CERAMIC MATERIALS MANUFACTURING

Dr. Alaa Aladdin

FINISHING OPERATIONS

INTRODUCTION

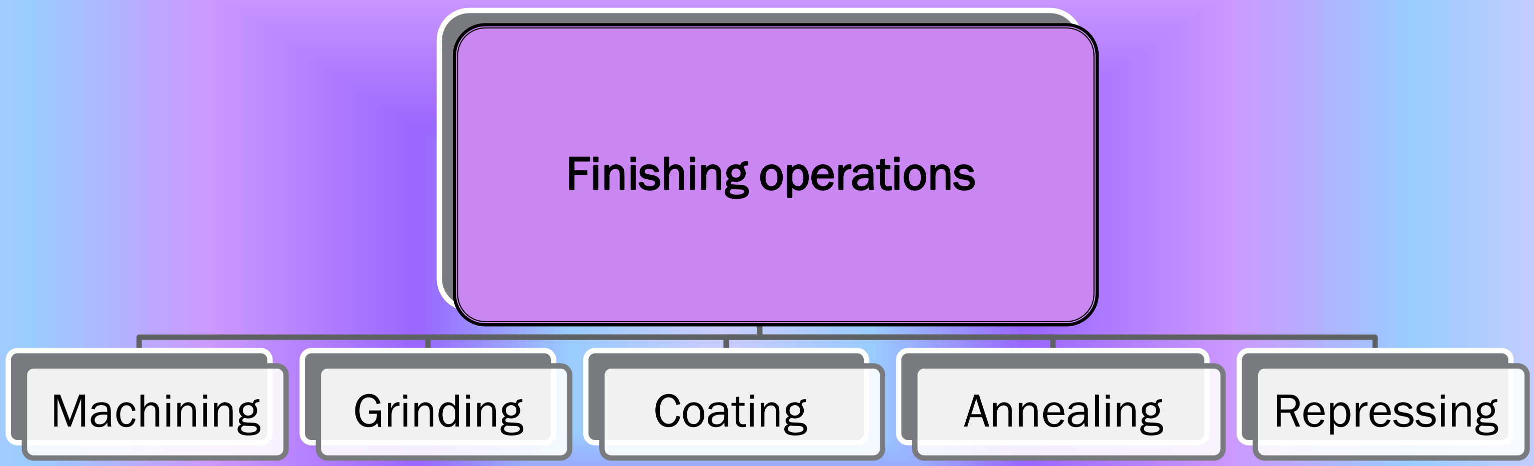
This Section is a very brief and qualitative review of the activities associated with finishing the ceramic after it has been sintered .

After sintering, we have a dense ceramic piece. It consists of polycrystalline array of grains with mostly random orientation .

At this stage, ceramic powder processing is over for the most part. Because there is usually some degree of warping during sintering, the ceramic must be machined to the final dimensions desired within specified tolerances.

This machining can cause surface flaws which will weaken the ceramic and effect other properties. To counteract these surface flaws, coatings and glazes are applied. These glazes also hermetically seal the ceramic.

INTRODUCTION



1- Ceramic Machining

Section 8

1- CERAMIC MACHINING

a-Green Machining

Many green pieces made by slip casting, uniaxial die pressing, or isostatic pressing are used as "base".

That means they are further shaped by machining techniques before subsequent processing.

In the green state, ceramics are easily cut with cutting tools and ground with grinding wheels typically used in the machining of metals because the forces holding the particles together in the green body are weak, being essentially those of the polymeric binder.

1- CERAMIC MACHINING

- The surface finish of the machined green piece will have a roughness on the scale of the particles used in fabrication of the ceramic piece.

For smoother machined surfaces, the binder should be easily deformable, which means that machining should take place above the glass transition temperature of the polymeric binder system.

1- CERAMIC MACHINING

Because machining friction is dissipated in heat, the polymer binder is often above its glass transition temperature during machining. In some cases, the entire green body is heated to above the glass transition temperature of the binder before machining to make it easier to machine.

Green machining is much easier than machining after sintering, where it is used to achieve the final dimensional tolerances of the final piece. After sintering, the ceramic is very hard and difficult to machine, as well as very brittle and easy to break.

