1,150°C, h-BN particles grow considerably coarse are precipitated because the growth of h-BN nuclei takes place prior to the precipitation of h-BN nuclei conversely relative to the tempering at or around 800°C.

**[0036]** Therefore, selection of tempering temperature is important for precipitation of h-BN particles with a preferable particle diameter and a preferable dispersion state. As a result of a trial experiment, it was found that the range of tempering temperature that provides a preferable particle diameter and a preferable dispersion state is from 950 to 1,100°C, preferably from 1,000 to 1,050°C. This tempering heat treatment temperature is very advantageous because the tempering heat treatment temperature is within the temperature range of heat treatment for solid solution that takes place after the hot working process and hence the solution heat treatment of stainless steel after the hot working process can be replaced by a heat treatment process for precipitating h-BN particles.

**[0037]** Additionally, as for the tempering holding time, it can be very short when the temperature is high enough so the diffusion rates of B and N are high. The range of the tempering holding time is from 0.5 to 3 hours, preferably from 1 to 2 hours. The steel material is then quenched to stop any further growth of h-BN particles.

**[0038]** On the other hand, dissolved h-BN by heating re-precipitate by slow cooling rate to the amount of its corresponding saturated concentration level, as solubility limit of the both B and N that are dissolved in steel matrix decreases. h-BN can be re-precipitated for Inventions 1 and 2 by this method. The cooling rate necessary for re-precipitating h-BN particles is between $1 \times 10^1$ and $1 \times 10^4$ °C/hour, preferably between $1 \times 10^2$ and $1 \times 10^3$ °C/hour.

**(Example 1)**

**[0039]** A round rod of commercially available austenitic stainless steel (SUS304) (weight: 18 kg) was melted as a molten source material by using a vacuum induction melting furnace. The composition (mass%) of the source material was 0.07 %C, 0.33 %Si, 1.15 %Mn, 0.036 %P, 0.022 %S, 8.07 %Ni and 18.03 %Cr. During the melting process, N was introduced into the vacuum induction melting furnace to 0.07 MPa to adjust the N concentration. After the melting process, predetermined amount of commercially available ferroboron (19.2 mass %B) as listed in Table 1 was added into the molten steel to adjust the B concentration and the molten steel was held in a little reduced pressure N atmosphere for 1/3 hours. Then, themolten steel was cast at 1,600°C to produce an ingot.

**[0040]** The ingot was cut to upper and lower halves, one of which was hot-worked to produce a rod and the other was hot-worked to sheet. The hot-working temperature was 1,250°C for both of them. The rod was forged to 55 mm diameter, and the sheet was forged to a rectangular bar of 50 mm × 90 mm and then rolled to 15 mm thickness and 100 mm width by a hot rolling mill.

**[0041]** Both the rod and the sheet that had been hot-worked were then held to 1,250°C for 0.5 hours and water-cooled with water for the purpose to dissolve h-BN. Subsequently, they were held to 1, 050°C for 1 hour and water-cooled for the purpose to precipitate h-BN. Table 1 shows the chemical analysis of B and N (unit: mass%) in the stainless steel obtained after the above processes.

Table 1

| Sample No. | Added ferroboron g | Total B | Soluble B | N |
|---|---|---|---|---|
| A31 | 0 | 0.000 | 0.000 | 0.20 |
| A32 | 9.4 | 0.007 | 0.002 | 0.20 |
| A33 | 18.8 | 0.016 | 0.003 | 0.18 |
| Chemical analysis of B and N in samples (unit: mass%) | | | | |

**[0042]** As shown in Table 1, about 80% of the added B remained after the processes. The soluble B was not more than 0.005% and hence the added B mostly formed h-BN.

**[0043]** Since the atmosphere of N maintained at the same pressure level, N was added to a constant quantity ratio.

**[0044]** FIG. 1 is picture of a fracture surface of a sample taken through SEM (scanning electron microscope), showing the precipitating behavior of dispersion of particles in the sample after the tempering process. The sample of the picture is Sample A33 listed in Table 1. The rod of 3 mm diameter was cut out from the sample and then the rod sample was bent and fractured. The fracture surface of the rod sample (parallel section for the rolling direction) was observed through an SEM.

