Advanced Manufacturing Processes

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Module - 1
Introduction
Lecture - 3
Manufacturing Aspects Selection and Classification

Dear students, in this session we will discuss different aspects of manufacturing, process selection criteria, process capability, and classification of manufacturing processes. First let us look into the different aspects of manufacturing.

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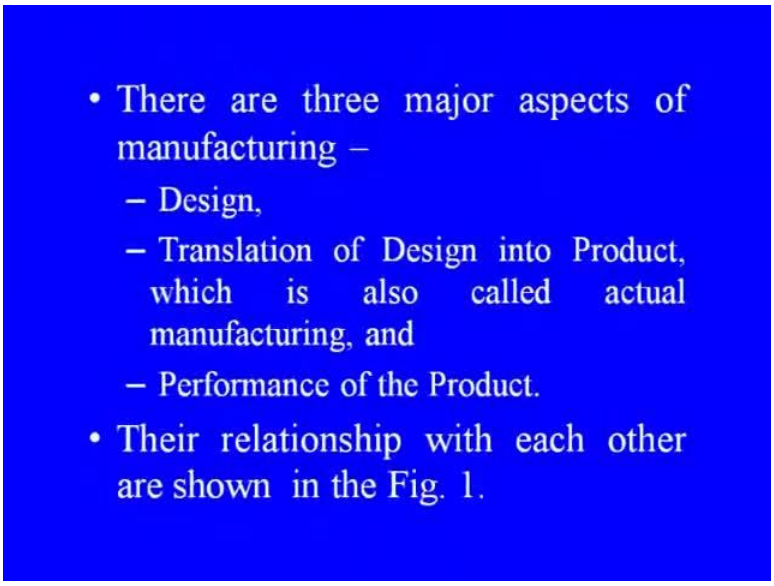

There are three major aspects of manufacturing; design, translation of design into product, which is also called actual manufacturing and performance of the product. The relationship between these are shown in figure one.

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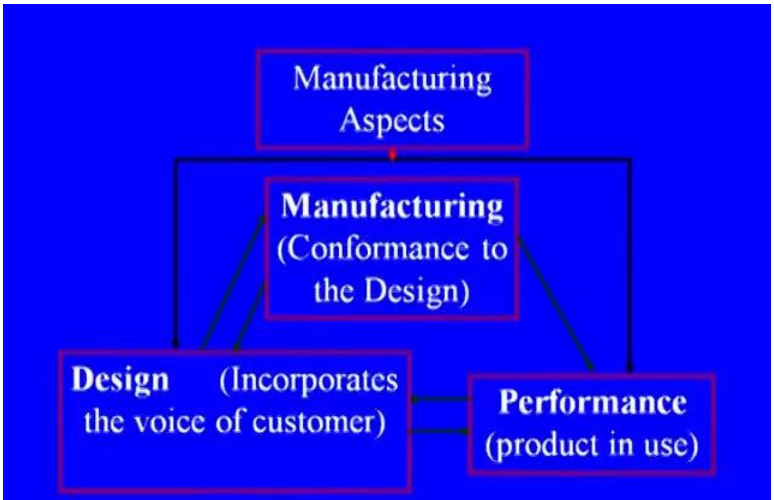

Fig. 1 Three aspects in manufacturing

Manufacturing aspects or design, performance, and manufacturing; in the design phase the concept of the product is translated into a written document. This incorporates the voice of the customer, then this design is converted into a product by means of various manufacturing techniques, which is called manufacturing. Here the design will be converted into the product by conforming to the design specifications. Then the resultant product will be moved to the market, where they will be put to use. Here at this stage, the performance of the product will be tested and depending on its performance.

The feedback of the user will be giving to the designers, where the design of the product may get improved according to the feedback of the customers. Then the improved design will be implemented in the manufacturing phase and or an improved product will be resulted and thus the cycle will continue. What is the customer prospective of this design process?

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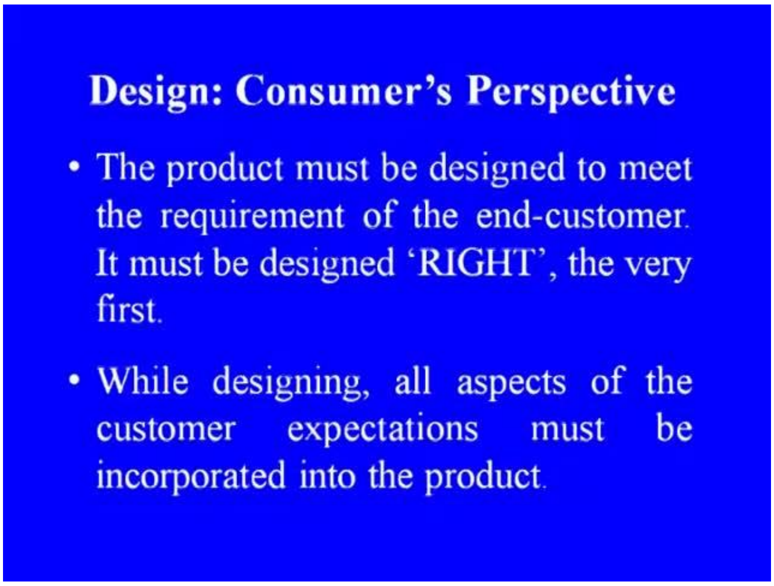

The product must be designed to meet the requirement of the end customer. It must be designed right the very first time. While designing all aspects of the customer expectations must be in cooperated into the product. And what is the manufacturers prospective?

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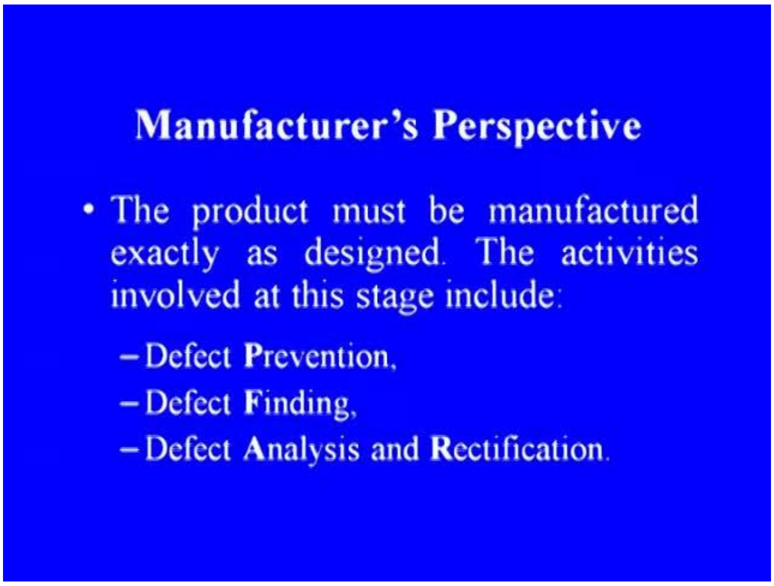

The product must be manufactured exactly as designed. The activities involved at this stage include; defect prevention, defect finding and defect analysis and rectification, if there is any. The difficulties encountered at the manufacturing stage must be conveyed to the designers for modifications in design.

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Two way communication between design and manufacturing, which is also called concurrent approach can help to improve the quality of the product to a great extent. As different issues such as practical difficulties, achievable tolerances and process capabilities will be addressed.

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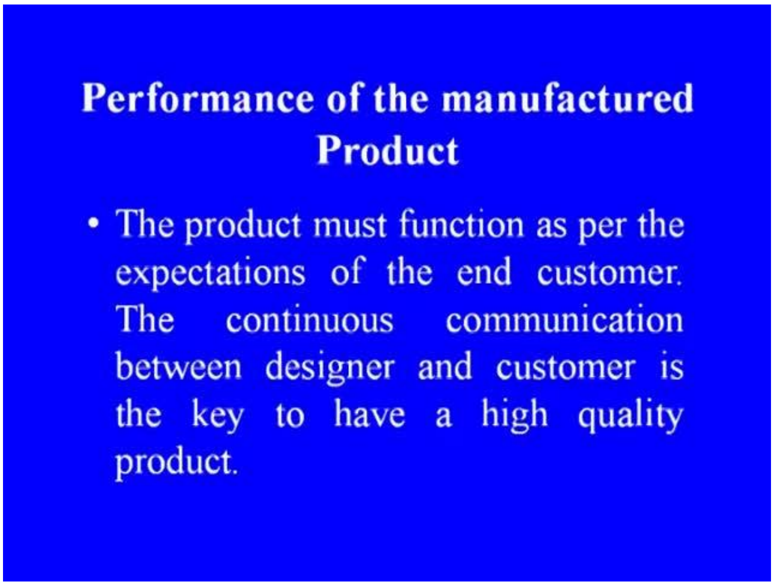

Performance of the manufactured product: The product must function as per expectations of the end customer. The continuous communication between designer and customer is the key to have a high quality product. Next come to the manufacturing process selection. There are different criteria for selection of manufacturing process, the following points need to be considered before actual product manufacturing.

