LAPPING & GRINDING

Purpose

Grinding and lapping remove deformations, surface irregularities, and saw marks induced during sectioning and provide a smooth, perfectly flat, and matt-finished surface. A finely ground surface is essential for detailed examination of materials in a low power reflected light microscope (stereomicroscope) at a magnification up to 100X.

Procedure

Grinding is usually done by using successively finer-grained abrasives in water, solvent, or oil-based carrier on a horizontal rotary grinding/lapping wheel. In transition from a coarse to the next fine grit size, the ground surface is thoroughly cleaned to remove the loose abrasives and fine particles of sample produced during coarse grinding. In the traditional approach to lapping and grinding, progressively smoother and finer ground surface with lesser sample removal is achieved by grinding with successively finer abrasives. Abrasive used for each grinding step is one or two grit sizes smaller than that used in the preceding step, which removes the surface deformation induced by the former coarser grit. The depth of surface damage decreases with the abrasive size and so does the sample removal rate. For a given size, the damage is greater for a soft material than for a hard material.

Grinding Machines

Three types of grinding machines are common:

(a) A large, bench top or stand alone unit containing a motor-driven, 18-24-in. diameter horizontal rotary iron lapping wheel (plain, or with radial or concentric grooves), with or without condition rings as sample holding fixtures, which can receive either loose SiC/alumina abrasive powder, or fixed abrasive papers with pressure sensitive adhesive (PSA) backing, or resin and metal-bonded diamond discs with magnetic backings. Large concrete samples up to 6 × 12-in. in cross section can be lapped by this unit;

(b) A single or dual-deck bench top or stand alone grinding/polishing unit housing horizontal rotary wheel(s) (usually 8 to 12 in. diameter) to accept clean, or PSA-backed grinding papers, or magnetic discs with or without single/multiple sample holding fixtures (head); a wide variety of samples can be both ground and polished by using various interchangeable magnetic plates with grinding abrasive papers or polishing cloths on the same single or dual

grinding/polishing wheels; and

(c) Micrometer-attached vertical, diamond cup wheel or plate to traverse the sample for controlled and precision grinding; this is used for grinding thin sections in thin-sectioning equipments (diamond particles embedded in cup wheels are usually 60-μm in size).

Grinding Abrasives

Abrasives used for grinding are:

(a) Either applied as loose grains or powdered form in a premixed slurry or suspension in water, oil, or solvent, or as powders charged concurrently with water spray and applied on a solid iron lapping/grinding wheel where the abrasive particles are free to roll around as they abrade the sample surface, or

(b) Fixed or bonded to a paper, polymeric, or cloth backing materials of various weights in the form of sheets or discs of various sizes which are attached to a horizontal rotary grinding wheel or as belts in a stationary roll (or belt) grinder, or

(c) A series of small (8 to 12-in.) or large (18 to 24-in.) diameter, fixed, metal-bonded or resin-bonded diamond discs of various grit sizes that magnetically adhere to the grinding wheels (for the same abrasive size, a metal-bonded diamond disc removes more material faster and produces a rougher or coarser surface finish than a resin-bonded disc).

Fixed abrasives (diamond discs or abrasive papers) are generally more aggressive and remove much more material per unit time for the same abrasive size than loose abrasives and tend to produce somewhat more deformation at the surface than that noted when abrasives roll over the plate during lapping. For both types, the size of the abrasives determines the cutting rate and surface damage depth. The coarser the abrasive, the faster the sample removal rate but the greater the damage depth at the surface, and vice versa. Soft and brittle materials should grind with as fine abrasive as possible, which, though takes a longer time to remove the sectioning damage, produces less damage from grinding than a coarser abrasive. Diamond discs have a long service life but can be far more aggressive for grinding soft and sensitive materials than the SiC abrasive papers, which have relatively short service life but are better for grinding soft materials.