1- CERAMIC MACHINING

ceramic green machining

1- CERAMIC MACHINING

Mechanical machining

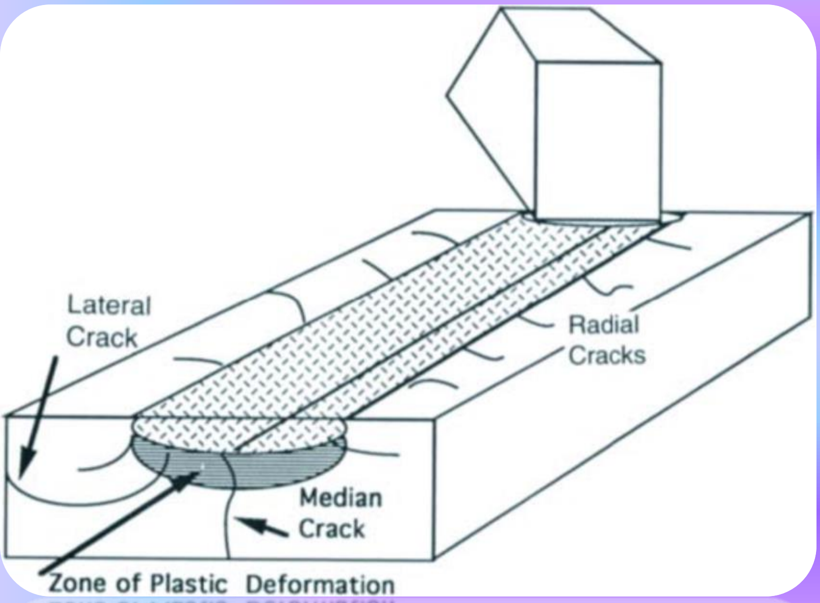
- **Mechanical machining: (small abrasive), hard part having sharp edges.**

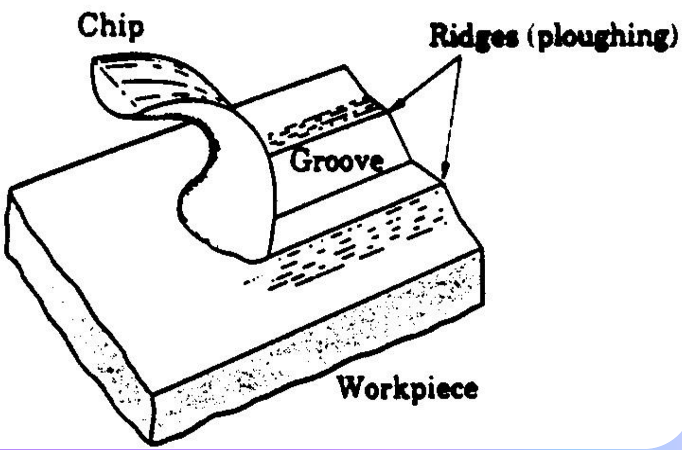
Small amount of metal can be removed as tiny metal chips

a series of abrasive steps are used, decreasing the size of the abrasive as one approaches the final piece.

material deformation caused by machining with a single abrasive piece.

1- CERAMIC MACHINING





1- CERAMIC MACHINING

2-Sand blast

If spray dried powders were used, then the surface roughness could be determined by the agglomerate size or the particle size depending upon whether pressing pressures used in green body fabrication were higher than the agglomerate yield stress, resulting in deformation and internal compaction of the aggregates.

Section 8

1- CERAMIC MACHINING

-The components of a sandblasting operation

- Compressed air supply

- Sandblast machine

- Remote control deadman valves for sandblast machine

Hopper feed with remote controls

- Abrasive metering valve

- Sandblast hose

-Nozzle pressure

1- CERAMIC MACHINING

WATER JET MACHINING

Water jet acts like a saw and cuts a narrow groove in the material.

Pressure level of the jet is about 400MPa.

