Computer Integrated Manufacturing
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Lecture – 31
Flexible Manufacturing System

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Welcome to the next topic in our course Computer Integrated Manufacturing which is on Flexible Manufacturing Systems. So, here the word flexibility has to be very clearly noted. The flexibility is within the given spectrum. For example, when we studied about CNC machines we saw basically two classifications. One is called as turning center; the other one is called as machining center. Wherever there was a cylindrical part, the operation was done using a CNC turning center.

When it is a prismatic part we use to do it in a milling center; we saw those classifications earlier. The flexibility is within the turning center, within the prismatic component machining center. So, that is what is the flexibility we are talking about. So, let us understand more about flexibility and by the way, flexible manufacturing systems are focused towards batch productions and discrete part manufacturing. Flexibility in manufacturing system will seldom be taught of a process industry or for a job shop production.

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So, let us see the content for today which is Flexible Manufacturing System. Then we will have FMC or FMS components we will see. So, what is FMC? Flexible Manufacturing Cell, the cell layout what we studied in group technology; the same link cell here. Then FMS application considerations, then analysis of flexible manufacturing systems. And the last one is going to be alternative approaches to flexible manufacturing. These are the topics which we will cover in this lecture.

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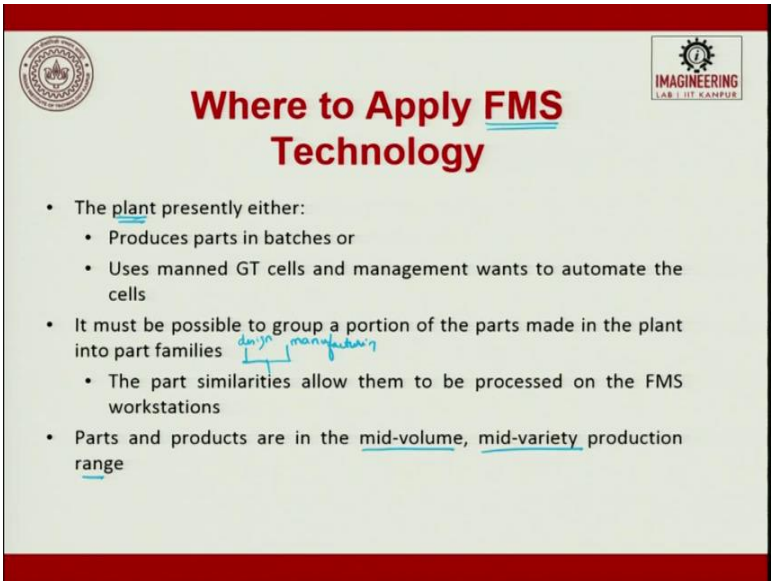

Where to apply FMS technology? That is the first question. The plant, here the plant means industry we are talking about. The plants presently either produce parts in batches or uses manned GT cell and management wants to automate the cell we always go for applying FMS techniques. The FMS can be applied for assembly stations; FMS can be applied for manufacturing of parts also. So, where a plant or industry presently either produces a part in batches or uses manned GT cell and the management has an inclination towards the automation, then we go for FMS.

It must be possible to group a portion of the parts made in the plant into a part family. So, we studied what is a part family while studying GT. The part similarity allows them to be processed on the FMS workstation; so the similarity in terms of design in terms of manufacturing. The part similar in design or a part similar in manufacturing allows them to be processed on FMS workstation. Parts and products are in the mid-volume, mid-variety production range there you can think of going for FMS.

So, there has to be a batch size and by the way today the state of the art batch size is one, which is difficult to be maintained; so with minimum volume batch size.

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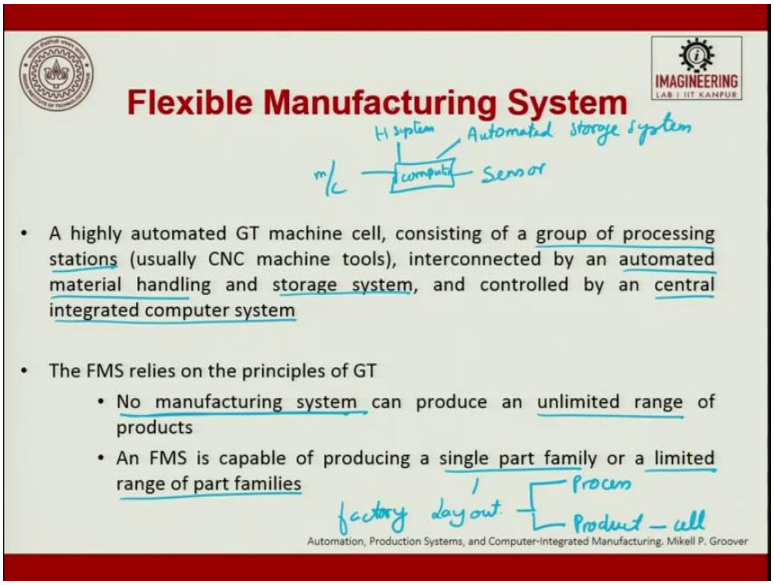

So, FMS system is nothing but a highly automated GT machine cell consisting of a group of processing stations. Usually, a CNC machine interconnected by an automated material handling and the storage system; that is controlled by a central integrated computer system. So, we should

mark the keywords here. A group of processing stations, it can be CNC. CNC means turning centre, machining centre, assembly stations.

It can also be robot for welding all those things. CNC machines interconnected by an automated material handling; again automated material handling is done by a robot or by a lever arm. And the storage system which all these things are controlled centrally integrated computer system. That means to say there will be a computer which can talk to machining centre; which can talk to handling system, which can talk to storage system automated storage system and which can also be talking to several sensors while it is moving.

So, all these machines get instruction from a central computer. The FMS relies on the principles of GT. No manufacturing system can produce an unlimited range of products. Please keep in mind, the flexibility is this is what it is. No manufacturing system can produce an unlimited range of products, within the spectrum it can do. And FMS is capable of producing a single part family or a limited range of part families. Single part family or a limited range of part families. Why are these two very important?

Because they have a direct influence on layout; so that means to say, factory layout or facilities layout. So, here we saw earlier about process layout, then we saw about product layout; so in product layout cell. So, all these things come for a single part family you decide to follow a process or you decide to follow product. So, there we tried to think of it and implement a FMS system.

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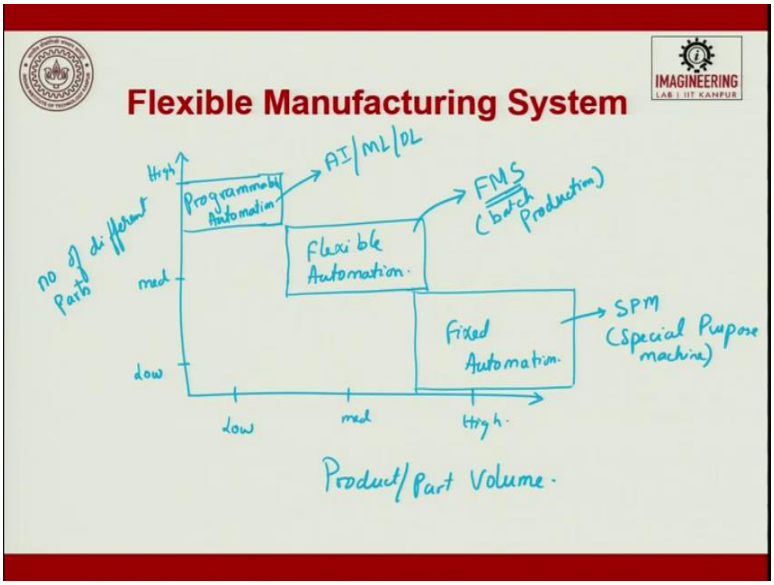

So, let us try to see where effectively FMS systems can be used. So, here it is going to be number of different parts and here it is going to be product slash part volume.

So, I make this as discrete, so I will make this low, medium, high and I will make low, medium and high. So, where you have part volume very low and the number of parts varieties which are produced is very high. So, here it is called as Programmable Automation. So, here, somewhere here there can be overlap also by the way. This is just for your understanding Flexible Automation and, here you will have where the volumes are high and then you will have is Fixed Automation.

So, here today we talked about involving artificial intelligence, machine learning, deep learning they all fall under this. Where and which we are talking about, your batch size of one, ten, fifteen; so here it falls. But, predominantly today FMS systems are used here; where it is a batch size. Batch size is reasonably varieties there and the reasonable part volume has to be produced. Fixed automations we always look at SPMs, Special Purpose Machines; so where day-in and day-out there is only a similar part or a product made.

Where there is a variation in the part of product. For example, nail, bolt, nut or some components; where there are features adjusted or elimination of features or addition of features is happened. So, there will be a machine where 6 or 7 operations will undergo and the part will be loaded in a fixture. The fixture keeps moving from station to station operation happens. So, that is called as

fixed automation; fixed automation are used for mass production. But still there will be a variation. So, flexible manufacturing system falls here, which is more towards batch productions.

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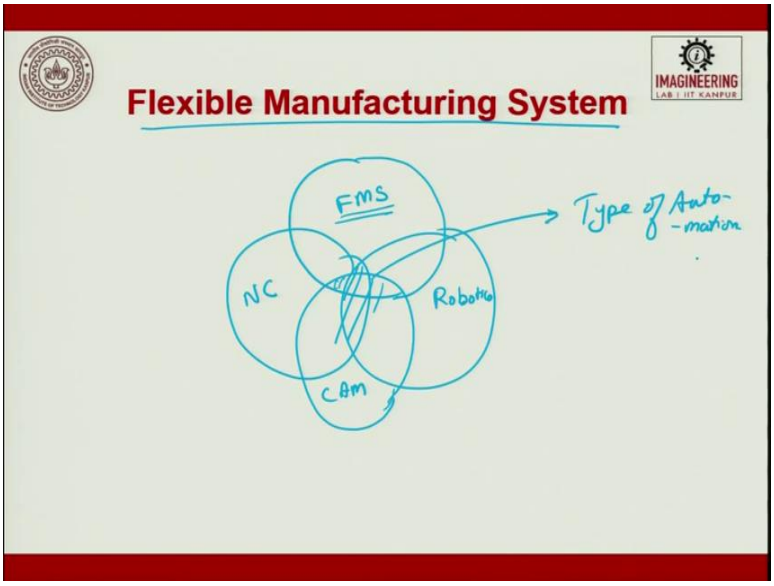

So, when we talk about flexible manufacturing system we will try to see. I will have four circles, so each circle here it is industrial, here it is CAM, Computer Aided Manufacturing. Here it is FMS, Flexible Manufacturing System, here is Numerical Controls and here it is Robotics; they all play an important role. So, the center portion what we are talking about, this dictates the type of automation. FMS system, numerical control, robotics and we talked about CAM. So, all these things put together and FMS comes here and the type of automation is decided based on, what are the components which are involved.

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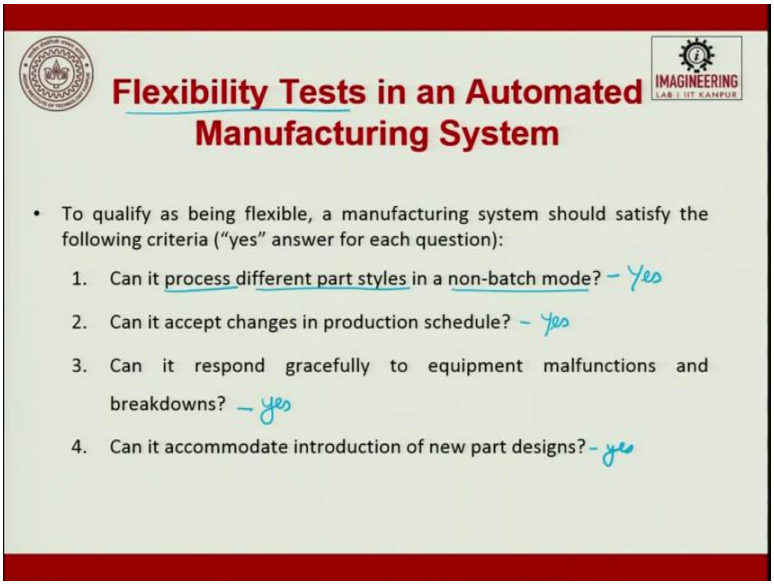

Flexibility test in an automated manufacturing system: To qualify as being flexible, a manufacturing system should satisfy the following criteria ("yes" answers to each question). You should ask five questions or, four questions, and everywhere if it comes "yes"; then it is worth for going for FMS system. And please do not think that implementing FMS will improve the productivity; no, it need not be. If you really want to automate a factory, there should not be much of input part variation into the system.