**[0045]** Additionally, the observed precipitates were analyzed EDS (energy dispersive X-ray spectroscopic analyzer) annexed to the SEM to identify the type of the precipitates. Ten of h-BN particles at the size of 1 to 3 μm were dispersed throughout at the 1,000 magnification sight. As for MnS, that is known as free-cutting element and exist in sulfur free-cutting stainless steel such as commercially available SUS303, six localized MnS particles were observed at the center part of this figure. Two MnS particles about 10 μm were observed coexisting with a BN particle. It seems that needle shape MnS particles at the length at about 20 μm elongated at hot working are destroyed into three pieces. Since MnS crystallizes during solidification process of ingot, MnS particles are apt to be segregate and to be elongated toward the rolling direction easily, the steels containing MnS have the anisotropy characteristics. On the contrary, as h-BN precipitates from supersaturated state of B and N, h-BN particles precipitate and comparatively distribute homogeneously, therefore, the feature of anisotropy of steel cannot be observed.

**[0046]** FIG. 2 shows the results of machinability test cutting by lathe conducted on round rod. This figure shows the relation between cutting speed and combined cutting force of the sample of different boron contents. The conditions of this test were depth of cut 1. 0 mm, feed of tool 0.1 mm/rev and tool material M30 without chip breaker.

**[0047]** Comparing the case of precipitating BN with congruent distribution and without BN, combined cutting force are reduced to 20 to 25% at high cutting speed, and it was shown that the machinability of BN stainless steel was improved, unless at the low cutting speed combined cutting forces were almost the same. This means that easy cutting by lathe at high cutting speed makes the improvement of productivity and energy saving.

**[0048]** FIG. 3 shows the results of corrosion resistance test for B bearing stainless steel sheets. FIG. 3 shows the results of a corrosion test of the samples of different B contents by sulfuric acid solution test standardized by JIS G 0591. The condition of this test is continuous immersion into boiling 5% $H_2SO_4$ solution continuously for 6 hours. The corrosion ratio of the samples is indicated as the ratio of weight loss by corrosion divided the samples obtained by dividing the quantity reduced by the initial surface area of the sample. There is scarcely increase of corrosion rate and addition of B has almost no influence on the corrosion.

**[0049]** The present invention is not limited to the above-described examples and any of the details of the samples may be modified in various different ways.

**[0050]** N may be added not only nitrogen gas but also nitrogen containing compounds selected from metal nitrides such as CrN (chromium nitride) and $Ni_3N$ (nickel nitride), inorganic nitrogen compounds such as $NH_3$ (ammonia), $(NH_4)NO_3$ (ammonium nitrate) and $Ca_3N_2$ (calcium nitride) and organic nitrogen compounds such as $CO(NH_2)_2$ (urea).

**(Example 2)**

**[0051]** A round rod of commercially available austenitic stainless steel (SUS304) (weight: 2 kg) was melted by using a cold crucible levitation melting furnace. The composition (mass%) of the source material was 0.06 %C, 0.28 %Si, 1.33 %Mn, 0.035 %P, 0.025 %S, 8.05 %Ni and 18.39 %Cr. N was introduced into the levitation melting furnace to 0.075 MPa to adjust the N concentration. After the melting process at 1,600°c, 0.73 g of commercially available ferroboton (19.2 mass%B) was added to the molten steel and the molten steel was held in a little reduced pressure N atmosphere for 1/6 hours. Then, the molten steel was solidified in the furnace to produce an ingot.

**[0052]** The ingot was heated to 1,200°C and hot worked to 14.3 mm square rod at that temperature. The rod was held to 1,250°C for 1/2 hours ana cooled from this temperature at cooling rate of 100°C/hour for the purpose of dissolving h-BN into steel matrix and re-precipitating h-BN. Table 2 shows the content of B and N (unit: mass%) in the stainless steel and made after above heat treatment processes.

Table 2

| | total B% | sol. B% | N% |
|---|---|---|---|
| Ingot | 0.0070 | 0.0058 | 022 |
| After heat treatment processes | 0.0049 | 0.0006 | 022 |

**[0053]** The difference between total B% and sol. B% in Table 2 corresponds to the amount of h-BN in steel. As the amount of h-BN remarkably increased after the heat treatment processes, this shows that h-BN was re-precipitated by this heat treatment processes.

**[0054]** FIG. 4 is an image of SEM (scanning electron microscope), showing the behavior of precipitation and dispersion of particles in the sample held to 1,250°C for 1/2 hours and subsequently cooled to the room temperature at a cooling rate of 100°C/hour. Comparing to Example 1, it was observed that spherical h-BN particles about 3 μm particle diameter had been dispersed and re-precipitated throughout the sample.

## Industrial Applicability

**[0055]** As described above in detail, the present invention can provide stainless steel which improve machinability without being inferior to corrosion resistance and environmental problems. Such stainless steels can be advantageous for applications in various fields of industry.

