Metal Additive Manufacturing

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Lecture 03

Additive Manufacturing Processes:
Applications and Challenges

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Welcome to the next lecture on applications and challenges. Till now, we have seen the benefits of metal additive manufacturing and the market size, how exponentially it is growing. In this lecture, we will try to see various segments or sectors, how additive manufacturing are used.

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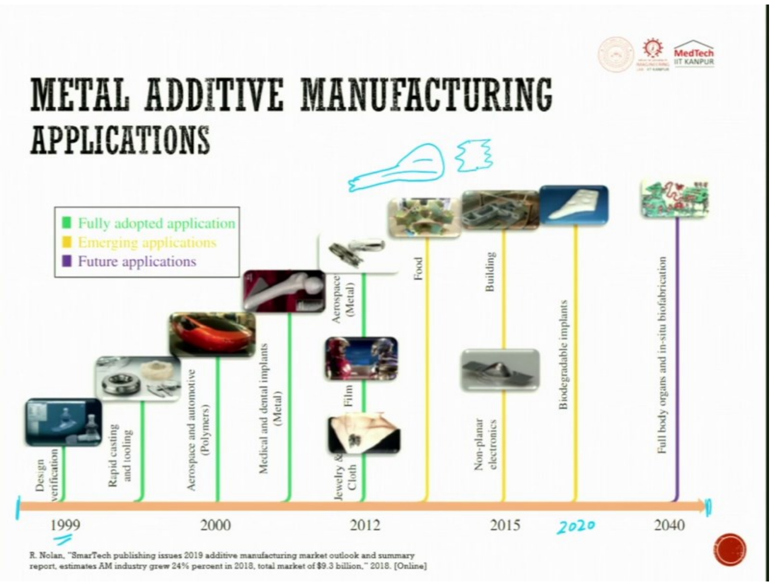

So, the applications were predominantly used in 1999. We were trying to talk about design verification, then, we were trying to talk about rapid tooling and rapid casting, and rapid tooling was the next somewhere in 1999 to 2000 we have been talking about it.

In 2000, aerospace and automobile parts, where polymers were used came into existence. Market was ready to make and it was used in a full extent then, by 2010, you had this medical and dental implants which are made out of metals, which found its place in real time usage.

In 2012, you can see jewelry and clothing industry, film and aerospace started using additive manufacturing in a big way. Then, in food industry, today, we are printing food, we are using additive manufacturing for as to print the icing layer, to print a complete cartoon figure to make the final product into a cookie or something like that.

So, food industry has started using additive manufacturing and then in 2015 non planar electronic structures have been made out of additive manufacturing, 3D rapid prototyping buildings are also constructed today. In 2020, you see biodegradable implants are made out of it.

So, it is somewhere around about 2020. By 2040, we are hoping that full body organs and in-situ bio-fabrication will happen so that all the damaged parts of our body can be replaced by using additive manufacturing, but there it is more polymer based, but I have put the entire spectrum of the additive manufacturing which has played an important role from 1990s to

2040. If you look at it, fully adopted applications are all green, yellow is emerging application.

For example, if you want to have a chicken piece exactly like this, with some features like this, then the chicken is converted into a wire or into a powder and a liquid then it is extruded, it is extruded through your food based additive manufacturing it is printed and then it is either taken for heat treatment or either the final part. The cookies today are made to come in this form.

So, food industry is coming up in a very, very big way. So, this is what we are looking at it, so fully green. So, design verification, rapid casting and tooling, aerospace, medical application, clothing application, they are all fully adopted in use, now they are all in use. For example, the gold industry. International gold industry use material jetting process and they print the wax patterns for real time applications.

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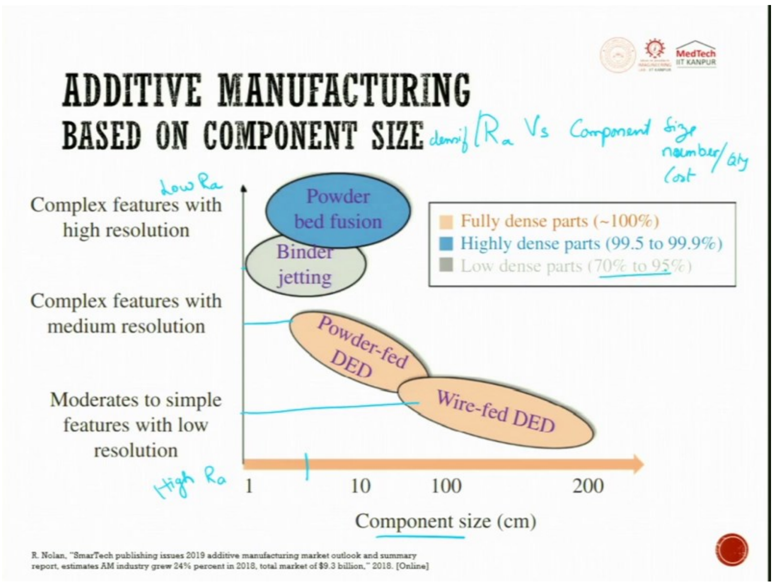

So, when we look at the additive manufacturing based on component size, if you look at this side, you have powder bed fusion. So, in the y axis, you will have complex features with high resolution and at the bottom you have moderate to simple features with low resolution, resolution here we talk about so I can convert in terms of Ra, this is poor Ra or low Ra, this is good Ra or high Ra good. So, I will convert it into high Ra value and I will make this into low Ra value.

