6.5. Ultrasonic Machining, Water Jet Machining and Abrasive Water Jet Machining

10.1 Ultrasonic Machining

10.1.1 Introduction

Ultrasonic machining is a non-traditional machining process. USM is grouped under the mechanical group NTM processes. Fig: 10.1 briefly depicts the USM process.

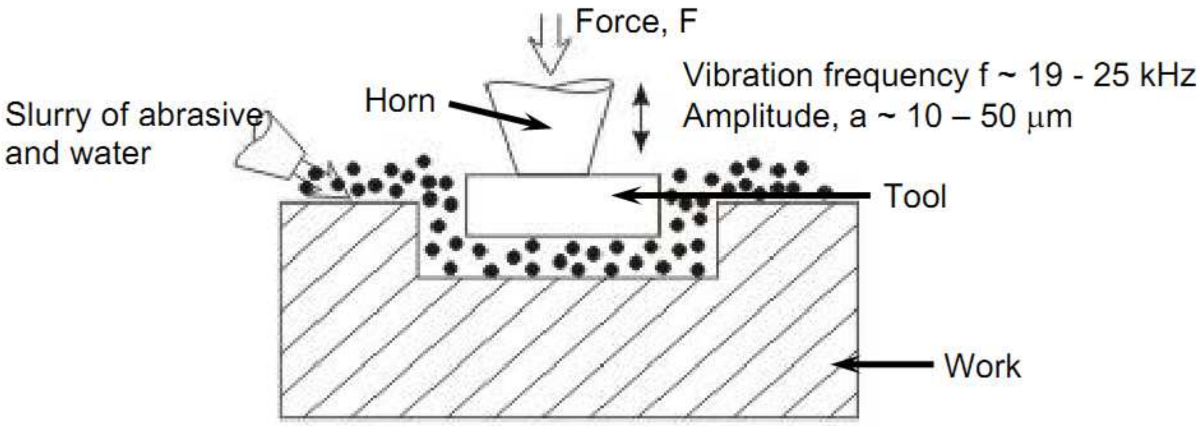

Fig: 10.1 The USM Process

In ultrasonic machining, a tool of desired shape vibrates at an ultrasonic frequency (19 ~ 25 kHz) with an amplitude of around 15 – 50 µm over the workpiece. Generally the tool is pressed downward with a feed force, F. Between the tool and workpiece, the machining zone is flooded with hard abrasive particles generally in the form of water based slurry. As the tool vibrates over the workpiece, the abrasive particles act as the indenters and indent both the work material and the tool. The abrasive particles, as they indent, the work material, would remove the same, particularly if the work material is brittle, due to crack initiation, propagation and brittle fracture of the material. Hence, USM is mainly used for machining brittle materials {which are poor conductors of electricity and thus cannot be processed by Electrochemical and Electro-discharge machining (ECM and EDM)}.

10.1.2 Machine

The basic mechanical structure of an USM is very similar to a drill press. However, it has additional features to carry out USM of brittle work material. The workpiece is mounted on a vice, which can be located at the desired position under the tool using a 2 axis table. The table can further be lowered or raised to accommodate work of different thickness. The typical elements of an USM are (Fig. 10.2)

- Slurry delivery and return system
- Feed mechanism to provide a downward feed force on the tool during machining
- The transducer, which generates the ultrasonic vibration
- The horn or concentrator, which mechanically amplifies the vibration to the required amplitude of 15 – 50 μm and accommodates the tool at its tip