And there has to be sensors which is working perfectly and the programming whatever is carried on which has to be in a controlled fashion. This variation has to be controlled, which puts a major load on implementing FMS system. So, implementing FMS need not lead to higher productivity. So, now let us look at the flexibility test. Can it process different part styles in a non-batch mode? Please understand, can it process different part styles in a non-batch mode? Yes, if your answer is.

Can it accept changes in production schedule? So, one day five, next day twenty-five, third day thirty-five, on next day zero; so if again it comes as yes. Can it respond gracefully to equipment malfunctioning and breakdown? If it is yes, because if you solely depend on the system and if the system breakdowns. Now, the production is completely stopped; so look at the question very beautifully drafted. Can it respond gracefully to equipment malfunctioning and breakdown? Can it accommodate introduction of new part designs? Yes.

So, now the four questions are answered, yes. Now, in the flexibility test you win and you think of implementing a flexible manufacturing system.

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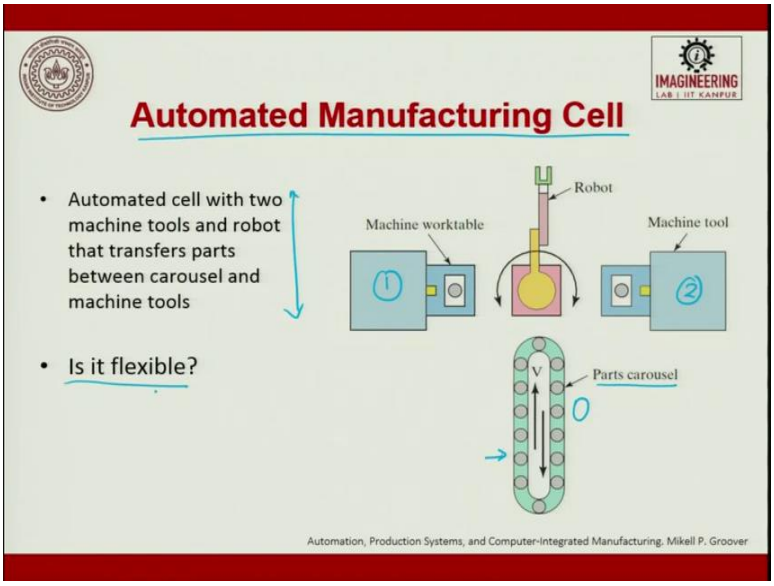

So, this is an automated manufacturing cell. What is automated manufacturing? Automated cell with two machine tools; here is one and here is two. Okay two machine tools and a robot arm that transfer's part between the machines and the carousel. Carousel is something like a conveyor belt in the airport whatever we have. A conveyor endless belt which keeps ongoing where luggage comes inside; and you stand here to pullout your luggage.

So, that is called as part carousel or it is called as conveyor belt. So, automated cell with two machines one and two and a robot in between, I told you in a flexible manufacturing system you should have automated handling system and storage and retrieval system. Automated cell with two machine tool and robot that transfers part between carousel and the machine tool. This carousel, this is machine tool. Is it flexible? This a definition for automated cell and let us think whether it is flexible?

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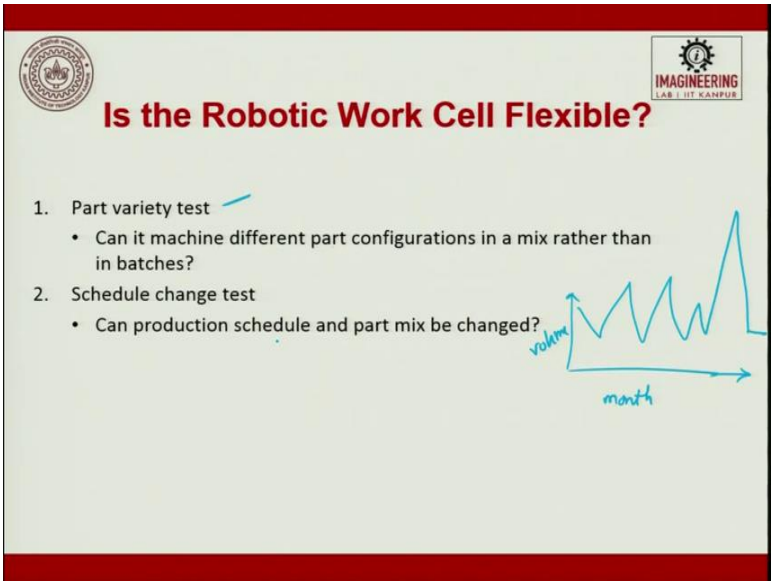

Is the robotic work cell flexible? Can it handle part variety test? So, can it machine different part configurations in a mix rather than in batches? This is part variety test; then schedule change test. Can production schedule and part mix be changed? As I told you in a month, if you take this as volume; so it goes up and down, up and down, up and down like this and then comes. So, product variety test is can it machine different part configurations in a mix rather than in batches?

The second test is, can production schedule and part mix be changing from day-to-day or month-to-month. So, if this is there, then flexibility can be thought off.

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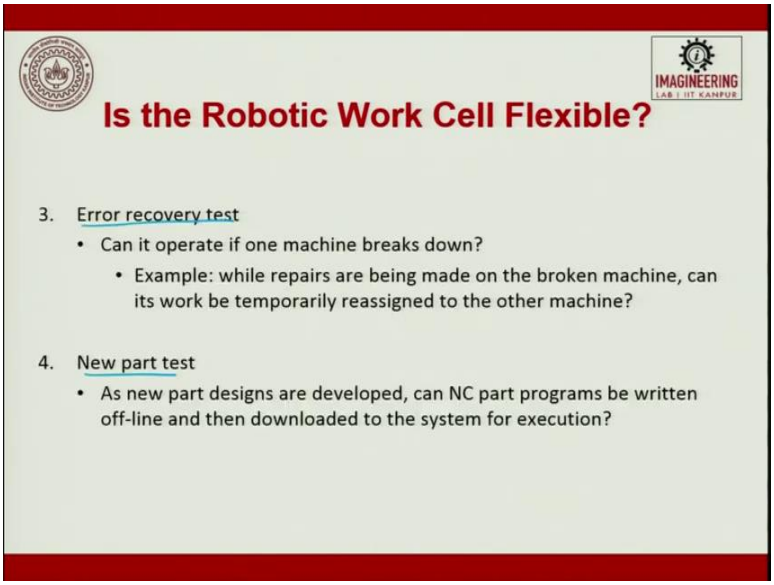

Then error recovery test is also very important. Can it operate if one machine breaks down? Example: while repairs are being made on the broken machine, can it work be temporarily reassigned to another machine such that the other production can do? For example, if you go back in this machine and let us assume this machine is turned off.

I port one more machine here and still continue to operation or I pre-process this machines job and directly load into the machine and try to get the output. While repairs are being made on the broken machine, can it work be temporarily reassigned to another machine. Next new part test: As new part designs are developed, can NC part program be written offline and then downloaded on the system for execution? So, this is whenever a new part comes, offline programming or you can do a camp base system. Today you have camp software's which are available.

You draw, you generate the G-code and, G-code is validated and, then you fit into the system of a central computer; such that it can start taking it. So this is a new part test, so we are seeing part variety test, schedule change test, error recovery test, and new part test.

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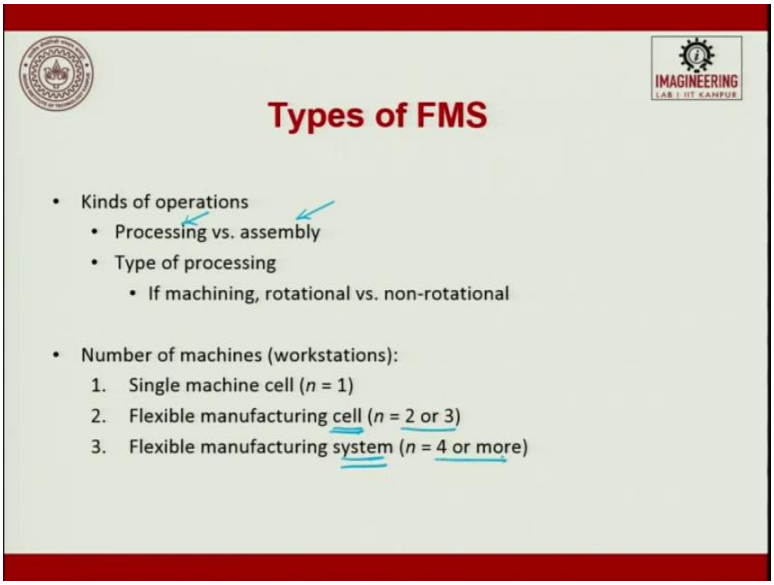

So, when all these things are done, then it is good for implementing on FMS. Kinds of operations: processing versus assembly, you have to be very clear. It can be used for both processing as well as assembly. So, for example in spot welding which is done for an automobile; the number of spots can be increased, decreased.

The length of the frame or the width of the frame can be increased, decreased. So, there the program is done on a material handling device or on an assembling device and the new device. Type of processes in machining, rotational versus non-rotational; these are the different kinds of operations. Number of machines in the bracket workstations: Single machine cell where n equal to 1. Flexible manufacturing cell where n is equal to 2 or more. Flexible manufacturing; see there is a cell, there is a system. When it is a cell, it is 2 or 3 machines; when it a system, it is 4 or more machines.

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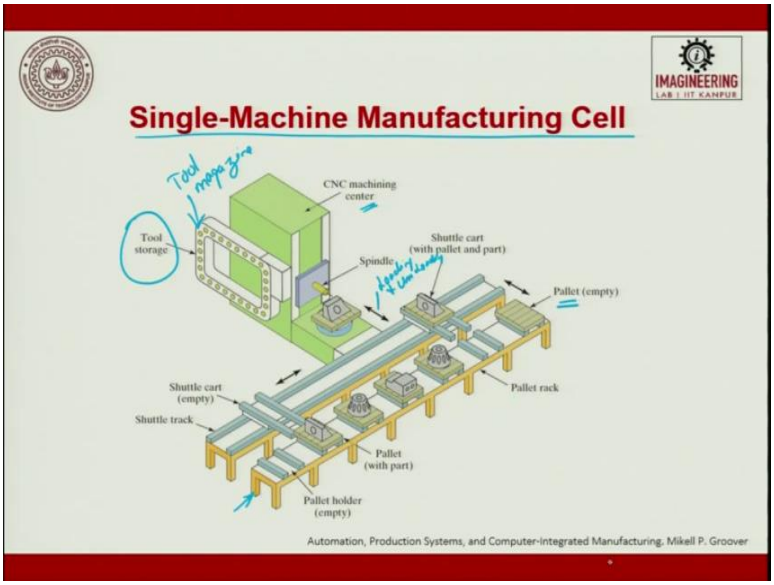

So, this is a single machine manufacturing cell; so here there is a conveyor which goes. The parts are loaded in a pallet; pallet is nothing but a fixture and this keeps moving so then what happens. As and when the part is required in the machine, so what it does is, it tries to pull from this pallet, the part is pushed inside. It is brought close to the machine and then it is loaded on to the machine. So, here it is loading, unloading to the machine. Loading and unloading into the machine happens.

So, here the part is not re-oriented, the part is fixed in a pallet and, the pallet is kept in front of a machine. The machining happens here and then you start giving features. As and when the operation is over, it moved out and then it is pushed inside. So, then the part is put back into the rack and this rack can be moving. So, here you see the pallet, this is a pallet rack, pallet rack or conveyor whatever it is. So, here a pallet with a part; pallet holder which is empty. Because these are empty which is moving from place-to-place, place-to-place.

So, as and when the operation is over it tries to fit inside. So, this is a shuttle track and then here is a CNC machining center and here you can see here tool storage. This is called as a tool magazine, which we saw in the CNC lecture. Tool magazine, where more than two hundred and fifty-four tools are loaded today. It starts with eight tools, ten tools so it is lesser number of tools, they call it as a turret. If there are more, then it is called as tool magazine. So, this is a spindle and the pallet along with the part is moved inside operation is done, and it is removed. So, this is a single-machine manufacturing cell.

