Manufacturing Tooling Tool Materials

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Tool Materials

- Ferrous materials
  - Tool steel, alloy steel, carbon steel, cast iron
- Non-ferrous materials
  - Aluminum, Zinc, Lead, Bismuth
- Non-metallic materials
  - Plastics, rubbers, epoxy resins

Physical and Mechanical Properties

- Weight
- Thermal and electrical conductivity
- Melting point
- Strength
  - Tensile
  - Compressive
  - Shear
  - Yield

Physical and Mechanical Properties

- Hardness
  - Rockwell
  - Brinell
- Wear resistance
- Toughness
- Plasticity
- Ductility
- Brittleness
- Malleability

Ferrous Tool Materials

- Conditions
  - Hot rolled
  - Cold rolled
  - Ground

Ferrous materials

- Carbon steels
  - Low carbon 0.05% to 0.30% C
    - Soft,
    - Tough,
    - Easily machined, and
    - Welded
    - Case hardened
  - Used for tool bodies, handles, die shoes, where strength and wear resistance is not required.

Ferrous materials

- Carbon steels
  - Medium carbon 0.30 to 0.70% C
    - Great strength and toughness
    - Normal heat treatment can be given
  - Used for tool parts such as studs, pins, axles and nuts
  - High carbon 0.70 to 1.50% C
    - Wear resistance is required
  - Used for Drill bushings, locators, and wear pads

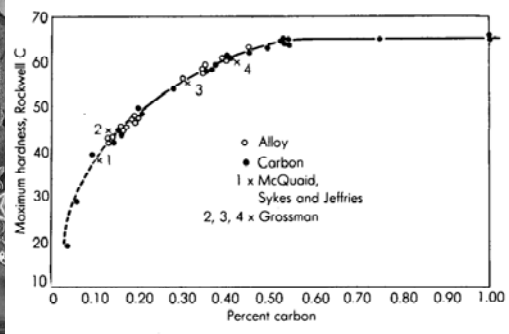


Figure 2-5. **Carbon content in relation to hardness possible.**

Alloy steels

- Carbon steels with additional alloying elements
- Expensive

Tool steels

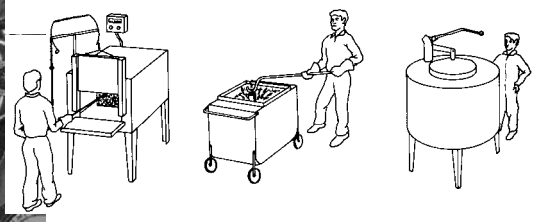
- W – water hardening tool steels
  - Plain carbon (W1) and carbon vanadium (W2)
  - Low cost
- O – oil hardening tool steels
  - Manganese oil hardening steels
  - Better wear resistance
- A – Air hardening die steels
  - Better wear resistance

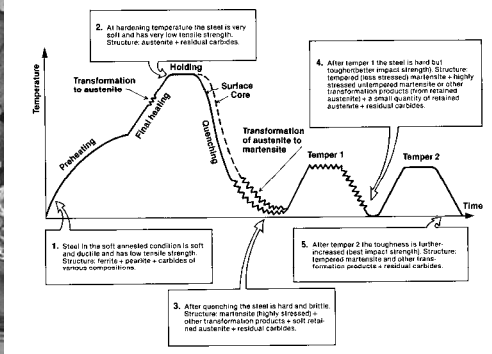
Heat treatment for ferrous materials

- Normalizing
- Spheroidizing
- Stress relieving
- Annealing
- Hardening
- Tempering
- Case hardening

Hardening consists of three operations

HEATING	QUENCHING	TEMPERING
— preheating — final heating — soaking	immersing the heated tool in a liquid (oil, water, fused salt) or cooling in a gas (air)	reheating the quenched tool to a lower temperature (150—600°C) one or several times





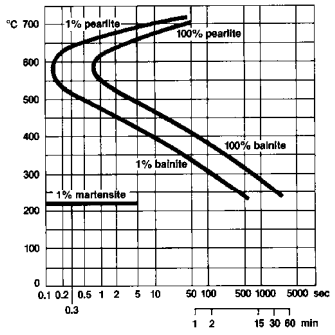


Fig. 62. TTT diagram for UHB 20 (AISI W1). Austenitizing (hardening) temperature 780°C.

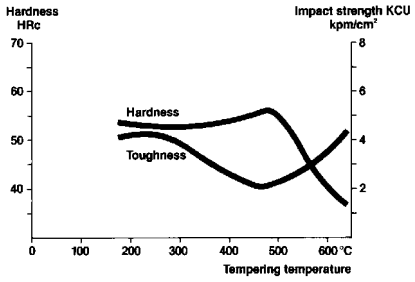


Fig. 71. Hardness and toughness of Stavax after tempering at different temperatures. Tempering at 250°C gives a good combination of hardness and toughness.

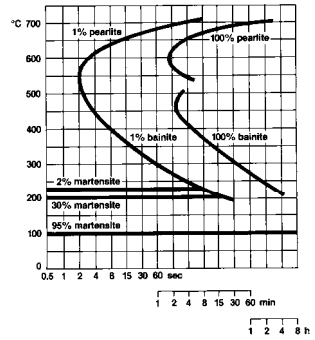


Fig. 63. TTT diagram for Arne (AISI O1). Austenitizing (hardening) temperature 810°C.

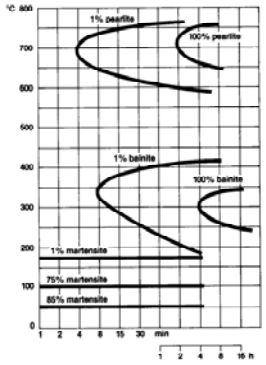


Fig. 64. TTT diagram for Rigor (AISI A2). Austenitizing (hardening) temperature 950°C.

