Advanced Manufacturing Processes
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Module - 3
Advanced Machining Processes
Lecture - 3
Abrasive Jet Machining (AJM)

Welcome to this session on abrasive jet machining process under the course advanced manufacturing processes. In the previous session we have discussed a process, again a mechanical based process abrasive flow machining process. This is another process that works on mechanical principle.

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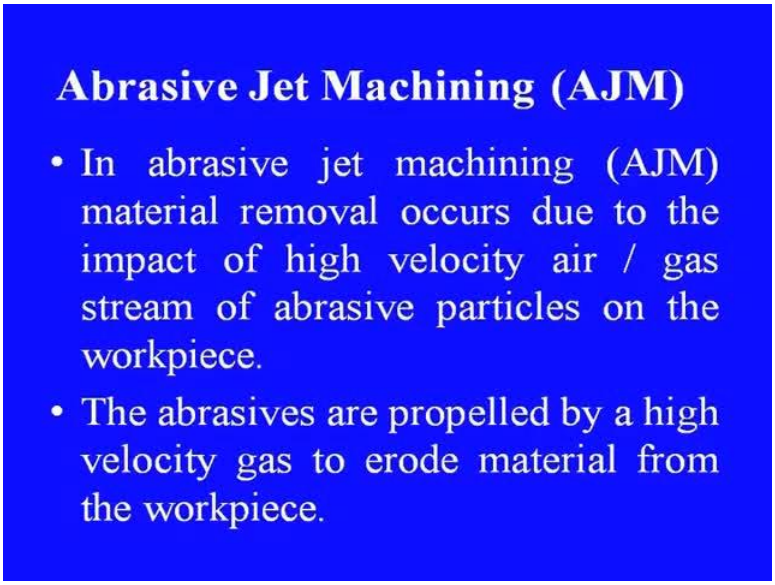

In abrasive jet machining material removal occurs due to the impact of high velocity air or gas stream of abrasive particles on the work piece. The abrasives are propelled by a high velocity gas to erode material from the work piece. As an outcome of the impact of the abrasive particles on the work piece, tiny brittle fracture occurs at the surface of the work piece and the carrier gas carries away the fractured fragments. This process is also called abrasive blasting process. The basic principle of this process can be seen like this.

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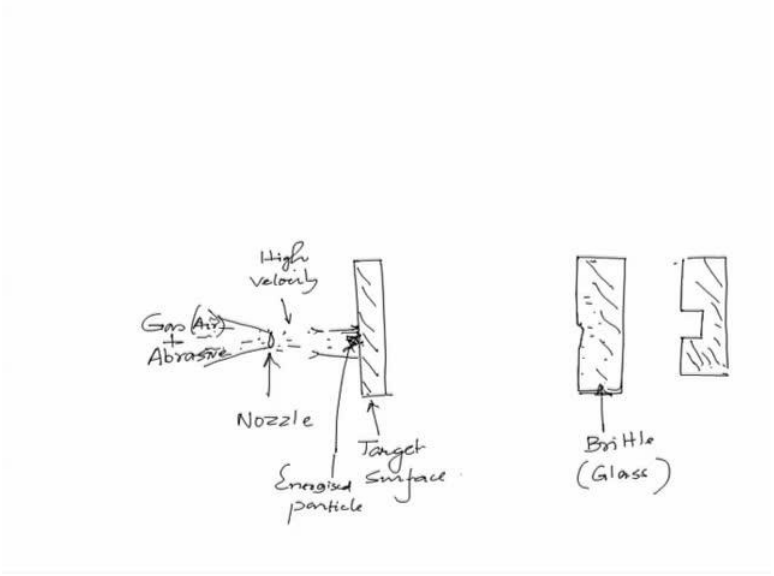

If this is a work surface which is to be either cut or finished. Then the abrasive jet, one abrasive jet will be just forced from this nozzle. So, this is the nozzle. Nozzle and this will be directed towards this surface, this is we call that target surface and this will be at very high speed. This will be moving towards the surface and here a gas will be there which is in most of the cases it is air or it can be a argon gas or it can be other generally neutral gas plus abrasive materials.

So, this is a mixture which is moving at very high velocity, this velocity is very high and this will be striking on this work surface work surface at with very high energy impact energy. Now, these particles abrasive particles will strike this this work surface, this particles are say energized particle and they will cause stresses on this surface. Because of this stresses this material will get fractured and the material on subsequent impact on this surface the material will get removed finally, like this.

So, this portion is removed and finally, if we continue this the material will get cut according to the size of the jet. And this is like this. Now, here in this process there are several factors which are very, very important. One important factor is this distance and then the angle of this nozzle at which it is striking this work surface. Of course, the concentration of the abrasive particles with this gas is also another important factor, but the limitation, basic limitation of this process is that this material, work material should be preferably brittle like say glass, etcetera.

In these brittle materials, this brittle fracture phenomenon occurs more readily and we get measuring effect more prominently. This process is also known by several other names like abrasive micro blasting, pencil blasting, micro abrasive blasting etcetera. This abrasive jet machining process is an effective measuring matter for hard and brittle materials such as glass, silicon, tungsten and ceramic. As we know tungsten and tungsten carbide these materials are very, very hard and very difficult to be machined by other machining methods. However, this process like abrasive jet machining process is useful for machining or at least finishing these materials like tungsten carbide or tungsten, tungsten or silicon etcetera apart from of course, glass.

