A. Finkl & Sons Co.

DATA SHEET

DURODI®
Forging Die Steel

Cleanest . . . Toughest . . . Most Machinable

DURODI

Increased Carbon, Molybdenum and Nickel over basic die steel compositions offer enhanced abrasion resistance and good impact toughness for the following applications.

Aluminum and Titanium Forging

Appropriate for hammer forging of aluminum where strain rates and the formation of abrasive aluminum-oxide exert strong wear forces on the die.

Warm (Ferrous) Forging

Forging steel at lower temperatures offers improved dimensional precision and improved heating efficiency, but subjects the dies to increased cavity pressures and strong abrasion forces. Water quenched DURODI offers excellent performance under these conditions through a balanced combination of enhanced wear resistance and good impact toughness.

Counterblow Hammers

Large counterblow hammer dies are subjected to incredibly high impact forces and flow stresses. The combination of cold-water quenching and the deep hardening capacity of DURODI provide the microstructure and hardness needed for large counterblow hammer dies.

Finkl Standard Hardness Ranges for DURODI

Finkl Std.	HB	HRC
TXH	495-534	51-54
TH	444-477	47-50
T1	401-429	47-50
T2	352-388	38-42
T3	311-341	33-37
T4	277-302	29-32
Annealed	248 approx	24 approx.

Nominal Chemistry* (Wt. %)

0.55%	CARBON
0.60%	MANGANESE
0.50%	SILICON
1.55%	NICKEL
1.00%	CHROMIUM
0.80%	MOLYBDENUM
0.05%	VANADIUM
17.0	Ideal Diameter (DI)**

* Plus patented microalloying additions

** For more information on this topic, please refer to the **Finkl Die Handbooks**.

Machinability

Machinability at all hardness levels is enhanced through patented micro-alloying additions, but where maximum machinability is desired, a fully annealed condition (approximately 248 HB) is available.

* Covered under one or more of the following U.S. Patents: 5,496,516 and 6,398,885. Covered under U.K. Patent: 2,302,334.

Right is reserved to change chemistry at any time to improve product.

Recommended DURODI® Die Steel Minimum Preheating Temperatures ˚F

Increased Wear Resistance → Increased Fracture Sensitivity	DIE HARDNESS	Die Block (Thickness) inches / mm 5 / 127	10 / 254	15 / 381	20 / 508
	XH	300	350	400	400
	H	250	300	350	400
	T1	200	250	250	300
	T2	150	150	200	250
	T3	150	150	200	200

Conversion:

˚F	150	200	250	300	350	400
˚C	65	95	120	150	175	204

Heating beyond the recommended minimum preheating temperature by 200˚ to 300˚F (95˚ to 150˚C) will achieve the full toughness ("Upper Shelf" energy) capability of the die steel.

Critical Temperatures

Equilibrium A_1 1331 ˚F (722 ˚C)
Equilibrium A_3 1450 ˚F (788 ˚C)

Tempering according to the temperatures in the following table is employed with water-quenching to establish the standard hardness ranges. For a given hardness, employing *lower* temperatures may be used for **Stress Relieving** with minimal effect on the base hardness.

Tempering Table

Nominal Tempering Temperatures for Water-Quenched Forgings

Temperature	Finkl Std.	HB	HRC
900˚F (482˚C)	XH	495-534	51-54
1020˚F (482˚C)	H	444-477	47-50
1080˚F (582˚C)	T1	401-429	43-46
1120˚F (604˚C)	T2	352-388	38-42
1150˚F (621˚C)	T3	311-341	33-37
1180˚F (638˚C)	T4	277-302	29-32

Sub-Critical Anneal

Softening may be achieved through ***Sub-Critical annealing*** by holding at 1220˚F (660˚C) for an extended period, typically 1.5 hrs/inch (1.5 hrs/25 mm). Expected hardness is approximately 248 HB maximum.

Full Anneal

Softening with additional refinement to the microstructure may be achieved through a ***Full Anneal:***

- **Heat to 1460/1480˚F (793/804˚C) and Hold 1/2 hr/inch (25mm)**
- **Drop to 1220˚F (660˚C) and Hold 4 hrs.**
- **Furnace Cool to 800˚F (425˚C)**
- **Air Cool to ambient temperature**

Expected hardness is approximately 229 HB

Hardening

Increasing the hardness requires heating to an austenitizing temperature (1550-1600˚F/840-870˚C) followed by a quenching operation. (Some oxidation/decarburization will occur on the block surface unless heating is performed in a vacuum or protective atmosphere furnace.) *Quenching is a high stress operation introducing a risk of cracking, particularly for a machined block with contours, sharp edges, drilled holes or thin-web features.* For such product, employing a quenchant with a lower quench-severity rating will lower the risk of cracking.

- **Heat to 1680/1700˚F (9160/927˚C) and Hold 1/2 hr./inch (25mm) of thickness**
- **Drop to 1470˚F (799 ˚C) and Hold 2 hrs.**
- **Quench (Oil, Polymer or Molten salt bath)**
- **Immediately temper according to the Tempering Table to the left. Lower severity quenchants may require a downward adjustment to tempering temperature.**

Physical Properties

Test Temperature	20˚C/68˚F	200˚C/390˚F	400˚C/750˚F
Density	7800 Kg/m³	7750	7700
	0.282 lbs/in³	0.280	0.277
Coefficient of Thermal Expansion	$11.9x10^{-6}$ cm/cm/˚C	$12.7x10^{-6}$	$13.6x10^{-6}$
	$6.6x10^{-6}$ in/in/˚F	$7.0x10^{-6}$	$7.5x10^{-6}$
Thermal Conductivity	29.0 J/m²/m/s/˚C	29.5	31.0
	202 BTU/ft²/in/hr/˚F	205	216
Modulus of Elasticity	$205x10^3$ N/mm²	$200x10^3$	$185x10^3$
	$29.7x10^6$ lbs/in²	$29.0x10^6$	$26.8x10^6$
Specific Heat	460 J/Kg ˚C	492	538
	0.110 BTU/lb ˚F	0.118	0.129
Poisson's Ratio	0.3	0.3	0.3

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