So, if you want moderate to simple features with low resolution can be built by using wire fed DED, directed energy deposition, wire can be used. If you want to have complex features with minimum then you can go for powder, you can also use the binder jetting where in which, the number of parts produced will be very less and powder bed fusion method can be used where the component size becomes smaller. But, you get low Ra highly complex features to meet out the requirements there is always a tradeoff between Ra versus component size. There is always a tradeoff component number, or quantity then cost .

So, you can replace this Ra with densification etc. So, here fully dense parts are produced, here highly dense. Fully dense parts 100 %, highly dense parts 99.5 – 99.9 are done here, low dense parts are done between 70- 95.

So, here this is what we are doing. With binder jetting, we will always get low dense part. You get dense parts 99.5- 99.9 in this powder bed fusion method and the fully dense part 100% you get through wire and powder fed DED.

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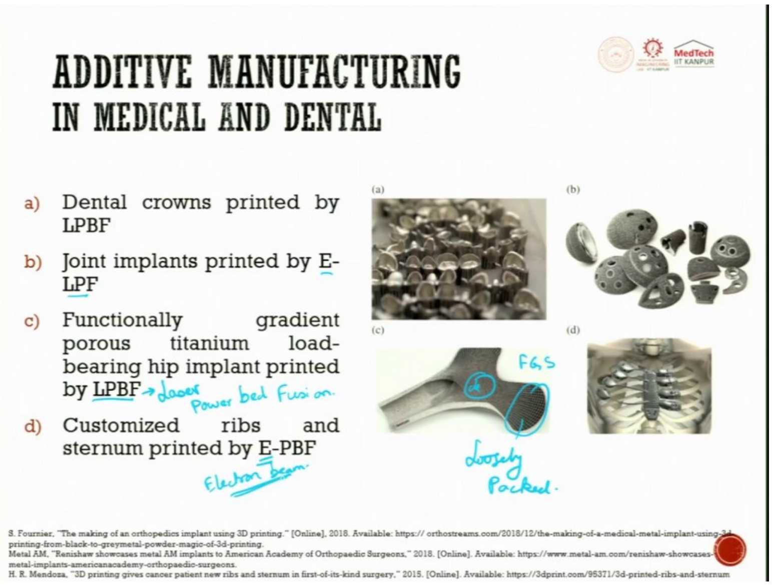

So, some of the applications which we would like to see for our interest is additive manufacturing in medical industry and dental industry. Medical crowns are being printed, joint implant printed by process E-LPF, then you can see functionally graded so, here it is dense, here it is loose loosely packed.

So, here again it is a functionally graded strength functionally graded strength material or functionally graded properties are their strength properties. So, here it can take toughness, here it can take maybe load.

So, functionally graded porous titanium load bearing hip implant is printed by laser-based powder bed fusion method. Here E is nothing but electron beam. See, there are only few heat sources it can be laser, it can be electron it can be plasma, so, you can use it. So, large electron and laser are used today.

So, by using electron beam, they have printed the ribs. So, all these things are being printed and now, few trials are going on. Some of the big companies internationally are already into market for producing it. So, here they do lot of mass customization to meet out to the customers' needs.

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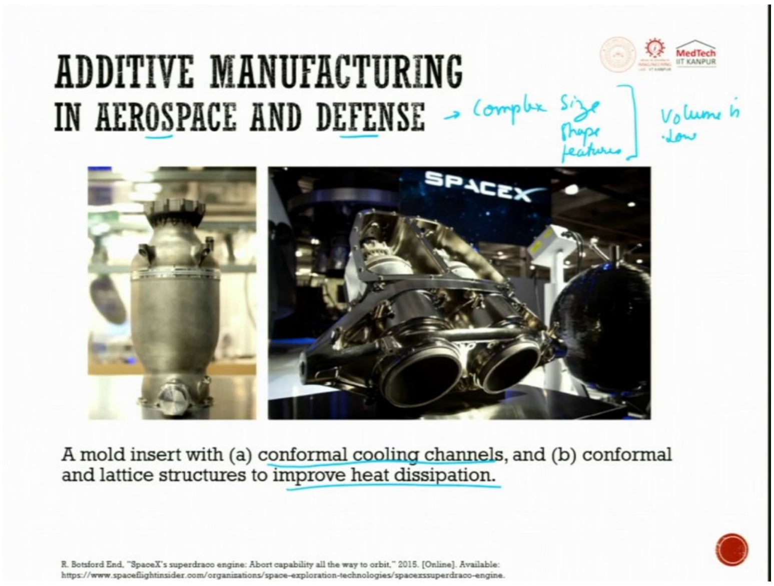

So, this is for aerospace conformal cooling system or a cooling channel generated or is fabricated inside this structure. Then conformal and lattice structure to improve heat dissipation is done for auto mobile applications.

