

Magnetic Particle Inspection of Tool Steel

Magnetic particle inspection finds the surface and near-surface cracks that no chemical test reaches and no radiograph resolves. The tables below give what the method finds, the current levels measured on an O1 tool steel ring, the ways a part is magnetized and the demagnetizing choices.

Reference only. This is a reference summary of published practice and it is not a specification of ours. The values are reproduced from the source tables, and tool material, machine rigidity, cutting fluid and workpiece condition will all move them. Final conditions are set on the job.

What it finds, and how far it reaches

Wet particles for cracks, dry particles for rough and buried flaws

Alternating current stops at the surface

The tool steel test that set the depth limit

Drilled hole and depth below the surface	Current type	Current needed
Hole 1, 1.8 mm (0.07 in.)	60 Hz alternating current	about 475 A
Hole 2, 3.56 mm (0.14 in.)	60 Hz alternating current	over 1000 A
Hole 2, 3.56 mm (0.14 in.)	Straight direct current	450 A
Hole 2, 3.56 mm (0.14 in.)	Direct current with a surge	320 A
Hole 2, 3.56 mm (0.14 in.)	Half-wave direct current	250 A
Hole 3, 5.33 mm (0.21 in.)	60 Hz alternating current	not reachable at any available level
Hole 10, 17.8 mm (0.70 in.)	Straight direct current	975 A
Hole 12, 21.3 mm (0.84 in.)	Half-wave direct current	750 A

Threshold currents at which drilled holes in an O1 tool steel ring gave readable magnetic particle indications, with dry particles, a central conductor and continuous magnetization, reproduced from Magnetic Particle Inspection in ASM Handbook, Volume 17. The alternating current column is the one to read first, because it shows the method failing at a depth of 5.33 mm no matter how much current is applied. With wet particles the levels are higher again, and the source gives about 440 A of direct current for hole 1 and about 910 A for hole 3.

Drilled hole and depth below the surface	Half-wave direct current	Direct current with a surge	Straight direct current
Hole 1, 1.8 mm (0.07 in.)	about 200 A	about 300 A	about 450 A
Hole 3, 5.33 mm (0.21 in.)	about 1300 A	about 1875 A	about 2700 A

Current needed to indicate two depths of drilled hole in the same O1 tool steel ring after hardening to 63 HRC, reproduced from Magnetic Particle Inspection in ASM Handbook, Volume 17. A hard part needs more current still than an annealed one, and at hole 3 the straight direct current figure is about 2700 A.

How the part is magnetized

Magnetization method	Where it is used	Advantages	Limitations
Coils, single or multiple loop	Medium-size parts whose length predominates, such as a shaft or a crankshaft, and large castings, forgings or shafts	A longitudinal field over the whole surface, or easily wrapped with a flexible cable	The part should be centred in the coil, length may need more than one shot, and sensitivity falls at the ends
Yokes	Large surface areas, and localized areas on miscellaneous parts	No electrical contact, highly portable, finds a discontinuity in any direction with the yoke turned across it	Time consuming, the yoke has to be repositioned systematically, and sensitivity to subsurface flaws is poor
Central conductors	Short parts with a hole, such as rings, hollow cylinders, gears and couplings, and long tubular parts	No electrical contact so no risk of burning, a circumferential field on every surface around the conductor	The conductor must be central and large enough to carry the current, and large parts need several setups
Direct contact, head shot	Solid, relatively small cast, forged or machined parts on a horizontal wet-method unit	Fast, easy, a complete circular field around the current path and good sensitivity to surface and near-surface flaws	Burning is possible if contact is poor, and long parts are inspected in sections
Direct contact, clamps and cables	Large castings and forgings, long tubular parts and long solid parts such as billets, bars and shafts	The whole length is circularly magnetized end to end and the amperage is independent of length	High amperage, 8000 to 20 000 A, needs a special power pack, and the ends must carry the current
Prod contacts	Welds, for cracks, inclusions, open roots or incomplete penetration, and large castings or forgings	The circular field can be aimed at the weld, and with half-wave current and dry powder subsurface sensitivity is excellent	Only a small area per shot, arc burn from poor contact, and large areas take many shots
Induced current	Ring-shaped parts, balls, disks and gears	No electrical contact, full coverage in one magnetization, and the process can be automated	A laminated core is needed through the ring, and the current type must suit the magnetic hardness of the metal

General applications, advantages and limitations of the ways a part is magnetized for magnetic particle inspection, condensed from Table 1 of Magnetic Particle Inspection in ASM Handbook, Volume 17. On a long solid part such as a bar or a billet, contacting the ends circularly magnetizes the whole length at once, and on a coil the part should be centred so that the length effectively magnetized in one shot is as large as possible.

Current, and turning the magnetism off again

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Magnetization	Current rule
Circular, current passed through the part	12 to 31 A per mm (300 to 800 A per in.) of the part diameter, and normally 20 A per mm (500 A per in.) or less
Circular, at the top of the band	Up to 31 A per mm (800 A per in.), used for inclusions or for precipitation-hardened alloys
Prod contacts	4 to 4.92 A per mm (100 to 125 A per in.) of the prod spacing, with the spacing kept between 50 and 203 mm
Coil, longitudinal	From the ampere turn figure of 45 000 times the length to diameter ratio of the part

Current rules for magnetizing a part, reproduced from Magnetic Particle Inspection in ASM Handbook, Volume 17. The diameter is the largest distance between any two points on the outside circumference of the part.

Method	Part size	Metal hardness	Production rate	Small	Medium	Large	Soft	Medium	Hard	Low	Medium	High
Coil, 60 Hz ac	A	A	N	A	A	N	A	A	A			
Coil, dc, 30 point reversing step down	N	A	A	A	A	A	A	N	N			
Through current, ac, 30 point step down	N	A	A	A	A	A	A	A	N			
Through current, ac, reactor decay	N	A	A	A	A	A	A	A	N			
Through current, dc, 30 point reversing step down	N	A	A	A	A	A	A	N	N			
Yoke, ac	A	Used for local areas only	N	A	A	A	N	A	N			
Yoke, reversing dc	A	Used for local areas only	N	A	A	A	N	A	N			

Applicability of demagnetizing methods on the basis of part size, metal hardness and production rate, reproduced from Table 2 of Magnetic Particle Inspection in ASM Handbook, Volume 17. A is applicable and N is not applicable. Where the entry reads that a yoke is used for local areas only, the source limits a yoke on a medium-size part to local work.

Grades and stock

Aobo Steel, tool steel supplier

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Source, ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control, ASM International, 1989.

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