## Claims

1. Free-cutting stainless steel produced by adding a free-cutting additive, **characterized in that** the free-cutting additive thereof is spherical h-BN (hexagonal boron nitride) particles dispersed and precipitated homogeneously in the stainless steel.

2. The free-cutting stainless steel according to claim 1, **characterized in that** the particle diameter of the h-BN particles is 0.2 to 3 μm.

3. A method of manufacturing free-cutting stainless steel produced by adding a free-cutting additive, **characterized in that** free-cutting stainless steel where h-BN particles are precipitated is heated to dissolve the h-BN particles into steel matrix, quenched and subsequently tempered to disperse and precipitate spherical h-BN particles homogeneously again as free-cutting additive.

4. A method of manufacturing free-cutting stainless steel produced by adding a free-cutting additive, **characterized in that** free-cutting stainless steel where h-BN particles are precipitated is heated to dissolve the h-BN particles into steel matrix and subsequently subjected to slow cooling to disperse and precipitate spherical h-BN particles homogeneously again as free-cutting additive.

5. The method of manufacturing free-cutting stainless steel according to claim 3 or 4, **characterized in that** the addition of B (boron) is not less than $3 \times 10^{-3}$ mass% and less than $2 \times 10^{-1}$ mass% and the content of N (nitrogen) is not less than $1.5 \times 10^{-2}$ mass%, while the relation between the content of B and that of N satisfies the formula 1 shown below:

   (formula 1)

$$N \geq \frac{14}{10.8} B \qquad (1)$$

6. The method of manufacturing free-cutting stainless steel according to claim 5, **characterized in that** the relation between the content of B and that of N satisfies the formula 2 below:

   (formula 2)

$$N \geq 2B \qquad (2)$$

7. The method of manufacturing free-cutting stainless steel according to claim 5, **characterized in that** the addition of B (boron) is less than $1 \times 10^{-1}$ mass%.

8. The method of manufacturing free-cutting stainless steel according to claim 3 or 4, **characterized in that** B is added by adding ferroboron or metallic boron and N is added by atmospheric (argon + nitrogen) or by reduced atmospheric nitrogen, to molten stainless steel.

9. The method of manufacturing free-cutting stainless steel according to claim 3 or 4, **characterized in that** B is added

by adding ferroboron or metallic boron and N is added by adding nitrogen-containing compounds, to molten stainless steel.

## Patentansprüche

1. Nichtrostender Automatenstahl hergestellt durch Zugabe eines Automaten-Zusatzes, **dadurch gekennzeichnet, dass** der Automaten-Zusatz aus sphärischen h-BN (hexagonalen Bornitrid-) Teilchen besteht, die in dem nichtrostenden Stahl dispergiert und homogen ausgefällt sind.

2. Nichtrostender Automatenstahl nach Anspruch 1, **dadurch gekennzeichnet, dass** der Teilchendurchmesser der h-BN-Teilchen 0,2 bis 3 $\mu$m beträgt.

3. Verfahren zum Herstellen von nichtrostendem Automatenstahl, hergestellt durch die Zugabe eines Automaten-Zusatzes, **dadurch gekennzeichnet, dass** der nichtrostende Automatenstahl, in dem h-BN-Teilchen ausgefällt sind, zum Auflösen der h-BN-Teilchen in der Stahlmatrix erwärmt, abgeschreckt und anschließend getempert wird, um die sphärischen h-BN-Teilchen erneut als Automaten-Zusatz zu dispergieren und homogen auszufällen.

4. Verfahren zum Herstellen von nichtrostendem Automatenstahl, hergestellt durch Zugabe eines Automaten-Zusatzes, **dadurch gekennzeichnet, dass** der nichtrostende Automatenstahl, in dem h-BN-Teilchen ausgefällt sind, zum Auflösen der h-BN-Teilchen in der Stahlmatrix erwärmt und anschließend einer langsamen Kühlung unterworfen wird, um die sphärischen h-BN-Teilchen erneut als Automaten-Zusatz zu dispergieren und homogen auszufällen.

5. Verfahren zum Herstellen von nichtrostendem Automatenstahl nach Anspruch 3 oder 4, **dadurch gekennzeichnet, dass** die Zugabe von B (Bor) mindestens 3 x $10^{-3}$ Gewichts-% und weniger als 2 x $10^{-1}$ Gewichts-% und der Anteil an N (Stickstoff) mindestens 1,5 x $10^{-2}$ Gewichts-% beträgt, wobei die Beziehung zwischen dem Anteil an B und dem Anteil an N die nachstehende Formel 1 erfüllt:

$$N \geq \frac{14}{10.8} B \qquad (1)$$

6. Verfahren zum Herstellen von nichtrostendem Automatenstahl nach Anspruch 5, **dadurch gekennzeichnet, dass** die Beziehung zwischen dem Anteil an B und dem Anteil an N die nachstehende Formel 2 erfüllt:

$$N \geq 2B \qquad (2)$$

7. Verfahren zum Herstellen von nichtrostendem Automatenstahl nach Anspruch 5, **dadurch gekennzeichnet, dass** die Zugabe von B (Bor) weniger als 1 x $10^{-1}$ Gewichts-% beträgt.

