# United States Patent

**Kirby et al.**

[15] **3,663,208**

[45] **May 16, 1972**


[54] **CHROMIUM-NICKEL ALLOY STEEL CONTAINING COPPER**


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[22] Filed: **June 19, 1969**

[21] Appl. No.: **834,878**

[30] **Foreign Application Priority Data**

June 20, 1968 Great Britain ........................29,473/68

[52] **U.S. Cl.** ..............................**75/125,** 75/128 B, 75/128 W, 75/128 V, 75/128 N

[51] **Int. Cl.** .......................................**C22c 39/54,** C22c 39/20

[58] **Field of Search** .............75/128 V, 128 G, 128 W, 128 F, 75/128 N, 128 O, 125


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[57] **ABSTRACT**


An alloy steel for high temperature applications, such as for compressor and turbine discs in gas turbines consists essentially of: 0.02–0.25 percent carbon, 0.05–1.5 percent silicon, 0.1–1.5 percent manganese, 7.0–12.0 percent chromium, 0.2–4.0 percent nickel, 0.2–5.0 percent molybdenum, 0.10–0.60 percent vanadium, 0.05–0.70 percent niobium, up to 7.0 percent cobalt, up to 5.0 percent copper, 0.002–0.03 percent boron, at least 0.010 percent but less than 0.050 percent nitrogen, the balance, apart from incidental impurities being iron.


**12 Claims, No Drawings**

# A CHROMIUM-NICKEL ALLOY STEEL CONTAINING COPPER

## BACKGROUND OF THE INVENTION

This invention concerns improvements in or relating to alloy steels for high temperature applications, and in particular to alloy steels suitable for use in the fabrication of compressor and turbine discs in gas turbines and in similar applications.

## SUMMARY OF THE INVENTION

According to the present invention there are provided alloy steels having the following percentage weight composition:

| | |
|---|---|
| Carbon | 0.02 – 0.25 |
| Silicon | 0.05 – 1.5 |
| Manganese | 0.1 – 1.5 |
| Chromium | 7.0 – 12.0 |
| Nickel | 0.2 – 4.0 |
| Molybdenum | 0.2 – 5.0 |
| Vanadium | 0.10 – 0.60 |
| Niobium | 0.05 – 0.70 |
| Cobalt | up to 7.0 |
| Copper | up to 5.0 |
| Boron | 0.002 – 0.03 |
| Nitrogen | at least 0.010 but less than 0.050 the balance being iron and incidental impurities. |

In cases where optimum creep resistance is required combined with high proof, plain and notched tensile strength, compositions in the following ranges, in percentages by weight, are preferred:

| | |
|---|---|
| Carbon | 0.03 – 0.10 |
| Silicon | 0.10 – 0.80 |
| Manganese | 0.50 – 1.0 |
| Chromium | 9.0 – 11.0 |
| Nickel | 0.2 – 1.0 |
| Molybdenum | 1.5 – 3.0 |
| Vanadium | 0.2 – 0.5 |
| Niobium | 0.3 – 0.6 |
| Cobalt | 3.0 – 5.0 |
| Copper | 1.0 – 3.0 |
| Boron | 0.005 – 0.020 |
| Nitrogen | at least 0.010 but less than 0.050 the balance being iron and incidental impurities. |

## DESCRIPTION OF THE PREFERRED EMBODIMENTS (1)

Typical examples of such a composition are as follows:

| | Ex. 1 | Ex. 2 | Ex. 3 | Ex. 4 | Ex. 5 |
|---|---|---|---|---|---|
| C | 0.05 | **0.07** | **0.06** | **0.07** | **0.04** |
| Si | 0.45 | **0.50** | **0.45** | **0.40** | **0.20** |
| Mn | 0.80 | **0.80** | **0.85** | **0.90** | **0.75** |
| Cr | 10.5 | **9.0** | **10.7** | **10.5** | **10.1** |
| Ni | 0.5 | **0.4** | **0.4** | **0.5** | **0.3** |
| Mo | 1.5 | **1.5** | **1.6** | **1.6** | **1.5** |
| V | 0.22 | **0.20** | **0.21** | **0.21** | **0.22** |
| Nb | 0.45 | **0.60** | **0.46** | **0.46** | **0.48** |
| Co | 4.0 | **4.0** | **4.2** | **4.2** | **4.2** |
| Cu | 2.0 | **1.35** | **1.8** | **2.9** | **2.0** |
| B | 0.010 | **0.010** | **0.010** | **0.012** | **0.009** |
| $N_2$ | 0.025 | **0.020** | **0.025** | **0.012** | **0.031** |

Iron and incidental impurities: Balance

Following are the results which have been obtained as a result of the application of the standard tests to alloy steels of such composition:

| | (1) Tensile tests | | | | |
|---|---|---|---|---|---|
| | Ex. 1 | Ex. 2 | Ex. 3 | Ex. 4 | Ex. 5 |
| (a) Room temperature: | | | | | |
| 0.1% proof stress (tons/sq. in.) | 66 | 64 | 66 | 67 | 63 |
| Ultimate tensile strength (tons/sq. in.) | 77 | 74 | 78 | 77 | 76 |
| Percentage elongation | 20 | 16 | 17 | 14 | 16 |
| Reduction of area (percent) | 60 | 54 | 62 | 59 | 67 |
| N.T.S. (tons/sq. in.) | 127 | 118 | 127 | 131 | 110 |
| (b) 500° C.: | | | | | |
| 0.1% proof stress (tons/sq. in.) | 47 | 46 | 47 | 47 | 45 |
| Ultimate tensile strength (tons/sq. in.) | 60 | 58 | 60 | 60 | 58 |
| Percentage elongation | 14 | 15 | 12 | 16 | 15 |
| Reduction of area (percent) | 45 | 52 | 40 | 64 | 67 |
| | (2) Creep tests | | | | |
| T.P.S. for 32 tons/sq. in. at 550° C. in 100 hours | 0.130 | 0.170 | 0.127 | 0.150 | 0.135 |

In cases where higher proof and tensile strength are required together with a better impact strength and good creep resistance compositions falling within the following percentage weight ranges are preferred:

| | |
|---|---|
| Carbon | 0.10 – 0.20 |
| Silicon | 0.10 – 0.80 |
| Manganese | 0.50 – 1.0 |
| Chromium | 9.0 – 11.0 |
| Nickel | 1.5 – 3.5 |
| Molybdenum | 1.5 – 3.0 |
| Vanadium | 0.20 – 0.50 |
| Niobium | 0.10 – 0.40 |
| Cobalt | 2.0 – 3.5 |
| Copper | up to 2.0 |
| Boron | 0.005 – 0.020 |
| Nitrogen | at least 0.010 but less than 0.050 the balance being iron and incidental impurities. |

## DESCRIPTION OF THE PREFERRED EMBODIMENTS (2)

Typical examples of this second preferred type of composition are as follows:

| | Ex. 6 | Ex. 7 | Ex. 8 | Ex. 9 | Ex. 10 |
|---|---|---|---|---|---|
| C | 0.15 | **0.16** | **0.11** | **0.16** | **0.18** |
| Si | 0.35 | **0.18** | **0.51** | **0.49** | **0.32** |
| Mn | 0.70 | **0.63** | **0.72** | **0.66** | **0.87** |
| Cr | 10.0 | **9.6** | **11.0** | **10.1** | **10.1** |
| Ni | 2.5 | **2.4** | **2.3** | **2.3** | **2.4** |
| Mo | 2.5 | **2.8** | **2.0** | **3.0** | **3.0** |
| V | 0.35 | **0.35** | **0.31** | **0.37** | **0.38** |
| Nb | 0.25 | **0.15** | **0.11** | **0.20** | **0.23** |
| Co | 3.0 | **2.9** | **2.9** | **3.0** | **3.1** |
| Cu | 0.25 | **0.40** | **0.30** | **0.25** | **0.25** |
| B | 0.010 | **0.009** | **0.006** | **0.005** | **0.006** |
| $N_2$ | 0.020 | **0.016** | **0.023** | **0.028** | **0.024** |