So, you can see for defense and aerospace industry, metal print and additive manufacturing are finding a lot of applications in defense there will be complex jobs. So, complex job in the sense complex size, shape and features are there. So, all these things can be integrated and you should also understand the volume is low.

So, if you want to have a break between all these things, then additive metal manufacturing becomes your only way out.

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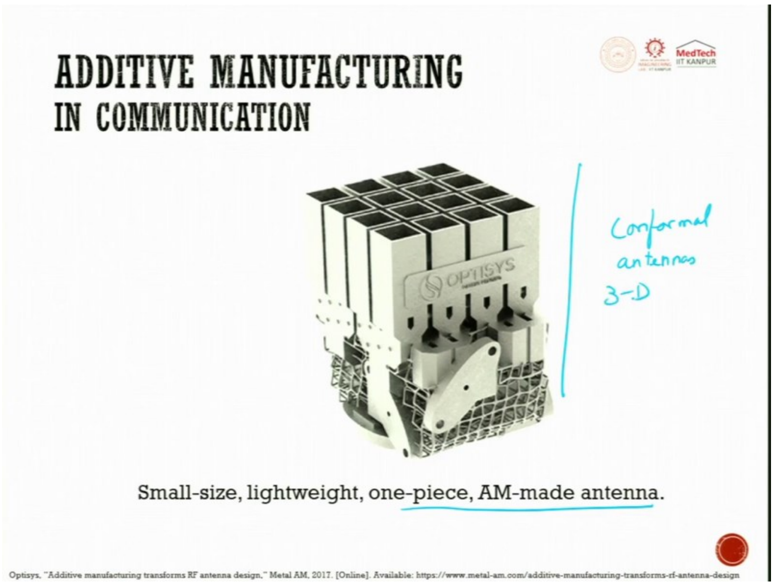

So, next in terms of communication, it is a small size lightweight one-piece additive manufactured antenna. This is exhaustively used today, there are conformal antennas which are three dimensional is being made. So, earlier they used to make it planar, now, they are making it three dimensional.

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Additive manufacturing in heavy engineering industry, several hydraulic valves are getting manufactured in one go. So, you will have so many channels which are getting integrated.

So, you can see all these things are made out of metal additive manufacturing which plays a very important role in oil and gas industry. So, I would say that instead of heavy engineering, you can make it also additive manufacturing in energy-based engineering applications.

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Next, when we look at the automotive, such complex small thin features can be printed. So, Ford customized anti-theft V lock was being printed by powder bed fusion system. You can also have customized wheel locks. So, if you have to customize, you have to use automotive metal additive manufacturing, then custom titanium door handle frame with DS3 dark side edition from DS Automotive.

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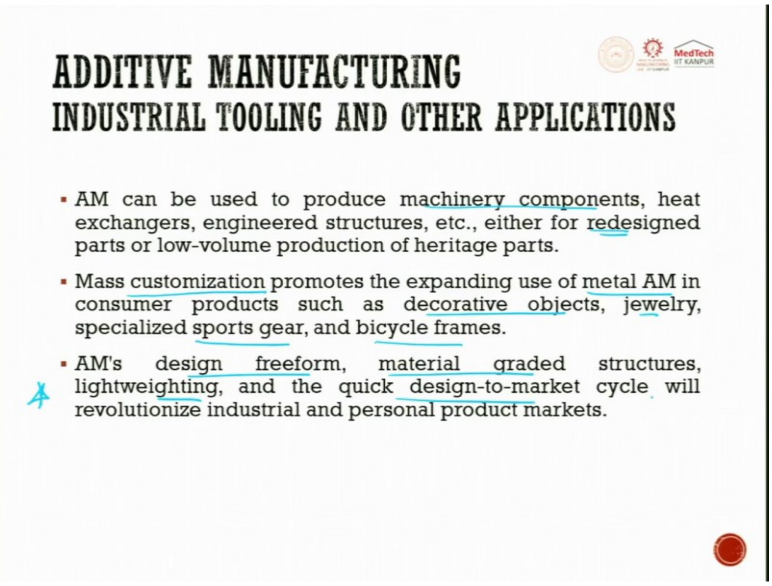

When we talk about industrial tooling and other applications, AM can be used to produce machinery components, heat exchangers, engineering structures either for redesigned part or low volume production for heritage purpose.

So, machinery components can be used. Recently, for our aerospace industry, they approached us in redesigning and fabricating metal part which is used in our fighter jet planes, since the industry abroad are now closed. So, they wanted somebody to manufacture. We designed it and now it is under testing.

So, if you want to produce missionary components, heat exchangers, engineering structures either for redesigning parts or for raw production, then our metal additive comes in a big way. Mass customization promotes the expanding use of metal additive manufacturing in decorative objects, industry, jewelry, sports and bicycle framing.

Everywhere this metal additive manufacturing is being used. AM designs free form material grade AM structures, light weighting and the quick design to market cycle with revolutionized industrial and personal product markets.

So, this is a very important point which consolidates everything designed freeform materially graded structures, lightweight, quick to designs quick to design cycle with revolutionizing industry and personal product market.