Advantages

- no heat produced

- cut can be started anywhere without the need for holes

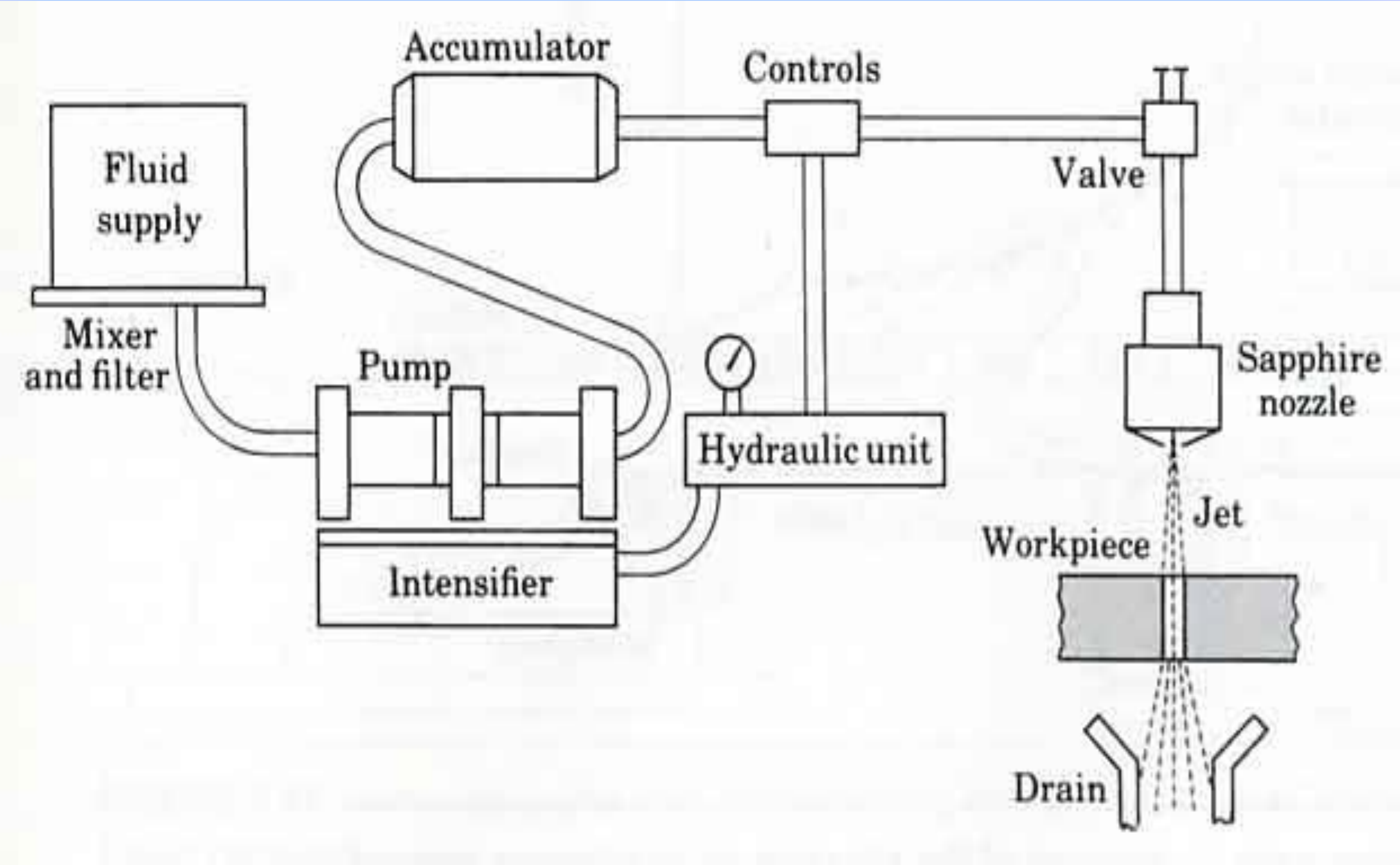
- burr produced is minimum

- environmentally safe and friendly manufacturing.

Application – used for cutting composites, plastics, fabrics, rubber, wood products …….etc.

Also used in food processing industry

1- CERAMIC MACHINING



1- CERAMIC MACHINING

Chemical machining,

such as the hydrofluoric acid, HF, attack of silica glass, and the molten sodium borate, Na_2B_4OT, attack of alumina.

Local melting of material by suitable diluent.

Removing speed of material independence on hardness and on toughness,

Surfaces with complicated shape with high accuracy and quality,

Here is no originated heat and mechanical influence area,

Large areas – more economical than milling

1- CERAMIC MACHINING

Machining by active substance

Machining shape difficult surfaces.

Semi-solid substance of cellulose (electro gel) impregnated by acid is attach to the work piece surface.

In the place of contact the work piece is melted.

Is possible to achieve step by step removing until depth 10 mm.

Dimension accuracy is from 0,02 to 0,07 mm.

For acceleration of process is possible to connected electric voltage until 10V.

1- CERAMIC MACHINING

Electrical Discharge Machining EDM

Working Principle

Electrode Material: Graphite

Material is removed from the work piece by a series of rapidly current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage.

Electrodes:

One of the electrodes – ‘tool-electrode’ .

Other electrode – ’work piece-electrode ’.

Distance: between the two electrodes is reduced .