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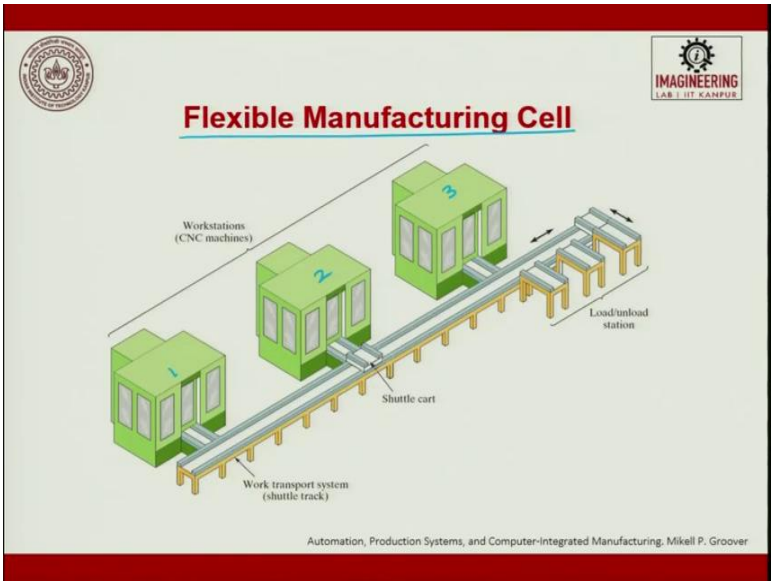

So, this is the flexible manufacturing cell; we have one, two, three machines. So, this is the rack where and which it is going, so apart most from station one does the operation puts back goes to station two, does the operation puts back station three and then goes. There are certain parts you can use only one, three, two is override or it is no operation is done in two. And the other thing suppose if two fails, then in flexible manufacturing cell if two fails we should be able to push one more machine and try to get the load done by the machine and put back into the system; it should not be fixed.

So, that is what I said in the example here when we studied we said, while repairs are being made on the broken machine, can it work be temporarily reassigned to the other machines. So, this is error recovery test, so that also possible in a manufacturing cell. Here it was only one machine, here it is three machines.

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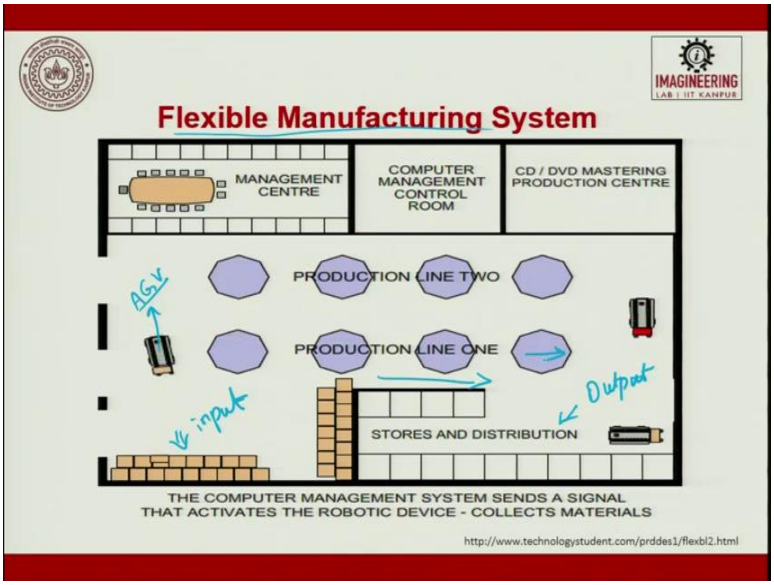

So, when we talk about flexible manufacturing system, flexible manufacturing system, this is a layout of a factory, this is management center and, here it is computer management control system. We will have CDs and DVDs master production center and these are the machine tools and these are the material handling devices.

Here it is called as Automated Guided Vehicle, AGVs. Depending upon the instruction which is given by the computer room to the production line one and two. We can see there, the machines start executing the job. As and when the instruction comes what happens? The material is moved from the stores, from the stores it is moved and it is loaded into the cell. It can move like this, the parts can move from here to here. Once the part is over this AGV tries to get the instruction and then puts it here. So, this is in, input and this is the final output.

So, this is finished part and then this is the input part. So, the AGV coordinates, gets the instruction from the computer management control room; saying that, there needs a part, so it tries to move the part from here and puts into the system. So, you can see there how beautifully it goes and it is also interesting there are assigned space, where the parts have to be loaded. So, the AGV or the fork lift comes and takes that and gives it to the machine. So, you can also see here, so this can be input and this can be output. So, I have given instructions so you can see very clearly.

So, first station four: so now automatic robotic device collects the completed batch of CDs and takes them to the distribution area. This is the distribution area or this can be in or this can be out;

so let me redrafted. So, it can be in and this can be out, the instructions are very clearly given here you can see it. A robotics device collects the completed batch of CDs and takes them to the distribution area; this is the distribution area. Once it is loaded, then an important aspect of the flexible manufacturing system is the computer control, it gives an instruction.

The computer management system sends a signal to the AGVs is to pick it. The first, second production station manufactures the blank and the third station inject molds the CD, and the fourth station is the CDs given aluminum coating. So, you can see it is very clearly it is done. So, now I have just done everything inverse so just for an understanding it can go from both places; so this time little more from here. So, it will move from here and this is here; so this is a flexible manufacturing system.

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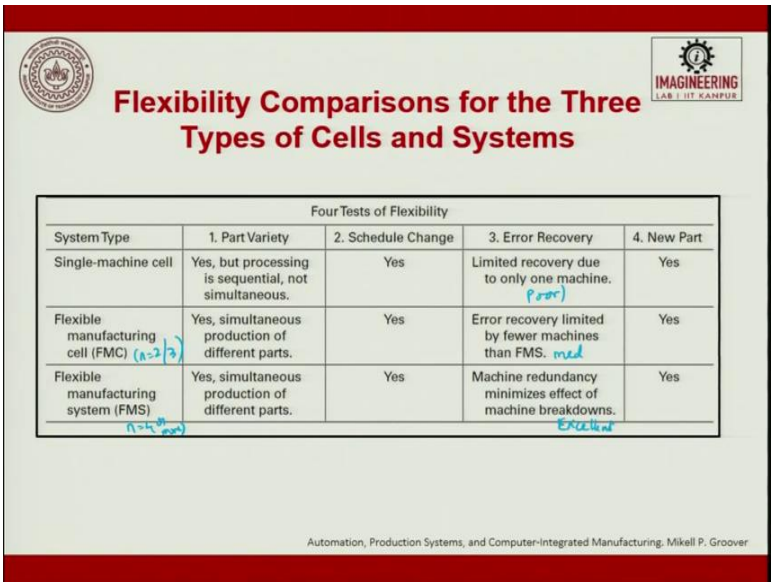

So, now let us see the comparison between flexibility between the three types. So, system type: single-machine cell, flexible manufacturing cell; where n equal to 2 or 3 where n equal to 4 or more. So, part variety, yes; but processing is sequential not simultaneous. So, in flexible manufacturing cell, yes; simultaneous production of different parts can happened. In FMS, yes; simultaneous production of different parts can happen. Schedule change all the three, yes. Error recovery, limited recovery due to only one machine involved; so error recovery is very poor here.

When it goes here, machine redundancy minimizes the effect on the machine break down. Here error recovery limited by few machines than FMS. So, this is poor, error recovery, this is okay

medium and this is high or excellent. When you talk about new parts, all these things, all the three fellows can handle new parts. So, a single CNC machine along with the conveyor is called as a single-machine cell.

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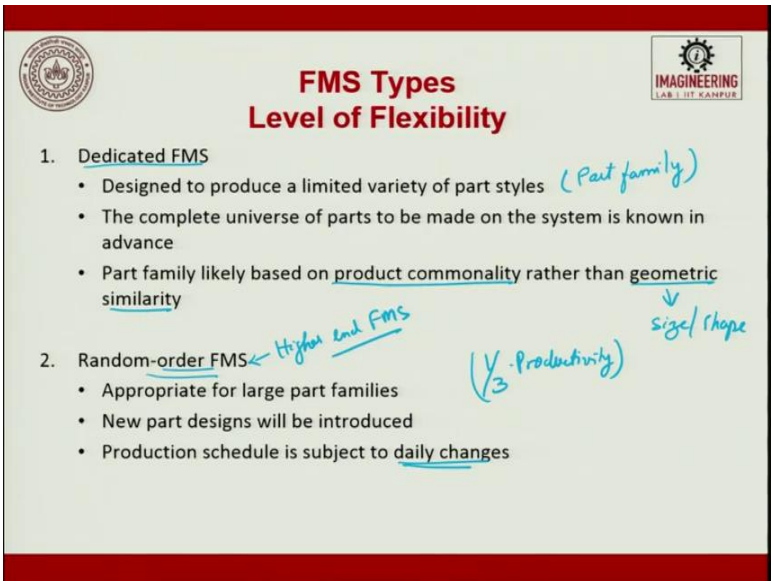

So, there are different types of FMS, levels of flexibility; one is Dedicated FMS and another one is Random-order FMS.

In dedicated FMS, designed to produce a limited variety of part styles is a dedicated FMS. So, that means to say, one family alone part family one family it will do. The complete universe of parts to be made on the system is known as advance. Part family likely based on product commonality rather than geometric similarity. Based on product commonality rather than geometric similarity; that means to say this we are talking about in terms of size and shape. So, Random-order FMS is nothing but, appropriately for large part families.

A variety of families we are trying to do, new part design will be introduced; if new is introduced it can be done very fast. Production schedule is subjected to daily change, but please understand really-really the system should be so robust to undergo such amount of dynamic changes. So, it is really-really tough and it is the higher end higher end FMS systems. Still it is in lab scale and few industries are trying and, if are random order FMS has to happen in one shift. Minimum they need two shifts of preparation so people say one third productivity is achieved.

Because all the racks have to be loaded, the sensors have to work, machines have to be there, the part consistency has to be there, and then only this can be executed. Few car, auto gents are trying to implement this random-order FMS and, they run it only in one third. That means to say, one shift of running and two shifts of preparation is going on. So, dedicated FMS which is there in all part manufacturing and random FMS people are trying to implement in assembly first and then go towards part production.

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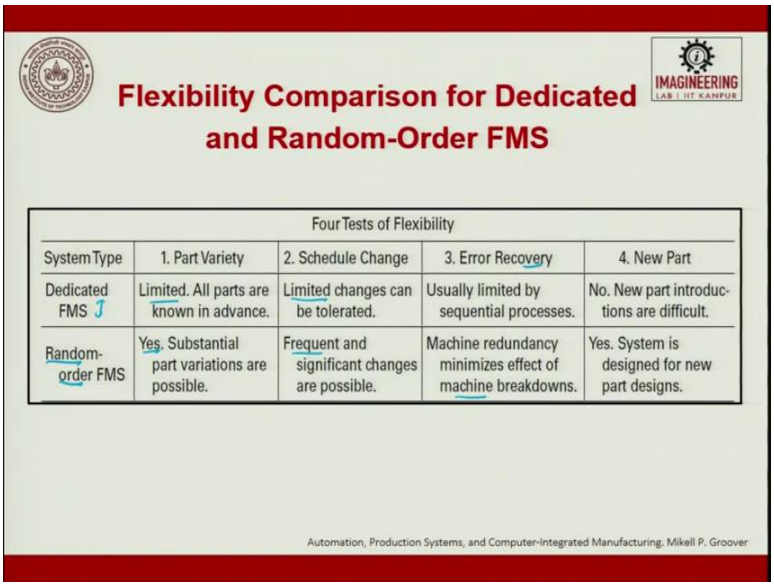

So, when we try to compare these two dedicated FMS, part variety is limited. Random the part variety is substantially large, schedule change it is limited; here it is frequent so they are talking about daily change. In fact, shift wise change; error recovery usually limited by the sequential processes. Machine redundancy minimizes the effect of machine breakdown. So, there will be redundancy machines also available; so moment the machines are redundant. You should also understand cost confront is very high; so one machine face the other follows because you are trying to work on random orders.