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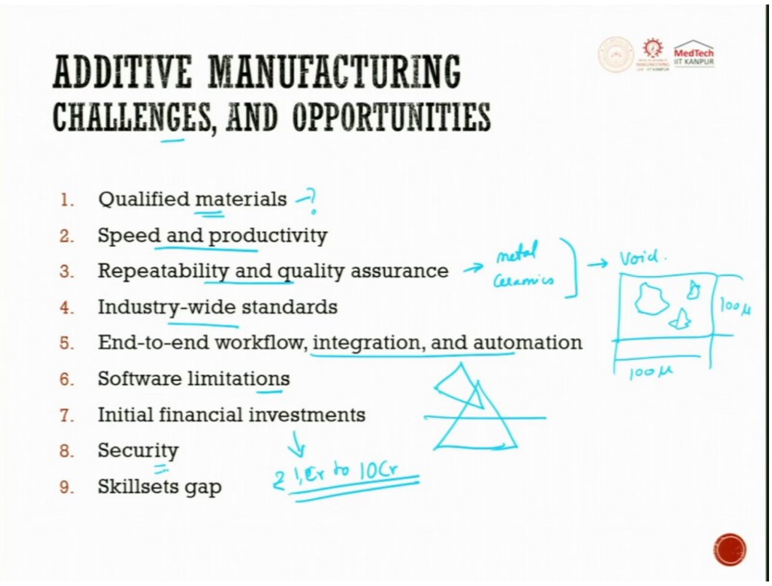

So, some of the challenges till now, I have been showing only the green part of it, some of the major challenges in additive manufacturing or in particular metal additive manufacturing is qualified material.

So, we have standards and these standards have to be maintained. So, the products which are produced the powder, the wire which are produced to maintain up to the standard, even today is a challenge. For pure materials it is okay, alloys of mixed to composition, it is still a challenge.

So, the qualified material is a big challenge, which is in front of us because we know additive manufacturing is going to be the future but the input raw material qualifying is a big challenge. The speed and the productivity of these machines are as of today low.

In Europe, there are big giants who are working with the technical universities in developing high speed and high productive additive manufactured machines to meet to customer demands, the repeatability and quality assurance is also a problem for metals and ceramic materials. Because, if there are wires inside, then it becomes safer. Wire inside means you have a part, there is a wire, there is a very small wire. Assume this, whatever I have done is around about 100μ x 100μ cross-section.

So, in this you see wires, so, removing these wires or trying to optimize and get parameters such that these wires are not there is a major challenge even today. So, repeatability and quality assurance are a big challenge and wherein which there is lot of opportunities for developing tools, process optimization, deep learning understanding, machine learning understanding, industry wise standards are still in a nascent stage.

Many of the standards are just tweaked a little bit to meet out to the requirements, but industry wide standards are still not established, end to end workflow integration and automation is not truly done.

For example, we have done CAD after CAD pushing it into the machine without any error and then getting it printed, then doing post processing and getting the final product required, that is not still complete integration and automation has not happened in the workflow. Software has a lot of limitations, when we start looking into the tessellations, they are between the layers coming then there are tessellations intersecting.

So many software limitations are there today, there are errors, there are few custom build software, but they are pretty expensive to come to the open domain. So, software limitation is one then initial financial investment, metal additive manufacturing in Indian costs, they range from 1 crore to if you are looking for an industrial work, fast production means it goes up to 10 cr. The typical cost is 1 cr to 10 cr.

So, 1 cr means it is 100 lakhs, so, if you divide it by 80, so that will be USDs, then security is also a problem. So, whatever we try to have a CAD and this machines today are connected with a vendor like cloud and then they also try to give online suggestions, inspection of the machines all these things they do. Security is also a big challenge where in which when we talk about cyber security for producing parts, you have major challenge cyber security.

Then skilled set of labors are even now not available, people who start producing these additive manufactured parts, they just replaced from a conventional part to an additive manufacturing part, but they have not used the fullest extent of doing topology optimization, increasing, reducing the weight and increasing the strength is not part. So, topology optimization, deep learning, machine learning, software understanding, process to produce having good repeatability and quality assurance, all these things need lot of skill currently it lacks. So, these are some of the challenges and these challenges can be converted into an opportunity for you.

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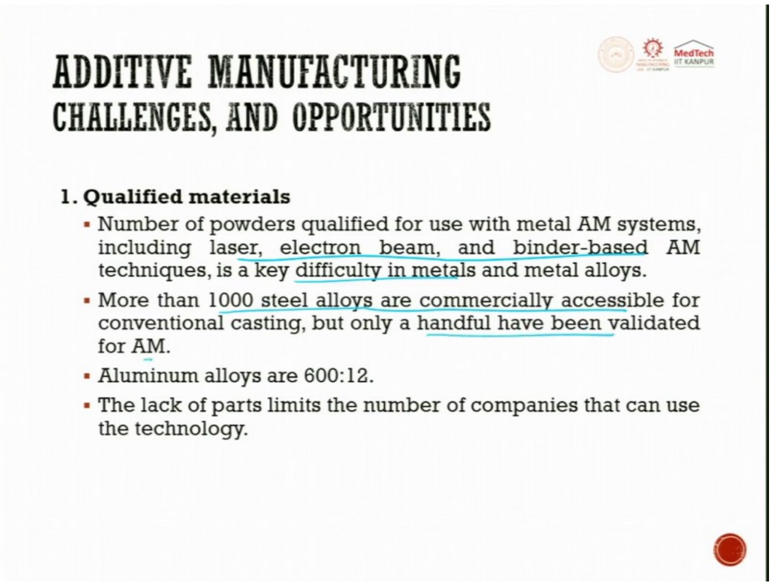