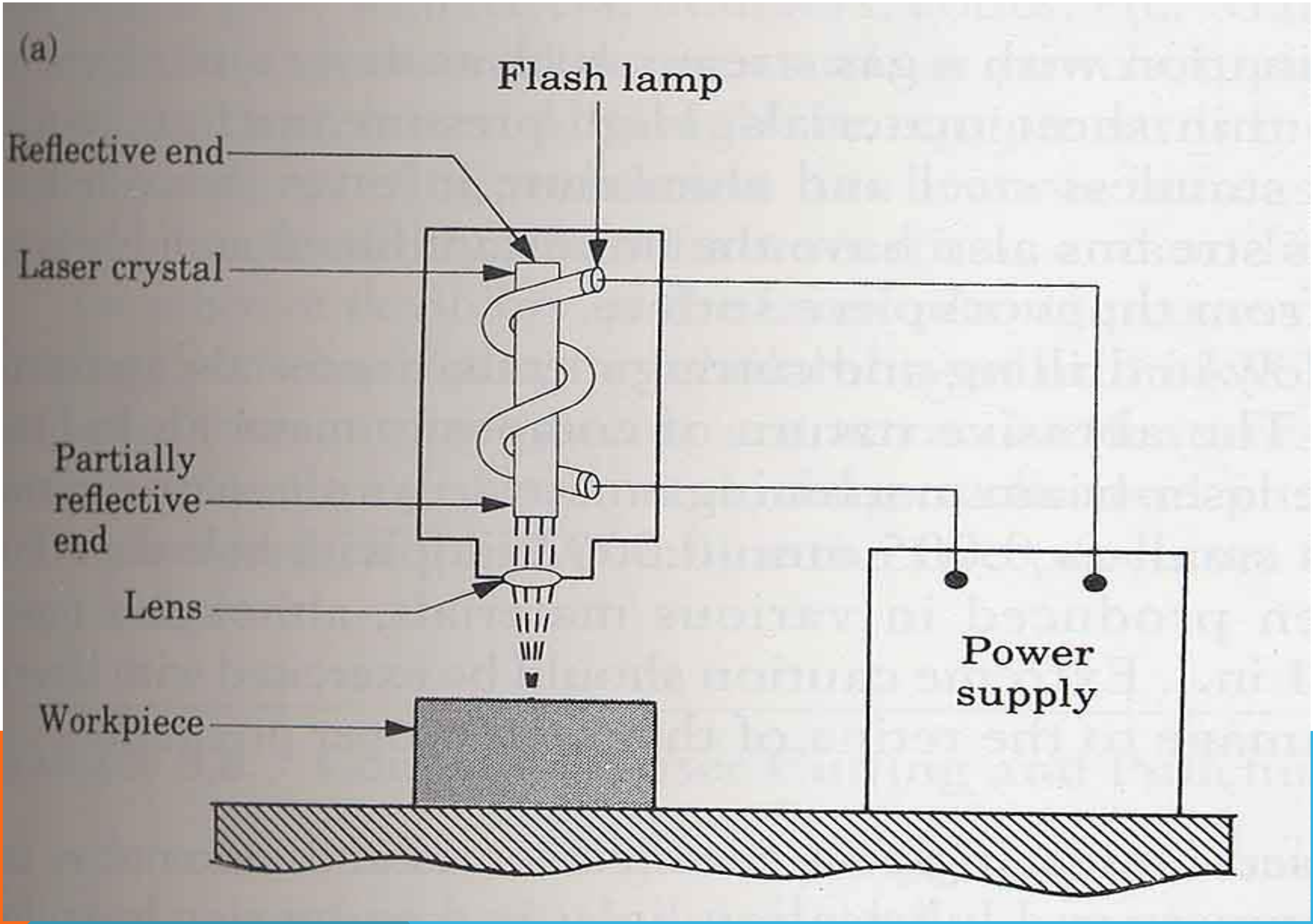
1- CERAMIC MACHINING

LASER BEAM MACHINING

In LBM laser is focused and the work piece which melts and evaporates portions of the work piece.

Low reflectivity and thermal conductivity of the work piece surface, and low specific heat and latent heat of melting and evaporation – increases process efficiency.

Application - holes with depth-to-diameter ratios of 50 to 1 can be drilled.


(a)
Flash lamp
Reflective end
Laser crystal
Partially reflective end
Lens
Workpiece
Power supply

1- CERAMIC MACHINING

Electron beam machining (EBM)

similar to LBM except laser beam is replaced by high velocity electrons.

when electron beam strikes the work piece surface, heat is produced and material is vaporized.

surface finish achieved is better than LBM.

Used for very accurate cutting of a wide variety of metals.

