

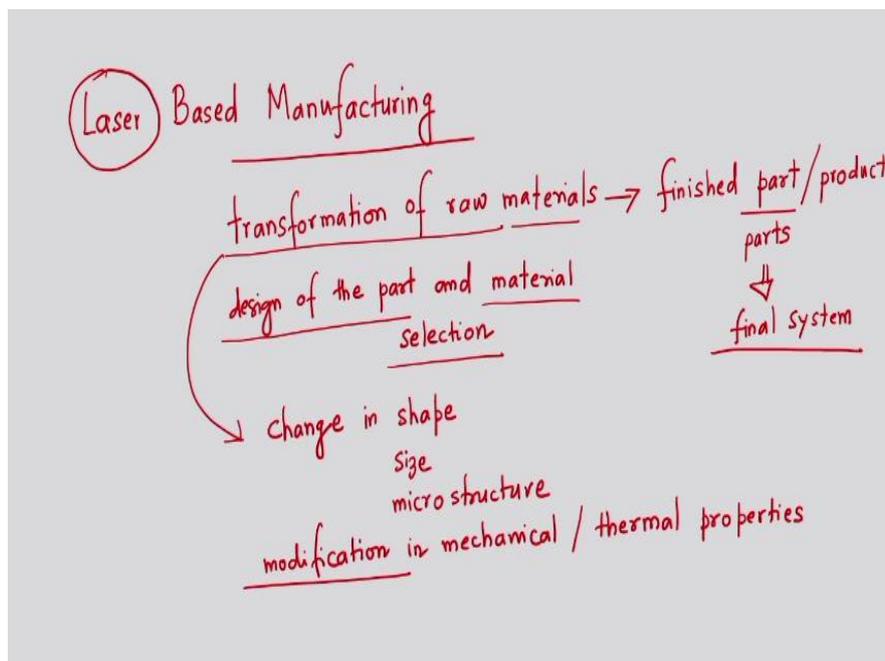
**Laser Based Manufacturing**  
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**Module # 01**  
**Lecture # 01**

**Lasers in Manufacturing: Importance and Applications**

Hello everyone. I welcome you all to the first lecture of the course: Laser-Based Manufacturing. In the introductory session of this course, we have seen the importance of the lasers to be used in the manufacturing processes and then applications of lasers in the manufacturing processes. In the coming 20 hours we will be studying in details about the lasers which are used in the manufacturing and their applications in further details about the process characteristics, process parameters, process mechanisms, how to achieve the optimal parameters, what are the various advanced techniques used in the laser based manufacturing domain.

Well, let's begin the course with the definition of manufacturing.

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The course is Laser Based Manufacturing. It is very essential for us to first understand what is the meaning of manufacturing? Manufacturing is nothing, but the transformation of raw materials into finished products or finished parts. These finished parts are further assembled together to get the final system or final product. So, manufacturing is transformation process, transformation of raw materials into finished part or it can be directly the product itself. If the parts we are manufacturing we have to assemble them, these parts we have to assemble and then we are getting the final product or system.

Some of the definitions also include the design as well; design of the part and the material selection, as part of the definition of manufacturing. We can consider the manufacturing as the transformation operation, design of the part and material selection.

As far as our course is concerned, we will be focusing more on the transformation of raw materials into the finished parts by using a variety of techniques. One of the technique is the Laser Based Manufacturing; the laser based or laser applied manufacturing processes. Which are these processes and how these are useful to the industry? That is the main objective of this course.