Typically, the process is used for cutting intricate shapes or forms of specific edges. The process is inherently free from chatter, vibration and heat problems because the tool never touches the substrates. In fact there is no conventional tool here. Here the tiny abrasive particles that forms the tool, we can say these tools are micro tools which are coming at a very high velocity with high energy along with the gas stream.

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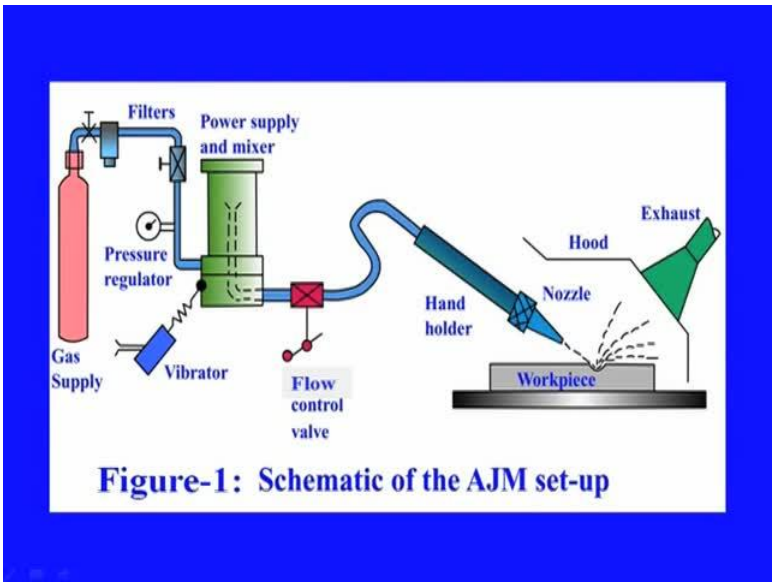

The schematic of this process is like this. So, this is what the nozzle I was talking about through which the mixer of the abrasive and air is coming at a very high velocity. And this is the work piece on which this mixer of abrasive particles and air or other gas generally some neutral gas like argon etcetera are used, are striking on this work piece surface. As I told earlier the angle at which this is striking the work piece is very, very

important. In this particular configuration it is shown the angle is something around 45 to 50 degree with this work piece surface, but not necessarily. It can be 90 degree as well or it can be at 60 degree or something like that.

However, if we make this angle smaller and smaller the effectiveness of this cutting jet will come down and again the distance from this nozzle tip to this work piece is also very vital. We will discuss this point later on with different schematic. Here the other arrangements are shown like this is the gas intensifier or the gas supply pressurized gas device. This comes through this nozzle or some gas flow control device and here this is one of the very crucial component in this entire set up in which the gas and the abrasive gets mixed.

And since we know the abrasive particles can abrade any surface therefore, during mixing itself the inner surface of this mixing chamber gets abraded by this abrasive particles. More over to get proper mixing of this gas and the abrasive particles these are kept at some frequency vibration vibrated at some frequency and therefore, the problem becomes magnified. Therefore, the life of this particular component is generally very less and this causes the increase in the cost of operating this particular setup. Generally, tungsten carbide material is used for this chamber as well as this nozzle which also experiences the abrading high velocity abrading particles while flowing through this.

This pressurized gas and abrasive mixture is then being flown through this whole system, through this flow control valve and this can be made handheld as well as it can be mechanized, at times it can be robo controlled as well and can be made to target the point where the cutting or the finishing is to be carried out. However, one big problem with this particular process is the control of the abrasive particles after working as we know all, almost all abrasive particles are injurious for our health, inhaling this particles can cause disorder in our biological system.

Therefore, the control or managing of this particles which will be flowing with this gas mixer is a, is an important task for which different are being placed like here as shown here a covered hood type of arrangement have been have been shown through which the abrasives as well as these gas can be sucked or taken away for proper handling of these particles. Otherwise, this can cause environmental problems and health hazards to the operators. This arrangements can be made flexible as far as, as far as the length of

cutting or machining is concerned, as far as the arrangement of the angle of this jet is concerned etcetera. Now, let us quickly look at different advantages of this process.

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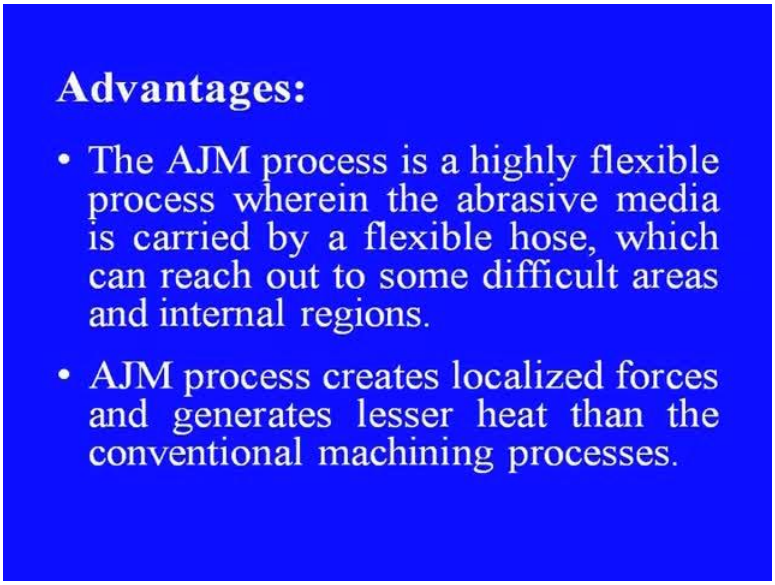

This process is considered highly flexible where the abrasive media is carried by a flexible hose which we have already seen in the previous schematic. And this can reach out to some difficult areas and internal regions. Thus abrasive jet machining process creates localized forces and generates lesser heat than the conventional machining processes. Basically, it is a mechanical process where no heat is generated and it is eroding in nature. There is no damage to the work piece surface and also the process does not have tool work piece contact. Hence, lesser amount of heat is generated. The power consumption in abrasive jet machining process is considerably low.