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Number one, material selection this includes; the considerations related to product requirements, environmental and recycling aspects and cost.

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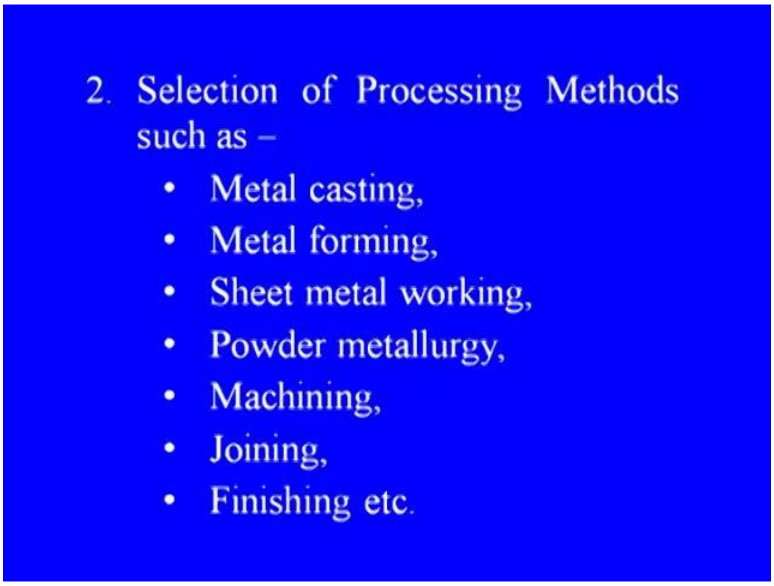

Number two selection of processing methods, such as metal casting. metal forming, sheet metal working, powder metallurgy, machining, joining, finishing etcetera. Selection of the process sequence appropriate tooling and equipment constitutes the third step.

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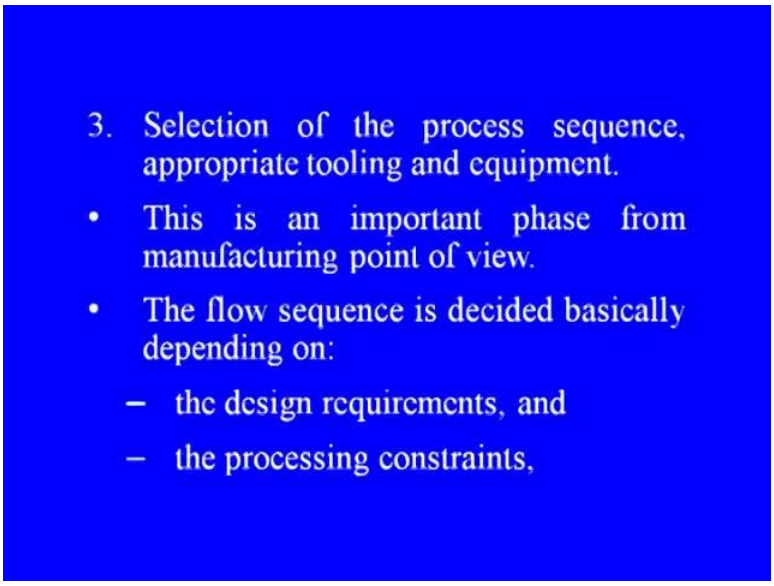

This is an important phase from manufacturing point of view. The flow sequence is decided basically depending on the design requirements and the processing constraints. An engineering drawing is the fundamental element for deciding process and sequence. Right equipment and tool selection is vital in order to produce the product most economical and quality wise competitive.

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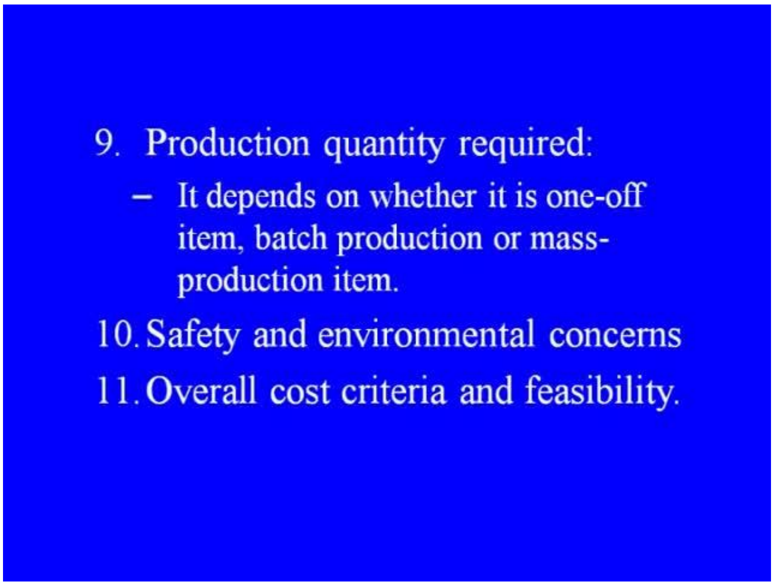

Number nine, production quantity required, it depends on whether it is one off item batch production or mass production item. Safety and environmental concerns is the next step. And number eleven overall cost criteria and feasibility. Now, let us move on to process capability.

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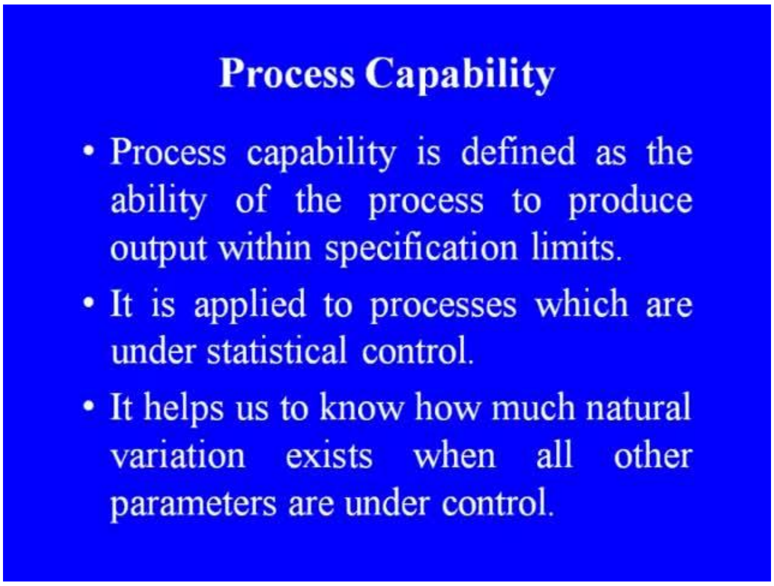

Process capability is defined as the ability of the process to produce output within specification limits, it is applied to processes which are under statistical control. It helps us to know, how much natural variation exists, when all other parameters are under control.

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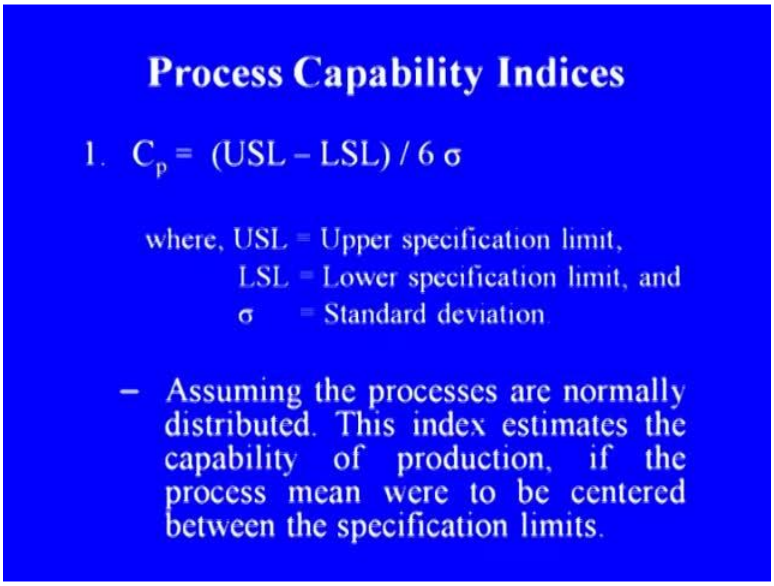

There are number of process capability indices number one, C p. It is defined as the ratio of differences between the upper specification limit and lower specification limit, to the 6 sigma, where sigma stands for standard deviation. Assuming the processes are normally distributed, this index estimates the capability of production. If the process mean were to be centered between the specification limits.