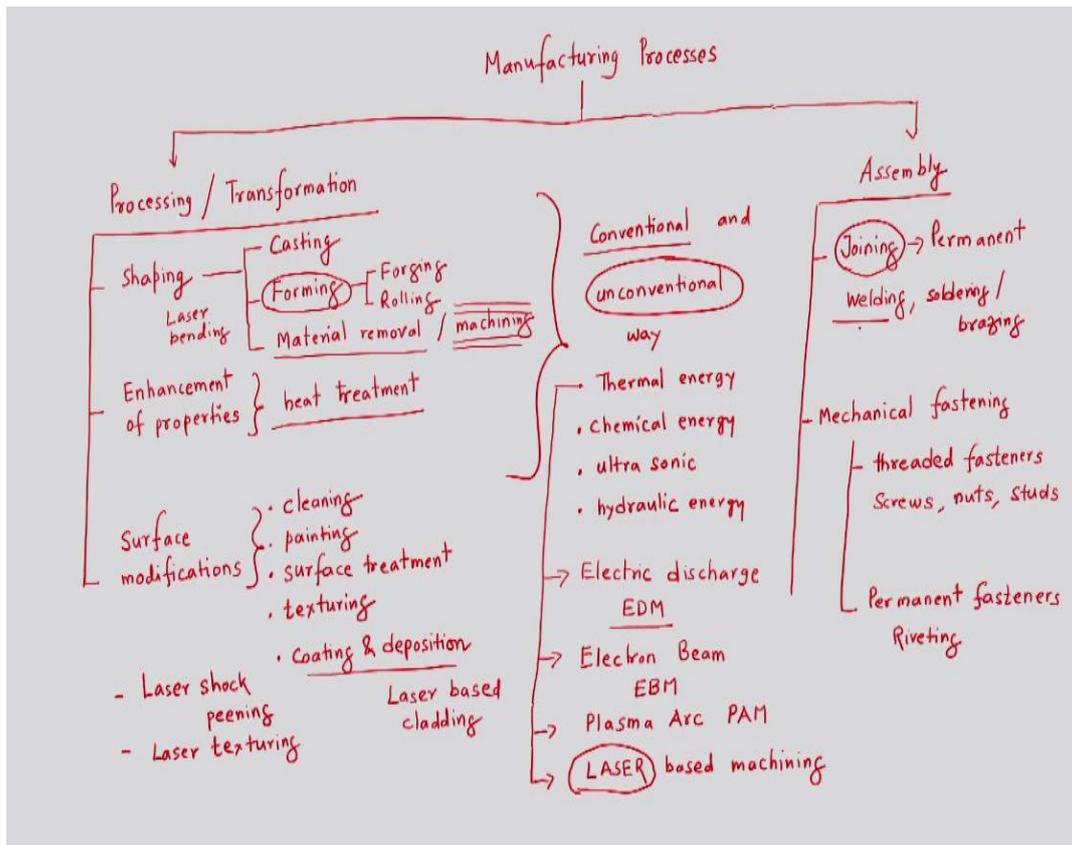
Well, what do you mean by the transformation? What exactly are we doing in the transformation? In transformation, we are changing the shape of the raw material, we are changing the size of the raw material, then in some of the processes there is a change in microstructure as well, for example, in a rolling operation: metal sheet rolling operation, there is a grain refinement during the rolling operation. We are reducing the thickness of the sheet during the rolling operation; simultaneously, there is a change in the microstructure as well. Then, in the casting operation as well, when we pour the molten metal inside the mould cavity, it gets solidified, and during the process of solidification, there is a change in the microstructure of that particular metal. Then there is a change or modification in the mechanical properties, modification in mechanical properties, as well as, we can say, thermal properties. Both properties are modified or changed during the process of transformation.

Now, we have various finished parts or products which we are using at our domestic level, in our office, for your study, for your research projects, in society as well, various parts various product systems we are using and we need to manufacture them. If we are relying on imported manufactured products, then we have to pay a huge cost for that. Therefore, it is essential for every country or nation to rely on itself to produce the parts in-house: inside the country itself. That is why our nation has started the 'Make in India' initiative, where you have to manufacture in-house and then utilize it at an affordable price and generate employment or generate human resources as well.

With this in mind, it is very essential for us to go through the various advanced techniques which can be used to enhance the productivity of this manufacturing sector or the domain.

Let us look at the various operations pertaining to the manufacturing.

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We can classify the manufacturing processes into two major classes or groups. Manufacturing process can be classified into two groups. The first set of operations are related to the processing or we can consider or we can say these are the transformation operations, transformation processes, the transformation of material will be carried out by using this operation. And the second set of operations are related to the assembly of parts, assembly operations, that is the second group.

In the processing or the transformation operation, again we can have various groups that is the operations related to the shaping, shaping of raw materials, enhancement in the property of the product or the part, enhancement of properties, in general, the material properties and the third one is surface modifications. We generate the products, but later, we want to modify their surfaces, which are called surface modifications. The surface modifications may be needed to improve the wear properties, lubrication properties, cleaning, textures, coatings, colour, and appearance.