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Let us also look at the disadvantages of this abrasive jet machining process. The process as we have already discussed is basically a finishing process or low level cutting process. Therefore, the material removal rate in this process is usually very low and as I have already indicated the process is also limited to brittle and hard materials. For ductile materials the cutting may not be very, very effective rather there will be flow of material and actual material removal will not take place and thereby we may not get the appropriate result. The ware rate of nozzle is very high which already I have indicated.

The mixing chamber and the nozzle these two are the very critical components and they need to be changed very frequently because of the wear. The process results in poor machining accuracy because of the deflection of the of the jet that is striking on the surface. Unless we control the jet in a proper way there is a possibility of straying of the materials and thereby it may affect on accuracy of the machined part. Also, as I have already indicated the process is not environment friendly, not operator friendly.

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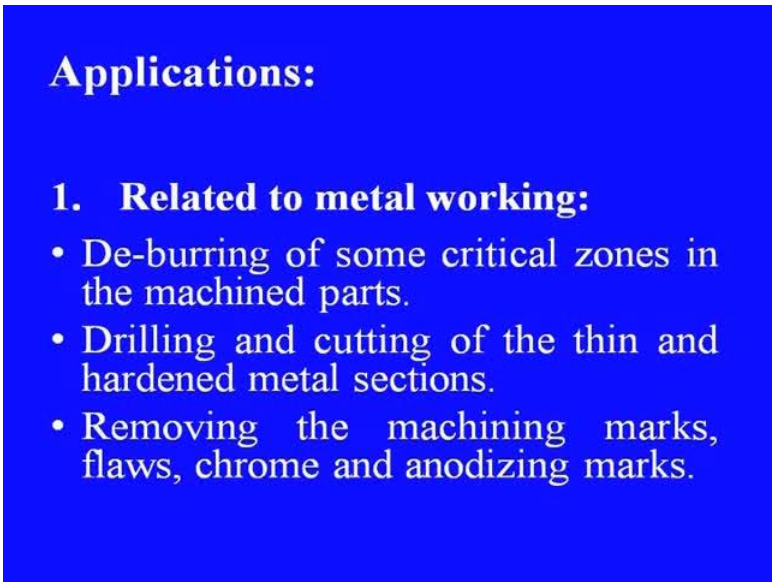

Now, let us look at the applications, probable applications of this particular process. This applications we can group under few headings like related to metal working. So, this process can be used for de burring of some critical zones in the machined parts, then drilling and cutting of the thin and hardened metal sections because this is essentially a process for hard and brittle materials, removing the machining marks, flaws, chrome and anodized marks etcetera. The next category of application can be related to glass working.

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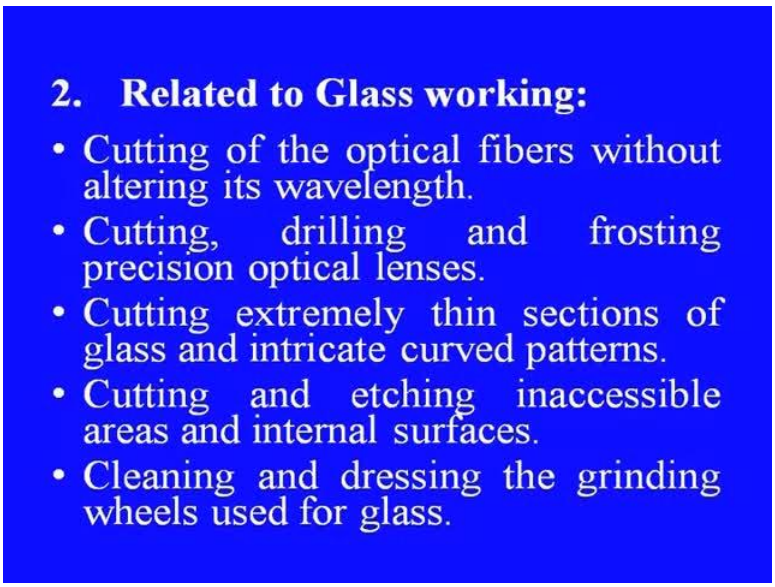

The processes I already indicated, mostly suitable for glass and related materials. So, cutting of optical fibers without altering its wavelength is one of the most important applications of this particular process. Otherwise, handling of optical fibers itself is a hazardous act. However, with application of this process the task becomes simpler. Cutting, drilling and frosting of precision optical lenses can be done with help of this process. Cutting extremely thin sections of glass and intricate curved patterns can be achieved with this particular process.

Cutting and etching of inaccessible areas and internal surfaces can be done, then cleaning and dressing the grinding wheels used for glasses can also be carried out. Another category of application is related to grinding which is cleaning the residues from diamond wheels, dressing of wheels of any shape and size for this purposes this process can be effectively utilized. Now, let us look into the working principles of abrasive jet machining.

