D2 Tool Steel: Technical Specification Brief

1. Introduction and Classification

AISI D2 is classified as a high-carbon, high-chromium cold work tool steel. It is an air-hardening grade known for its excellent abrasion resistance and dimensional stability during heat treatment, making it a widely utilized material for demanding cold work tooling applications.

2. Chemical Composition (Typical Mass Percent)

- **Carbon (C):** 1.52 - 1.55%
- **Chromium (Cr):** 11.50 - 12.05%
- **Molybdenum (Mo):** 0.76 - 0.80%
- **Vanadium (V):** 0.90 - 0.92%
- **Manganese (Mn):** 0.34%
- **Silicon (Si):** 0.31%
- **Iron (Fe):** Balance
- **Total Alloy Content:** Approximately 14.75%

Note: The high C and Cr content results in a significant volume fraction of chromium-rich carbides, contributing significantly to the material's properties.

3. Key Mechanical and Physical Properties

- **Hardness:**
  - *As-Quenched:* Typically 60-65 HRC, dependent on austenitizing temperature and quench parameters.
  - *Tempered:* Hardness decreases with increasing tempering temperature (e.g., ~61 HRC @ 205°C, ~55 HRC @ 425°C, ~40 HRC @ 650°C). A typical working hardness range is 60-62 HRC.
  - *Annealed:* Maximum 255 HB (or 220 HB as per heat treatment section).
  - *Surface (Nitrided):* Can achieve 750-1200 HV (core 61-64 HRC) via ion nitriding.
- **Strength (Representative Values):**
  - *Ultimate Tensile Strength (UTS):* 758 MPa
  - *Yield Strength (0.2% Offset):* 411 MPa
  - *Compressive Strength:* High, particularly at lower tempering temperatures, correlating directly with hardness.
- **Toughness and Ductility:**
  - Considered to have moderate toughness compared to shock-resisting grades but superior to higher-carbon D-series steels (e.g., D3).

    - Tensile fracture is typically ductile (dimpled surface) but occurs with minimal necking and low area reduction (~1.3%).
    - *Modulus of Toughness:* 81 MPa (from one study).
    - *Fracture Strain:* 1.97% (from one study).
    - Properties exhibit anisotropy due to carbide alignment during hot working.
- **Wear Resistance:**
    - Excellent abrasion resistance, often used as a benchmark for cold work tool steels. Attributed to the high volume of hard chromium carbides.
- **Dimensional Stability:**
    - Excellent stability during hardening, with minimal distortion compared to other tool steels, especially when air quenched.
    - Expected size change (expansion/contraction) during air hardening is approximately 0.0005 in/in (or mm/mm). Total distortion is influenced by part geometry and pre-existing stresses.

4. Heat Treatment Overview

- **Stress Relieving (Unhardened):** Heat slowly to 649–677°C (1200–1250°F), soak 1-2 hr/inch, slow furnace cool. Recommended after significant machining.
- **Preheating:** Essential due to low thermal conductivity. Heat slowly to ~650°C (1200°F), hold 10-15 min.
- **Austenitizing:** Heat to ~1010°C (1850°F). Soak time approx. 1 hr/inch of thickness. Control temperature carefully to manage retained austenite.
- **Quenching:** Air quench from austenitizing temperature down to ~65°C (150°F). Minimizes distortion.
- **Tempering:** Crucial for toughness and stress relief. Double tempering is standard.
    - *Example Cycles:* 1st temper @ ~515°C (960°F), 2nd temper @ ~480°C (900°F). Soak time approx. 2 hr/inch per temper.
    - Tempering induces secondary hardening via alloy carbide precipitation.
- **Retained Austenite Management:** D2 can retain significant austenite (~20%). Subzero treatment (cryogenic tempering, e.g., to -184°C / -300°F) can transform retained austenite, improving dimensional stability. Requires an additional temper after cold treatment.
- **Stress Relieving (Hardened):** Recommended after grinding/EDM. Temper 14-28°C (25-50°F) below the final tempering temperature.

5. Processing Considerations

- **Machinability:** Poor. Rated at 45 (relative to 100 for 1% Carbon Steel) in the annealed condition.
- **Weldability:** Generally considered difficult or non-weldable by conventional

methods due to high carbon and carbide content. Specialized techniques (e.g., thixowelding) may offer potential.
- **Grinding:** Can be difficult due to high carbide content.

6. Typical Applications

D2 is primarily used for cold work tooling requiring high wear resistance and good toughness:

- **Dies:** Blanking, stamping (long runs), cold forming, coining, drawing, trimming, thread rolling, lamination dies.
- **Punches:** Piercing, cold forming, extrusion.
- **Blades/Knives:** Shear blades, slitter knives, industrial knives (paper, wood).
- **Rolls:** Forming rolls, seaming rolls, drive rolls.
- **Wear Parts:** Mandrels, gages, lathe centers, guides, bushings (where abrasion resistance is critical).

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