8. Verfahren zum Herstellen von nichtrostendem Automatenstahl nach Anspruch 3 oder 4, **dadurch gekennzeichnet, dass** B durch Zugabe von Ferrobor oder metallischem Bor und N durch Umgebungsluft (Argon + Stickstoff) oder durch reduzierten atmosphärischen Stickstoff zum geschmolzenen nichtrostenden Stahl hinzugefügt wird.

9. Verfahren zum Herstellen von nichtrostendem Automatenstahl nach Anspruch 3 oder 4, **dadurch gekennzeichnet, dass** B durch Zugabe von Ferrobor oder metallischem Bor und N durch Zugabe von Stickstoff enthaltenden Verbindungen zum geschmolzenen, nichtrostenden Stahl hinzugefügt wird.

## Revendications

1. Acier de décolletage inoxydable produit par ajout d'un additif pour décolletage, **caractérisé en ce que** l'additif pour décolletage est constitué de particules sphériques de h-BN (nitrure de bore hexagonal) dispersées et précipitées de manière homogène dans l'acier inoxydable.

**2.** Acier de décolletage inoxydable selon la revendication 1, **caractérisé en ce que** le diamètre des particules de h-BN est compris entre 0,2 et 3 μm.

**3.** Procédé de fabrication d'acier de décolletage inoxydable produit par ajout d'un additif pour décolletage, **caractérisé en ce que** l'acier de décolletage inoxydable où les particules de h-BN sont précipitées est chauffé pour dissoudre les particules de h-BN dans la matrice d'acier, trempé puis revenu pour à nouveau disperser et précipiter les particules sphériques de h-BN de manière homogène en tant qu'additif pour décolletage.

**4.** Procédé de fabrication d'acier de décolletage inoxydable produit par ajout d'un additif pour décolletage, **caractérisé en ce que** l'acier de décolletage inoxydable où les particules de h-BN sont précipitées est chauffé pour dissoudre les particules de h-BN dans la matrice d'acier avant d'être soumis à un refroidissement lent pour à nouveau disperser et précipiter les particules sphériques de h-BN de manière homogène en tant qu'additif pour décolletage.

**5.** Procédé de fabrication d'acier de décolletage inoxydable selon la revendication 3 ou la revendication 4, **caractérisé en ce que** l'ajout de B (bore) n'est pas inférieur à $3 \times 10^{-3}$ % en masse, et inférieur à $2 \times 10^{-1}$ % en masse, et la teneur en N (azote) n'est pas inférieur à $1,5 \times 10^{-2}$ % en masse, la relation entre la teneur en B et celle en N satisfaisant à la formule 1 suivante :

(formule 1)

$$N \geq \frac{14}{10,8} B \qquad (1)$$

**6.** Procédé de fabrication d'acier de décolletage inoxydable selon la revendication 5, **caractérisé en ce que** la relation entre la teneur en B et celle en N satisfait à la formule 2 suivante :

(formule 2)

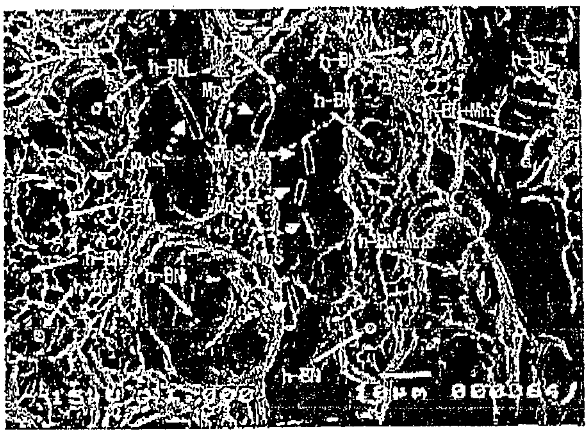
$$\mathrm{N} \geq 2\mathrm{B} \qquad (2)$$

**7.** Procédé de fabrication d'acier de décolletage inoxydable selon la revendication 5, **caractérisé en ce que** l'ajout de B (bore) est inférieur à $1 \times 10^{-1}$ % en masse.