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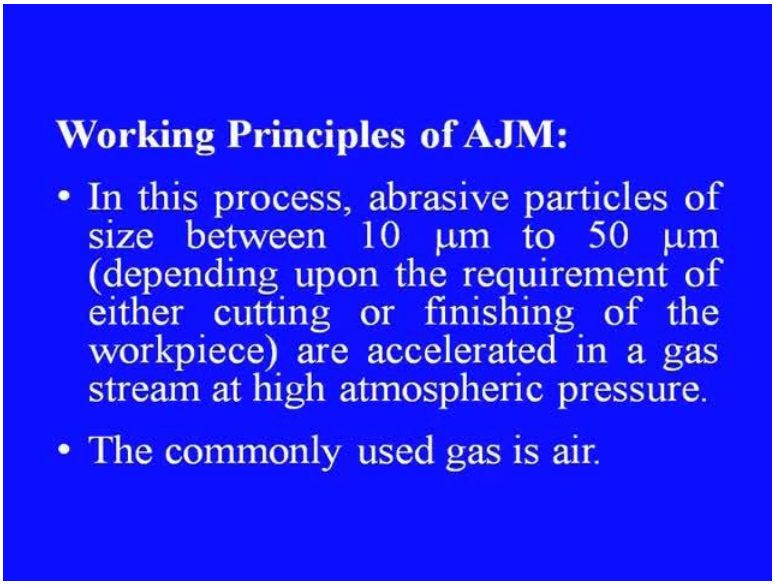

In this process as I have already indicated abrasive particles of size between 10 micro meter to 50 micro meter average diameter depending upon the requirement of either cutting or finishing of the work piece are accelerated in a glass, in a gas stream at very high atmospheric pressure. Finer finer grades of abrasive particles are used for basically for cleaning and finishing operations and coarser grades of abrasive particles are used basically for cutting operations.

This commonly used gas is generally air, the abrasive particles are directed through the nozzle towards the work piece surface, where cutting or finishing is to be carried out. This I have already indicated at beginning of this session. The distance between the tip of the nozzle and the work surface is normally within 1 millimeter.

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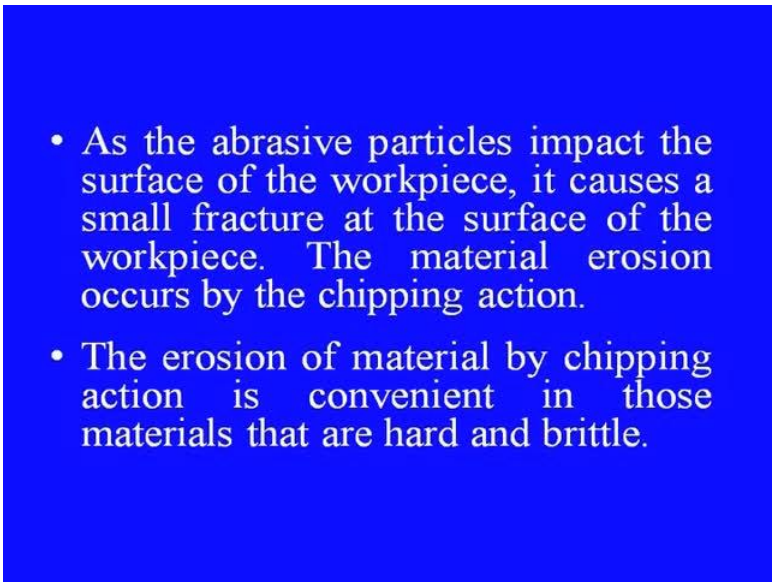

As the abrasive particles impact the surface of the work piece it causes a small fracture at the surface of the work piece, the material erosion then occurs by the chipping action. The erosion of material by chipping action is convenient in those materials that are very hard and brittle.

The abrasive particles once once used cannot be reused as its shape changes partially and the work piece material is also clocked with abrasive particles during (( )) and subsequent flushing by the carrier gas, moreover the abrasive material themselves get fractured on impact, and as they get fractured and forms a powder their effectiveness as material removal agent will come down. Therefore, the reusability of this abrasive materials are not very good here.

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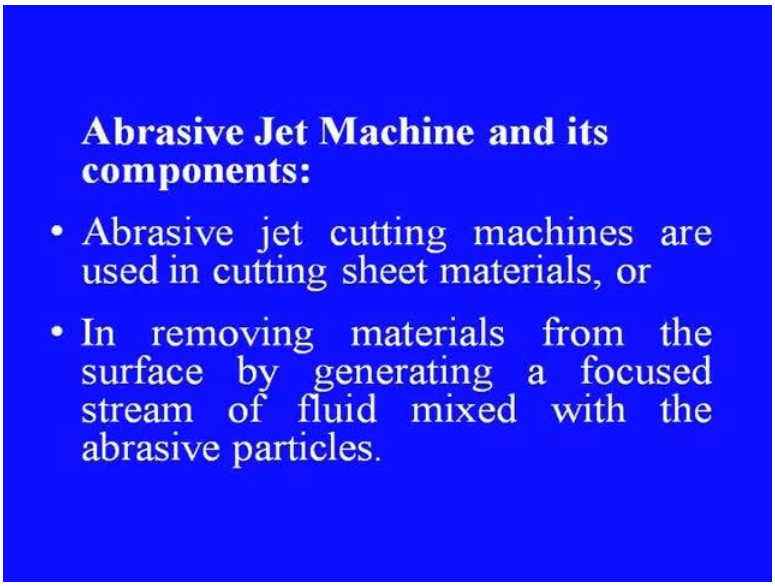

Abrasive jet machine and its components, abrasive jet cutting machines are used in cutting sheet materials or in removing materials from the surface by generating a focused stream of fluid mixed with the abrasive particles. They make use of compressed air as the driving fluid in order to propel the abrasive particles. Abrasive jet cutting machines are available as complete systems with all the components required for blasting or jet machining applications such as pressure generation or intensification, cabinets, nozzles or wheels and dust collectors.