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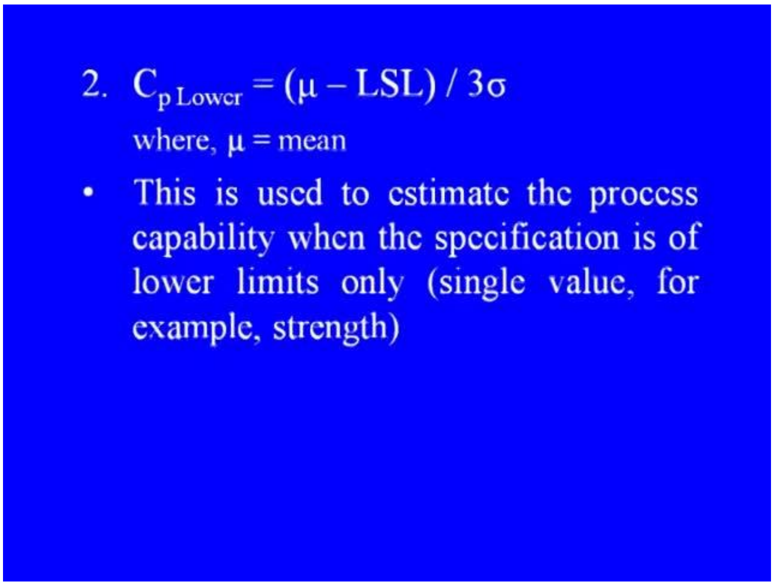

Number two, C p lower, which is defined as mu minus lower specification limit divided by 3 sigma, where mu stands for mean. This is used to estimate the process capability when the specification is of lower limits only, that is single value. For example, strength.

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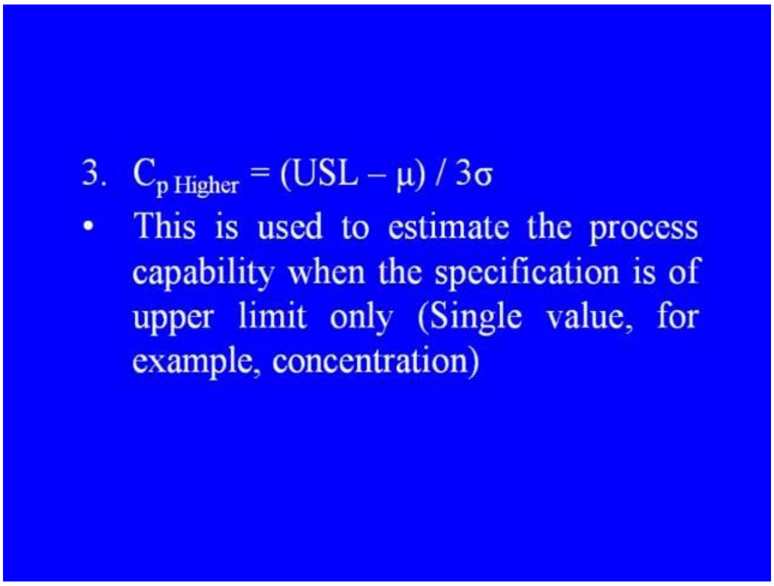

Number three, C p higher, which is defined as upper specification limit minus mu divided by 3 sigma. This is used to estimate the process capability, when the specification is of upper limit only, this is also single value, for example concentration.

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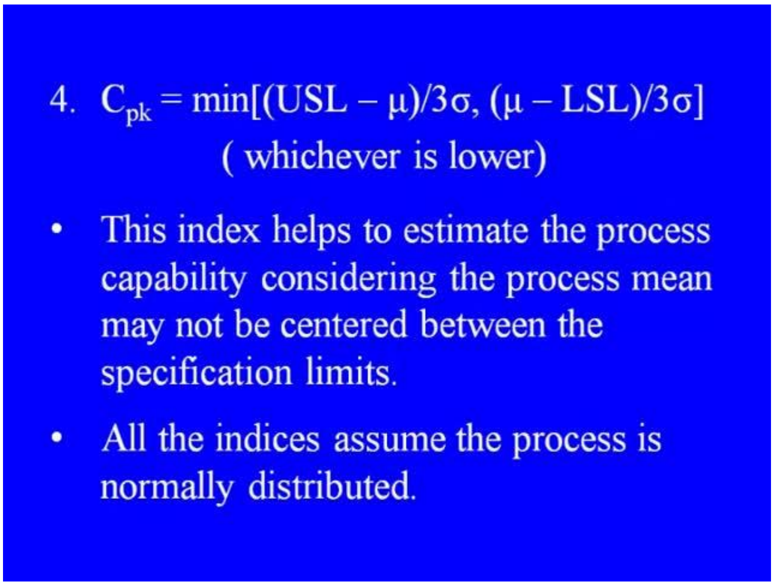

The fourth index is C pk, which is defined as the minimum of upper specification limit minus mu divided by 3 sigma and mu minus lower specification limit divided by 3 sigma, whichever is lower is accepted. This index helps to estimate the process capability, considering the process mean may not be centered between the specification limits. All the indices assume the process is normally distributed.

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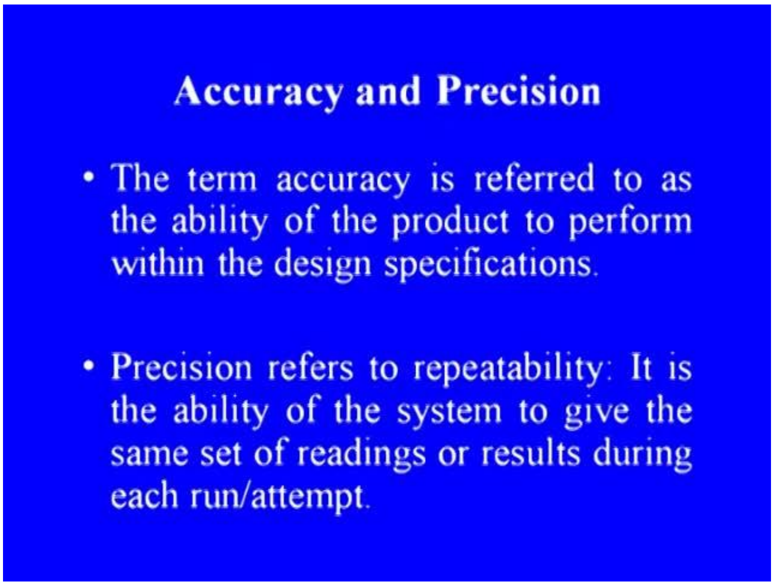

Then what accuracy and precision? The term accuracy is referred to as the ability of the product to perform within the design specifications. While precision refers to the repeatability, it is the ability of the system to give the same set of readings or results during each run or attempt. Here is an example, a very good example of accuracy and precision can be understood, considering the shooting. Example as shown in the subsequence slide, the inner most circle and this represents the tolerance or specification limit.

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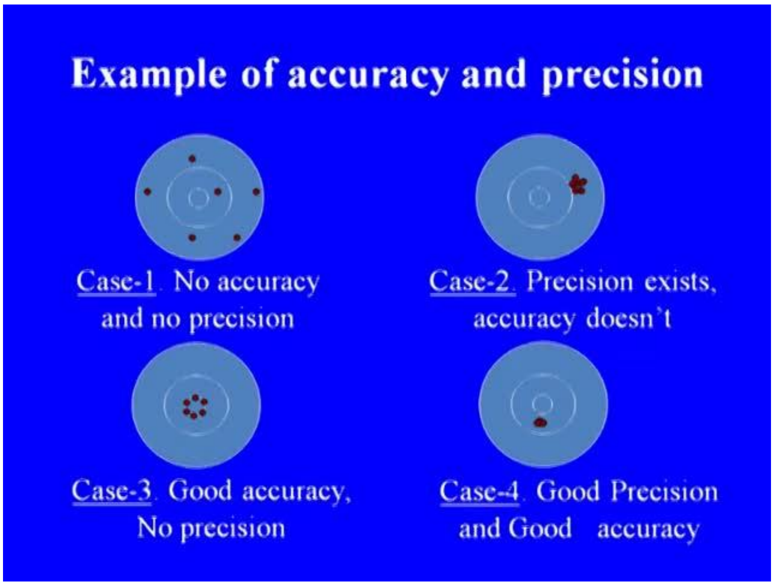

Here, there are four cases. In case one, bullets are being fired in this fashion. This represents a case where no accuracy and no precision. Whereas in case two, bullets are fired in a very narrow zone. Here we can say precision exist, but accuracy does not. In the third case the bullets are being fired near to the target, but not consistently in the single place. Here we can term this as having good accuracy, but without any precision. On the other hand, the fourth case represents a case were good precision and good accuracy both exist. In this case bullets are being fired very near to the target and all shots are concentrated very near.