**8.** Procédé de fabrication d'acier de décolletage inoxydable selon la revendication 3 ou la revendication 4, **caractérisé en ce que** B est ajouté par ajout de ferrobore ou de bore métallique, et N est ajouté au moyen d'azote atmosphérique (argon + azote) ou d'azote atmosphérique réduit pour fondre l'acier inoxydable.

**9.** Procédé de fabrication d'acier de décolletage inoxydable selon la revendication 3 ou la revendication 4, **caractérisé en ce que** B est ajouté par ajout de ferrobore ou de bore métallique, et N est ajouté par ajout de composés à teneur en azote pour fondre l'acier inoxydable.

F I G. 1


h-BN
h-BN
MnS
h-BN
h-BN+MnS
MnS
MnS
h-BN+MnS
h-BN
h-BN
h-BN

F I G. 2

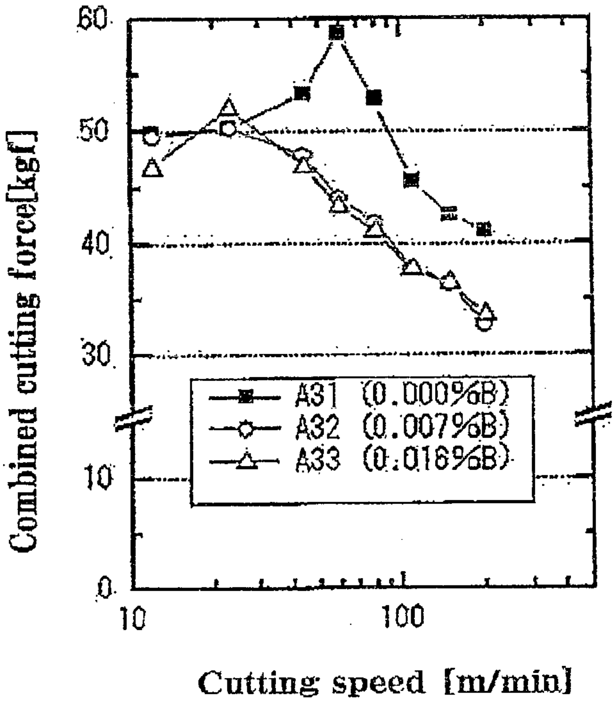

60
50
40
30
10
0
10
100
Combined cutting force[kgf]
Cutting speed [m/min]
A31 (0.000%B)
A32 (0.007%B)
A33 (0.016%B)

FIG. 3

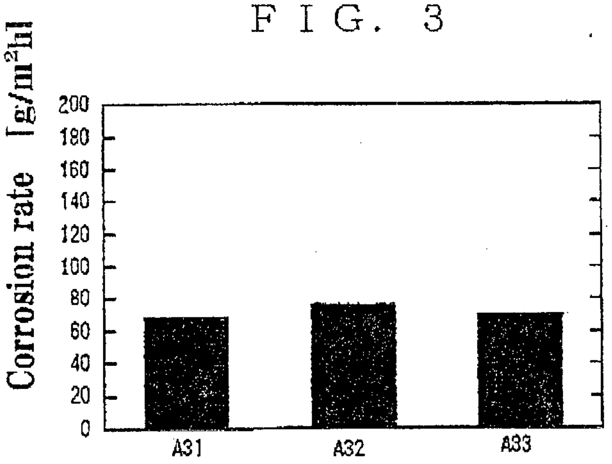
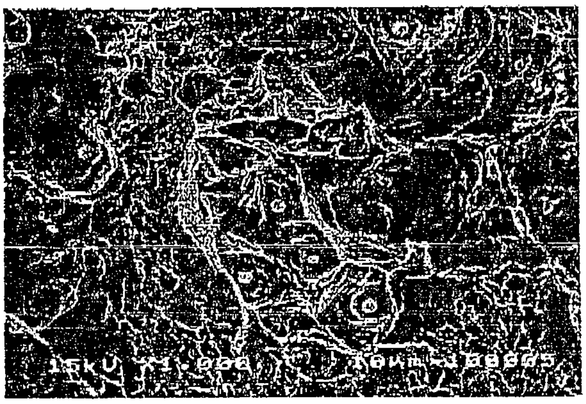

Corrosion rate [g/m²h]
200
180
160
140
120
100
80
60
40
20
0
A31
A32
A33

FIG. 4


15kU ×1,000
10μm

## REFERENCES CITED IN THE DESCRIPTION

### Patent documents cited in the description

- JP 2003129191 A **[0005]**