Electron-Beam Machining Process

Figure illustration of the electron-beam machining process. Unlike LBM, this process requires a vacuum, so work piece size is limited to the size of the vacuum

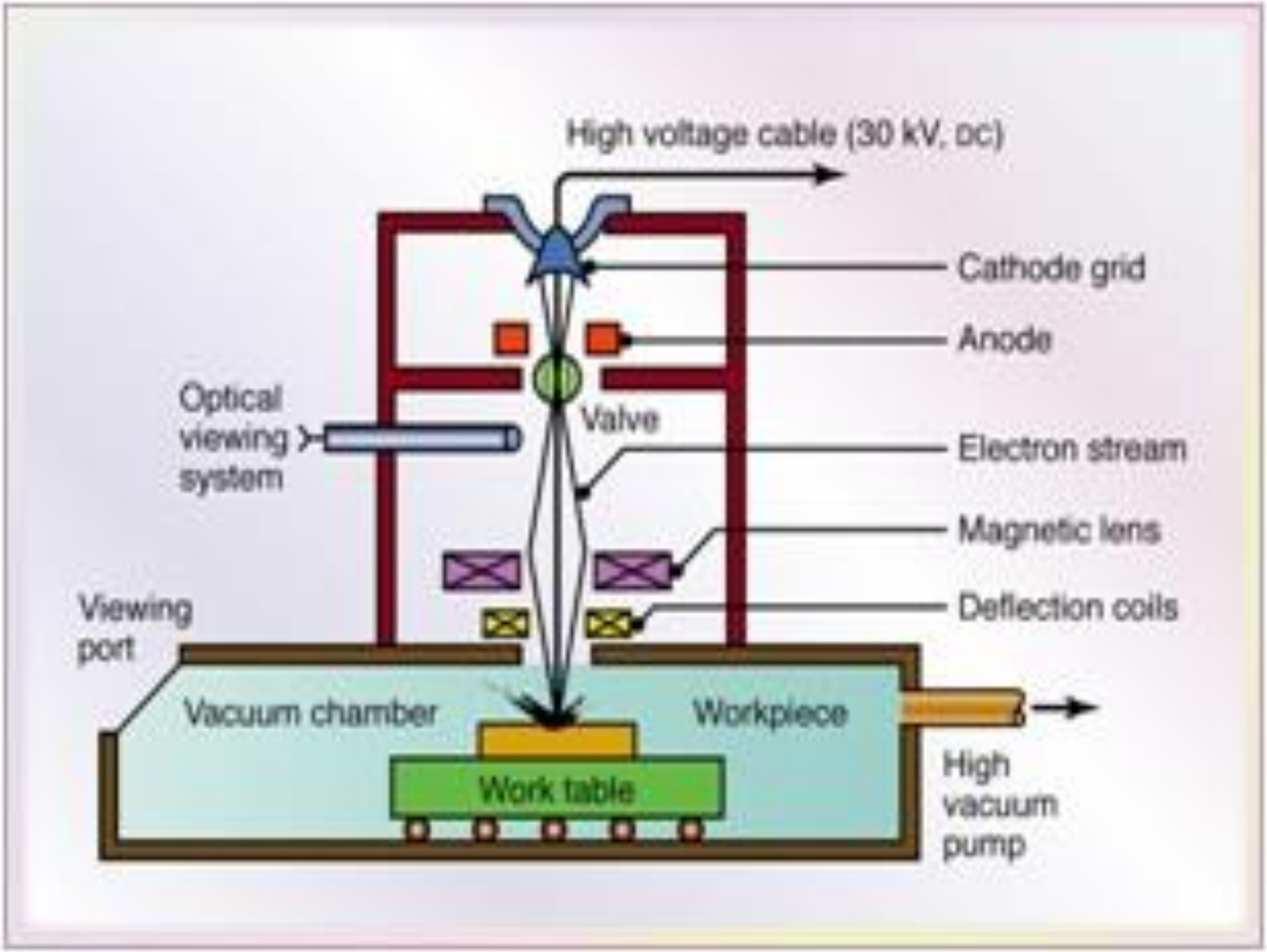

High voltage cable (30 kV, DC)
Cathode grid
Anode
Optical viewing system
Valve
Electron stream
Magnetic lens
Deflection coils
Viewing port
Vacuum chamber
Workpiece
Work table
High vacuum pump