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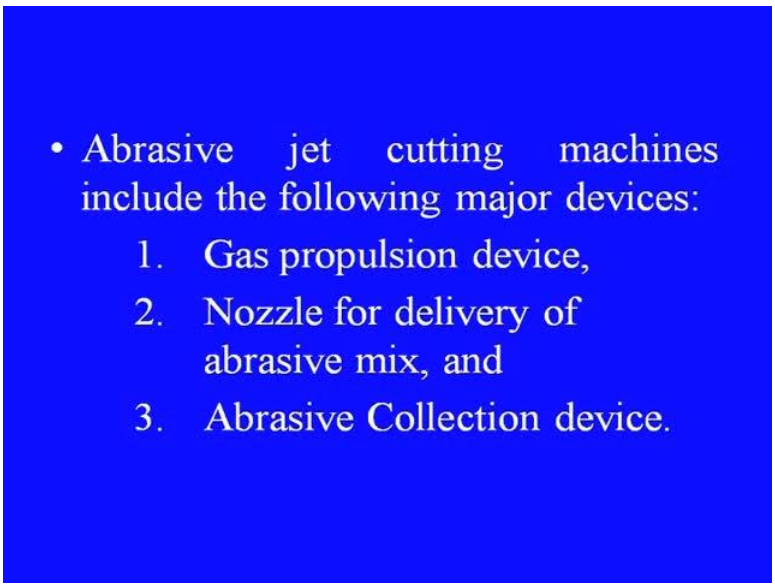

Abrasive jet cutting machines include following major devices. Number one gas propulsion device, number two nozzle for delivery of abrasive mix and number three abrasive collection device. The gas propulsion system provides the supply of clean dry gas or air to propel the abrasive particles to the work piece. In this system care must be taken to have the filters attached in so that moisture content or any oil or grease contents can be filtered out at first stage itself. Otherwise this moisture or grease content will bring down the efficiency of the abrasive particles considerably.

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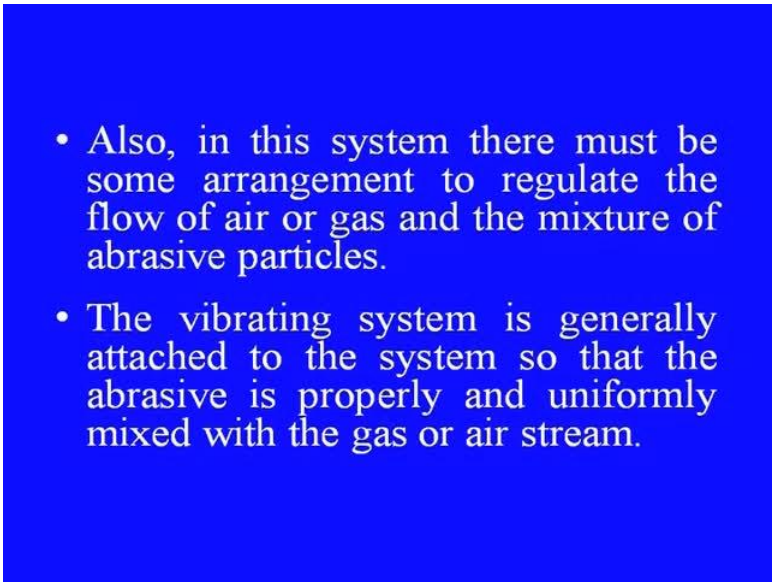

Also, in this system there must be some arrangement to regulate the flow of air or gas and the mixture of abrasive particles. The vibrating system is generally attached to the system so that the abrasive is properly and uniformly mixed with the gas or air stream. The nozzle used to deliver the mixer at the work piece should be manufactured from such materials which can withstand the erosive action of the abrasive particles and should be wear resistant.

Generally, the tungsten carbide is a very popular material for nozzles. The size of the nozzle opening depends on the flow rate requirement of the abrasive mix on the surface of the work piece. The abrasive dust collector system is essential as I have already indicated. This process is hazardous to the health and therefore, the safety of the operator. Generally, vacuum based dust collector system is the most preferred choice. A typical nozzle used in the AJM abrasive jet machining setup is shown in this figure.

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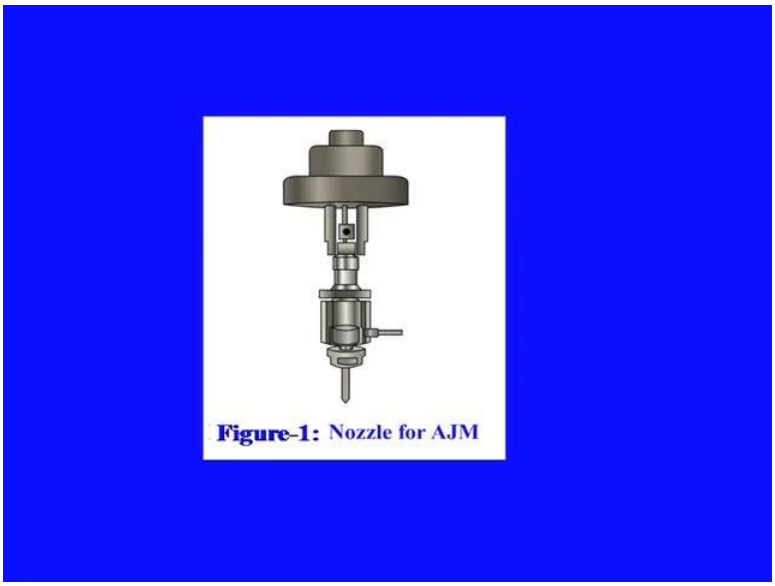

So, this is the nozzle used for AJM process in the screen. Now, let us look into the process parameters in this abrasive jet machining process. The process parameters in abrasive jet machining can be grouped into four major categories as usual an Ishikawa cause and effect diagram is constructed, and it depicts the affect of various process parameters on the accuracy and quality of the machined products by the abrasive jet machining process.