Then new part know new part introduction are very difficult in dedicator but in random, it is going to be easy. This is the comparison between dedicated FMS and random FMS; previously we saw machine cell FMC, FMS.

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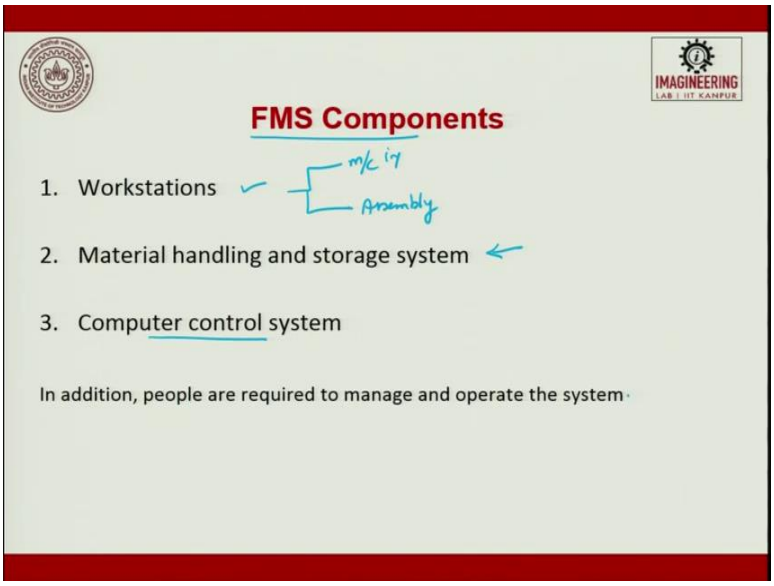

Now, let us see what are the FMS components? There are three components by and large; one is called as the workstation which can be divided into two. It can be machining, it can be assembly; it is a place where some value addition to the part happens. So, that is called as the workstation.

In fact, heat treatment is also a workstation, cleaning, degreasing is also a workstation. So, then next is material handling and storage system, very important. So, in the house if the storage system is very chaotic; half of the time we spend only in figuring out where have we kept or where is the particular item is left. In the modular kitchen the concept of modular kitchen which is used to today is to make sure that, you have allocated space for storage and, you store what is required there. However, material handling in a modular kitchen is done by a human.

That in industry it will be done by automatic and why is it done automatic? Because everything will be controlled by a central computer. So, computer control system is the third big component in FMS. In addition, people are required to manage and operate the system.

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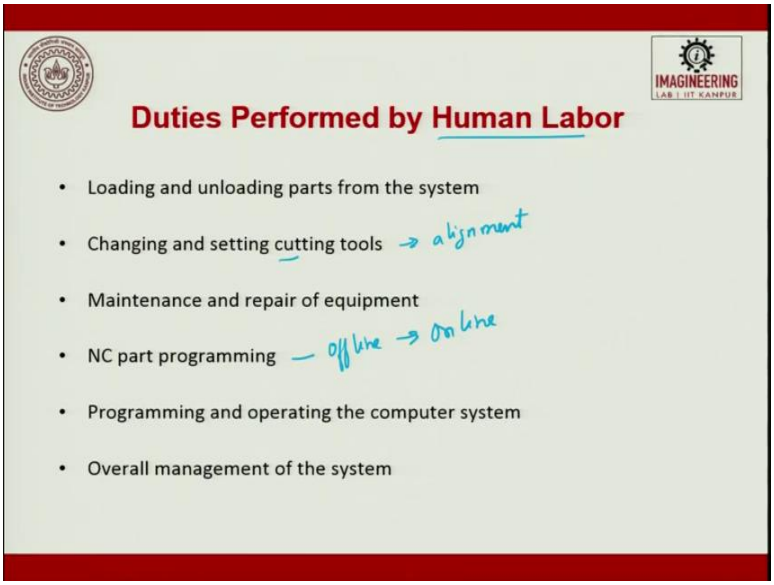

So, the duty performs by and large by human labor are loading and unloading parts changing and setting of cutting tools. Maintenance and repair of equipment, NC part programming offline then transfers it to online. Then programming and operating the computer system and last overall management of the system.

These are some of the jobs which are done by human. This loading and unloading can definitely be done by a robot. But if it is the tricky job, then we try to go up by a human related thing and, the changing mounting the job on a fixture and setting the cutting tool; because in cutting tools we always look for alignment. So, in a lathe machine when you do an experiment you will see; if the tool post is not exactly aligned to the spindle axis. So, then what will happen is you will try to have a small bur projection when you do a facing operation, that is alignment.

Settings of the cutting tool, height of the cutting tool all these things and, sometimes it is rake angle which plays an important role. Clearance angle; putting a spacer when the tool is worn out, how you modify all these things?

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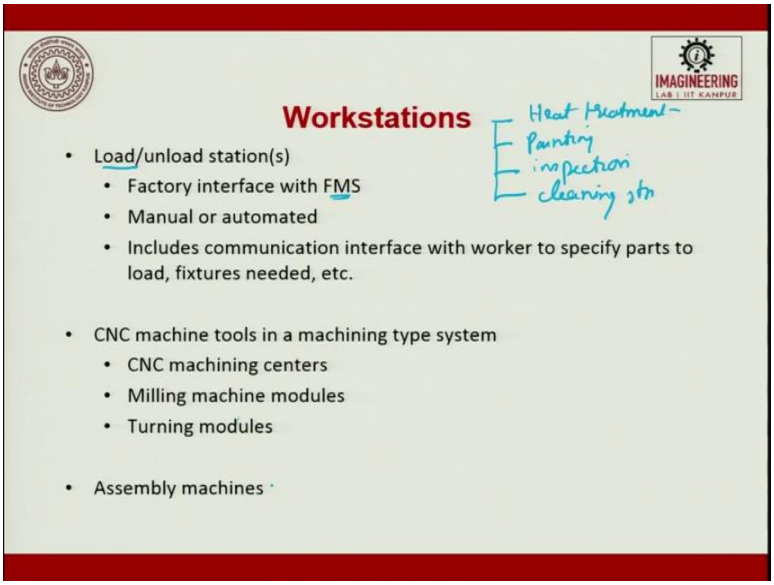

Loading and unloading of workstations: factory interface with FMS, manual or automated, include communication interface with worker to specify parts to load, fixtures needed etc. These are all the loading and unloading stations we will have in a FMS system.

CNC machine tool in a machining type system: CNC machining centers, milling machine modules and turning modules and, you can also have assembly as I told you. You can have loading and unloading, you can even have heat treatment, you can have painting stations, you can have inspection stations, you can have cleaning stations. So, all these things are called as workstations. So, this is loading and unloading station, where manual and automatic can be there; machining centers and assembly also I have talked.

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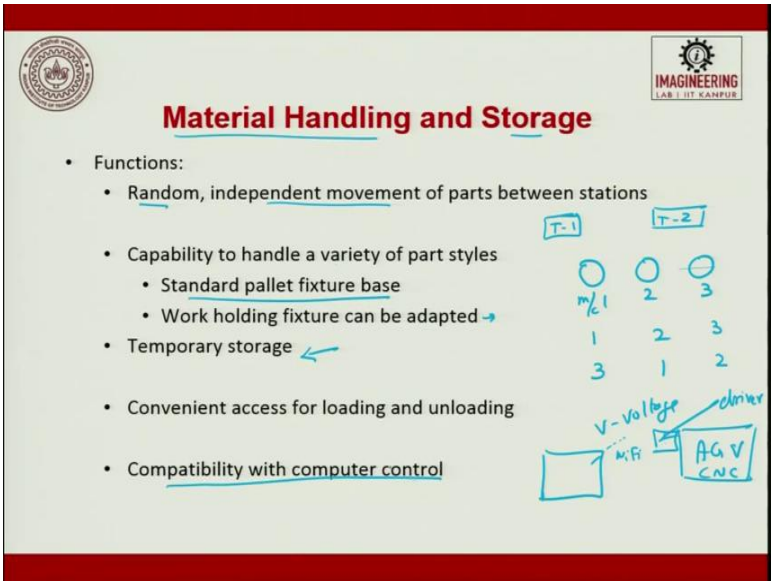

When we try to talk about material handling and storage; the functions are it is random; it is independent moment of parts between stations. For example, you have three machines, so machine 1, 2, 3 and you have a transportation system: one and, transportation system two which is trying to move parts into it. So, it need not always follow in sequence. First machine then going to the second machine and, then going to the third machine. It can be going to the first here and then going here and, then coming here; so this is what is saying random.

Depending upon the machine requirement that transportation will be going to different stations. So, if you look at it, in a train what happens? If there are humpty number of stations 1, 2, 3, 4. A train wants it can bypass a station; it need not stop in a station, but the root is fixed. So, here it is a fixed root but what we are talking here is random and independent moment of parts between stations. So, it need not after finishing one it goes, after finishing two, three it goes; from three it can go to two and then move from here to here, depending upon the machine requirement and machine starving.

So, material handling system need not follow a fixed root and it need not follow fixed order. Capacity handling a variety of part styles: Standard pallet base system.

So, today if you go to airports, the inspection is done on a standard pallet base. So, they ask put to put the baggage on a container on a plastic container and, then large bucket and then you put your baggage there. So, that is nothing but a standard pallet fixture; so in a CNC machine we fix it on a

pallet and then the part moves. Work holding fixtures can be adopted, so rather than screws, bolts, nuts you can also have pneumatics and magnetic which can adopt. Then you can have temporary storage which is part of the material handling and storage system.

Then convenient access for loading and unloading and compatible with computer control. See why it is very important because computer use out a signal, the voltage is very low. For AGV or a CNC machine to work you need to have a higher voltage coming. So, there is a Wi-Fi communication and there has to be a driver which drives it. Driver circulates which drives it; so that is what compatible with computer control. Computer control will be on and off, yes/no. A small voltage signal can be given but not a heavy signal such that it starts a CNC machine.

So, you should have intermediate drive; so this is what we are trying to talk about compatible with the computer drive.

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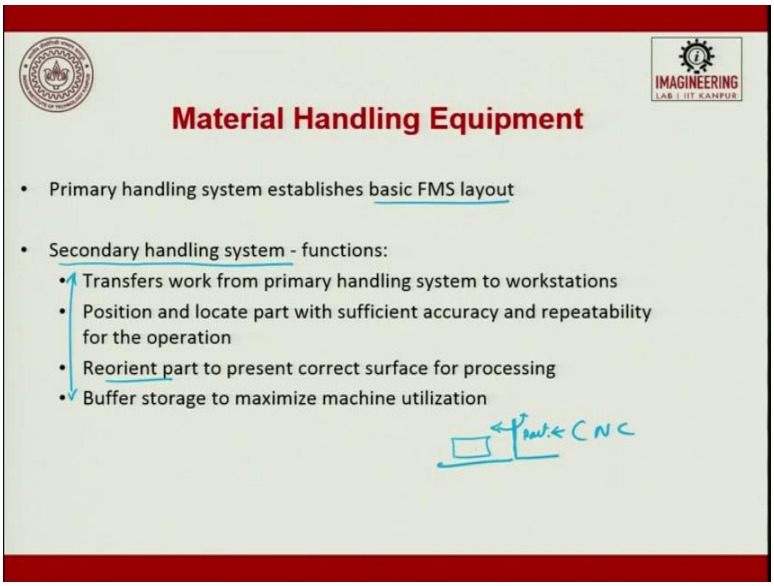

The material handling equipment, there are two classifications of material handling equipment. One is called as primary handling system; the other one is called as secondary handling system. So, the primary handling system establishes a basic FMS layout. The secondary handling system basically transfers work from primary handling system to workstation. Then position and locate part with sufficient accuracy and repeatability for the operation.

Then, reorient part to present correct surface for processing. Buffer storage to maximize machine utilization. All these things are secondary handling system, transfers work from primary handling system to workstation. Primary handling system can be conveyor; from a conveyor into CNC machine. Then once you put in a CNC machine you have to load the component exactly, such that when you execute a CNC program you get what is required. Then many a times we will do multiple surface machining. When we do multiple surface machining we have to reorient the part and again clamp it at that exact location; such that we do not loose the accuracies of alignment.