PHOTO ETCHING

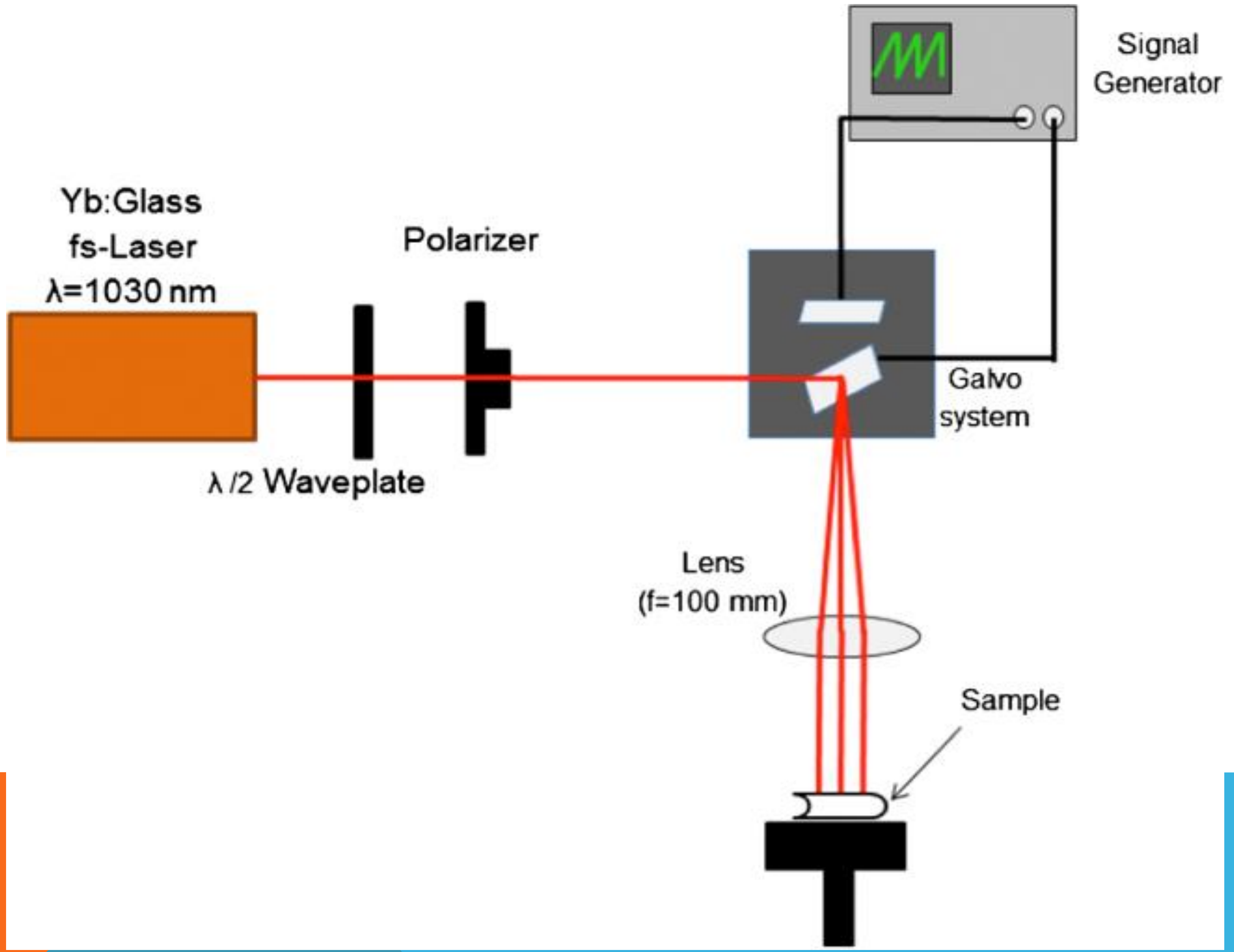
pattern production – laser beam creating the sign in the photographical film.

This picture ((patern).) is frequently applied to photo tool.

Preparation of surface – surface must be cleaned, grease removing, eventually to pickle,

Coating of photoresist – it is polymer sensitive to ultraviolet emission is necessary to dry him.

Processing of photoresist – through the pattern is photoresist emissed by light of suitable wave length (UV) and is created mask (positive, negative).


Signal
Generator
Yb:Glass
fs-Laser
λ=1030 nm
Polarizer
Galvo
system
λ /2 Waveplate
Lens
(f=100 mm)
Sample

Effect of Machining on Ceramic Strength

To understand the effects of machining on the strength of a ceramic material, we must examine the interactions that occur at the tool wookpiece interface.

The abrasive particles can make a series of grooves into the surface of the ceramic,so very high stress and temperature occur , often broken and deformed.

These cracks are usually the deepest and produce the greatest strength

reduction in ceramics. Cracks lateral and parallel to the surface extend

away from the plastic zone.