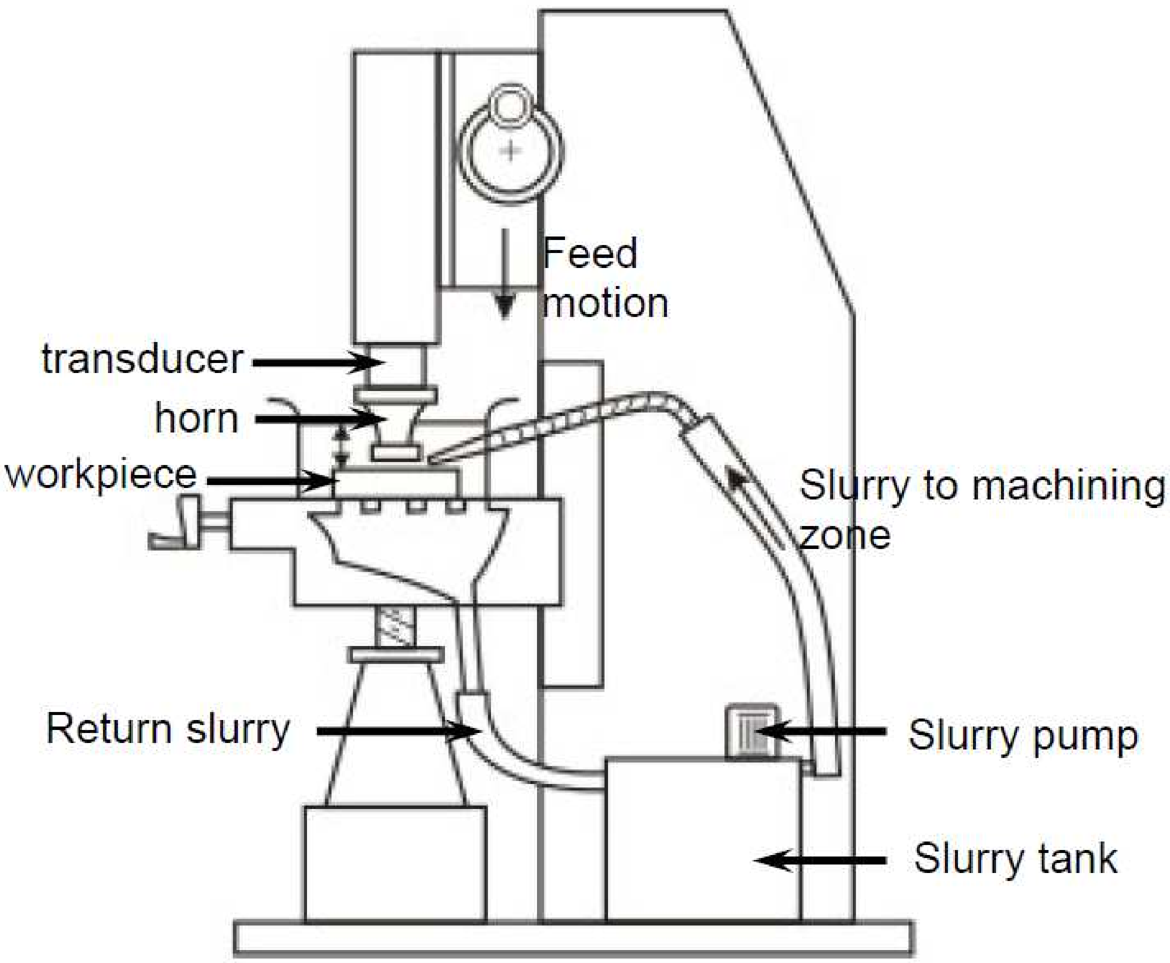

Fig: 10.2 Schematic view of an Ultrasonic Machine

The ultrasonic vibrations are produced by the transducer. The transducer is driven by suitable signal generator followed by power amplifier. The transducer for USM works on the following principle.

- Piezoelectric effect
- Magnetostrictive effect
- Electrostrictive effect

Magnetostrictive transducers are most popular and robust amongst all. Fig. 10.3 shows a typical magnetostrictive transducer along with horn. The horn or concentrator is a wave-guide, which amplifies and concentrates the vibration to the tool from the transducer.