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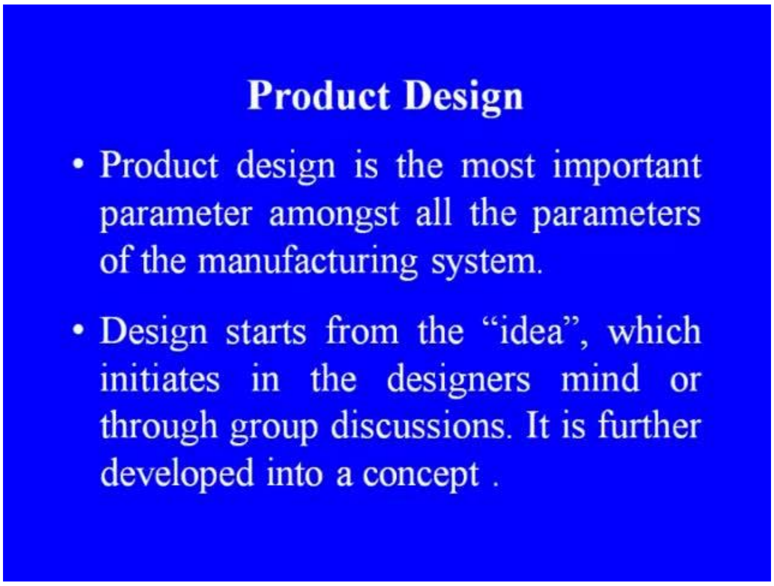

Then let us move on to product design, product design is the most important parameter amongst all the parameters of the manufacturing system. Design starts from the idea, which intimates in the designers mind or trough group discussions it is further developed into a concept.

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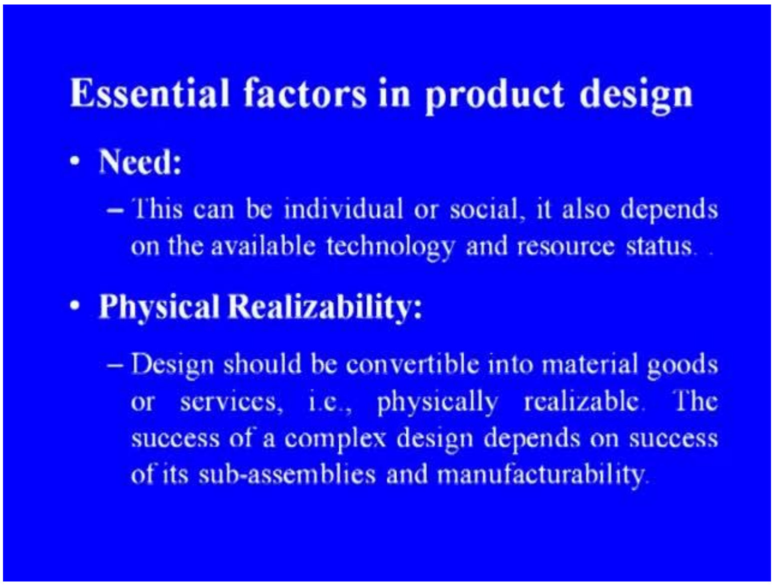

Essential factors in product design are; need. This need can be individual or social. It also depends on the available technology and resource status. The next factor is physical realizability. Design should be convertible into material goods or services, that is physically realizable. The success of a complex design depends on success of its sub assemblies and manufacturability.

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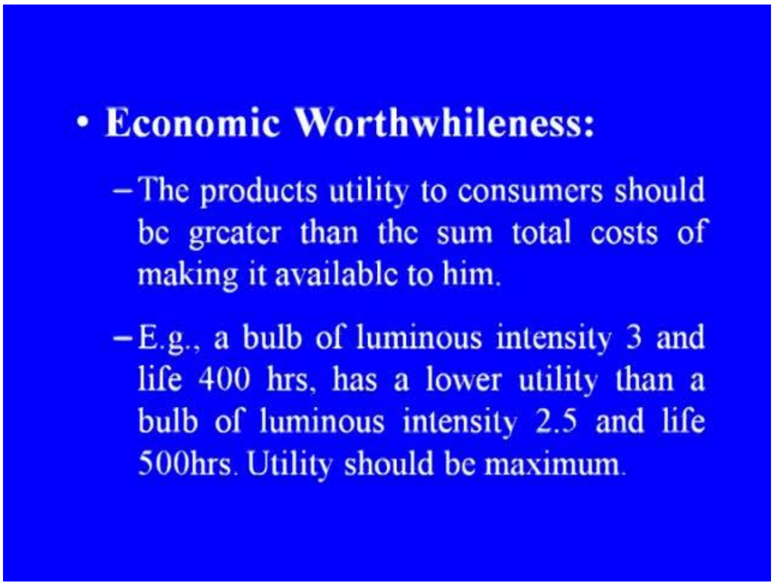

Next factor is economic worthwhileness. The product utility to consumers should be always greater than the sum total cost of making it available to him. For example, a bulb of luminous intensity 3 and a life of 400 hours has a lower utility than a bulb of luminous intensity 2.5 and life of 500 hours. Utility should be maximum.

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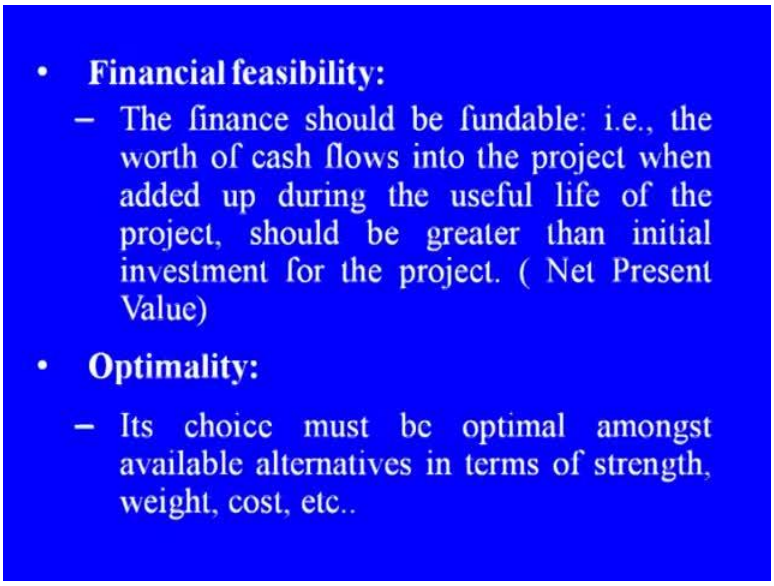

Next factor is financial feasibility. The finance should be fundable, that is the worth of cash flows into the project when added up during the useful life of the project, should be greater than initial investment for the project, which is net present value. Next is optimality. Its choice must be optimal amongst available alternatives in terms of strength weight cost etcetera.

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Next comes design criteria. Optimality must be established relative to a design criteria, which represents the designers compromise among possible conflicting value judgments, which include those of consumer, producer, distributor and of his own. Next is morphology of design.

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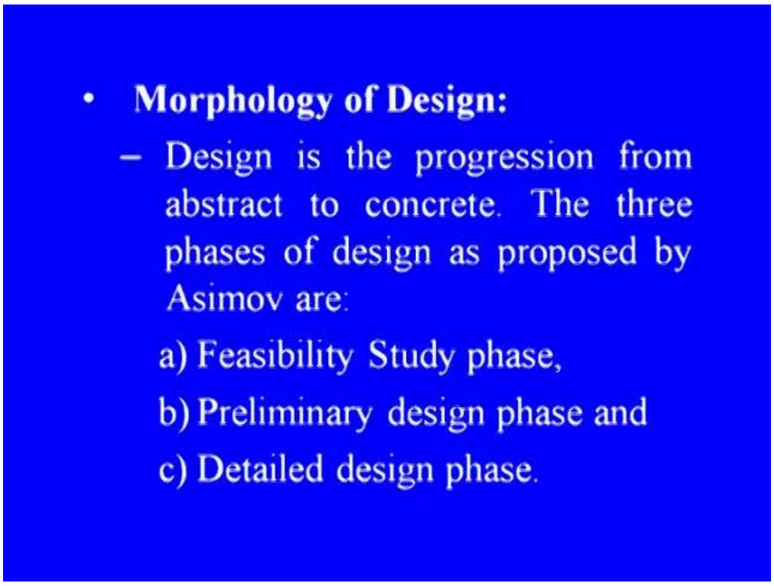

Design is the progression from abstract to concrete, the three phases of design as proposed by Asimov are; Feasibility study phase, then followed by preliminary design phase and finally, the detailed design phase. What are the idea and concepts? The idea initiates from requirements of customers or in some case by the imagination of the designer, to benefit the individual by some means. Developing the idea further requires transforming idea into a concept and further into a product.

