**AISI M2**

**High Speed Steel**

**Typical Analysis**

Carbon 0.85; Chromium 4.15; Molybdenum 5.00; Tungsten 6.40; Vanadium 2.00

**Advantages**

Very high red hardness

High hardening response

Outstanding wear resistance

**Applications**

AISI M2 is the most widely used high speed steel for general purpose cutting applications. At relatively high working hardness, this grade has an optimum combination of wear resistance and toughness making it desirable for noncutting applications beyond the capability of conventional die steels. AISI M2 has better retention of fine grain over a hardening range than other molybdenum high speed steels.

Typical cutting tools made from AISI M2 include drills, end mills, milling and form cutters, gear cutters, reamers, broaches and wood working tools. In the noncutting tool area, AISI M2 has been used for cold heading inserts and punches, blanking and forming punches and dies, and cold forming rolls.

**Thermal Treatment Summary**

**Critical Points**

 Heating (Ac) - 100⁰F/Hr. – begins 1526⁰F, ends 1580⁰F

 Cooling (Ar) - 50⁰F/Hr. – begins 1434⁰F, ends 1390⁰F

**Forging** – 2000 to 2100⁰F, stop at 1700⁰F, cool slowly

**Annealing** – 1550 to 1600⁰F, furnace cool, BHN 248 max

**Preheating** – 1500 to 1550⁰F, prior to hardening

**Hardening** – 2150 to 2250⁰F, oil or air quench to 150⁰F

**Tempering** – 1000 to 1075⁰F Rc 62-66

**FABRICATION**

**Forging**

AISI M2 should be heated slowly to 1400 to 1500⁰F and then more rapidly to the forging temperature of 2000 to 2100⁰F. Do not work below 1700⁰F. Protective coatings are usually unnecessary, but powdered borax is sometimes sprinkled on the steel as it reaches a red heat.

After forging, cool slowly out of drafts or contact with moisture. Burying in such insulating materials as vermiculite, sand, lime or warm, dry ashes is desirable. Always anneal after forging before hardening.

**Annealing**

For adequate protection against decarburization, AISI M2 should be annealed in a controlled atmosphere or vacuum furnace or pack annealed in a sealed container using a neutral packing compound. Heat slowly and uniformly to 1150-1600⁰F, soak thoroughly, and furnace cool at a rate not exceeding 30⁰F per hour to about 1000⁰F. The load may then be either cooled faster in the furnace or pulled and air cooled.

Resulting hardness from the above cycle should be Brinell 202-248.

AISI M2 can be cycle (isothermal) annealed to machinable hardness by heating to 1600⁰F, holding for at least 2 hours, quickly cooking to 1400⁰F, holding at least 6 hours at temperature and air cooling.

**Machinability**

The machinability of fully annealed AISI M2 is rated at 55 as compared to 1% carbon tool steel which is rated at 100.

**Grindability**

AISI M2 has a relatively low grindability index, rated at 4.5\* when hardened and tempered to full working hardness (Rc 64).

\* courtesy of Norton Company

**HEAT TREATMENT**

**Hardening**

To harden these steels, first preheat slowly to 1500-1600⁰F. Large sections may be given this preheat in 2 stages, first to 1100-1200⁰F and then on to 1500-1600⁰F. After this initial slow heating, the temperature can be increased rapidly to the hardening range of 2150-2275⁰F. Protective atmosphere, vacuum, or salt bath heat treating is necessary to prevent decarburization.

Maximum toughness results from hardening at 2150⁰F, at the expense of slightly lower hardness. The other extreme of the range, 2250-2275⁰F, gives maximum red hardness and cutting ability with somewhat decreased toughness. Lathe and similar single point cutting tools may be safely treated in the 2250-2275⁰F range for best performance. All other cuttings tools, such as drills, taps, countersinks, cutters, reamers and so on, should be hardened at 2175-2225⁰F. Punches, dies and other tools subject to shock should be hardened at 2125-2175⁰F.

Holding time in the high temperature range should only be sufficient for the steel to reach the desired temperature throughout and soaking at temperature thereafter should be brief. With salt bath hardening, a temperature 25⁰F below that used in protective atmosphere furnaces will give similar results.

Quenching in oil or air is satisfactory for sections not exceeding about 1 inch in maximum thickness. Larger sections are best given an interrupted or step cooling, either by quenching in oil until just black, or quenching in molten lead or salt at 800-1200⁰F. In either case, after equalizing at this intermediate temperature, the tool may then be cooled in air. Sections of more that about 1 ½ to 2 inches thick will not attain maximum hardness if cooled in air directly from the hardening temperature.

**Hardening Series**

Annealed bar stock samples 1 inch diameter by 2 inches long were preheated to 1500⁰F, then heated to the indicated hardening temperatures. After being cooled in oil or air, the samples were tested for hardness and then fractured.

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| **Oil Quenched** |
| **Hardening Temperature ⁰F** | **Hardness Rockwell C** | **Shepherd Fracture Rating** |
| 2050 | 65.0-65.5 | 9 ½ |
| 2100 | 65.0-66.0 | 9 ½ |
| 2150 | 65.0-66.0 | 9 ½ |
| 2200 | 64.5-65.5 | 9 ¼ |
| 2250 | 64.5-65.0 | 9 |
| 2300 | 64.0-64.5 | 8 ½ |
| 2350 | 63.0-63.5 | 7 |

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| **Air Quenched** |
| **Hardening Temperature ⁰F** | **Hardness Rockwell C** | **Shepherd Fracture Rating** |
| 2050 | 63.5-64.0 | 9 ½ |
| 2100 | 64.5-65.0 | 9 ½ |
| 2150 | 64.0-65.0 | 9 ½ |
| 2200 | 64.0-64.5 | 9 ¼ |
| 2250 | 63.5-64.0 | 9 |
| 2300 | 63.0-64.0 | 8 ½ |
| 2350 | 62.5 | 7 |

**Tempering**

The most common tempering range for cutting tools of AISI M2 is 1000-1100⁰F. A double temper is desirable for maximum toughness and the usual time for each temper is 1 ½ to 2 hours at temperature. It is safest to place the tools in the tempering furnace as soon as they have cooled down enough to be touched without discomfort. Air cool to room temperature after each tempering treatment.

Good results have been obtained with tools tempered to the hardness shown in the following table.

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| **Tool** | **Hardness Rockwell C** |
| Twist Drils | 63.5-65.5 |
| Finishing Reamers | 65.0-67.0 |
| Bridge Reamers | 63.0-64.0 |
| Lathe Tools | 64.0-66.0 |
| Taps | 63.0-65.0 |
| Millings Cutters | 64.0-65.0 |
| Punches | 62.0-64.0 |
| Die Inserts | 62.0-64.0 |