Shaping, in general, is done by using the casting operation, which we know very well. The casting is the shaping operation where the molten metal is cast inside a mould to get the required shape. Then, in the forming operation, we heat up the material above the recrystallization temperature, and then we apply the mechanical loading. Examples of the forming operation are the forging operation and the rolling operation. The third is material removal or machining operation – here, we are using plastic shear deformation to remove the excess material from the raw material block to get the required part done.

Enhancement of properties will be carried out by using the various heat treatment processes where the hardness can be increased. Various processes are there, such as the annealing operations. As far as surface modifications are concerned, we have seen that we have to carry out for cleaning purposes, for painting purposes - painting operations, then surface treatment, then texturing, coating and deposition.

As far as assembly-related operations are concerned, we can assemble the various parts of a system by carrying out two types of operations. First are the joining operations, joining, and joining is of the permanent type, so permanent joining and a very well-known operation or process is the welding - welding operation, soldering and brazing. These are all operations pertaining to the joining.

The next group of operations is mechanical fastening. Mechanical fastening is carried out by using threaded fasteners or by using permanent fastening, which is the riveting operation - either by using threaded parts or by using permanent fasteners, which we call riveting operations, screws, bolts, nuts and studs.

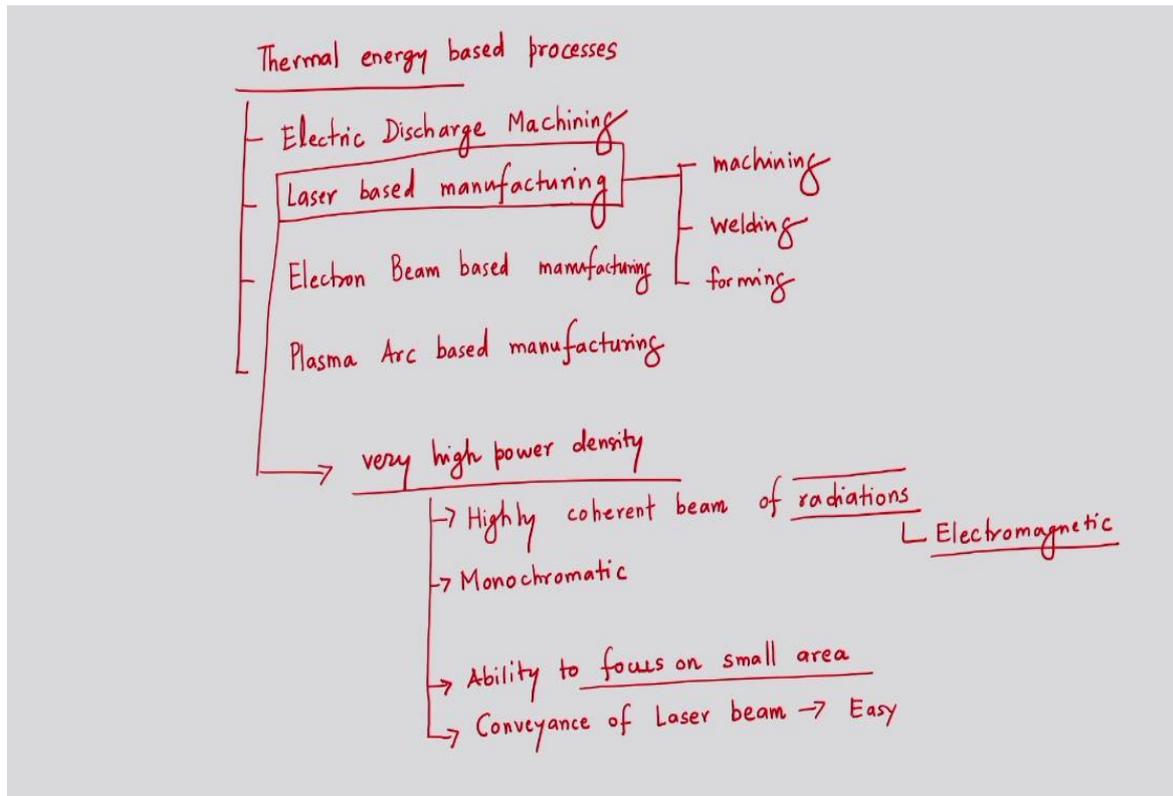
Grossly, we classify the manufacturing operations into transformation and assembly.

