# United States Patent

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[54] **AGE-HARDENING MARTENSITIC STEELS**
**4 Claims, No Drawings**


[52] **U.S. Cl.** .......... **75/124,** 75/128 V
[51] **Int. Cl.** .......... **C22c 39/20**
[50] **Field of Search** .......... 75/128 V, 128 W, 124



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**ABSTRACT:** Age-hardening martensitic steel consisting essentially of 0.2% to 0.6% carbon, 4% to 6% chromium, 1% to 2% molybdenum, 0.2% to 0.8% vanadium, 0.25% to 3% aluminum and 2% to 7% nickel.

## AGE-HARDENING MARTENSITIC STEELS

In the past, improvements in tool steels have generally been made by increasing the carbon content and/or adding carbide forming elements to decrease the hardness and provide improved abrasion resistance. Such alloy modifications have improved tensile properties but at a sacrifice of ductility. In fact the workability of such steels has been reduced to such an extent that they are very notch sensitive and properties are difficult to obtain by testing.

Recent efforts to improve tool steels have been directed to incorporating age-hardening elements to facilitate aging reactions in normal martensitic steels. At first this approach was tried with high-speed tool steels but was unsuccessful since the maximum hardness attained was the same as that achieved with the base composition. The present invention involves a composition in which aging response is induced in a hot worked die steel. The compositions in accordance with the invention contain nickel and aluminum which result in the improved hardness and strength with no apparent loss of toughness. As will be hereinafter discussed in connection with examples of the preferred embodiments of the invention, it is possible by practicing the invention to provide an increase in room temperature hardness and an improvement in tensile strength by control of alloying addition. It has been determined that an aging reaction in addition to the martensitic hardening appears responsible for the improved properties.

The following examples illustrate practice of the invention with respect to presently preferred embodiments.

A series of steels of the compositions described in table I were prepared and plate samples thereof were subjected to the treatments described in table II.

TABLE I

| Heat No. | C | Mn | P | S | Si | Cr | Mo | V | Al | Ni |
|---|---|---|---|---|---|---|---|---|---|---|
| RV1947 | .25 | .30 | .006 | .004 | .31 | 5.01 | 1.00 | .49 | | |
| RV1619 | .25 | .38 | .004 | .003 | .30 | 5.04 | .97 | .50 | 1.04 | 4.14 |
| RV1618 | .39 | .41 | .004 | .003 | .85 | 5.06 | 1.35 | .48 | | |
| RV1620 | .38 | | | | | 5.02 | 1.30 | .50 | 1.41 | 4.04 |
| RV1948 | .41 | .32 | .003 | .003 | .32 | 4.97 | 1.30 | .50 | | 3.95 |

TABLE II

| Treatment | Hardness | .2% yield strength (p.s.i.) | Tensile strength (p.s.i.) | Percent elongation | (Long.) CVN impact (ft.-lbs.) | Shepherd fracture, g. size |
|---|---|---|---|---|---|---|
| | | RV1947 (.25 C, no Al or Ni | | | | |
| 1,800° F.-AC+2 hrs. 900° F. AC | 49 C | 187,800 | 245,000 | 16 | 14 | 5½ |
| | | RV1619 (.25 C-1 Al-4 Ni) | | | | |
| 1,800° F—AC+2 hrs. 1,000° F. AC | 54 C | 238,000 | 267,400 | 14 | | 6½ |
| 2,100° F—AC+2 hrs. 1,000° F. AC | 54.5 C | 231,300 | 264,900 | 14 | 12 | 6½ |
| | | RV1618 (.40 C Base) | | | | |
| 1,800° F.—AC+2 hrs. at 1,000° F. AC | 54 C | (1) | (1) | 4 | 7 | 8 |
| 2,000° F.—AC+2 hrs. at 1,000° F. AC | 55 C | 243,800 | 286,100 | 4 | 7 | 6 |
| 1,875° F. AC+3 tempers at 1,000° F. AC | 55 C | 234,000 | 293,500 | 7 | | 9½ |
| | | RV1620 (.40 C-1.4 Al-4 Ni) | | | | |
| 1,800° F.-AC+2 hrs. at 1,000° F. AC | 60 C | 288,600 | 335,100 | 7 | 7 | 9 |
| 2,100° F.-AC+2 hrs. at 1,000° F. AC | 60 C | 348,100 | 364,600 | 1 | 4 | 7 |
| | | RV1948 (.40 C-0.0 Al-4 Ni) | | | | |
| 1,800° F.—AC+2 hrs. at 900° F. AC | 54.5 C | 238,800 | 315,900 | 3 | 17 | |

[1] Bad sample crack in fillet.

It is apparent in the data in the aforementioned tables that the compositions without aluminum or nickel have a hardness of about 48.5 RC after air cooling from 1800° F. and holding 2 hours at 900°–1000° F. In contrast thereto Heat RV1619 which contains 1 percent aluminum and 4 percent nickel develops a maximum hardness after 2 hours at 1000° F. of about 540$R_c$. After a heat treatment at 1100° F. this hardness decreases to 48.5 and continues to decrease to a hardness of 38 $R_c$ after holding at 1200° F. The compositions without aluminum and nickel soften to about 30 $R_c$ after a treatment at 1200° F. As the data in table II indicates the yield strength of the compositions containing nickel and aluminum increases about 50,000 p.s.i. A tensile strength increase of about 22,000 p.s.i. is accompanied by a very small change in elongation. Preferred compositions in accordance with the invention contain 0.4 percent to 0.6 percent carbon, 0.4 percent to 0.6 percent vanadium, 0.5 percent to 1.5 percent aluminum and 3 percent to 5 percent nickel. Such steels may also contain up to 1 percent silicon, some manganese and other minor alloying elements.

It has been found that with heat treatments at higher temperatures the room temperature hardness decreases to about 41 $R_c$ after 2 hours at 1200° F. If only 4 percent nickel is added then the hardness decreases still further. If both aluminum and nickel are present in the steel maximum hardness approaching 60 $R_c$ can be obtained by holding two hours at 1000° F.

Mechanical property testing indicates that an improvement of 45,000 p.s.i. in yield strength and tensile strength can be obtained in steels containing nickel and aluminum. This improvement will occur if the steel is quenched from 1800° F. austenitizing temperature. The strength improvement will not be accompanied by a change in elongation or impact strength. If hardened at a higher temperature, e.g. 2100° F., rather than 1800° F., an improvement in yield strength of 100,000 p.s.i. and a tensile strength increase of 70,000 p.s.i. can be achieved. However, this improvement in strength is accompanied by a decrease in ductile properties and impact strength.

I claim:

1. An age-hardening martensitic steel consisting essentially of 0.2 percent to 0.6 percent carbon, 4 percent to 6 percent chromium, 1 percent to 2 percent molybdenum, 0.2 percent to 0.8 percent vanadium, 0.25 percent to 3 percent aluminum and 2 percent to 7 percent nickel, the balance iron and residuals.

2. A steel according to claim 1 containing 0.4 percent to 0.6 percent carbon.

3. A steel according to claim 1 containing 0.5 percent to 1.5 percent aluminum.

4. A steel according to claim 1 containing 3 percent to 5 percent nickel.