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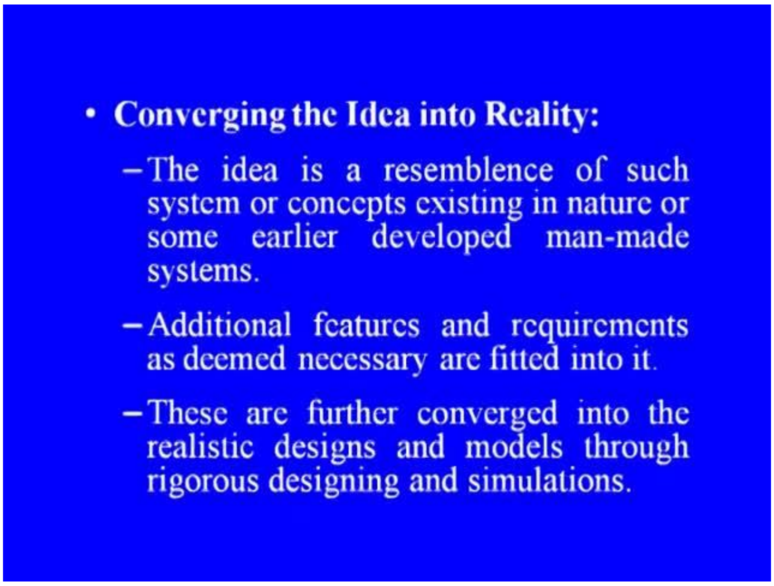

Converging the idea into reality, the idea is a resemblance of such system or concepts existing in nature or some earlier developed man made systems. Additional features and requirements as deemed necessary are fitted into it. These are further converged into the realistic designs and models through rigorous designing and simulations. Let us now see what is meant by a product?

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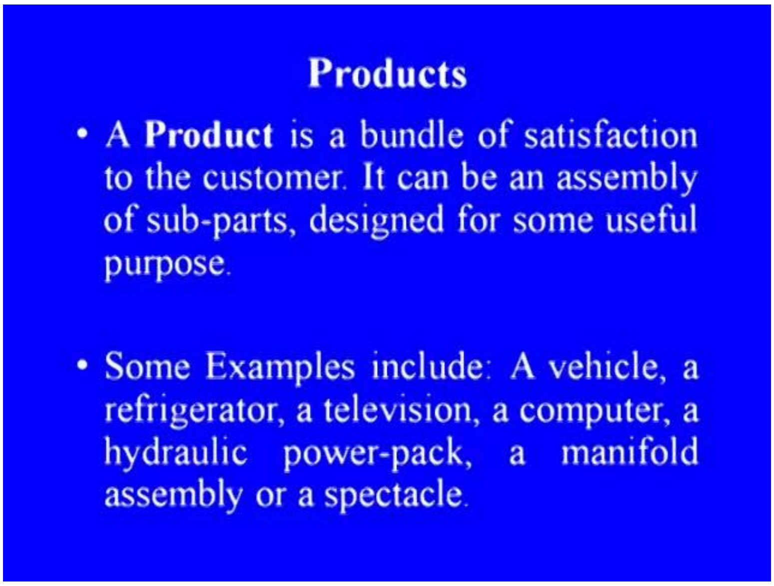

A product is a bundle of satisfaction to the customer it can be an assembly of sub parts designed for some useful purpose. Some examples include; a vehicle, a refrigerator, a television, a computer, a hydraulic power pack, a manifold assembly and a spectacle. Let us move on to quality control.

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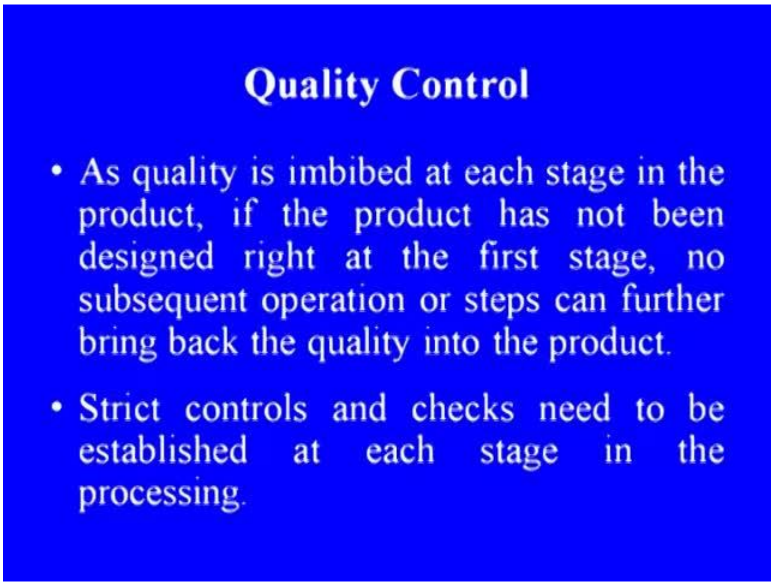

As quality is imbibed at each stage in the product, if the product has not been designed right at the first stage no subsequent operation or steps can further bring back the quality into the product. Strict controls and checks need to be established at each stage in the processing let us move on to classification of manufacturing processes.

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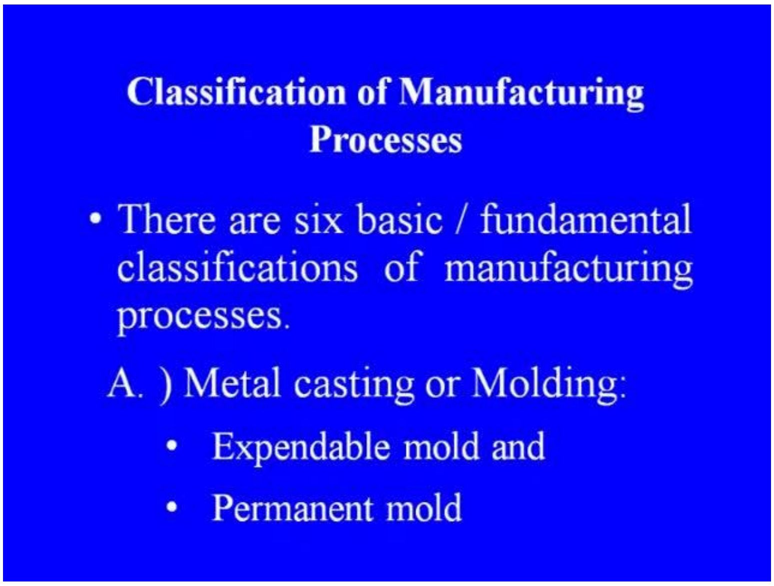

There are six basic fundamental classifications of manufacturing processes. The first metal casting or molding, there are two different approaches in this. Number one expendable mold and number two permanent mold. Next class is metal forming and shearing.

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This includes a number of techniques called rolling, forging, extrusion, drawing, sheet forming and powder metallurgy. Next category is material removal, which are also called machining processes. In this there are two broad categories termed as conventional and non conventional.

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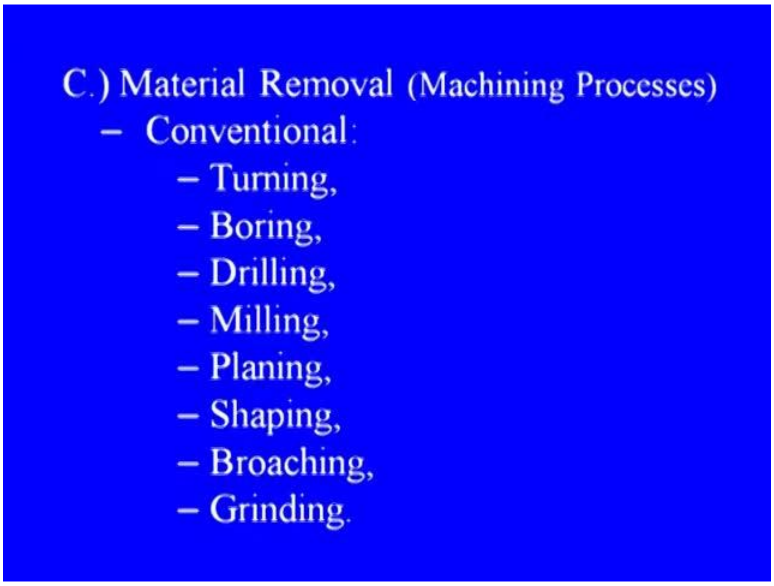

In the conventional category the processes include; turning, boring, drilling, milling, planning, shaping, broaching, grinding etcetera.

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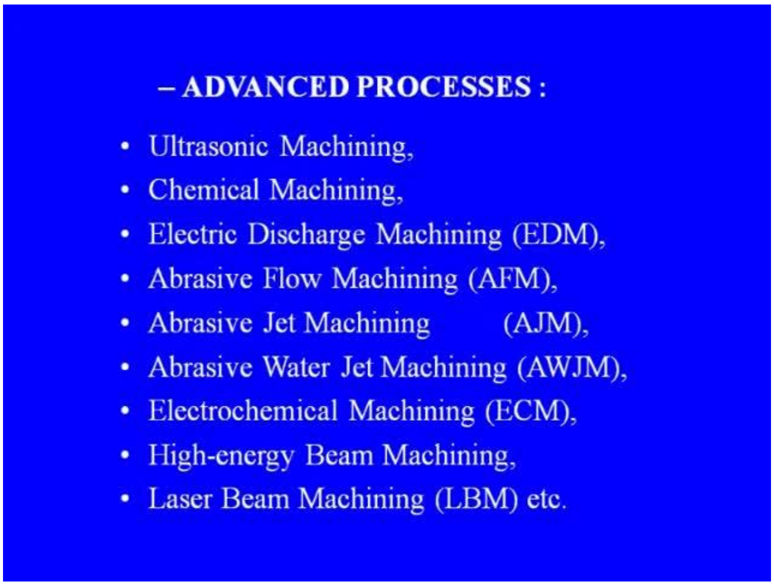

Advanced processes; ultrasonic machining, chemical machining, electro discharge machining, abrasive flow machining, abrasive jet machining, abrasive water jet machining, electrochemical machining, high energy beam machining, laser beam machining etcetera. These processes are also termed as unconventional or nontraditional machining processes. Next major classification is joining.