Common abrasive grains are: (a) silicon carbide (SiC) or aluminum oxide (Al_2O_3) with the following various ANSI/CAMI (USA) grit numbers (the corresponding median micron size of the particle size distribution is in parenthesis): 60 (268-μm), 80 (188-μm), 100 (148-μm), 120 (116-μm), 180 (78-μm), 220 (66-μm), 240 (51.8-μm), 280 (42.3-μm), 320 (34.3-μm), 360 (27.3-μm), 400 (22.1-μm), 500 (18.2-μm), 600 (14.5-μm), 800 (12.2-μm), 1000 (9.2-μm), 1200 (6.5-μm), and 3000

(3.5-μm); and (b) diamond paste or suspension applied on a grinding paper, disc, or cloth attached to a horizontal rotary wheel (10 to15-μm size diamond paste and 9.5-μm alumina powder slurry are commonly used for the intermediate to final fine grinding operations). The Mohs hardness of alumina and SiC are 9, and diamond is 10 (corresponding Knoop hardnesses are 2100, 2300, and 8000, respectively). Due to its high hardness, diamond is the abrasive of choice for grinding hard materials such as rocks, concrete, ceramics, and glass. Diamond abrades faster, removes more material per unit time, and produces a more consistent surface finish (usually with less relief) than alumina or SiC. SiC and alumina both occur either as loose powders or as fixed abrasive paper. Aluminum oxide crystals are more blocky than SiC crystals - the former breaks down into uniformly shaped particles. Alumina is a better choice for a scratch-free surface and for grinding a soft material than SiC. Alumina is available in hexagonal and cubic crystal forms and produced by calcination (tends to have agglomerated forms) or by sol-gel process (agglomerate-free). Deagglomerated alumina produces a better surface finish than agglomerated form of the same particle size. Methods for sizing the SiC/Al_2O_3 abrasives in the abrasive papers are by sieving for the coarsest grits, sedimentation grading for the intermediate grits (240-600), and electrical resistance method for the very fine grits. Hack-sawed, bandsawed, and other rough sections produced on a rough or thick diamond blade or abrasive cut-off wheel require coarse grinding to remove surface irregularities by using grit sizes of 60 to 100; whereas samples sectioned by using a thin, precision blade (which produces minimum surface deformation) should start grinding with grit sizes of 320 or 400.

A grinding disc of fine stainless steel mesh attached to a substrate (e.g., Buehler's Ultra-Plan disc charged with 10 to 15-μm size diamond slurries or sprays) is promising to produce a surface finish between grinding and coarse polishing, for rapid sample removal without producing large amounts of deformation in the sample, and to minimize surface relief, especially during the final thinning of a thin section on a glass slide from 30 to 40-μm down to 15 to 20-μm).

Rock, Clinker, Cement, and Concrete Grinding

Sectioned rock, whole or crushed clinker samples, and encapsulated cement samples are commonly ground on a horizontal rotary wheel with successively finer sized fixed abrasive papers charged with SiC, Al_2O_3, or diamond and lubricated with a solvent (propylene glycol), or oil. Concrete samples are lapped on a larger diameter (18 to 24-in.) horizontal rotary cast iron lapping wheel charged with SiC or Al_2O_3 powder abrasives, or, more efficiently, with a series of diamond magnetic discs. Samples are either lapped by holding in hand (for larger samples) or placed inside a lapping ring on the lapping plate with weights on the

samples (for samples up to 4 × 6-in. dimension). Single or dual-wheeled 8 to10-in. diameter horizontal rotary grinding/polishing machines are also used for grinding concrete samples prior to thin sectioning, and for polishing.

Carrier

Water-sensitive and anhydrous materials are ground with a suitable low-viscosity lapping oil or other organic solvents such as ethanol, glycol, or alcohol. Good non-water-based carriers are propylene glycol, 1:1 mixture of propylene or ethylene glycol and alcohol, or a low-viscosity water-free lapping oil such as denatured kerosene mixed with 1/10th part motor oil or a hydraulic food-line mineral oil (e.g., such as the one used in commercial baby oil or Mobil's DTE FM-32). The diamond saw manufacturers sell a variety of light lapping oils. The flatness of the finely ground surface can be checked by viewing it at a low angle of incidence in a strong light or in a stereomicroscope. In an air-entrained concrete, the margins of air voids should be sharply defined after the grinding operations

Lapping

Although in many literatures the term 'lapping' is used synonymously with 'grinding', lapping is the type of grinding where the abrasive particles are applied as loose grains and roll freely on the surface of a cast iron or plastic lapping wheel or disc. The wheel is usually charged with slurries of small amounts of SiC, alumina, or diamond.