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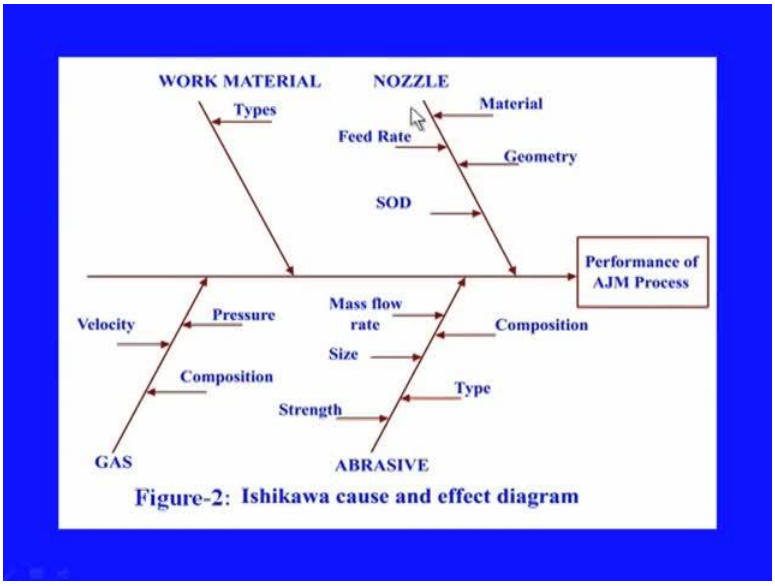

Here, this four categories are like work material based parameter that is mostly the type of the work material which which is basically a brittle material, then the nozzle. In this nozzle what is the nozzle material, nozzle geometry, flow rate and standoff distance.

These are the main parameters as far as the nozzle is concerned, then as far as the gas system is concerned, gas stream is concerned velocity and pressure and composition of the gas stream. Then as far as the abrasives are concerned the strength, the type, composition, size and mass flow rate of this abrasives that causes some quality effect on this machine surface.

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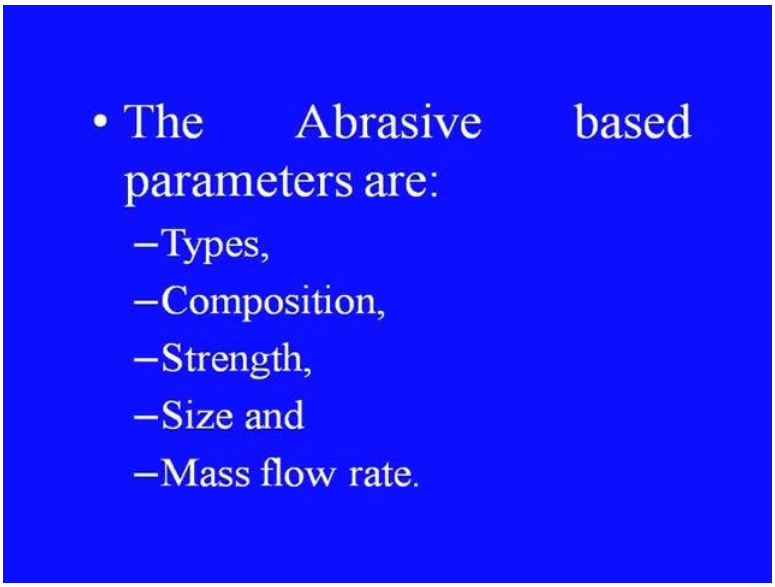

As I have already indicated this abrasive based parameters are types of the abrasives, composition, strength, size and mass flow rate. The gas based parameters are composition, pressure and velocity.

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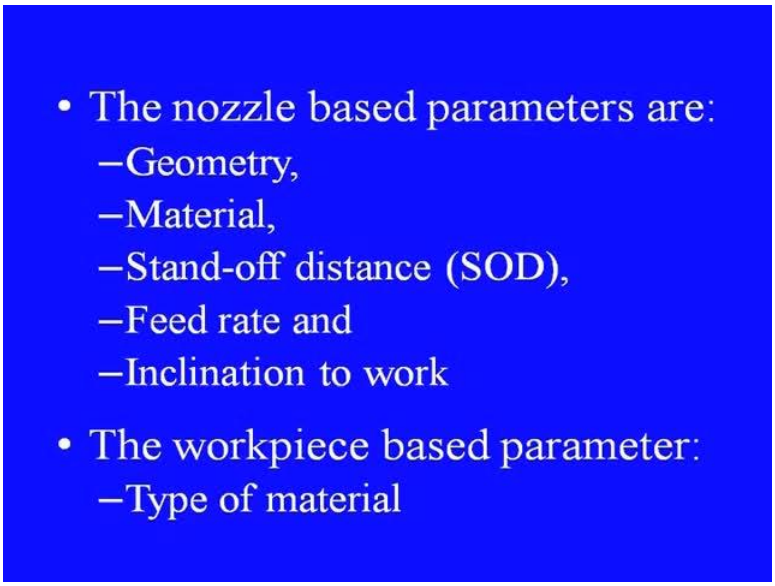

The nozzle based parameters are geometry, material, standoff distance, feed rate and then inclination to the work. Then the work piece based parameters type of materials. The selection of abrasive particles to be used in abrasive jet machining depends on the type of work material and the type of machining operations which needs to be carried out. Different machining operations such as finishing, roughing, this requires different types of abrasives for abrasive jet machining operations.