And the last one is buffer storage, so, if in a CNC machine we have a pallet. So, here we will have a part which loaded the CNC machine will start machining. While it is machining we will try to load the second part as and when the machining is over, there is an indexing happening. So, here what happens? The CNC machine time is maximize in terms of the utilization and, you will try to have one or two work pieces; which are loaded on the pallet and ready for machining.

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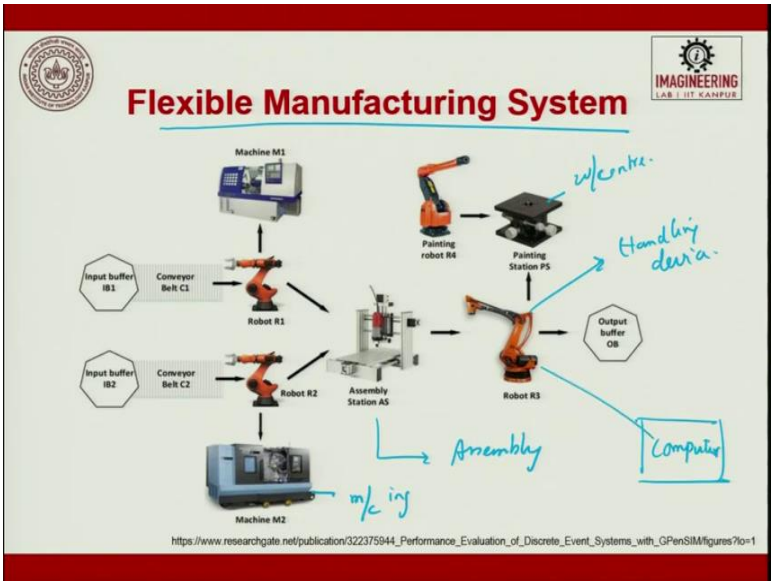

So, this is a flexible manufacturing system. So, here you see a machine 1, then you have input buffer, you have a conveyor. So, from input buffer conveyor comes, your robot takes it and loads it to the machine. After it is machined then what does is, it tries to take the part and keep it here to the assembly station and buffer 2 temporary buffer 2. It is stored for the parts, it is moved in the conveyor, robot is used; it pushes to machine 2 after machining it is kept on here. So, now there

will be a cycle time balancing between machine 1, machine 2, conveyor, indexing, and assembly station.

Once the assembly is over, then robot takes the part and sends it to the painting station. In the painting station, you will have one more 5 axis robot which tries to paint all the interior surface, exterior surface, counter surface. And once it is done then it pulls it back and push it to the outer buffer. So, the complete system, this is a handling device, this is a workstation, work center or, station, this is assembly station, and this is for machining. You see all the combinations are put here; so integrating and all these fellows talking to a central computer, which try to give signal to all.

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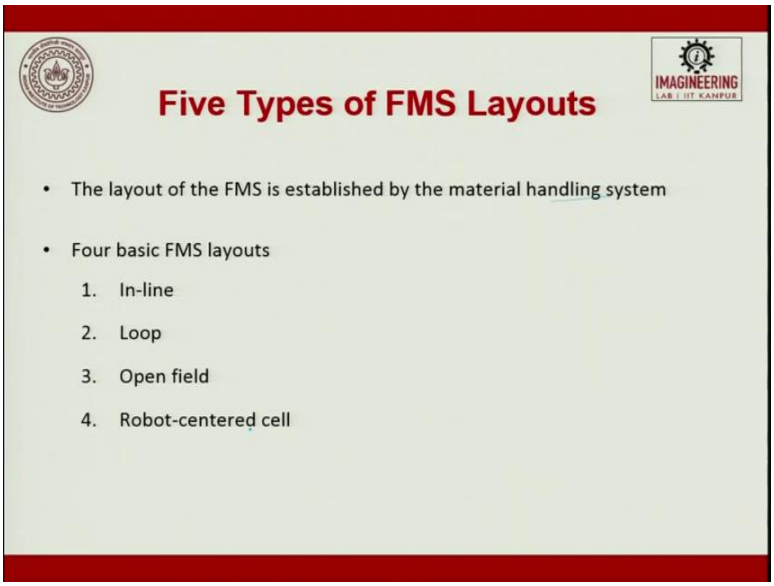

So, five types of FMS layouts: the layout of the FMS is established by the material handling system. So, there are five types, so, we will discuss four here. In-line, loop, open field and robot-centered cell.

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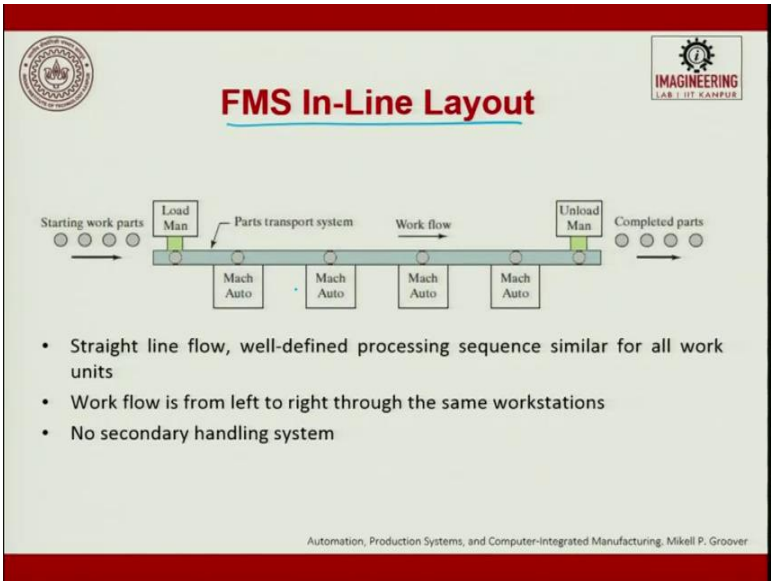

So, this is FMS in-line layout; so here we will see the starting work parts are lined up here. There is a loading station and then you have a conveyor which flows. The parts which are flowing here has to go all these operations machine 1, machine 2, machine 3, and machine 4. However, you are also left with an option of bypassing a station.

This is however flows and this is in-line layout. A straight line layout, well-defined processing sequence similar for all works units. The work flow is from left to right through the same workstation. No secondary material handling system is involved; so it goes from conveyor to conveyor and the machine takes the operation and, it does the work on the part and it put out to the conveyor.

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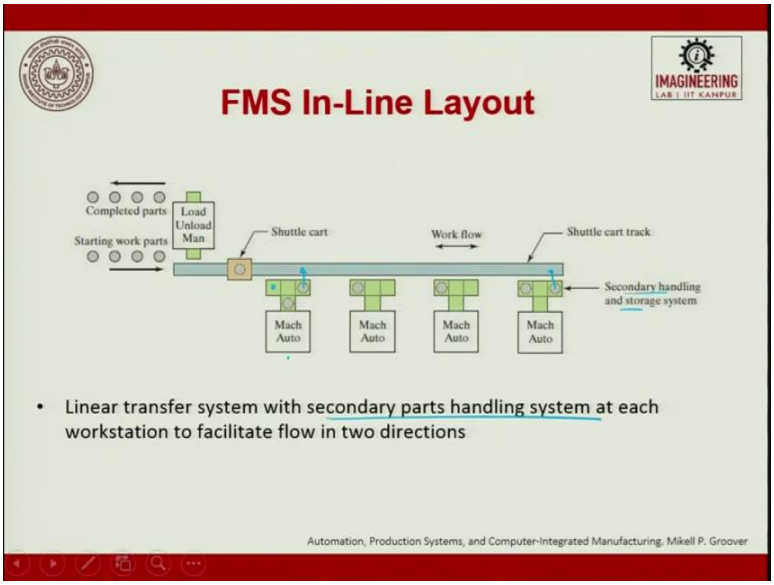

So, FMS in-line layout so here you see that you have a loading station and unloading station. The other thing is these two can be combined loading and, unloading can be combine at one place.

So, you will have a shuttle cart which moves in the conveyor or in the shuttle cart track; so you will have machines which are automated. These are buffers which are stored for the machine, so these are secondary handling and, storage systems; where and which it can be used to for loading and also use to for unloading the completed part. So, the shuttle will be using, so as and when it comes here, then you will put this here. So, then it undergoes machining so this will be pushed here.

So, one shuttle will be taking out all the finished parts as and when it comes here; that will be moved to the unloading portion, and loading portion will happen here. A linear transfer system with secondary part in the previous example we did not have a secondary handling. Here we will have a secondary handling part each workstation to facilitate the flow in both directions.

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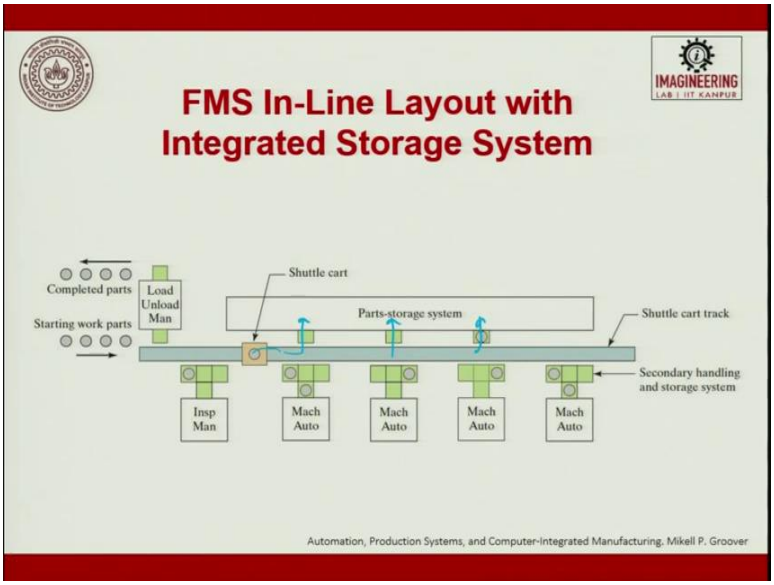

Next, the FMS in-line Layout with Integrated Storage System. So, the only difference between the previous one and this is a parts storage system will be here.

So, as and when the machining is done it will be stored in these regions. And then when the shuttle is free; it tries to take that part, and then it tries to come from loading and unloading station to get maximization of the machines which are used here.

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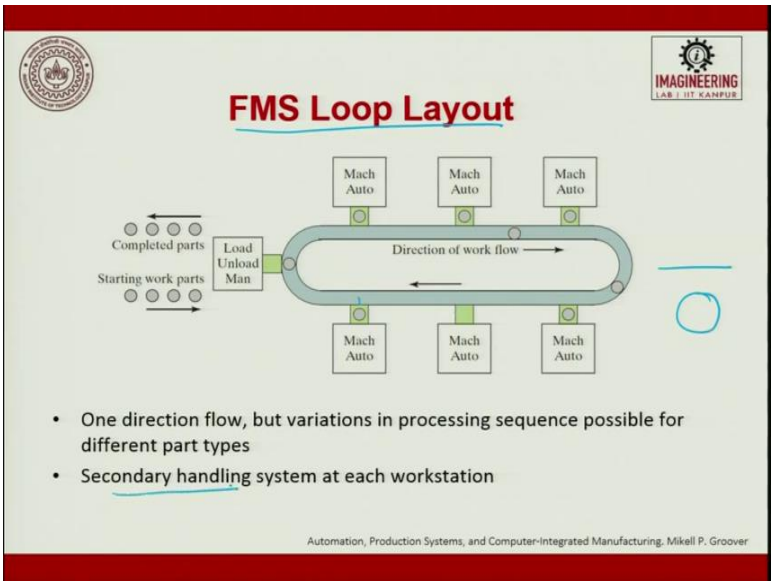

The next layout is FMS loop layout. Loop layout is you will form like a conveyor belts in the airports, so you start here, it keeps coming back to start once again. So, here will be a loading station and unloading station; so the advantages here it the straight line is now converted into a circle.

So, this spaces utilized for placing of these machines are reduced. So, you will have more machines, which can be placed around the conveyor, so that you can try to have a better control over the process of loading and unloading. And there is a control over the layout also. One direction flow, but variations in processing sequence possible for different parts to be produced. Secondary handling system at each station is here.