Tempering diagram

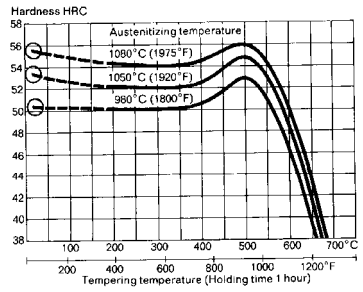


Fig. 61. Tempering diagram for Orvar. The beginning of each curve shows the normal hardness after quenching from each respective hardening (austenitizing) temperature.

Steel types*	Average Composition, percent C	Mn	Si	Cr	W	Mo	V
W1	1.00						
W2	1.00						0.25
O1	0.90	1.00		0.50	0.50		
O2	0.90	1.60					
O7	1.20			0.75	1.75	0.25	
A2	1.00			5.00		1.00	
A4	1.00	2.00		1.00		1.00	
A5	1.00	3.00		1.00		1.00	
A6	0.70	2.00		1.00		1.00	
D2	1.50			12.00		1.00	
D3	2.25			12.00			
D4	2.25			12.00		1.00	
D6	2.25		1.00	12.00	1.00		
S1	0.50			1.50	2.50		
S2	0.50		1.00			0.50	
S4	0.50	0.80	2.00				
S5	0.50	0.80	2.00			0.40	

Tool steels

- D – high carbon high chromium die steels
  - Used for long run dies
  - Tough and good wear resistance
- S – shock resisting tool steels
  - Low carbon and high toughness
- H – hot work die steels
  - Low carbon and high alloy content

Tool steels

- T and M – tungsten and molybdenum based high speed steels
  - Good red hardness and abrasion resistance
- L – low alloy tool steels
  - Limited application
  - Coining and impression dies
- F – finishing steel

Steel types*	Average Composition, percent C	Mn	Si	Cr	W	Mo	V	Other
T1	0.70			4.00	18.00		1.00	
T15	1.50			4.00	12.00		5.00	5.00 Co
M2	0.85			4.00	6.25	5.00	2.00	
M3	1.00			4.00	6.00	5.00	2.40	
M4	1.30			4.00	5.50	4.50	4.00	
L2	0.50			1.00			0.20	
L3	1.00			1.50			0.20	
L6	0.70			0.75				1.50 Ni
F2	1.25				3.50			

Cast iron

- High compressive strength and easy casting
- Large forming and drawing dies

Non-ferrous Tool Materials

- Aluminum
  - High strength to weight ratio
  - Corrosion resistant
  - Supports and locators to base plates and tool bodies
- Magnesium
- Bismuth alloys
  - Low melting temperature

Heat treatment for Non-ferrous materials

- Cold work
- Precipitation hardening

Hot working operations

- **Operations**
  - Warm forging, dies and punches
  - Roll forging, rolling segments
  - Upset forging, clamping tools
  - Progressive forging, dies
  - Axial closed die rolling, top and bottom dies
  - Cross forming, segments
  - Hot bending, tools
  - Hot calibration, tools
  - Zinc die casting, dies
  - Al-tube extrusion.

Hot working operations

- Properties required
  - Wear resistance
  - Toughness
  - High hot wear resistance
  - Very good high temperature properties
  - High resistance to thermal fatigue
  - Very good temper resistance
  - Very good thermal conductivity.

Cold working operations

- Operation
  - Cold Forging
  - Cold Rolling
  - Cold Extrusion
  - Sheet metal operations

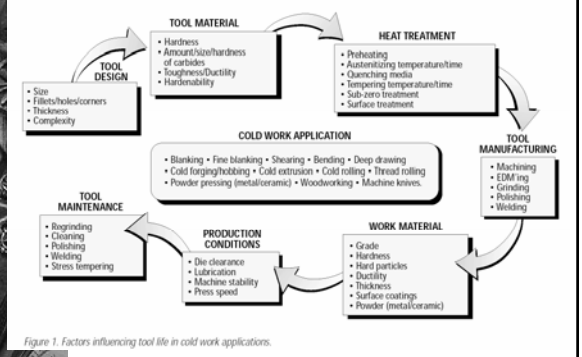


Figure 1. Factors influencing tool life in cold work applications.

Cold working operations

- Properties required
  - high hardness
  - high volume of carbides
  - high hardness of the carbides
  - large carbide size
  - Wear resistance
  - Toughness

Grade	Uddeholm	Chemical composition % C	Si	Mn	Cr	Mo	W	V
O1	*ARNE*	0,95	0,3	1,1	0,6	–	0,6	0,1
Spec. analysis	*CALMAX/ CARMO*	0,6	0,35	0,8	4,5	0,5	–	0,2
A2	*RIGOR*	1,0	0,3	0,6	5,3	1,1	–	0,2
Spec. analysis	*SLEIPNER*	0,9	0,9	0,5	7,8	2,5	–	0,45
D2	*SVERKER 21*	1,55	0,3	0,4	11,8	0,8	–	0,8
≈D6	*SVERKER 3*	2,05	0,3	0,8	12,7	–	1,1	
Spec. analysis	*VANADIS 4*	1,5	1,0	0,4	8,0	1,5	–	4,0
Spec. analysis	*VANADIS 6*	2,1	1,0	0,4	6,8	1,5	–	5,4
Spec. analysis	*VANADIS 10*	2,9	1,0	0,5	8,0	1,5	–	9,8
M3:2 PM	*VANADIS 23*	1,28	0,5	0,3	4,2	5,0	6,4	3,1