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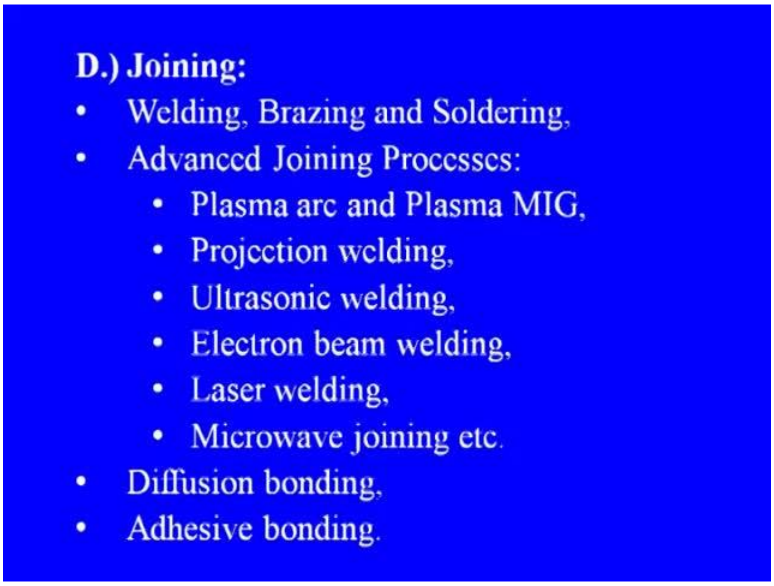

This include; welding, brazing and soldering. Then advanced joining processes this include; plasma arc and plasma MIG, projection welding, ultrasonic welding, electron beam welding, laser welding microwave joining etcetera. Other categories of joining include diffusion bonding and adhesive bonding. Then there are few finishing processes.

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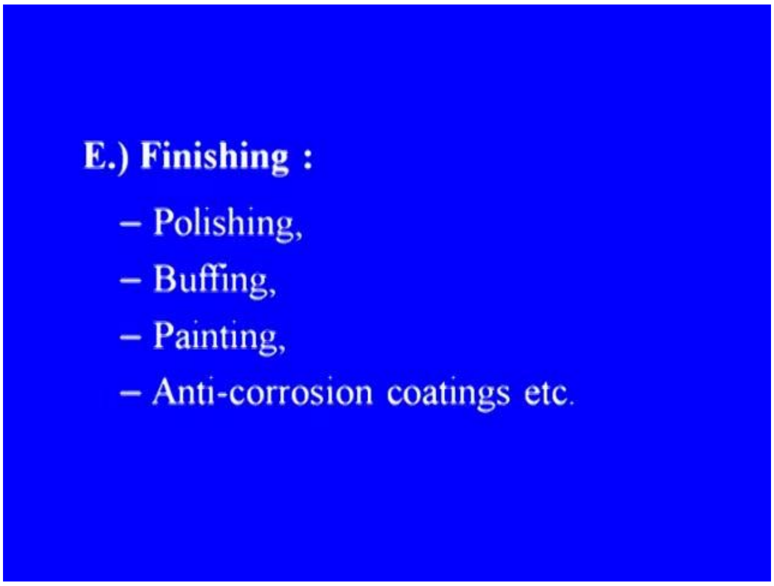

These include; polishing, buffing, painting, anti corrosion coatings etcetera.

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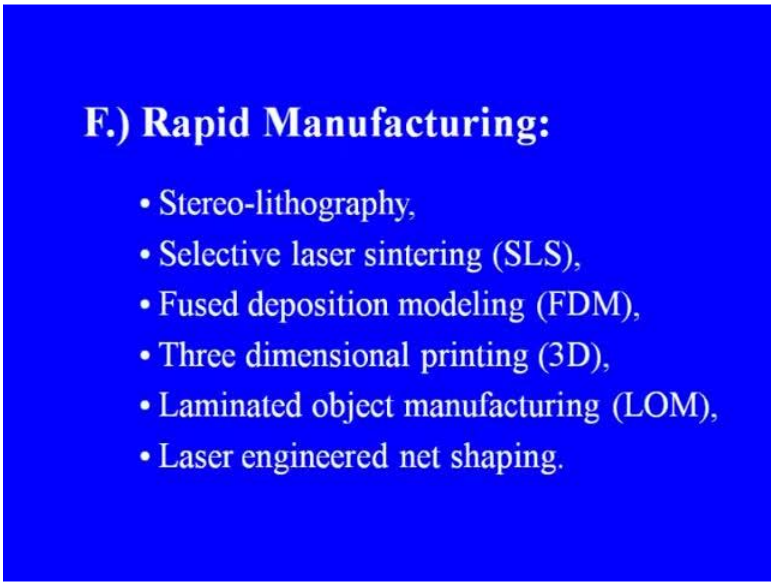

Next category is rapid manufacturing which include; Stereo lithography, selective laser sintering, fused deposition modeling, three dimensional printing, laminated object manufacturing, laser engineered net shaping etcetera. Selection of appropriate process one or more appropriate manufacturing processes amongst the discussed processes are chosen while considering the following factors.

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Number one the design requirement, number two the resource availability, number three process capability, number four feasibility, number five available skills and then rest leave the time. Let us consider some examples of manufacturing product.

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A hydraulic manifold is a classic example of manufacturing product, it is a machined component generally made of mild steal on which valves fittings and houses are seated. It reduces piping to a great extent and is considered as the heart of the hydraulic system. It resembles and integrated circuit of an electronic system machine requirements.

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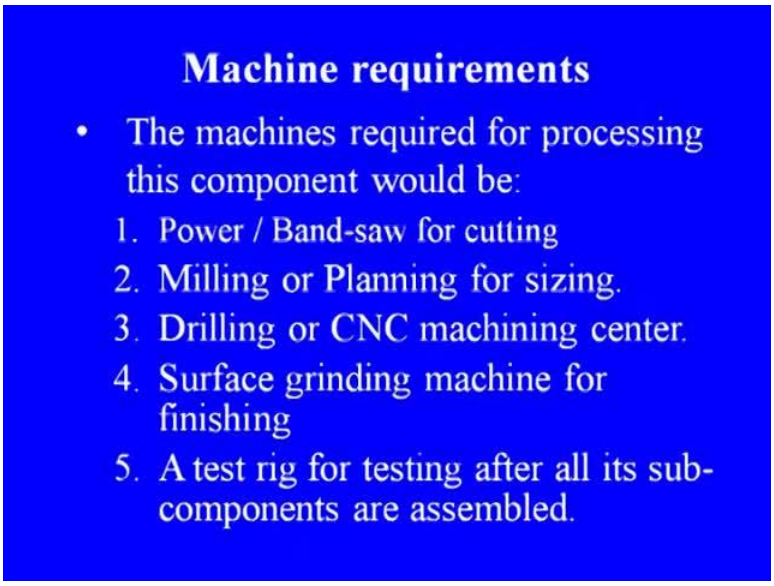

The machines required for processing this component would be, power or band saw of cutting, milling or planning for sizing, drilling or CNC machining center, surface grinding machine for finishing and a test rig for testing after all its sub components are assembled.

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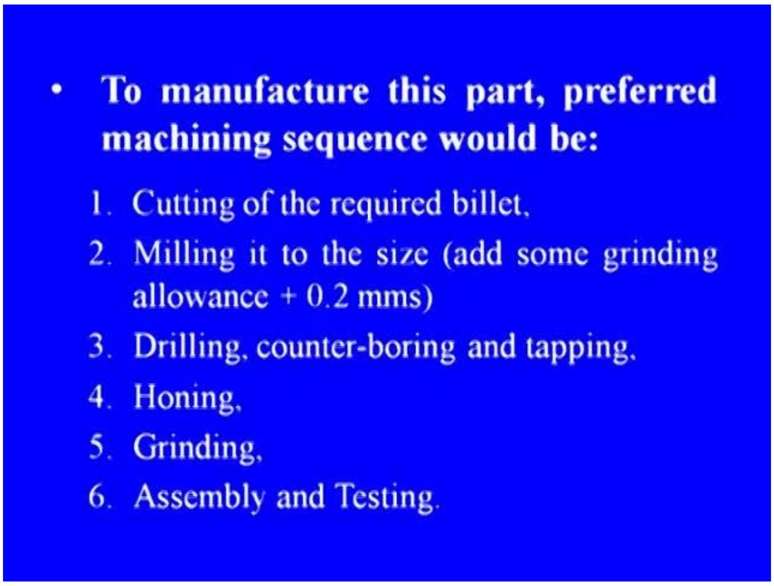

To manufacture this part preferred machining sequence would be, cutting of the required billet, milling it to the size adding some grinding allowance say for example, plus 0.2

millimeters, then drilling counter boring and tapping, honing and grinding for finishing and finally, assembly and testing.