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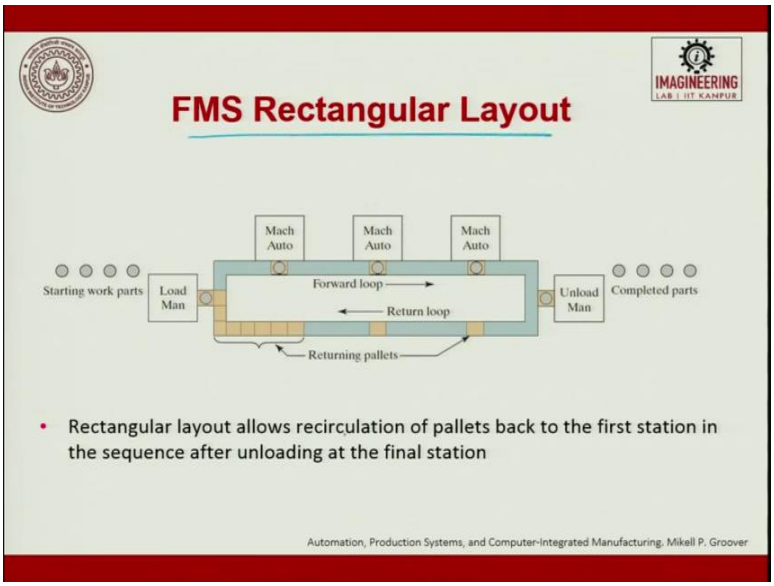

Next is FMS rectangular layout. Rectangular layout allows recirculation of a pallet back to the first station in the sequence after unloading at the final station.

So, you can see this is the returning of pallet which goes on which was not there in the previous one. So, here it is called as a FMS rectangular layout.

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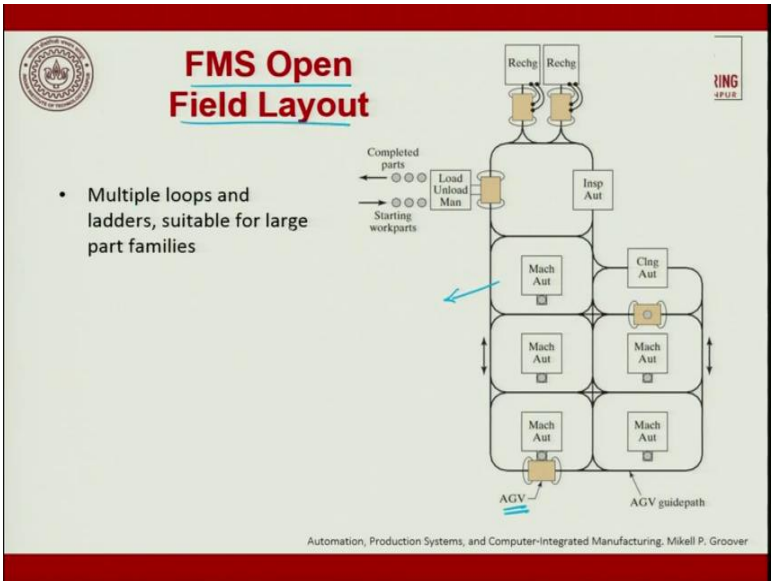

FMS open field layout is you keep adding, and deleting cell itself. So, multiple loops and ladders suitable for large part families can be done. Say for example, you can remove one, add one, you can go through the cell, you can nullify the cell; so each one of a cell of its own. So, you will have an automation so these are open loop system.

So, these are AGVs which are used for taking the parts from your loading station towards the machine tools, and then once the operation is over it comes and drops it back. So, here once the battery life is over it goes here for recharging and gets itself equipped. So, this is the ultimate open field layout, so multiple loops and ladders suitable for large part families are done in this.

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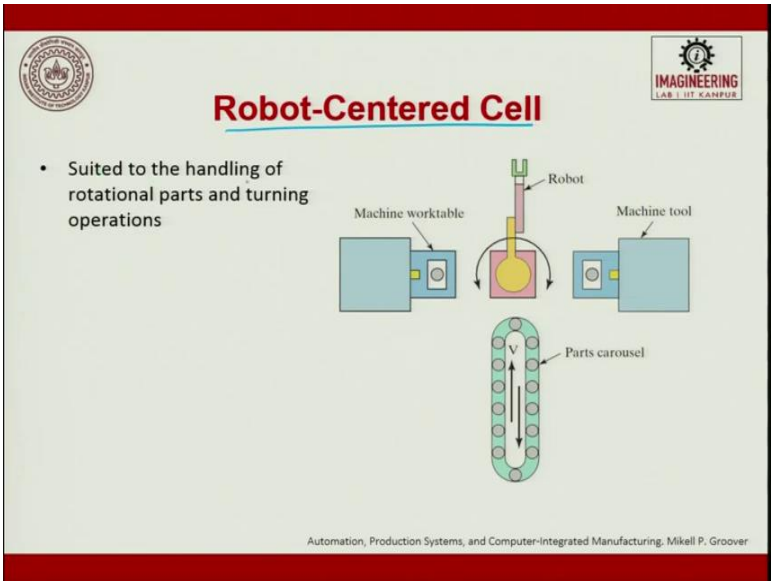

Next one is Robot-Centered Cell. A robot is placed which is used for handling the part between the workstations and the layout.

Suited to the handling of rotational parts and turning parts.

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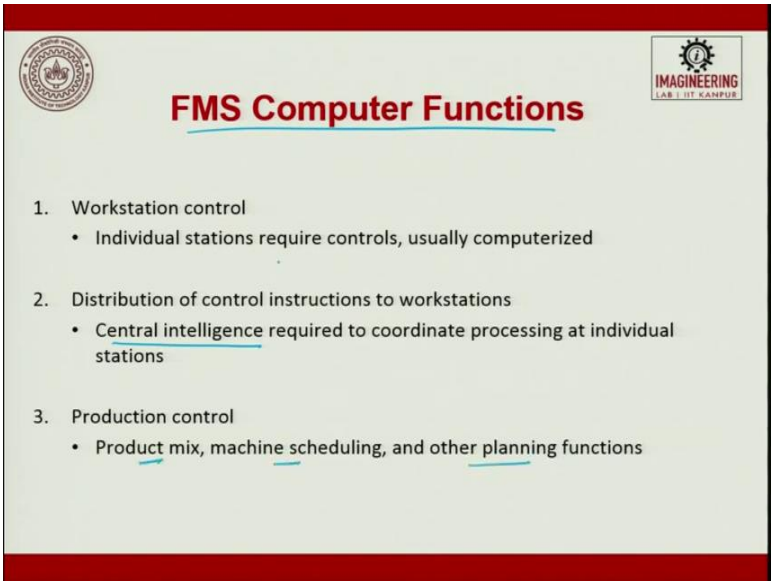

So, the FMS computer functions, there are three main functions so workstation control. It can help in distribution of control instruction to workstations, it can be production control. Individual stations require controls usually are computerized. It is workstation control, single machine

control. Distribution of control instruction to workstation; so central intelligence required to coordinate processing at individual workstations. Suppose if half of the work is going on rather than loading the new program there.

It will try to assess and other CNC machine, where it is free and upload the program; so, that is central intelligence control system is used. Then production control product mix, machine scheduling and other planning functions are some of the FMS computer functions which are used.

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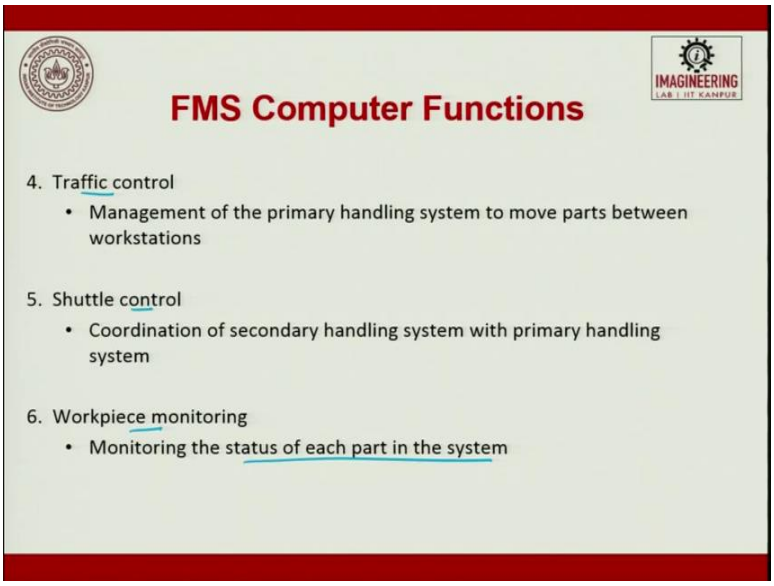

Next is traffic control, shuttle control and, workpiece monitoring. So, traffic control is, management of the primary handling system to move parts between the workstations. Then shuttle control is, coordination of secondary handling systems with primary handling systems is called as shuttle control.

And the last one is going to be workpiece monitoring; monitoring the status of each part in the system is called as workpiece monitoring system. So, you will have six components workstation control, then distribution of control instruction to workstations; then production control; then you will have traffic control because so many pallets are moving inside a system, so it has very clearly distinguished it is loaded, unloaded or it is new, old. It has to pull this out, or it has not to pull this out. So, the management of the primary handling system to move parts between the workstations. Then shuttle control coordinates, the secondary handling system with primary shuttle control. And the last one is the workpiece which is machined is good or bad that has also to be done.

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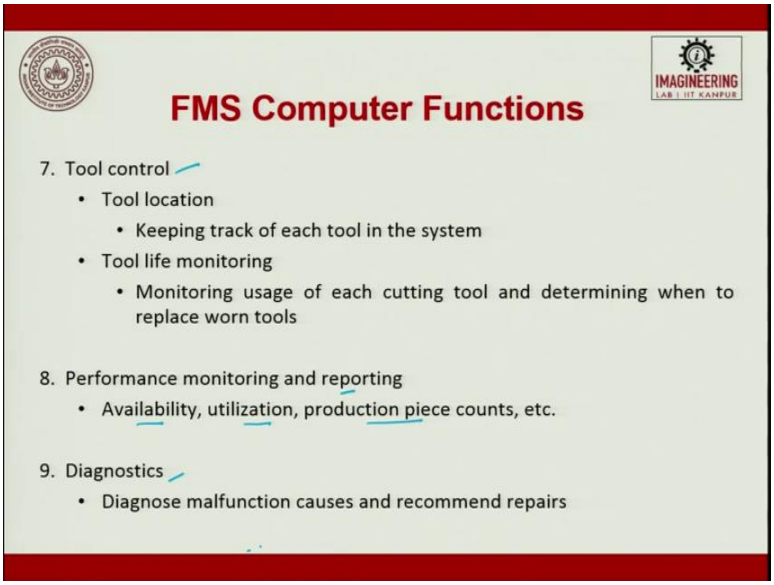

Then tool control is also there, performance monitoring report, diagnostic report; so this is also important. So tool control, we keep track of each tool in the system, monitor the tool life. Then performance monitoring reporting is availability, utilization and production piece count or performance monitoring. If there is a problem, then it tries to raise an alarm, when there is a malfunctioning or when there is a rework has to happen in a piece.

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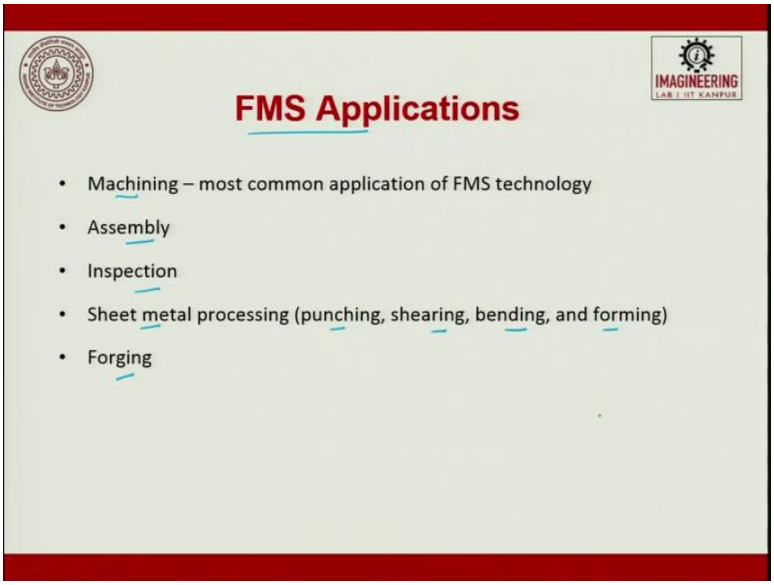

So, FMS applications can be in machining which is most commonly applied. It can be assembly; it can be inspection; it can be in sheet metal processing; it can be in forging. So, all these places FMS is exhaustively used. When we talk about sheet metal, we talk about operations like punching, shearing, bending and forming.