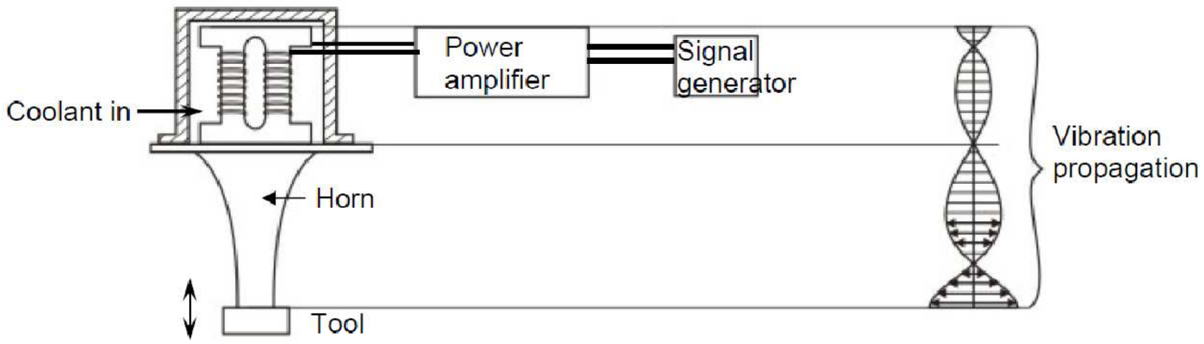

Fig: 10.3 working of horn as mechanical amplifier of amplitude of vibration

The horn or concentrator can be of different shape like

- Tapered or conical
- Exponential
- Stepped

Machining of tapered or stepped horn is much easier as compared to the exponential one. Fig. 10.4 shows different horns used in USM

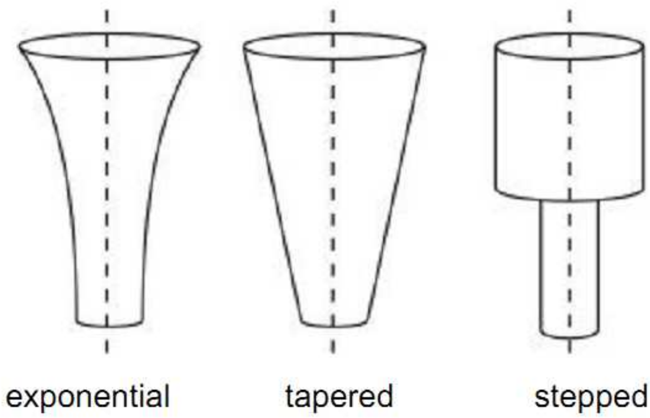

Fig: 10.4 Different Horns used in USM

Applications

- Used for machining hard and brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.

- Used for machining round, square, irregular shaped holes and surface impressions.
- Machining, wire drawing, punching or small blanking dies.

Limitations

- Low MRR
- Rather high tool wear
- Low depth of hole

10.2 PROCESSES USING WATER JETS

The two processes described in this section remove material by means of high-velocity streams of water or a combination of water and abrasives.

10.2.1 Water Jet Cutting

Water jet cutting (WJC) uses a fine, high-pressure, high-velocity stream of water directed at the work surface to cause cutting of the work, as illustrated in Figure 10.2.1. To obtain the fine stream of water a small nozzle opening of diameter 0.1 to 0.4 mm is used. To provide the stream with sufficient energy for cutting, pressures up to 400 MPa are used, and the jet reaches velocities up to 900 m/s. The fluid is pressurized to the desired level by a hydraulic pump. The nozzle unit consists of a holder made of stainless steel, and a jewel nozzle made of sapphire, ruby or diamond. Diamond lasts the longest but costs the most. Filtration systems must be used in WJC to separate the swarf produced during cutting.