Iron and incidental impurities: the balance.

| | (1) Tensile tests | | | | |
|---|---|---|---|---|---|
| | Ex. 6 | Ex. 7 | Ex. 8 | Ex. 9 | Ex. 10 |
| (a) Room temperature: | | | | | |
| 0.1% proof stress (tons/sq. in.) | 72 | 73 | 64 | 70 | 72 |
| Ultimate tensile strength (tons/sq. in.) | 95 | 90 | 83 | 96 | 98 |
| Percentage elongation | 21 | 20 | 18 | 19 | 20 |
| Percentage reduction of area | 61 | 59 | 59 | 60 | 60 |
| N.T.S. (tons/sq. in.) | 156 | 159 | 136 | 159 | 164 |
| (b) 500° C.: | | | | | |
| 0.1% proof stress (tons/sq. in.) | 50 | 49 | 43 | 50 | 51 |
| Ultimate tensile strength (tons/sq. in.) | 70 | 70 | 62 | 73 | 74 |
| Percentage elongation | 19 | 15 | 16 | 17 | 19 |
| Percentage reduction of area | 53 | 53 | 65 | 66 | 64 |
| N.T.S. (tons/sq. in.) | 118 | 117 | | | |
| | (2) Impact tests Charpy V Notch (ft./lbs.) | | | | |
| Room temperature | 20 | 16 | 10 | 12 | 21 |
| 100° C | 55 | 50 | 50 | 30 | 41 |
| 200° C | 70 | 65 | 75 | 50 | 65 |
| | (3) Creep tests | | | | |
| T.P.S. for 32 tons/sq. in. at 500° C. in 100 hours | 0.140 | 0.150 | 0.150 | 0.160 | 0.130 |

We claim:

1. An alloy consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.03 – 0.10 |
| Silicon | 0.10 – 0.80 |
| Manganese | 0.50 – 1.0 |
| Chromium | 9.0 – 11.0 |
| Nickel | 0.2 – 1.0 |
| Molybdenum | 1.5 – 3.0 |
| Vanadium | 0.2 – 0.5 |
| Niobium | 0.3 – 0.6 |
| Cobalt | 3.0 – 5.0 |
| Copper | 1.0 – 3.0 |
| Boron | 0.005 – 0.020 |
| Nitrogen | at least 0.010 but less than 0.050 |
| | Iron and incidental impurities: the balance. |

2. An alloy consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.10 – 0.20 |
| Silicon | 0.10 – 0.80 |
| Manganese | 0.50 – 1.0 |
| Chromium | 9.0 – 11.0 |
| Nickel | 1.5 – 3.5 |
| Molybdenum | 1.5 – 3.0 |
| Vanadium | 0.20 – 0.50 |
| Niobium | 0.10 – 0.40 |
| Cobalt | 2.0 – 3.5 |
| Copper | 0.25 to 2.0 |
| Boron | 0.005 – 0.020 |
| Nitrogen | at least 0.010 but less than 0.050 |
| | Iron and incidental impurities: the balance. |

3. An alloy according to claim 1 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.05 |
| Silicon | 0.45 |
| Manganese | 0.80 |
| Chromium | 10.5 |
| Nickel | 0.5 |
| Molybdenum | 1.5 |
| Vanadium | 0.22 |
| Niobium | 0.45 |
| Cobalt | 4.0 |
| Copper | 2.0 |
| Boron | 0.010 |
| Nitrogen | 0.025 |

Iron and incidental impurities: the balance.

4. An alloy according to claim 1 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.07 |
| Silicon | 0.50 |
| Manganese | 0.80 |
| Chromium | 9.0 |
| Nickel | 0.4 |
| Molybdenum | 1.5 |
| Vanadium | 0.20 |
| Niobium | 0.60 |
| Cobalt | 4.0 |
| Copper | 1.35 |
| Boron | 0.10 |
| Nitrogen | 0.20 |

Iron and incidental impurities: the balance.