As far as transformation is concerned, there are two ways, i.e., a conventional way of transformation and an unconventional way. In a conventional mode of transformation, we use the traditional way, such as in material removal, we use plastic deformation by contact type of process such as turning, milling, and all these processes we use mechanical energy to remove the material in these machining operations. However, many times, it is not possible to apply the contact type of tool for high-strain materials or delicate parts. In these scenarios, we have to think of some unconventional way of processing it. There are various modes of carrying out unconventional machining operations, and these are based on thermal energy-based operations, chemical energy-based operations, ultrasonic-based operations, or hydraulic energy-based operations.

Thermal energy-based operations are widely being applied in the industry, and these are known as electric discharge-based operations, which we call EDM or electric discharge machining. We can use high-speed electrons, that is, electron beam machining, which is called EBM, then plasma arc - plasma arc-based machining, and the last one is laser-based machining.

As we have seen, lasers have many advantages over other manufacturing processes in our previous lectures; also, we have seen that lasers are not only useful in machining operations in unconventional ways, but they are also very useful in forming operations in unconventional ways that we call the laser bending or laser forming. Lasers are also used for the surfaced modification, that is, the laser shock preening and laser texturing as well. Lasers are also used for coating operation; laser-based cladding we can do or laser-based deposition is also possible. So, lasers are not only used in transformation operations; they are also used in joining operations, that is, laser welding.

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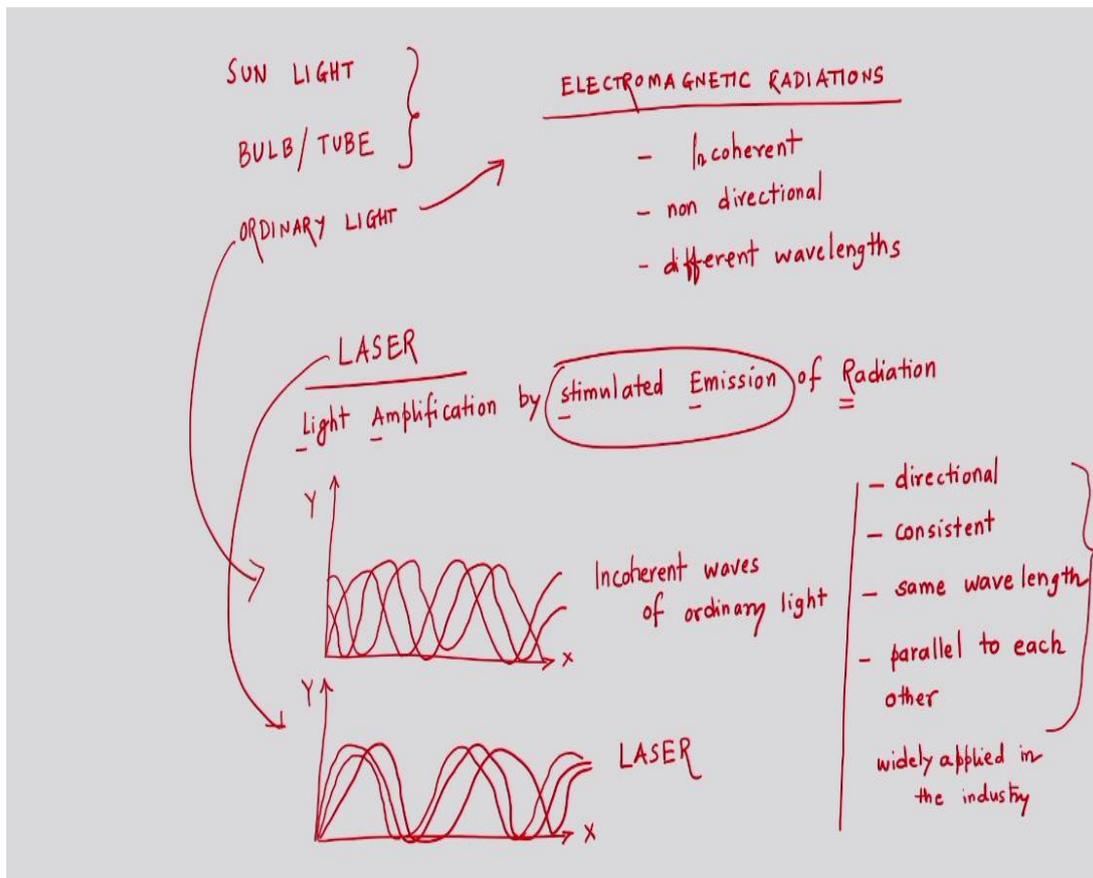


