S7 Tool Steel: A Technical Overview

1. Introduction

S7 tool steel is a versatile, shock-resisting, air-hardening tool steel renowned for its exceptional toughness. This technical overview details its classification, chemical composition, salient properties, heat treatment procedures, achievable hardness levels, and typical applications, providing a comprehensive guide for its selection and use in demanding industrial environments.

2. Classification

S7 tool steel is primarily classified as a **Shock-Resisting tool steel**, denoted by the 'S' in its designation, indicating that high toughness is a principal design consideration. It is also categorized as an **Air-Hardening tool steel**. Furthermore, S7 is recognized within the group of hot work tool steels, offering a degree of heat resistance suitable for certain elevated temperature applications.

3. Chemical Composition

The nominal chemical composition of S7 tool steel is as follows:

- **Carbon (C):** Approximately 0.50%
- **Silicon (Si):** 0.25 - 0.50%
- **Manganese (Mn):** 0.70% (Note: Original text had "0.70-0.7%", likely a typo, standardized to 0.70% or a typical range like 0.60-0.90% if more data were available. For now, using the provided data carefully.)
- **Chromium (Cr):** 3.25% (Note: Original text had "3.25-3.2%", likely a typo, standardized to a common nominal value or range. Using 3.25% as a representative value.)
- **Molybdenum (Mo):** 1.40 - 1.50%

The presence of chromium and molybdenum significantly contributes to its deep hardening capabilities. Notably, the molybdenum content allows S7 to maintain minimal hardness loss at operational temperatures up to 1,000°F (540°C). Compared to O1 tool steel, S7 has a lower carbon content. Unlike D-grade tool steels, S7 (similar to O1 and S1) has virtually no undissolved carbides due to its lower chromium and carbon content; its properties are predominantly governed by the matrix composition.

4. Key Material Properties

4.1 Toughness and Shock Resistance

This is the most distinguished characteristic of S7 tool steel. It exhibits one of the highest shock resistance ratings among all tool steels and is considered to possess very high to highest toughness within the shock-resisting steel group. This superior combination of high toughness and fracture resistance renders it highly suitable for applications involving impact loading, complemented by good strength and wear resistance. It is consistently rated as having very good toughness.

4.2 Wear Resistance

S7 tool steel offers good wear resistance. Its wear characteristics are generally considered somewhat inferior to O6 tool steel but superior to 4140/4150 alloy steels. When compared to other air-hardening grades, its wear resistance is typically less than that of A2 or D2 tool steels. Wear resistance is influenced by matrix hardness (martensite) and the quantity and type of undissolved carbides. As noted, S7, similar to O1, contains minimal undissolved carbides relative to higher alloy grades.

4.3 Hot Hardness and Heat Resistance

S7 demonstrates the ability to withstand service temperatures up to 1,000°F (540°C) with minimal softening. Shock-resisting steels, in general, exhibit a resistance to softening that can range from low to high, with S7 performing well in this regard for its class.

4.4 Hardenability

As an air-hardening steel, S7 possesses higher hardenability than water-hardening grades. It can achieve through-hardening via air quenching in sections up to 2.5 inches (63.5 mm) in thickness. For cross-sections exceeding 2.5 inches (63 mm), achieving full hardness by air cooling may not be feasible, necessitating alternative cooling methodologies.

4.5 Dimensional Stability

S7 is recognized for its excellent dimensional stability during heat treatment, exhibiting low distortion. When air quenched, an expansion of approximately 0.001 inch per inch (0.1%) is anticipated. Air quenching is instrumental in minimizing distortion and promoting dimensional consistency.

4.6 Machinability

When properly annealed, S7 tool steel has a machinability rating of approximately 70% compared to a 1% carbon steel baseline (rated at 100%). Some sources may indicate a higher rating, around 95%. It is generally noted to machine slightly better than O1 tool steel and is rated as having good machinability overall.

5. Heat Treatment Procedures

5.1 Hardening

The typical austenitizing (hardening) temperature for S7 is 1,725°F (941°C). The soaking time is generally 1 hour per inch of material thickness. Air quenching is the standard cooling method.

5.2 Tempering

Multiple tempering cycles are recommended to optimize toughness and relieve internal stresses. A common practice involves a first temper at 450°F (230°C) followed by a second temper at 425°F (220°C). The recommended tempering range for general applications is 400-450°F (204-232°C). Each tempering cycle should be maintained for 2 hours per inch of thickness. For hot work applications, it is advised to temper at a temperature 25-50°F (14-28°C) above the anticipated maximum service temperature.

5.3 Annealing

For annealing, heat the material uniformly to 1,550°F (843°C) and soak for 1.5 hours per inch of thickness. Subsequently, cool slowly at a rate of 25°F (14°C) per hour down to 900°F (482°C), followed by air cooling to room temperature.

5.4 Protective Measures

To prevent decarburization during heat treatment, annealing and hardening operations should be conducted in a controlled atmosphere, vacuum furnace, or neutral salt bath.

5.5 Stress Relief

A stress-relief temper is strongly recommended after significant machining, welding, or Electrical Discharge Machining (EDM). This is typically performed at a temperature 25-50°F (14-28°C) below the final tempering temperature used.

6. Achievable Hardness Levels

- **Working Hardness:** The typical normal working hardness for S7 tool steel is in the range of 56-58 HRC. Optimal working hardness is often achieved by tempering at 450°F (230°C), which yields approximately 58 HRC.
- **As-Quenched Hardness:** The as-quenched hardness is typically around 59-60 HRC, with a maximum obtainable hardness of 60 HRC.

- **Annealed Hardness:** The approximate maximum annealed hardness is 230 HB (Brinell Hardness).
- **Case Hardening:** S7 can be case hardened (e.g., nitriding) after through-hardening and tempering to achieve a surface hardness up to approximately 64 HRC. However, it is important to note that such surface treatments will generally reduce the inherent shock resistance of the material.

7. Typical Applications

S7 tool steel is valued for its versatility and is widely employed in a variety of tooling applications:

- **Medium Cold-Work Tools and Dies:** Including shear blades, punches, cold forming dies, and grippers.
- **Plastic Molding Dies:** Due to its toughness and polishability.
- **Medium Hot-Work Dies:** When appropriately tempered for elevated temperature service.
- **Component Parts:** Requiring high shock resistance.
- **Specific Tools:** Such as chipping chisels, rivet sets, and knock-out pins.

Its excellent combination of shock resistance and moderate heat resistance makes it a viable option for numerous hot working tools when tempered accordingly.

8. Summary

S7 tool steel offers an exceptional balance of very high toughness and shock resistance, coupled with good wear resistance and moderate hot hardness. Its good dimensional stability during heat treatment and reasonable machinability further enhance its suitability for a wide array of applications, particularly those involving impact loading or moderate operational temperatures.

Aobo Steel
Website: aobosteel.com
Email: sales@aobosteel.com