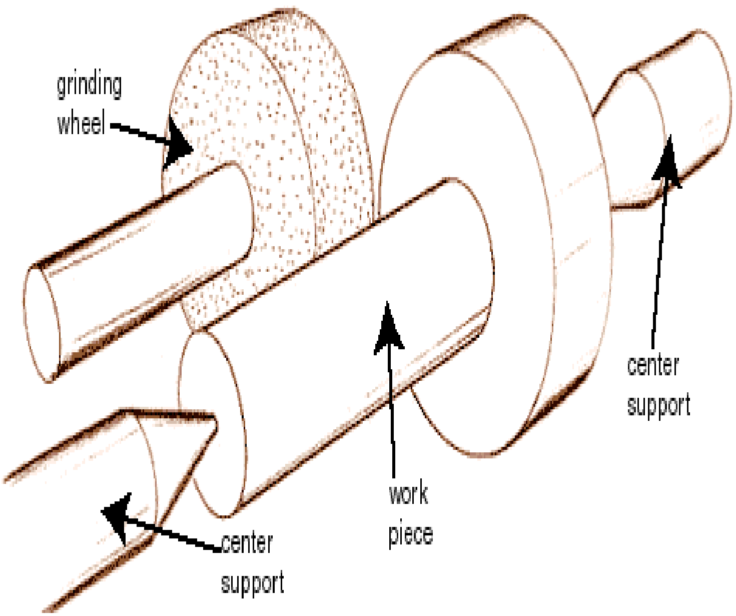
They result from high tensile stress at the groove edge as the abrasive particle passes. Lateral cracks tend to curve toward the surface and often result in a chip being sprawled off. Lateral cracks are parallel to the surface, and they do not lead to stress concentration during subsequent mechanical loading.

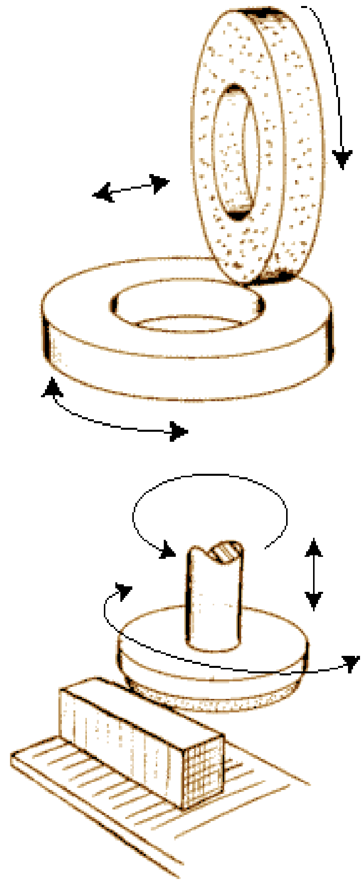
1- CERAMIC MACHINING

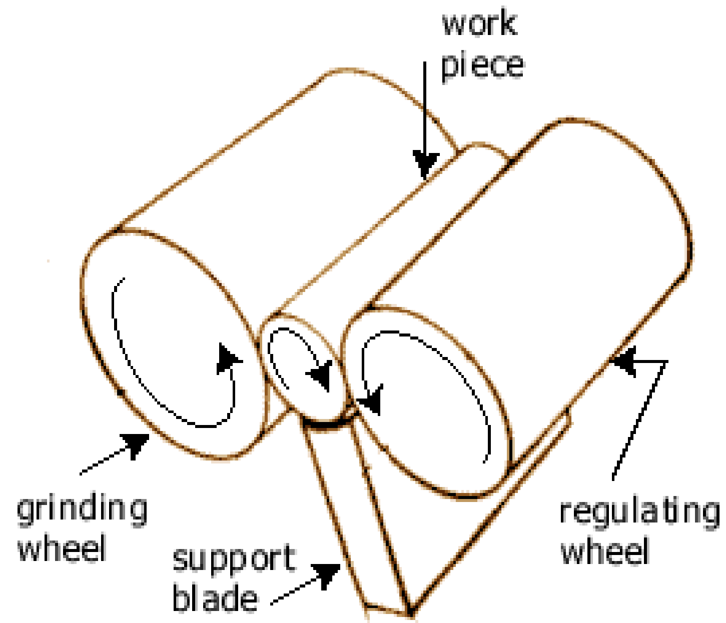
2- Ceramic Grinding

Sintered pieces can warp during densification. As a result they must be shaped to give the desired dimensional to the final ceramic piece .The shaping process is typically performed by grinding and polishing .

Grinding uses an abrasive encrusted tool such as a grinding wheel .







Centered cylindrical grinding	Flat surface grinding	Centerless grinding

1- CERAMIC MACHINING

-Polishing uses a free abrasive acting between a moving surface and the fixed ceramic surface.

Two examples of polishing include

(1) Lapping, where an abrasive suspension is used between a rotating aluminum metal plate and a fixed ceramic piece .

(2) Sand blasting : where abrasive grit is directed at a ceramic surface by a high speed air jet.

Because sintered ceramics are very hard, diamond encrusted tools and diamond grit are often used .

- These grinding and polishing tools are expensive, and for that reason, machining to near net shape at the green stage is desirable so that a large amount of the machining is not necessary after the ceramic has been sintered.

Grinding wheels come in a number of configurations and compositions. Coarse abrasives are used for rough machining, where rapid stock removal is desired.