Well, among all these thermal energy-based processes, today, laser beam-based manufacturing is finding very prominent applications in the industry. The reasons are quite obvious: lasers provide us with a very high-power density beam, and that beam size is very small. At a very small focal size on the workpiece or a part, we can have very high-power density generation, and due to that, we can ablate, or we can carry out the intended operation; it may be just a melting operation or vaporization operation. Laser-based manufacturing is found to have a prominent application in the industry due to the reason, that is, generation of very high-power density.

How this very high-power density is achieved in lasers? This is achieved by having a highly coherent beam - a highly coherent beam of radiations. These radiations are electromagnetic radiations. Then the next characteristic is that the beam is monochromatic, and it has the ability to focus on very small areas. Well, there is another usefulness of the laser beam, which is that we can carry it at the intended location – which means the conveyance of the laser beam is easy with all the optics or the instrumentation available.

Then you might say that these electromagnetic radiations are also available in the general lights that we have or in general sources of light. The major source of light is sunlight.

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We have sunlight, we have all these fluorescent tubes or bulbs, or we have a very simple incandescent bulb which we use for illumination purposes mostly. These sources of light generate the rays of electromagnetic radiation, but these are not coherent. The sunlight or the bulb or tube that we do have - that we use in our domestic applications, these are also generating the rays of light - rays of electromagnetic radiation, but these electromagnetic radiations are non-coherent, they are non-directional, they are scattered/random, and these electromagnetic waves are having different wavelengths - it is a mixture of rays with different wavelengths. So, they serve the purpose of giving us the required illumination, to see the objects, and that is their main purpose.

But when we talk about carrying out the manufacturing operation where we need to cut the bond between the molecules of a very high-strength material, then we have to apply a high level of energy and high-power density. To create that high-power density, we need to have a monochromatic beam of electromagnetic radiation. It should have almost the same wavelength, and it should be in one direction itself - that is, all the rays of the electromagnetic waves should pass, and they should travel in only one direction. That we call the laser.

Laser, as we know, is a 'light amplification by stimulated emission of radiation'. As you all know, the long form of laser is a 'light amplification by stimulated emission of radiation'. We have radiation, but that radiation is generated based on the stimulated emission, and due to that, we get amplified light. The high-power light is focused on a very small area, a very small