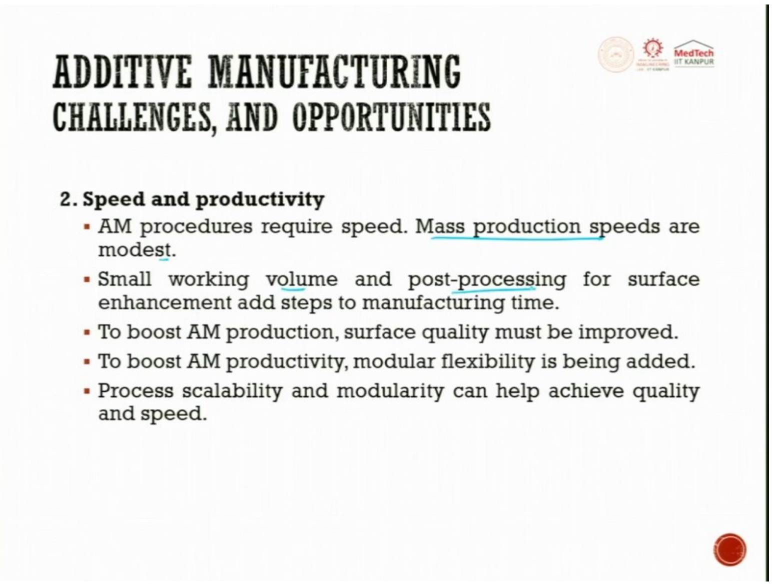

So, all these materials are also qualified material you can see with metal additive system including laser. Electron beam binder base has difficulty in getting the metals, then there are more than 1000 steel alloys that are commercially accessible, but only a handful of them are validated by additive manufacturing, same is the case with aluminium alloys.

Then speed and opportunity. I have said mass production speeds are the modest. So, small working volumes and post processing of surface enhances this step.

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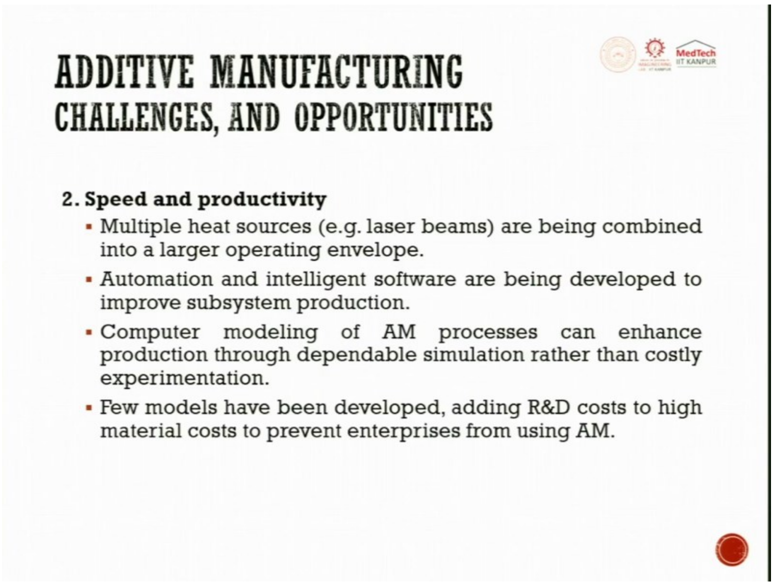

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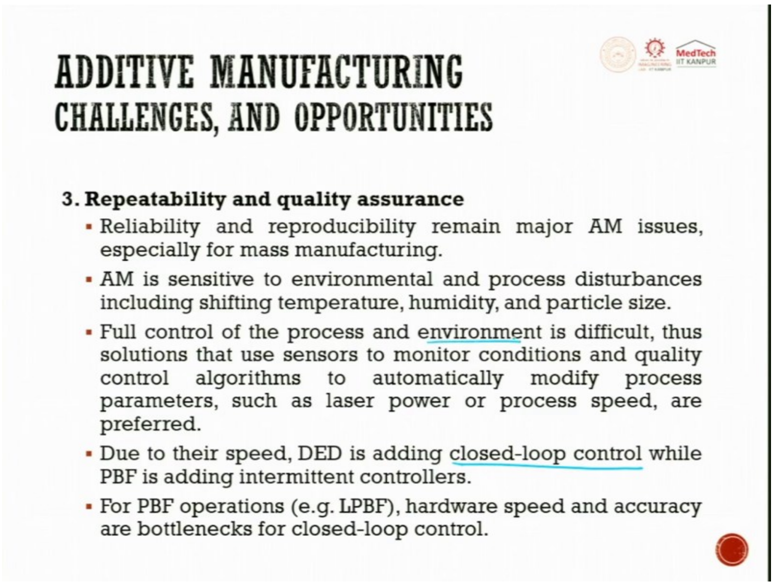

So, repeatability and reliability. We are nowadays looking for closed loop control system. In the closed loop control system we are looking at environmental conditions like temperature around and the dust around.