5. An alloy according to claim 1 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.06 |
| Silicon | 0.45 |
| Manganese | 0.85 |
| Chromium | 10.7 |
| Nickel | 0.4 |
| Molybdenum | 1.6 |
| Vanadium | 0.21 |
| Niobium | 0.46 |
| Cobalt | 4.2 |
| Copper | 1.8 |
| Boron | 0.010 |
| Nitrogen | 0.025 |

Iron and incidental impurities: the balance.

6. An alloy according to claim 1 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.07 |
| Silicon | 0.40 |
| Manganese | 0.90 |
| Chromium | 10.5 |
| Nickel | 0.5 |
| Molybdenum | 1.6 |
| Vanadium | 0.21 |
| Niobium | 0.46 |
| Cobalt | 4.2 |
| Copper | 2.9 |
| Boron | 0.012 |
| Nitrogen | 0.012 |

Iron and incidental impurities: the balance.

7. An alloy according to claim 1 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.04 |
| Silicon | 0.20 |
| Manganese | 0.75 |
| Chromium | 10.1 |
| Nickel | 0.3 |
| Molybdenum | 1.5 |
| Vanadium | 0.22 |
| Niobium | 0.48 |
| Cobolt | 4.2 |
| Copper | 2.0 |
| Boron | 0.009 |
| Nitrogen | 0.031 |

Iron and incidental impurities: the balance.

8. An alloy according to claim 2 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.15 |
| Silicon | 0.35 |
| Manganese | 0.70 |
| Chromium | 10.0 |
| Nickel | 2.5 |
| Molybdenum | 2.5 |
| Vanadium | 0.35 |
| Niobium | 0.25 |
| Cobalt | 3.0 |
| Copper | 0.25 |
| Boron | 0.010 |
| Nitrogen | 0.020 |

Iron and incidental impurities: the balance.

9. An alloy according to claim 2 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.16 |
| Silicon | 0.18 |
| Manganese | 0.63 |
| Chromium | 9.6 |
| Nickel | 2.4 |
| Molybdenum | 2.8 |
| Vanadium | 0.35 |
| Niobium | 0.15 |
| Cobalt | 2.9 |
| Copper | 0.40 |
| Boron | 0.009 |
| Nitrogen | 0.016 |

Iron and incidental impurities: the balance.

10. An alloy according to claim 2 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.11 |
| Silicon | 0.51 |
| Manganese | 0.72 |
| Chromium | 11.0 |
| Nickel | 2.3 |
| Molybdenum | 2.0 |
| Vanadium | 0.31 |
| Niobium | 0.11 |
| Cobalt | 2.9 |
| Copper | 0.30 |
| Boron | 0.006 |
| Nitrogen | 0.023 |

Iron and incidental impurities: the balance.

11. An alloy according to claim 2 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.16 |
| Silicon | 0.49 |
| Manganese | 0.66 |
| Chromium | 10.1 |
| Nickel | 2.3 |
| Molybdenum | 3.0 |
| Vanadium | 0.37 |
| Niobium | 0.20 |
| Cobalt | 3.0 |
| Copper | 0.25 |
| Boron | 0.005 |
| Nitrogen | 0.028 |

Iron and incidental impurities: the balance.

12. An alloy according to claim 2 consisting essentially of the following elements in the stated weight percentages:

| | |
|---|---|
| Carbon | 0.18 |
| Silicon | 0.32 |
| Manganese | 0.87 |
| Chromium | 10.1 |
| Nickel | 2.4 |
| Molybdenum | 3.0 |
| Vanadium | 0.38 |
| Niobium | 0.23 |
| Cobalt | 3.1 |
| Copper | 0.25 |
| Boron | 0.006 |
| Nitrogen | 0.024 |

Iron and incidental impurities: the balance.

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