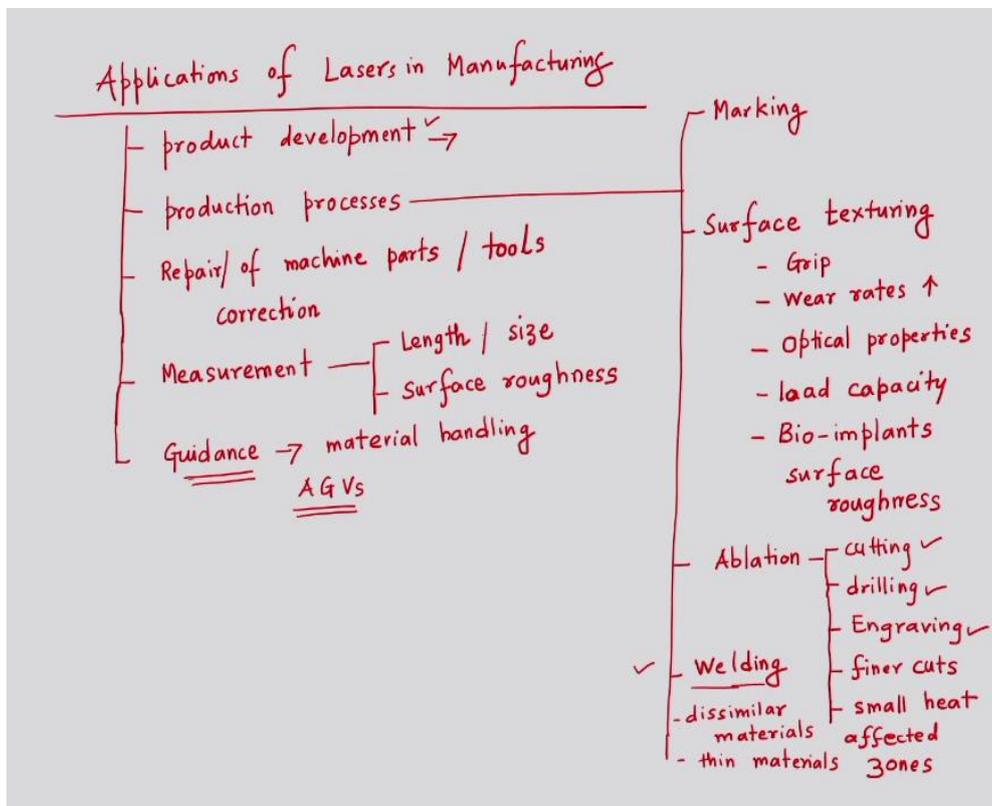
diameter beam and due to that very small diameter beam, the density is increased. The power density is increasing, and due to that high-density power, we can carry out the intended operation, say melting operation, vaporization operation or even the forming operation, or just the heating operation can carry out.

What do you mean by this coherent or the incoherent? Suppose we consider an ordinary light; how would these waves be in the ordinary light? Let us consider along the x and y. If we are having one wave of this, then the second wave or another wave of radiation may not be starting from the origin. It will start from some other direction, or we can have another wave which is in this wave. This we can call as the incoherent waves of ordinary light. And if you draw or if you want to just look at the waves in the laser device then you can have an idea like the laser is having the electromagnetic waves which are almost having the same wavelength. Here you can consider in a same way or in this way. This we can say about the laser.

Let us summarize the laser characteristics here. Lasers are having the waves which are directional, they are consistent, all the waves are having same wavelength which is very important and the rays are highly parallel to each other, they are parallel to each other - the waves are parallel to each other. Due to all these features lasers are widely being applied in the industry.

Fine, let us look at what are the various applications of lasers in the manufacturing.

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We will just have an overview of the applications of lasers in manufacturing. Lasers are used at the product development stage. How they are used in product development stage? Now all of us are very much fascinated about the 3D printing or the additive manufacturing technology. In 3d printing we are using lasers to manufacture or to fabricate the parts at a very rapid way. During the process of product development, it is very essential for us to generate the parts so that we can visualize or we can realize the shape and size of the parts at very early stage of its development. Therefore, we are using laser based 3D printing techniques to realize the parts in the product development. One application of laser is product development. The second application is the actual production, the production processes, production operations or the production processes. Variety of production processes, that we have seen, such as, the material removal that is ablation, then cutting operations, we are having forming operations, welding operations. All these are the production processes where lasers are widely being used. Third is the repair; consider repair of some parts of the machine or the machine tool need to be carry out repair of machine parts or tools. Repair and we can also consider that as the correction. Then in the manufacturing industry, we are using lasers for the measurement of length or you can consider the size, surface roughness, surface quality. Then in manufacturing we are using the lasers for guidance as well in material handling. The automated industries are equipped with lasers for the conveyance operation, such as, the automated guided vehicles. These automated guided vehicles are equipped with laser-based sensors which can guide them to maneuver or to convey the parts on the shop floor.

Now, if you look at the production processes, there are various other applications of the lasers and these are marking operation. If you just look at the various products which are there with you, particularly, the biomedical products. It is very essential to mark or to have the unique identify code on the products and these parts which are in working condition they are being applied with heat, humidity, dirt or friction. During this application of such factors this identification number should not get spoiled. Therefore, laser based techniques are used to manufacture or to mark the unique identity number on the products or parts

Then we are having surface texturing. We can generate various patterns or textures on the surface of parts and products and the purpose is for improvements in its grip - grip improvement, its wear property improvement, wear rates improvement, then, we can even modify the optical properties of the surface and the load capacity as well. Surface texturing of mesosize or microsize is being carried by using the lasers. The very simple example is the texturing of the tool rake surface. The students with a background from mechanical or production engineering will understand that on the rake surface of the cutting tool lasers is now applied to manufacture the dimples or serrations to improve the tool performance so that we can break the chips at convenience.