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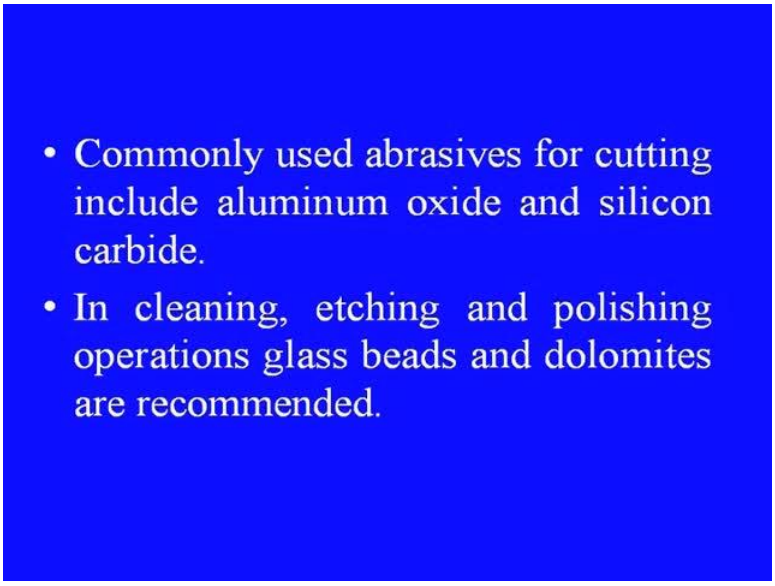

So, commonly used abrasives in this process include the aluminum oxide which is very, very popular one and then silicon carbide. Both this abrasives are very popular in almost all abrasive based processes. In cleaning, etching and polishing operations glass beads and dolomites are also used, rather they are recommended in such applications.

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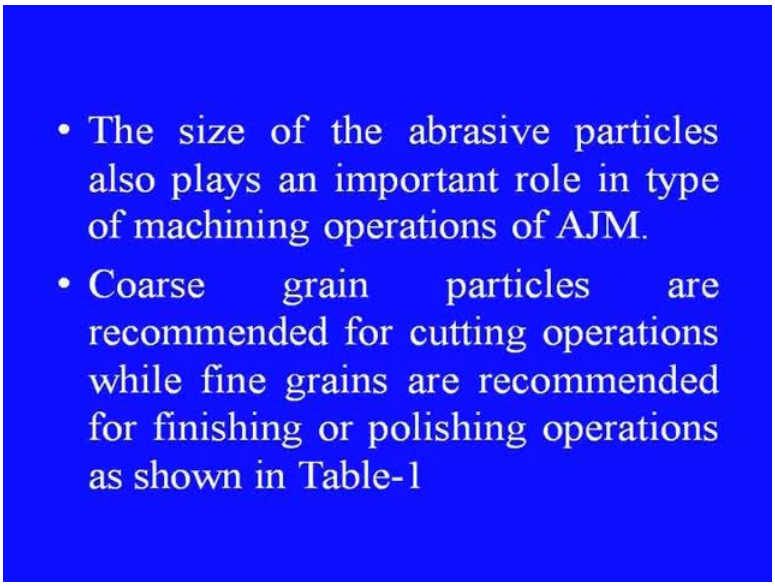

The size of the abrasive particles also plays an important role in type of machining operations in abrasive jet machining. Coarse grains particles are recommended for cutting operations while fine grains are recommended for finishing or polishing operations.

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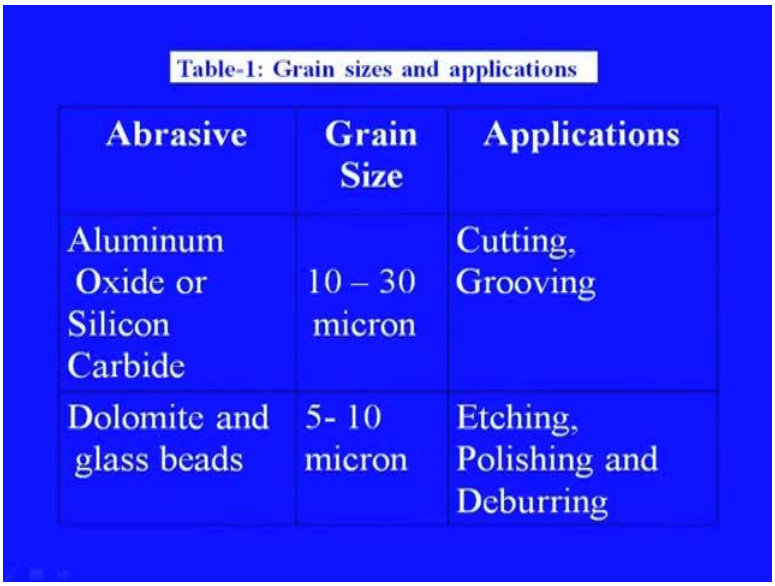

So, here the grain sizes and the materials are shown according to the applications for cutting and grooving generally 10 to 30 micron abrasives are used mostly aluminum oxide or silicon carbide and then for etching, polishing and deburring 5 to 10 micron size particles are used in this applications. Generally, dolomites and glass beads are recommended. So, we have seen for this etching, polishing and deburring processes finer abrasives are recommended. The gas used in the abrasive jet machining process must be non toxic. It should be very cheap and easily available, and therefore the common types of gas used in abrasive jet machining are air, nitrogen.