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And final product after getting assembled would look like this. Let us now see the processing summary for the above product.

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Processing Summary

Process	Finish Required	Equipment/ Tooling
Cutting	In mms	Power hack-saw, vernier
Milling	Size control in mms, (SF: Ra = 0.3-0.5 µ)	Milling machine, Verniers
Drilling, Tapping	Size control in mms, (SF: Ra = 0.3-0.5 µ)	Radial drilling machine or CNC

Here processes are cutting, milling, drilling, tapping etcetera. In cutting finish required in mms millimeters and equipment or cooling required are power hack saw and vernier. Similarly, in milling size control should be in millimeters, where a surface roughness in the order of 0.3 to 0.5 micrometer of R a values will be maintained and the equipment or tooling requirement will be milling machine and verniers. Then in drilling and tapping, again the size control will be in millimeters in a range of 0.3 to 0.5 micrometers as R a values and the machines required will be radial drilling machine or a CNC machining unit.

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Processing Summary

Process	Finish Required	Equipment/ Tooling
Grinding	Size control in microns (SF:Ra = 0.1-0.2 μ)	Surface grinding machine and micrometer, Surface finish tester.
Assembly and testing	Functionality and rated pressure tests	Test rig, pressure gauges, timers.

Then the grinding process in which the size control will be again in the range of 0.1to 0.2 micrometer of R a values and the equipment required will be surface grinding machine and micrometer. Of course, a surface finish tester, for verifying the surface is produced. Finally, the assembly and testing in which, the functionality and rated pressure test will be done. Here the required tooling may be a test rig, then pressure gauges, timers etcetera. Let us now see, one more example on the process capability to understand the concept.

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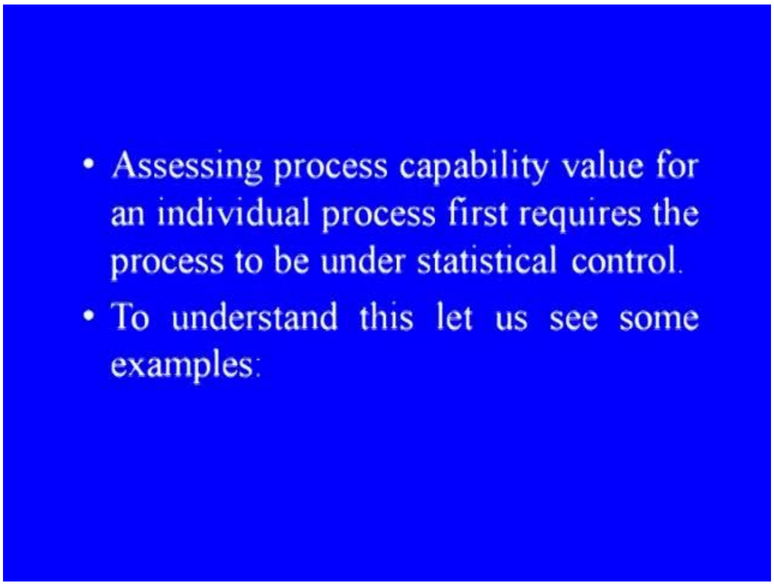

Assessing process capability value for an individual process first requires the process to be under statistical control. To understand this let us see some examples.

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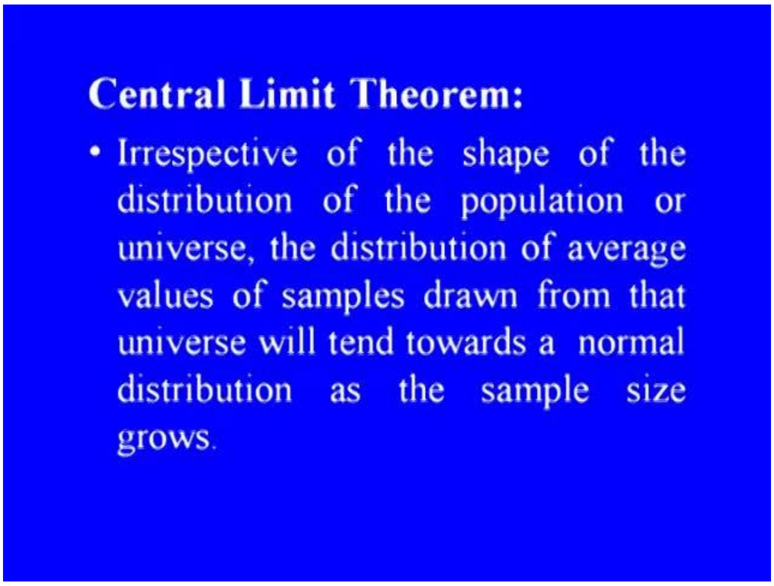

A very important consideration in this is the central limit theorem, which governs most of the control schemes or most of the control schemes use this theorem. So, this theorem says irrespective of the shape of the distribution of the population or universe, the distribution of average values of samples drawn from that universe will tend towards a normal distribution as the sample size grows. The practical applications of central limit theorem are immense further.

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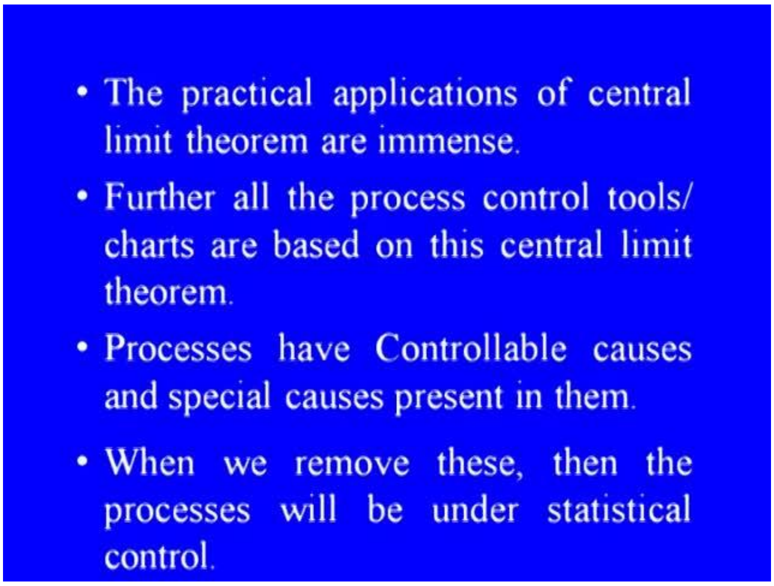

All the process control tools or charts are based on this central limit theorem. Processes have controllable causes and special causes present in them. When we remove these, then the processes will be under statistical control.

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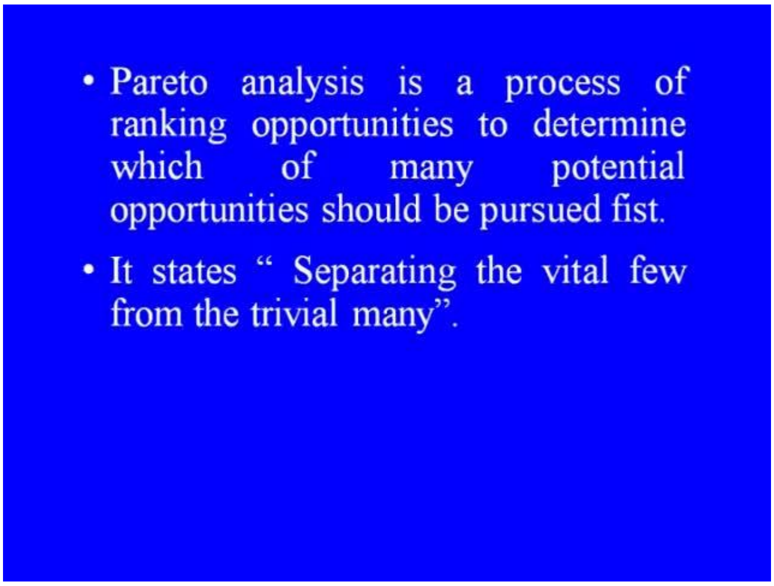

Pareto analysis is a process of ranking opportunities to determine which of many potential opportunities should be pursued first. It states, separating the vital few from the trivial many.