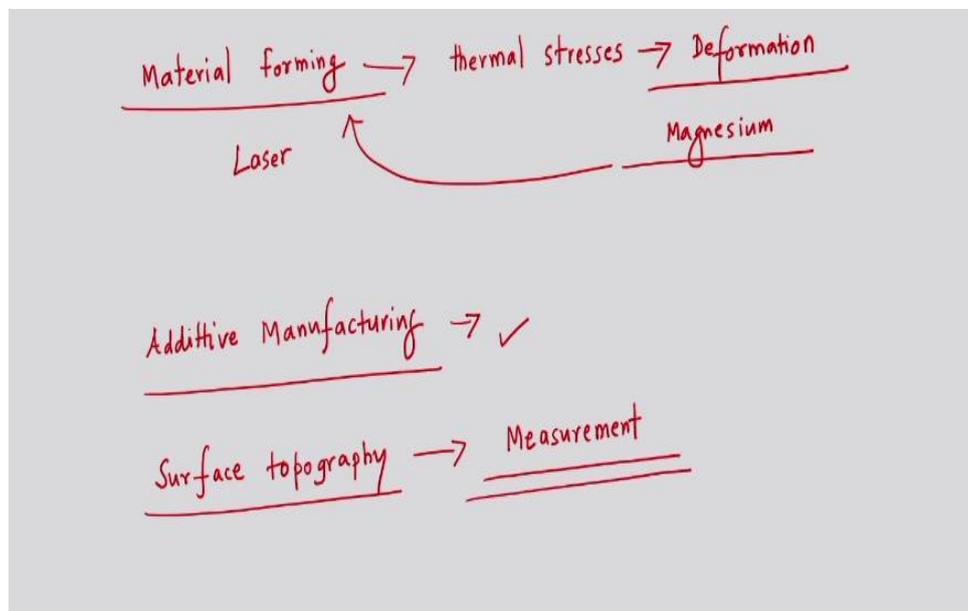
Moreover, the bio implants, the implants which are putting up are given with surface roughness - the surfaces are made purposely rough with certain RA value - certain roughness value. Why this roughness is given on the implants? So that the new tissues can grow on them or these implants can get very well adjusted with the bones and, so that the bones can hold the implants firmly and they grow over the implants. This roughness is deliberately provided on the bio implants to grow the issues and to have firm holding of bones with the implants.

We are also having application in ablation. In ablation, we are vaporizing the material and by vaporizing the material we can generate the required features on the work part. These ablations can further be considered as the cutting operation or we can consider these as the drilling operations, engraving operations. What are the advantages of all these things? Here, we are getting very finer cuts - finer cuts we can achieve, very small heat affected zones during the laser based ablation. We will be seeing all these operations in detail in the next weeks.

Then we are having applications of lasers in welding. Welding is having a very important application of lasers in the perspective of joining dissimilar materials and joining of thin materials. Well, we will also be studying the welding operation in the next weeks.

In addition, to the welding operation, lasers are also being used in material forming.

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Here we are applying the laser to heat up the material above the re-crystallization temperature and below the melting point temperature and that is generating the thermal stresses during the cooling operation. These thermal stresses will help us to deform the material - deformation of the material. Various materials which are difficult to form such as the magnesium, this magnesium material can easily be formed by using the laser based forming operation.

And the last is the additive manufacturing - laser based processes are used. Additive manufacturing also nowadays are having applications of lasers. We will be studying these all operations in detail.

We are also using lasers to measure the surface topography or to analyze the surface topography - measurements application of lasers. Thus lasers are not only used in the production processes of a product life cycle. These are used right from the start in product development, production process, product inspection, quality control and then to enhance the productivity by helping the material handling as well.

With this I would like to conclude my introduction lecture to this course Laser Based Manufacturing.

In the coming lecture, we will see how the lasers are getting produced. What is the mechanism of laser production, the principle of operations and what are the various process characteristics of the laser.

Ok till then good bye. Thank you very much for watching this video.