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So, industrial wide standards, there are several key players that have identified the challenges and began to act on it. So, they have now come up with ASTM standard, ANSI standard, ISO standards, these are some of the standards which are now coming into existence which are getting honed and polished for meeting to AM standards.

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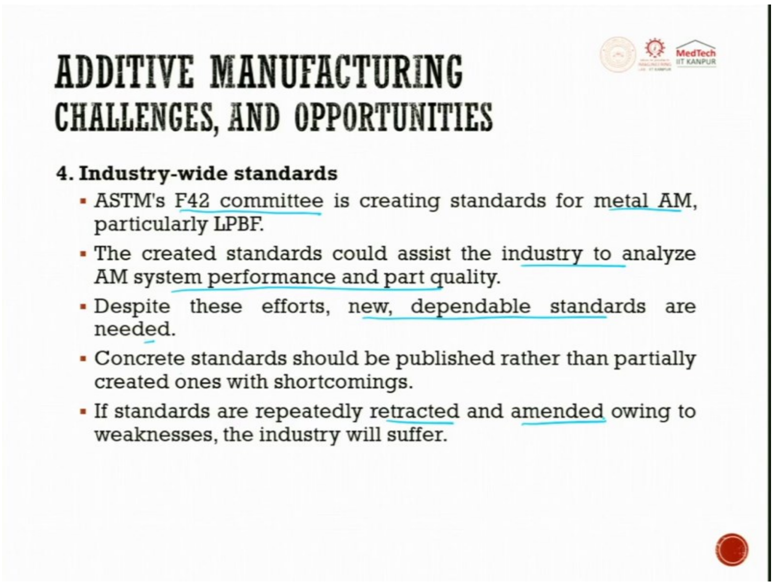

So, ASTM F-42 committee is creating standards for metal additive manufacturing. Creating Standards Code assists the industry to analyze the system performance and the part quality. Despite these efforts, new and undependable standards are still needed. Concurrent standards should be published rather than particularly creating ones with shortcomings, if standards are repeatedly retracted and amended owing to the weakness, the industry will suffer. So, if standards are repeatedly retracted and amended, then industry will suffer from producing.

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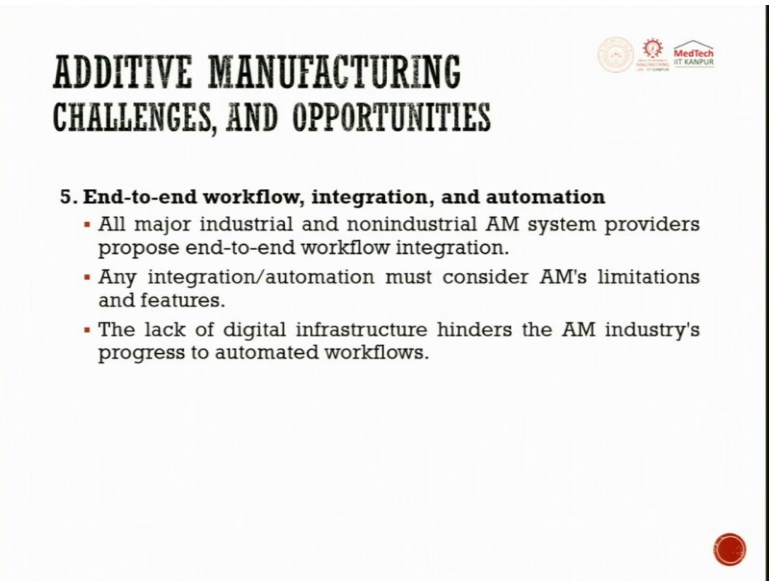