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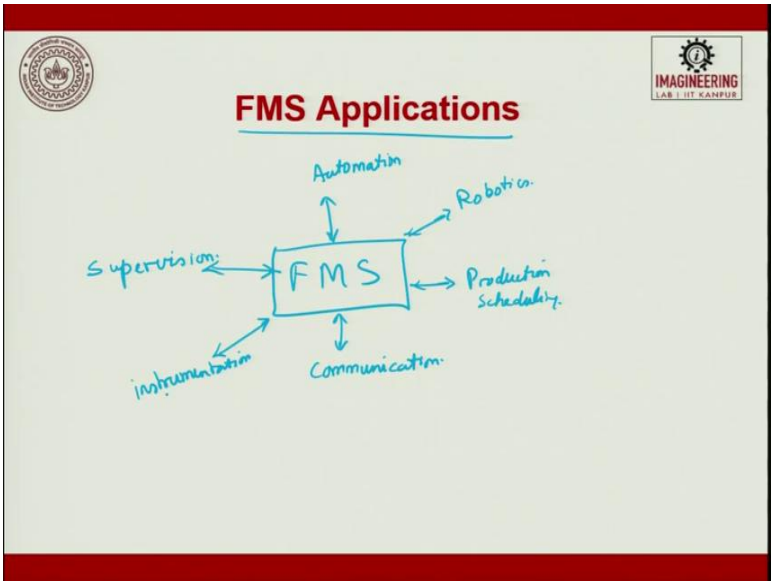

So, when we talk about FMS application we have an FMS here, so supervision, and automation, all these things are in the FMS. Then we have robotics, then we have production scheduling all these things are part of FMS. Then we will have communication, then we have instrumentation all these things are, where FMS applications are exhaustively used.

So, this is FMS system supervision, then we will have automation; then we will have robotics; then we will have production scheduling, communication, and instrumentation.

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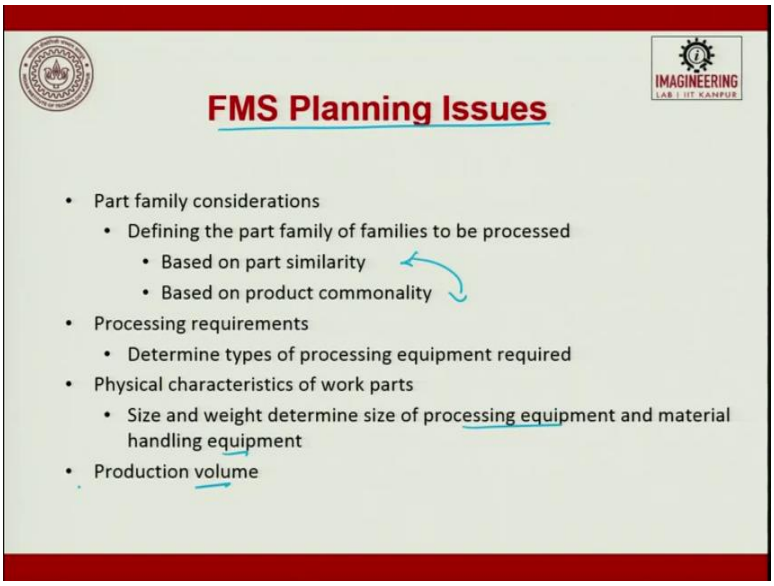

So, FMS planning issues: part family consideration has to be there. Defining the part family of families to be processed based upon the part similarity, and based upon the product commonality. So, these are very important things which will help us to look from the planning of implementing an FMS. Then, processing requirements: Determine the types of processing equipment required, then physical characteristics of work parts is very important.

The size, the weight of the processing equipment and material handling equipment, and finally the production volume. So, all these things play a very important role while planning an FMS system. One is part family consideration, processing equipment or requirements; then physical characteristics of the part and the quantity production volume.

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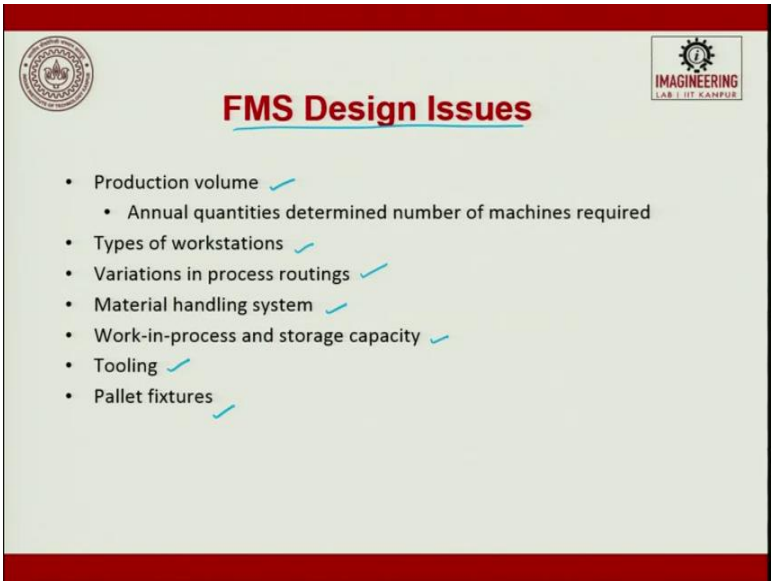

So, when the FMS system has to be designed, the design issues are to be the volume, type of workstations, variation in process routing, material handling system, work in progress and storage capacity, tooling, and pallet fixtures. All these things are design issues that are to be considered when we are trying to talk about FMS. All these things are very important because pallet changing tool; all these things have to be done automatically.

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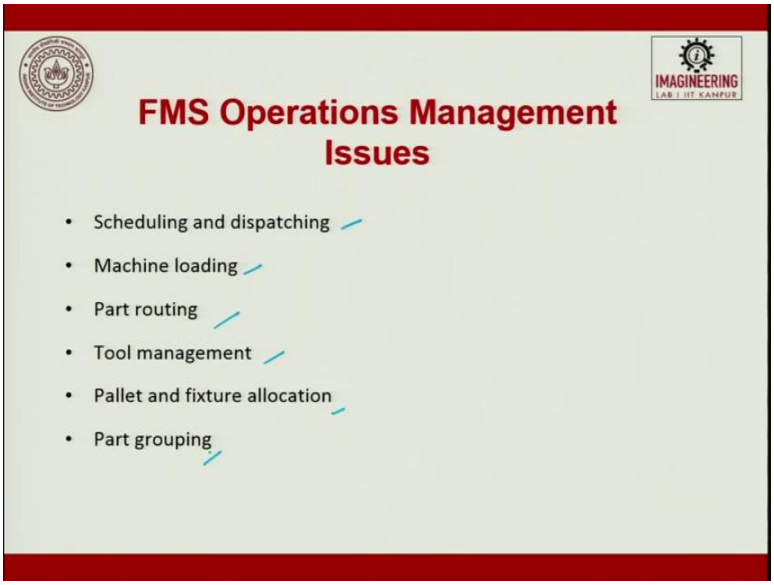

The FMS operation management issues are going to be scheduling and dispatching, machine loading, part routing, and then tool management, part and pallet allocation, and part grouping. So, all these things are FMS operation management related issues. So, we saw the first one is, planning issues; then we saw design issues.

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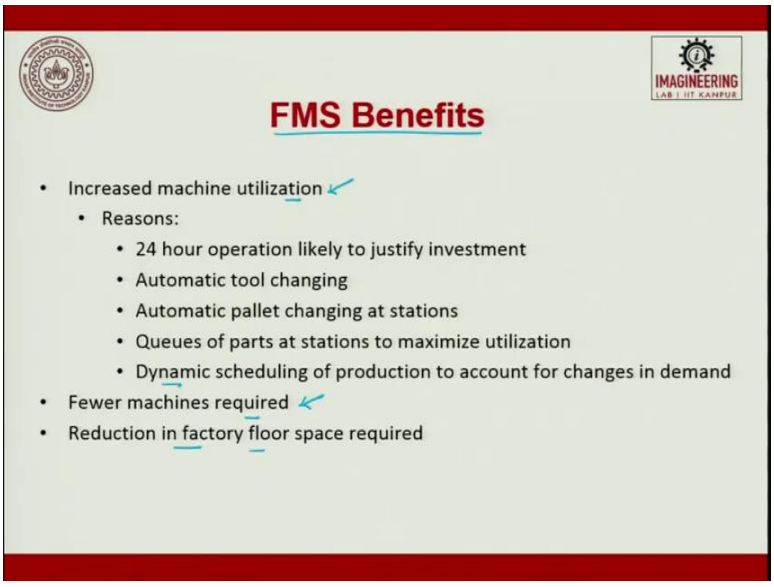

Then we are trying to see the management issues and, finally we will see, what are all the benefits of implementing this FMS? It increases the machine utilization, at any given point of time inside my factory. Every machine I will be able to see the utilization of the machine which is a big thing. So, which machine is loaded, which machine is overloaded, where are the failing happening? And what are all the failures? Where does it lead to all scraps? All this information will be there. When we talk about these management issues, we are talking about scheduling and dispatching.

So, by doing FMS or implementing FMS the machine utilization increases. Reasons are 24-hour operations can be done; automatic tool change can happen; automatic pallet change can happen; queues to parts at stations to maximize utilization can happen; dynamic scheduling can happen. So, all these things can happen; thus leading to an increase in meeting utilization. Fewer machines are required because if I am able to load a machine and if it is a flexible machine. So, I do not have to buy n number of machines; I can optimize and buy three or four machines where and which I can do various implements.

So moment three or four machines are only been used in the factory, then the floor space of the factory is also reduced. So, you see that by implementing FMS, I am able to increase utilization; I am able to reduce the number of machines; I am able to reduce the factory layout floor space, by doing so, I am able to control the factory. So, it is important to implement FMS but you have to make sure these are the challenges which are going to be ahead of you. Once you solve all these things, FMS is going to give you a big benefit.

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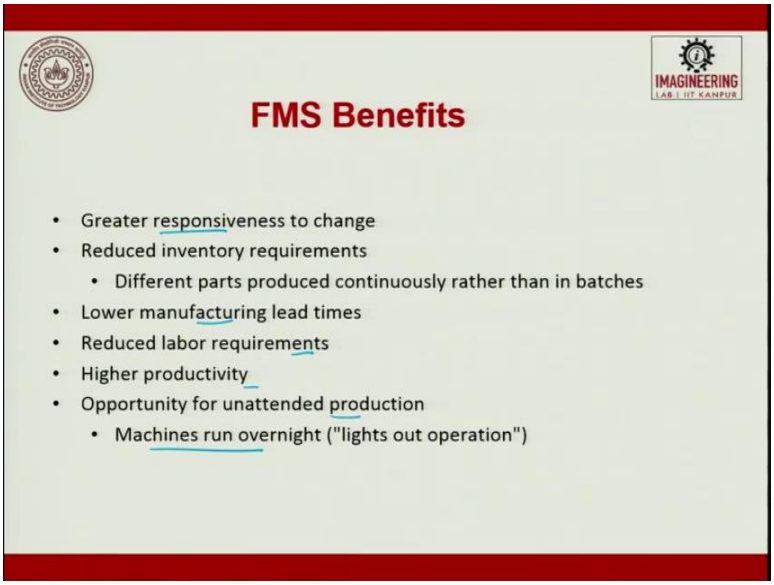

Next, a greater response to change can happen because now how machines which are very flexible. So, between machines, if the parts are below, then what is the work in progress status? What is the inventory status? So reduce in inventory requirement lowering the lead time. So, once it is greater responsive, then the lead time reduces. Then the labor requirement is reduced, it is highly productive. Opportunity for unattended production, so machine runs overnight "lights out operation". So, machines are 24 by 7 loaded, so this is the benefit of an FMS.