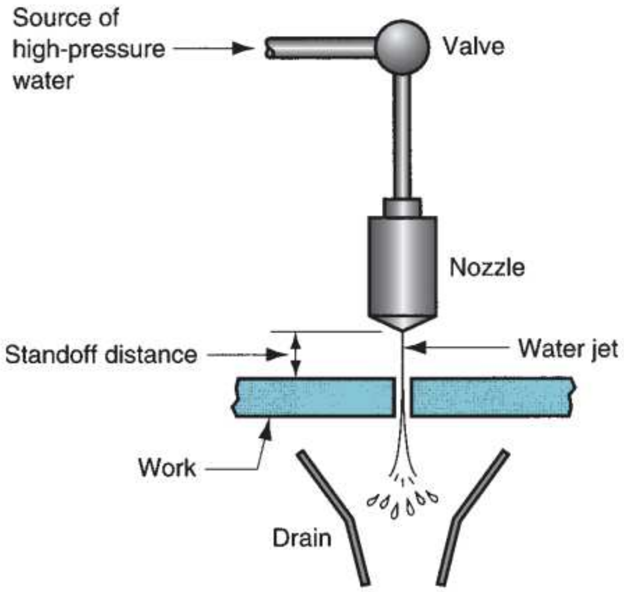

Fig: 10.5 Water jet cutting

Cutting fluids in WJC are polymer solutions, preferred because of their tendency to produce a coherent stream. We have discussed cutting fluids before in the context of conventional machining, but never has the term been more appropriately applied than in WJC.

Important process parameters include standoff distance, nozzle opening diameter, water pressure, and cutting feed rate. As in Figure 10.5, the ***standoff distance*** is the separation between the nozzle opening and the work surface. It is generally desirable for this distance to be small to minimize dispersion of the fluid stream before it strikes the surface. A typical standoff distance is 3.2 mm. Size of the nozzle orifice affects the precision of the cut; smaller openings are used for finer cuts on thinner materials. To cut thicker stock, thicker jet streams and higher pressures are required. The cutting feed rate refers to the velocity at which the WJC nozzle is traversed along the cutting path. Typical feed rates range from 5 mm/s to more than 500 mm/x, depending on work material and its thickness. The WJC process is usually automated using computer numerical control or industrial robots to manipulate the nozzle unit along the desired trajectory.

Water jet cutting can be used effectively to cut narrow slits in flat stock such as plastic, textiles, composites, floor tile, carpet, leather and cardboard. Robotic cells have been installed with WJC nozzles mounted as the robot's tool to follow cutting patterns that are irregular in three dimensions, such as cutting and trimming of automobile dashboards before assembly.

In these applications, advantages of WJC include:

1) No crushing or burning of the work surface typical in other mechanical or thermal processes
2) Minimum material loss because of the narrow cut slit
3) No environmental pollution
4) Ease of automating the process

A limitation of WJC is that the process is not suitable for cutting brittle materials (e.g.,glass) because of their tendency to crack during cutting.

10.2.2 Abrasive Water Jet Cutting

When WJC is used on metallic workparts, abrasive particles must usually be added to the jet stream to facilitate cutting. This process is therefore called ***abrasive water jet cutting*** (AWJC). Introduction of abrasive particles into the stream complicates the process by adding to the number of parameters that must be controlled. Among the additional parameters are abrasive type, grit size, and flow rate. Aluminum oxide, silicon dioxide and garnet (a silicate mineral) are typical abrasive materials, at grit sizes ranging between 60 and 120. The abrasive particles are added to the water stream at approximately 0.25 kg/min after it has exited the WJC nozzle.

The remaining process parameters include those that are common to WJC: nozzle opening diameter, water pressure and standoff distance. Nozzle orifice diameters are 0.25 to 0.63 mm – somewhat larger than in water jet cutting to permit higher flow rates and more energy to be contained in the stream before injection of abrasives. Water pressures are about the same as in WJC. Standoff distances are somewhat less to minimize the effect of dispersion of the cutting fluid that now contains abrasive particles. Typical standoff distances are between ¼ and ½ of those in WJC.