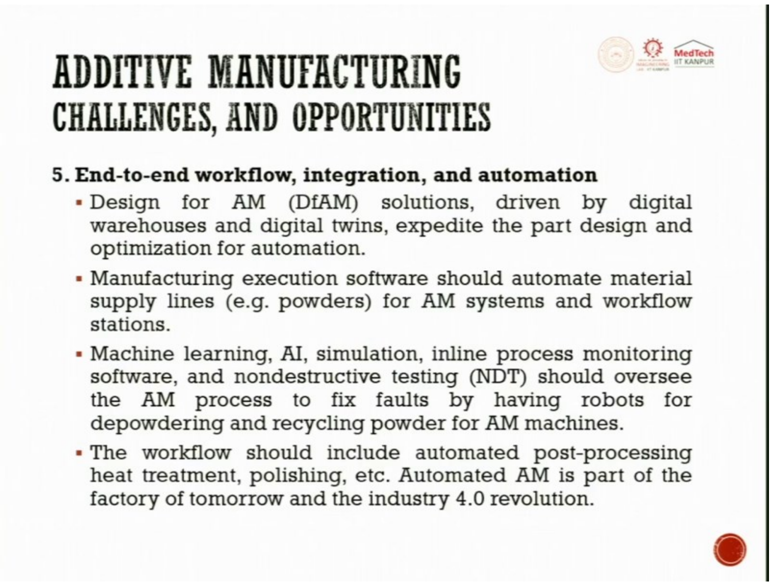

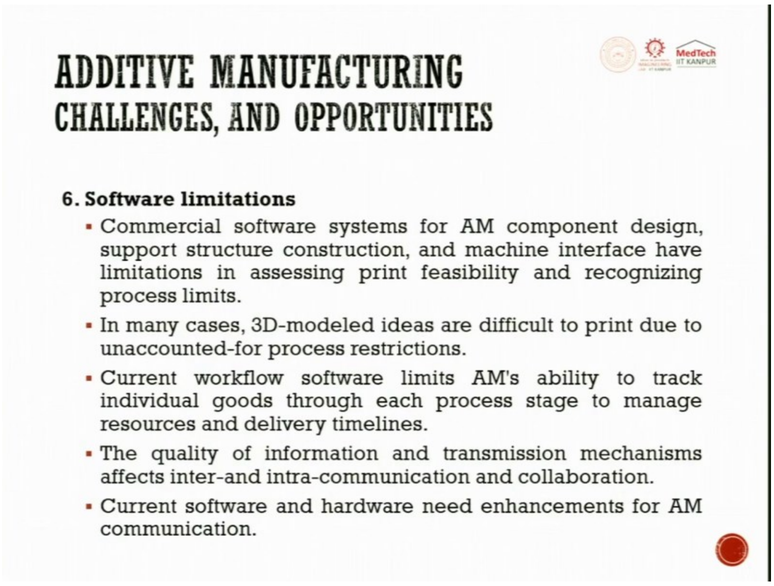

So, here the quality of the information and transmission mechanism affects the inter and intra communicational and collaboration in additive manufacturing.

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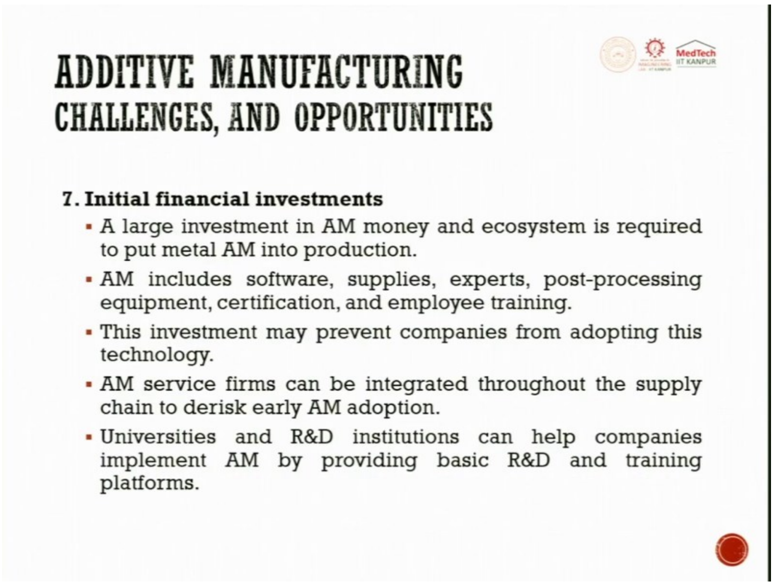

