W28 MACHINING HARD MATERIALS

In the fabrication of electrical, electronic or optical components it is often necessary to machine materials such as aluminium oxide, ferrites, tungsten... for use as insulators, electrical grids, diaphragms, etc. A whole range of machining techniques may be used depending on the material involved.

Abrasion

Abrasion consists in the removal of a thin surface layer, about one micron thick. The hardness of the abrasive used depends on the material. A tolerance of about one micron can be obtained. The surface finish can be improved by reducing the abrasive grain size, but it depends on the morphology of the surface.

Grinding

For this purpose a grinding wheel consisting of a binding material in which the abrasive is dispersed is used, at a linear speed of about 21 m/s. Ideally, only abrasive grains with sharp cutting edges should be used, so that as blunting progresses the grains are removed from the binding material. Soft binding materials are generally preferred for machining hard materials (except with diamond dust) and the porosity of such grinding wheels is usually suitable also for soft materials.
The apparent "hardness" of the grinding wheel increases with the rotation speed so that the quality of the finish obtained is related to the rate of displacement of the component to be machined.
Flat and cylindrical grinding (interior and exterior), profile screw cutting, form and coordinate machining may be performed with normal grinding wheels.
For finish-grinding rough-machined components made from most metals and alloys, abrasive grains such as corundum, emery, aluminium oxide or silicon carbide are used.
Various types of diamond grinding wheels (cylindrical, tubular) are used for machining and finishing components made from very hard materials. These are in general reserved for use with ceramics, oxides, carbides...

Ultrasonic machining

With this technique free abrasive grains are agitated by ultrasound waves emitted from a tuned sonotrode, the frequency used being some tens of kHz.
The power per unit surface area machined and the machining pressure are dependent on the hardness of the material involved. The working electrode, generally made of unhardened steel, has the contours of the imprint to be machined and the abrasives

used are either silicon carbide, boron carbide or diamond. Complex components may be produced in this way. The technique is particularly useful for machining non-conducting materials such as glass, ceramics, oxides and carbides.

Spark-machining

In this micro-machining technique an electric discharge between a suitable electrode (cathode) and the component to be machined (anode) results in removal of material from the electrodes, more particularly from the anode. The dielectric liquid of the cell helps to remove the eroded residue.
The size of the craters formed is proportional to the energy of the discharge. For a given cathode the machining speed increases with the energy and frequency of the discharge but is limited when the frequency is increased by the dielectric de-ionisation process which allows only small erosion rates in case of smooth finishing (small craters formed). For a given discharge energy the erosion speed passes through an optimum value as the cathode surface increases.
The discharge gap also modifies the machining speed. A servo-mechanism based on the discharge sparking potential is used to maintain an optimum gap within the limits of no-discharge and short-circuit regimes. The maximum gap, which increases with the discharge energy, must be as small as possible for precision work compatible with an efficient removal of residue which otherwise would decrease the machining speed, for example as the machined depth increases.
The machining of electrically conducting materials is essentially dependent on the thermal properties of the material (melting point, boiling point, latent heat for change of state, specific heat, thermal conductivity) and on the composition.
The cathode is normally made of either electrolytic copper or copper alloys (brass, Cu-Te, Cu-Cr). For precision machining, hard refractory materials such as W, Cu-W, W-carbide or special graphite cathodes are used, because of their slow erosion rate.
Cathode wear can be reduced by modifying the dissymetry, intensity and lifetime of the discharge and the turbulence of the dielectric liquid. The wear however is greater when a smooth anode surface finish is required.
This technique lends itself to the production of complicated structures with blind-holes, slits, etc... It is particularly useful for machining hard, electrically conducting or refractory materials for which chemical machining is difficult, e.g. W, Ta, Nb, tool steels, Al, Cu, Pb.

Results

The methods outlined above allow high precision machining of most hard materials for which conventional processes are unsuitable. For example 0.1 mm slits and 1 mm diameter holes can be machined with 10 % precision for depths up to 5 mm (less than 0.2 mm diameter for 1 mm depth). The average roughness obtained is about 0.1 μm if the grain size of the material involved is sufficiently fine.

References

Further information can be obtained from K. Kull, M. Sartorio, M. Steiner, Central Workshops, SB Division, CERN.

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