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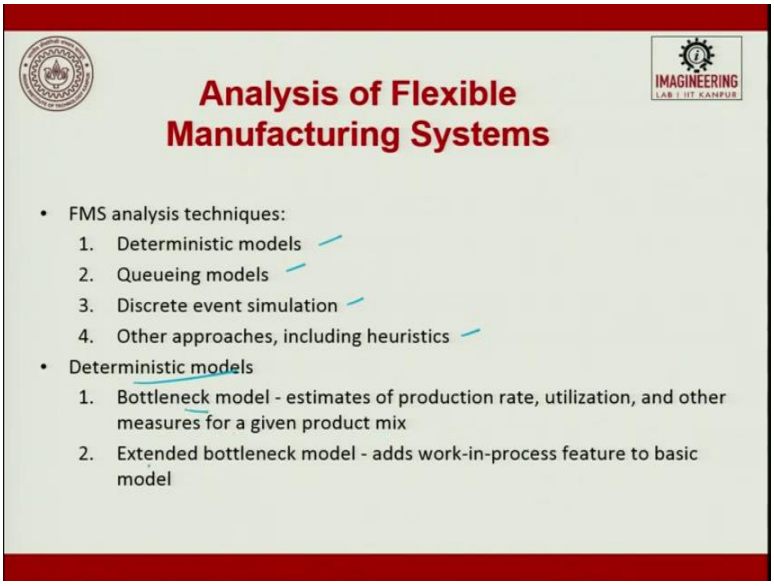

So, analysis of the FMS manufacturing system: The FMS analysis techniques are it is a deterministic model. You will have a Queuing theory model so these are some analysis we do. Then we have discrete event simulation; then other operations including heuristics. These are some of the analysis techniques which are used in assessing a flexible manufacturing cell. Because when we say that model product when there is product variety change and, there is scheduling change.

How are we going to operate the queuing theory? How is that deterministic model which we are going to see? The Deterministic model, we will use two types of models. One is called, Bottleneck model- estimates the production rate, utilization, and the other measures for a given product mix is done by bottleneck model. The extended bottleneck model adds work-in-progress along with the production rate utilization and the product mix.

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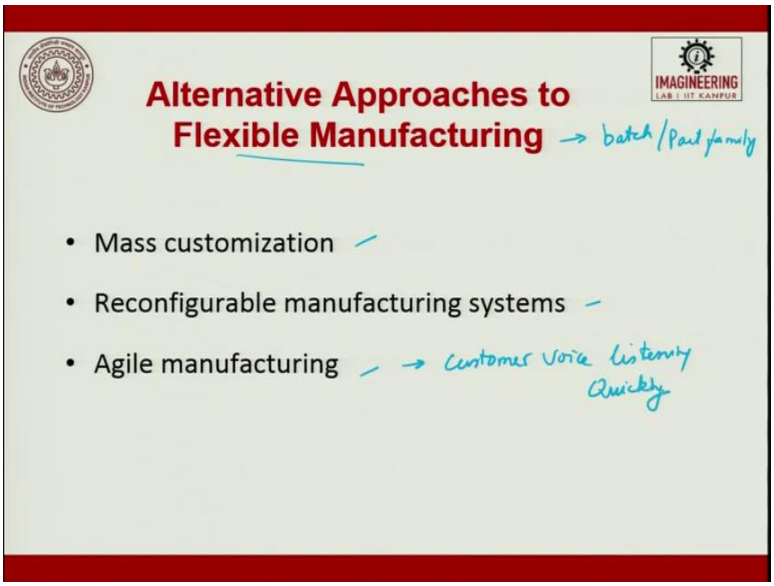

Alternative approaches for flexible manufacturing are mass customization which is the need of the hour. Reconfigurable manufacturing system and agile manufacturing system. These are the alternative approaches that are now talked off from flexible manufacturing. Because flexible manufacturing, the batch size and part family to a large extend is fixed.

So, if you do that, you will not be able to do mass customization then reconfigurable manufacturing systems and agile manufacturing will not be there. What is agile? It is quickly listening to customers; customer's voice listening quickly that is agile.

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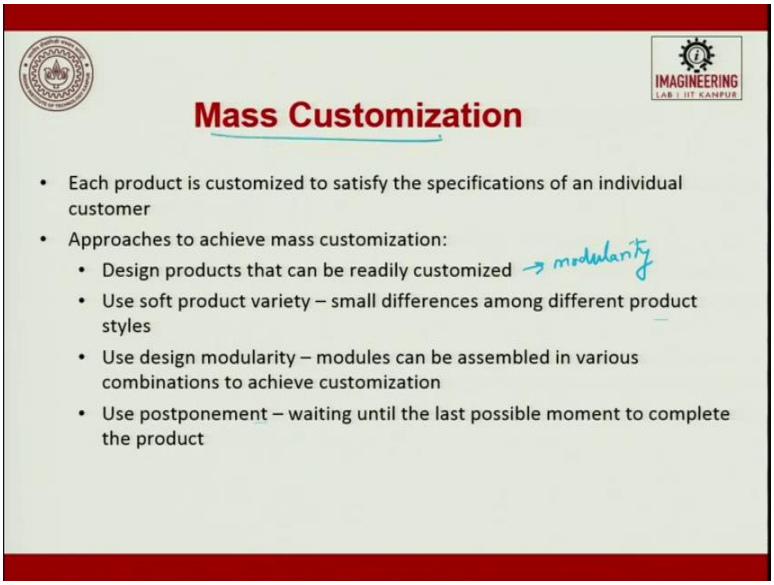

These are the alternate approaches. So, mass customization each product is customized to satisfy the specifications of an individual customer, mass customization. Or no two products will be the same, it will be similar. Approaches to achieving mass customization can be designing products that can be readily customized. So, we are more focused towards modularity.

For example, for a shoe, these are fixed number of parts, the variation depending upon the customer coming. You quickly do some small changes and make a shoe. Use soft product variety small differences among different product styles. Use design modularity, use postponement waiting until the last possible moment to complete the product.

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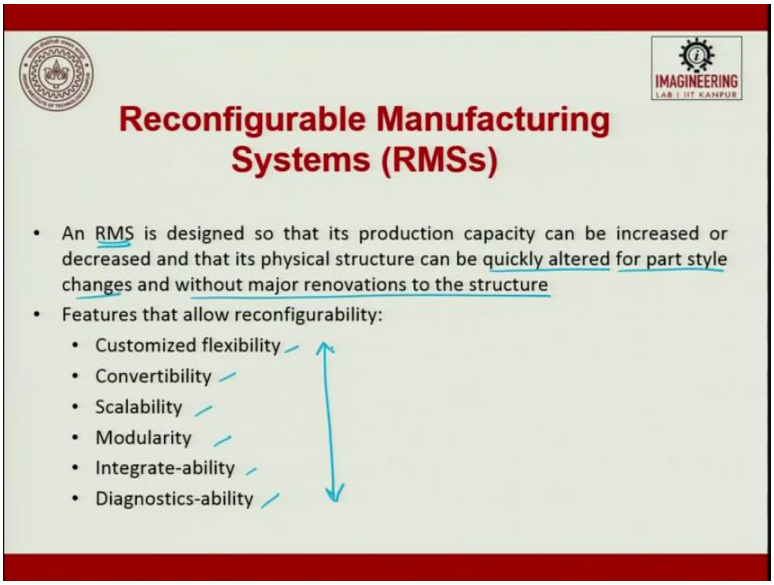

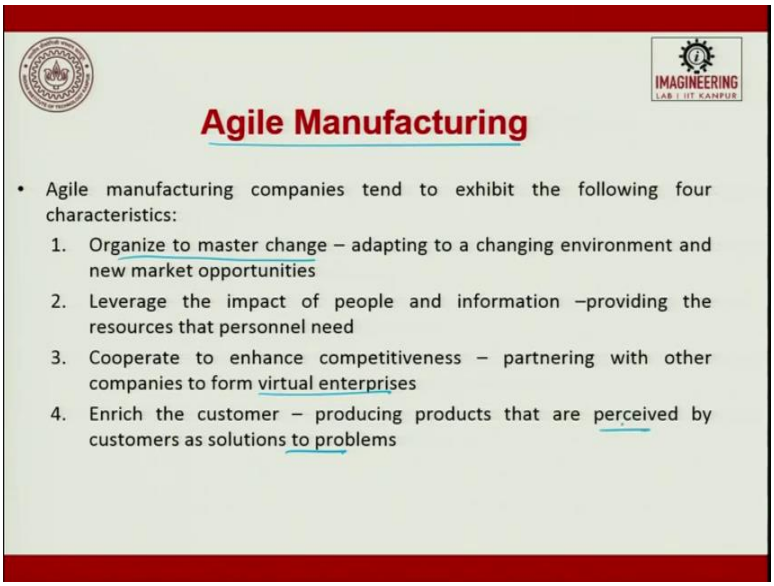

So, these are the different approaches when we think of mass customization. When we think of Reconfigurable Manufacturing System, RMS. An RMS is designed so that its production capacity can be increased or decreased, and that its physical structure can be quickly altered for part style changes and, without major renovation to the structure. So, this is reconfigurable so it can be quickly altered for part style changes without major renovations to the structure. So, the features that allow reconfigurability are customized flexibility, convertibility, scalability, modularity, integrated-ability, and diagnostic-ability.

These are the features of reconfiguration; it might look futuristic but now companies are moving towards it because now the productivity is very much talked about. Agile manufacturing: Agile manufacturing companies tend to exhibit the following four characteristics. Organize to master change, leverage the impact of people and information, cooperate to enhance competitiveness, and enrich the customer. These are the four characteristics that agile manufacturing has. Organize to master change - adapting to a changing environment and new market opportunities are agile manufacturing; organize to master change.

Next, leverage the impact of people and information - providing the resources that personnel needs. So, you tell them thee are the flexibilities you have and try to ask whether you want to choose within this you can try to make the product faster. Leverage the impact of people and information, cooperate to enhance competitiveness. So, partnering with other companies to form a virtual enterprise. So, if a company is very good at making tyre, collaborate with him. You do not make tyre or engine. But, you do the final assembly of a car.

So, cooperate to enhance competitiveness, agile manufacturing is pushing and, then enrich the customer producing the product that is perceived by the customer as a solution to the problem. So, the customer draws and gives you a solution. Today we have paints where and which you go to a paint booth and choose your color and then you quickly get the output. Whatever, it is from the booth itself and tries to go with the color of your choice.

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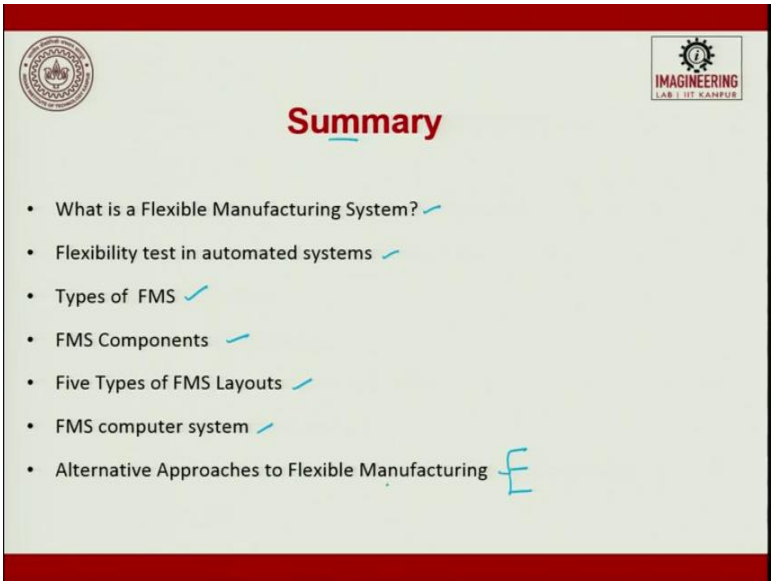

To summarize, first, we saw what is FMS? Then we saw how we do the flexibility test in an automated system to decide whether to go for FMS? Then, we saw types of FMS; then FMS components, we saw machine, computer, and handling. Then five different types of FMS layouts we saw; then five FMS computer systems we saw. Finally, we saw agile manufacturing, mass customization and reconfigurable manufacturing system. There are alternative approaches which are coming to flexible manufacturing in today's environment. Thank you.