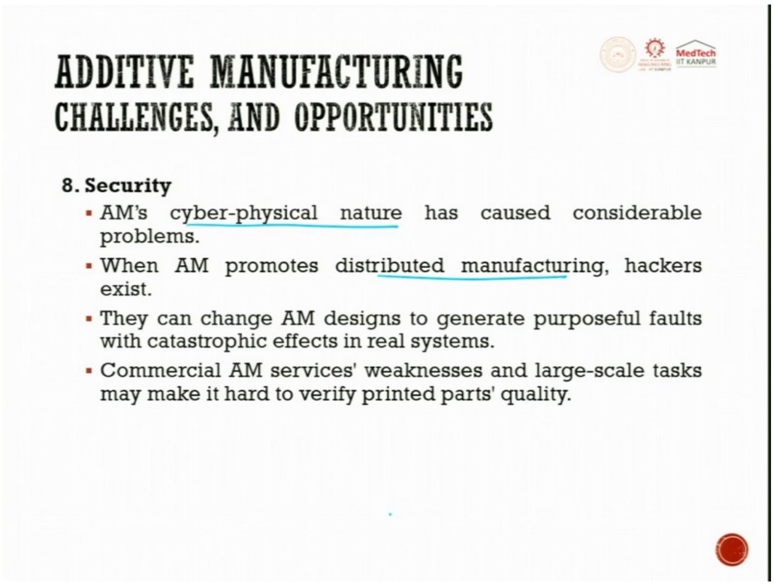

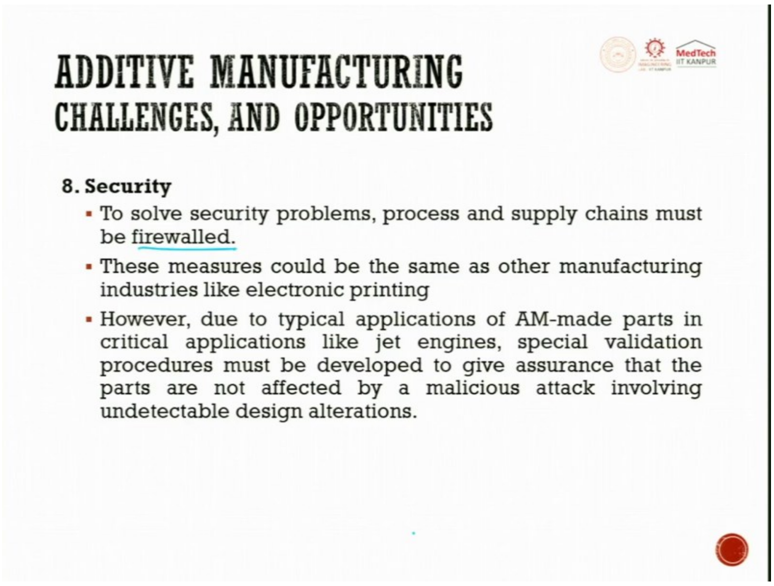

So, initial finance has been discussed. Then security cyber are physical in nature. So, this is there. So, distributed manufacturing hackers are also coming in. So, they try to weaken the system. To solve security problems, process supply chain must be firewalled, skill set we have discussed in length. So, these are some of the challenges and opportunities.

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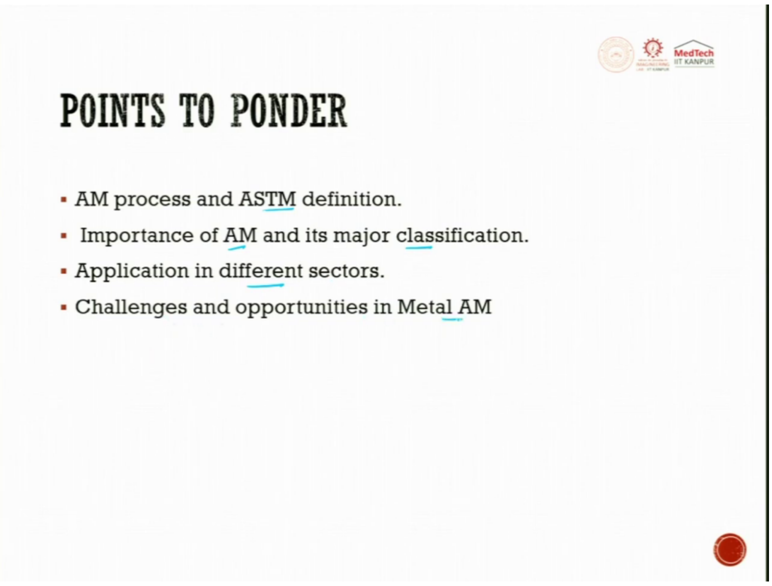

So, points to ponder. AM process and ASTM definition, can you just look into drafted and you do not have to submit to me. Make the classifications and then you can also try to see the ASTM standards. Importance of aim and its major classification which we have seen. You can try to add some more. Try to look at different sectors apart from what I have spelt it out here, to find out the fields where metal additive manufacturing can be done. Challenges and opportunities in metal additive manufacturing I have already spelt it out if you can add some more just by going through the literature these are something which you should look forward to enrich your horizon.

So, AM processes and ASTM definition, importance of aim in your own words apart from whatever I have discussed, then major classification, applications in different sectors apart from whatever I have spelt it out, challenges and opportunities in metal additive manufacturing.

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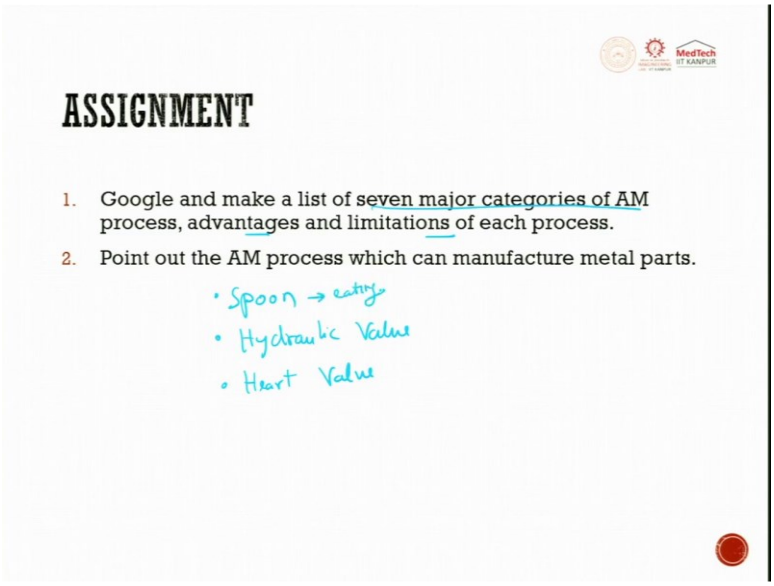

So, assignment- Google and make a list of seven major categories of additive manufacturing process, their advantages and limitations. Then, point out AM process which can manufacture metal parts like spoon, hydraulic wall, heart wall, so you just do Google search and try to figure out what process they use and you can see some videos and understand these spoons are for eating, this is used in the cosmetic industry or aesthetic industry. Thank you very much.