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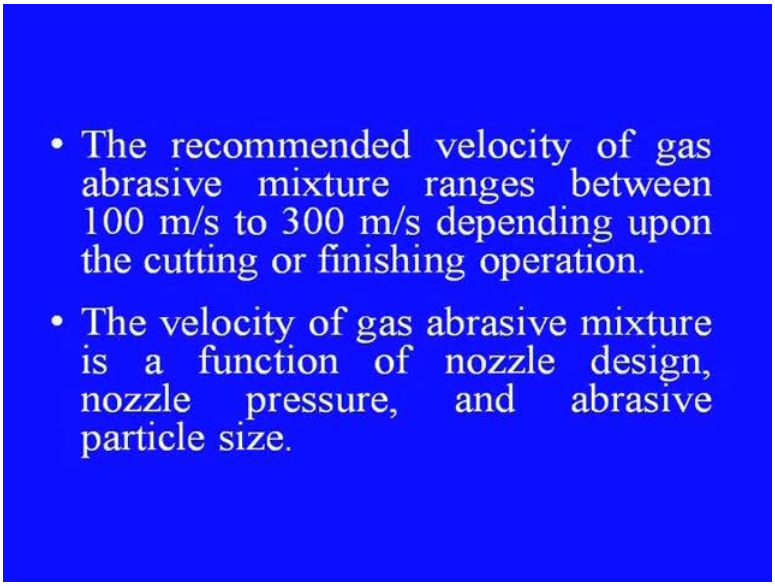

The recommended velocity of gas abrasive mixture ranges between 100 meter per second to 300 meter per second depending upon the cutting or finishing operations. The velocity of gas abrasive mixture is a function of nozzle design, nozzle pressure and abrasive particle size. Further, standoff distance which is also called SOD is a very important parameter in this process. The standoff distance is defined as the distance between the tip and the nozzle and the work surface. Larger the, this distance standoff distance poorer is the quality and accuracy of the cut. This affect of this standoff distance on this cutting or of this processing efficiency is shown in this figure, as you can see this is the nozzle through which the stream of abrasive is coming.

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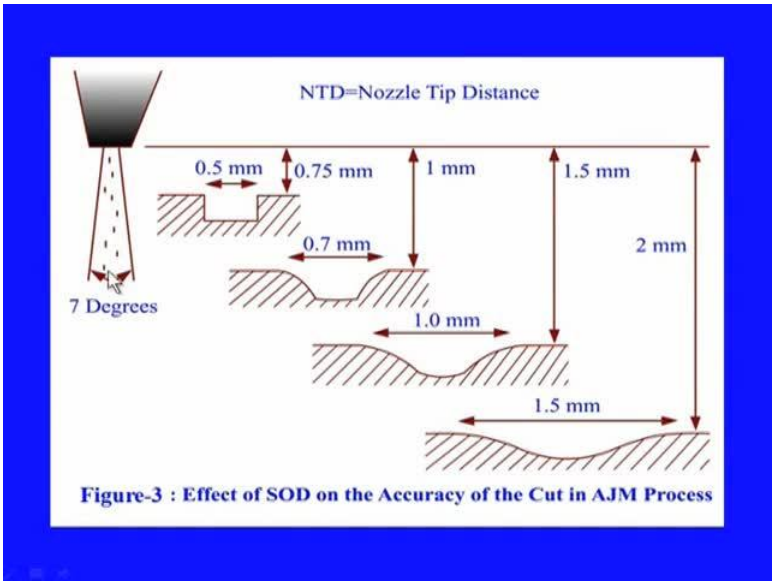

Figure-3 : Effect of SOD on the Accuracy of the Cut in AJM Process

And this stream is diverging stream and here at this moment it is shown as 7 degrees divergence is there and as we go on increasing this distance from the nozzle tip to the work piece surface this divergent stream will have more area and therefore, the cutting efficiency will come down. As you can see with less distance, the standoff distance we can get a sharp cutting profile as shown in this particular figure and as we go beyond a certain optimized distance then the stray cutting will be more, because of this divergence of this nozzle jet and the cutting efficiency of this particles will come down.

Also, this particles will lose some energy during flight while overcoming the resistance. And inaccuracy another important point here is the inaccuracy due to this divergence will increase. So, here we can say (( )) formation is taking place which can be minimized by

keeping the, this distance nozzle to work surface distance at a particular optimal distance. Therefore, this is in this process, this is an important design parameters according to different work material and different operation required that is cutting or cleaning etcetera. Of course, this is shown as in the vertical configuration which can be made inclined as well depending on the requirement.

In the end let us summarize what we have discussed in this particular session. In this session we have discussed the abrasive jet machining process, the principle operation of this process, the equipment used and different components used in this setup, the advantages and disadvantages of this process and the important process parameters, their affects on the quality and some of the applications of the process.

Thank you.