Fine abrasives are used for final machining, where close tolerances and smooth surface finishes are required. This procedure removes the surface flaws created by the large-sized abrasives and improves the strength of the ceramic, as will be discussed later .

Effect of Grinding Direction on Ceramic Strength

Most ceramics are machined with tools containing abrasive particles rather than just a single one.

However, it is likely that the resulting surface flaws are the same as discussed previously with median and radial cracks concentrating stress during loading of the ceramic, thus controlling the strength.

The surface flaw that will control the strength depends on the relative orientation of the grinding grooves to the direction in which the stress will be applied. This is shown schematically in Figure below for a specimen loaded in a bending mode.

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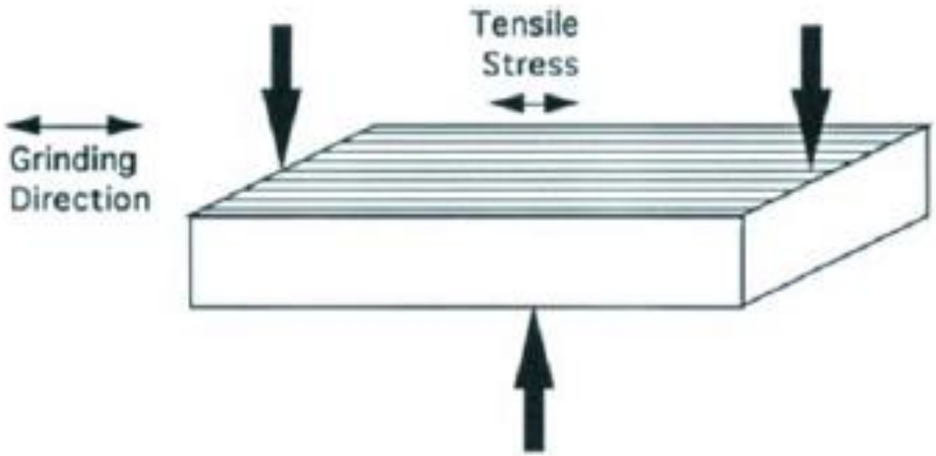
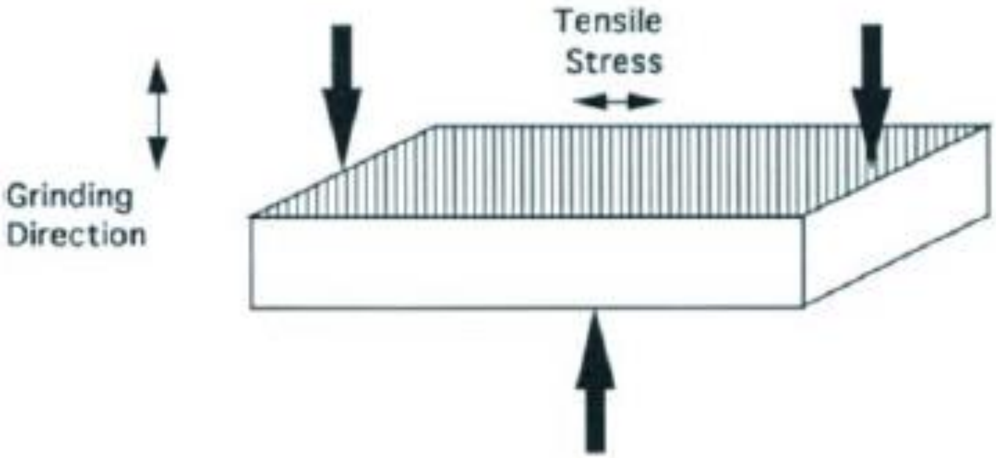


Loading of Radial Cracks is Responsible for Weakness



Loading of Median Cracks is Responsible for Weakness

- As a load is applied this specimen begins to bend.

Stress concentration will occur at the tips of the cracks perpendicular to the stress axis but not at the cracks parallel to this stress axis.

So, for specimens ground in a longitudinal direction, stress concentration will occur at the radial transverse cracks, leading to weakness.

For specimens ground in the transverse direction, stress concentration will occur at the median or longitude cracks, leading to weakness.

Because the median cracks are usually the largest ones caused by grinding, it is expected that the strength is the lowest for the transversely ground samples where the grooves and the median cracks are perpendicular to the tensile stress axis.

3- Coating and Glazing

At the ceramic surface, the liquidified powder cools and solidifies, forming a coating.

With glazing, a ceramic powder suspension or slip is used to coat the ceramic surface.

The suspension is dried, the binder burned out and then sintered, often using either liquid phase sintering or viscous sintering of glassy phases to form a coating.

Glazing is used to either hermetically seal the ceramic after manufacture to prevent its degradation (either strength or environmental attack) during use or to seal