M2 High-Speed Tool Steel Properties

M2 is a widely utilized molybdenum-type high-speed tool steel, renowned for its balanced combination of abrasion resistance, toughness, and exceptional red hardness. This makes it a preferred general-purpose high-speed steel across various industrial applications.

Chemical Composition

The typical chemical composition of M2 high-speed tool steel is as follows:

- **Carbon (C):** 0.83-0.85%
- **Chromium (Cr):** 4.15%
- **Molybdenum (Mo):** 5.00%
- **Vanadium (V):** 1.85-1.90%
- **Tungsten (W):** 6.30-6.35%
- **Iron (Fe):** Balance

These alloying elements are critical for M2's performance, particularly in promoting the formation of stable alloy carbides, such as MC and M6C, within the microstructure. These carbides are essential for resisting softening at elevated temperatures.

Performance Properties

Wear Resistance: M2 exhibits very high wear resistance, significantly enhanced by the presence of undissolved carbides. Its abrasive wear resistance is notably superior to many conventional cold work steels.

Toughness: This grade offers good toughness, categorized as medium among Molybdenum HSS types and high when compared to conventional cold work steels. The manufacturing process influences toughness; powder metallurgy M2 often demonstrates higher impact toughness than conventionally cast material due to a more uniform carbide distribution. However, it is crucial to note that hardening above 1210◦C or 1220◦C (approximately 2210–2230◦F) can lead to a substantial reduction in toughness.

Hot Hardness / Red Hardness: M2 is engineered to maintain its hardness at elevated temperatures, possessing good red hardness and very high hot hardness. This property, also known as tempering resistance, is paramount for tools operating under high thermal stress, as it dictates the steel's ability to sustain performance and hardness when exposed to heat. The addition of Cobalt to the M2 base alloy can

further augment hardness retention at higher temperatures.

Fabrication and Heat Treatment Characteristics

Machinability: In its properly annealed condition, M2 has a machinability rating of 65, based on a 1% carbon steel baseline at 100. This classifies it as having medium machinability among tool steels.

Dimensional Stability: During heat treatment, particularly air quenching from the correct hardening temperature, M2 typically experiences an expansion of approximately 0.001 inches per inch (0.001 mm/mm). The final dimensions post-heat treatment are also influenced by part geometry and potential distortion such as bending or twisting. Dimensional changes also occur during tempering, partly due to transformations in retained austenite.

Hardenability & Heat Treatment: M2 is an air-, oil-, or salt-hardening steel with deep hardenability. It is recognized for having the most forgiving hardening range among high-speed steels. However, the heat treatment process for high-speed steels like M2 is distinct and generally more intricate than for other tool steel types. It typically encompasses preheating, austenitizing (hardening), quenching, and multiple tempering cycles. A common preheat temperature is 1200◦F (650◦C). Austenitizing temperatures are typically high, around 1220◦C (2225◦F), with a short holding time at temperature. Tempering is critical after hardening to achieve the desired balance of hardness and toughness. M2 necessitates a complex tempering cycle. A common first tempering temperature is 1050◦F (565◦C), which can result in a hardness of approximately 65 HRC. Higher tempering temperatures, such as 1100◦F (595◦C), 1150◦F (620◦C), and 1200◦F (650◦C), would typically yield lower hardness levels, approximately 61, 56, and 52 HRC, respectively. Multiple tempering steps are often required due to the presence of retained austenite. To prevent decarburization during annealing and hardening processes, the use of a controlled neutral atmosphere, vacuum, or neutral-salt furnace environment is highly recommended. Cryogenic treatments can also be incorporated after a stress relief step, followed by tempering to prevent brittleness.

Hardness Values

- **Annealed Hardness:** Generally less than 241 HB.
- **Working Hardness (after full hardening and tempering):** Typically in the range of 60-65 HRC.

Applications

M2's versatility is evident in its wide array of applications. It is extensively used for standard cutting tools, including twist drills, turning tools, and, with cobalt additions, milling cutters and screw taps. Its combination of wear resistance and heat resistance makes it suitable for hot cutting operations. It also finds application in certain cold work tooling and under specific hot work conditions. For blanking steel thicker than approximately a quarter inch (6.4 mm), M2 is often preferred over carbide due to carbide's limited shock resistance. It performs effectively when machining materials with high tensile strength, such as heat-treated steels, and exhibits resistance to abrasion from materials like hard cast iron, cast steel, brass, aluminum, and certain plastics.

In conclusion, M2 high-speed tool steel is a robust and versatile material offering a superior balance of properties. Its suitability for a broad spectrum of cutting and forming applications under demanding conditions underscores its critical role in modern manufacturing. Maximizing tool life and performance necessitates a thorough understanding of its specific heat treatment requirements and material characteristics.

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