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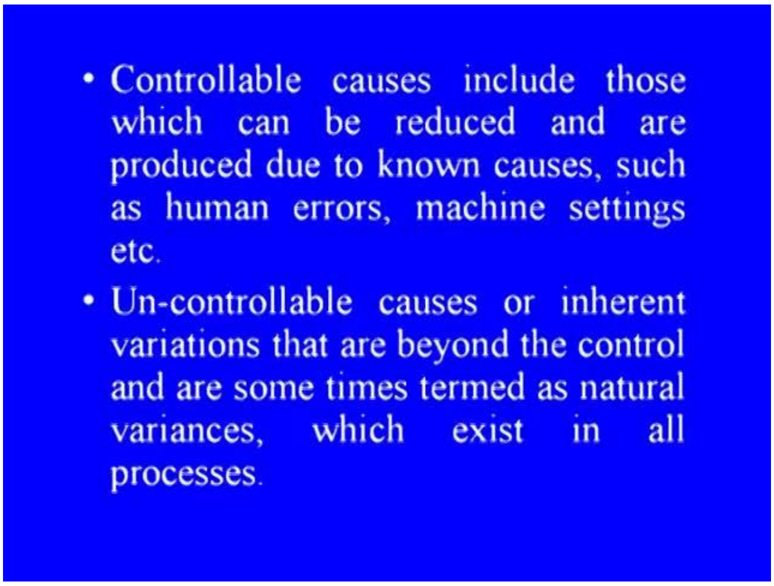

Controllable causes include those which can be reduced and are produced due to known causes such as human errors, machines setting, etcetera, etcetera. Uncontrollable causes or inherent variations that are beyond the control and are sometimes termed as natural variances, which exist in all processes.

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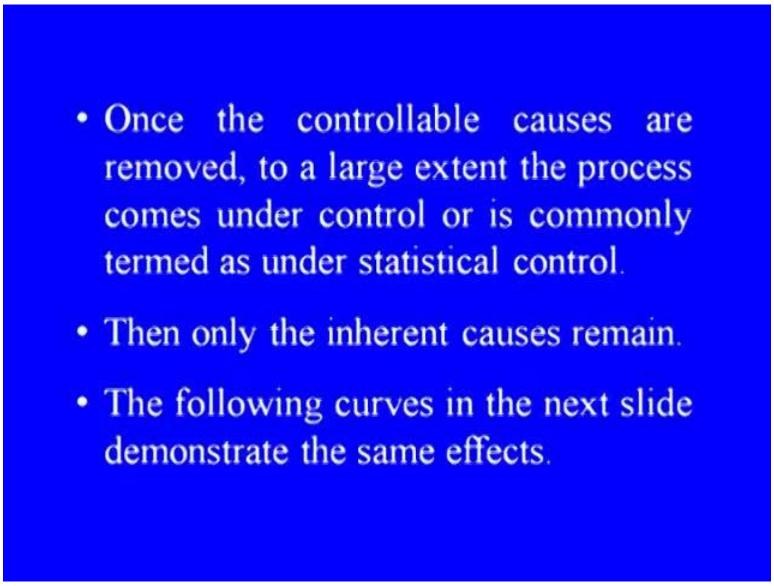

Once the controllable causes are removed to a large extent the processes come under control or a process is commonly termed as under statistical control. Then only the inherent causes remain, the following curves in the next slide demonstrate the same effects.

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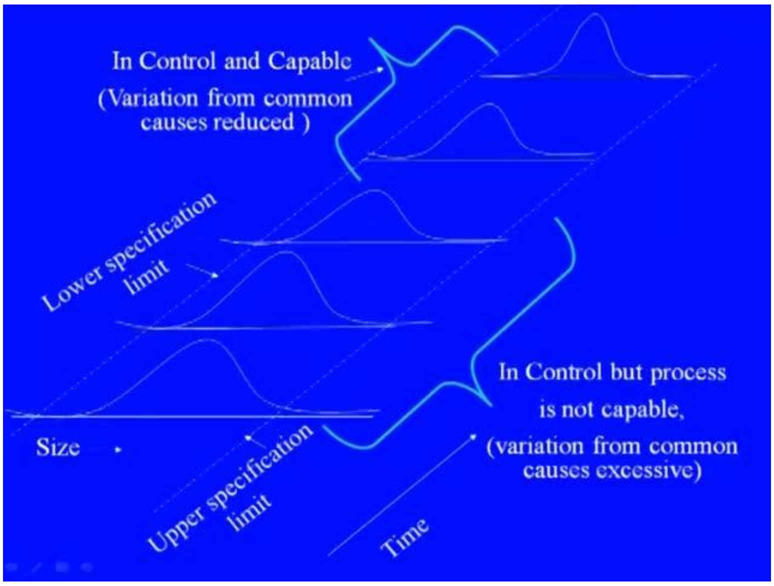

So, these curves are on the screen. So, here so this is let us consider as size, and this is the time axis, then this is the distribution. This shows the distribution and if we consider two limits, that is one is lower specification limit in short, known as l s l and the other one is upper specification limit in short u s l. Then we will call the process to be under control. Under statistical control, if the distribution is completely within these two limits. Now, here here we have seen the curve is going away slightly, that means we can interpret this.

So, in this case also it is although looks like within this, but there are little variations. So, in these cases we can interpret this as they are in control or these processes are in control, but the process is not capable. Since, they are going beyond this control limits. So, this can be variation of from common causes of excessive, on the other hand if we see the other two curves, normal distribution, these are normal distribution curves. So, if you see these curves as shown in the screen, they represent the processes which are under control and they are at the same time also capable, the process is capable. That means variation from common causes are reduced.

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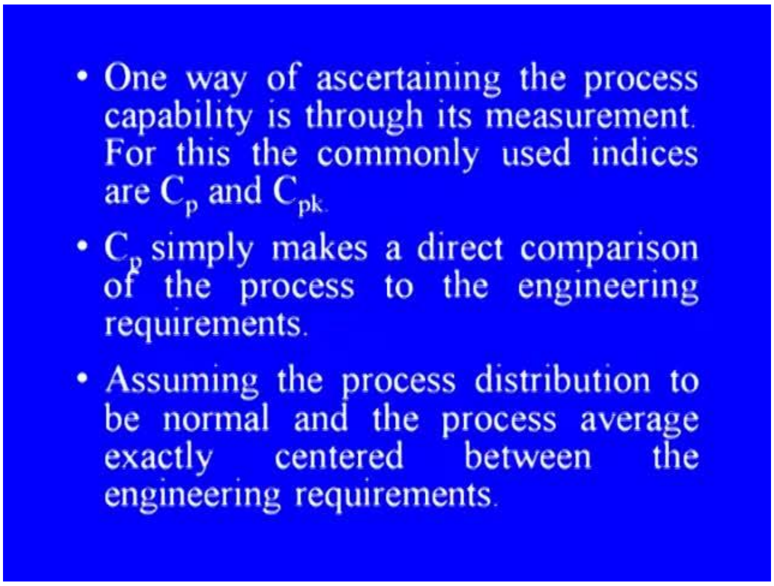

One way of ascertaining the process capability is through its measurement for this the commonly used indices are C p and C p k. C p simply makes a direct comparison of the process to the engineering requirements. Assuming the process distribution to be normal and the process average exactly centered between the engineering requirements.

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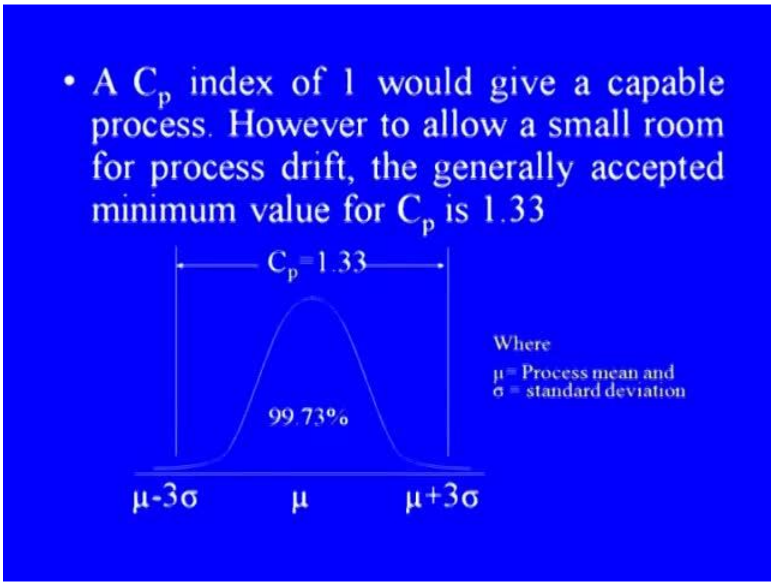

A C p index of 1 would give a capable process. However, to allow a small room for process drift, the generally accepted minimum value for C p is 1.33. This can also be explained with the help of this figure, in which a normal curve, bell curve is shown. And here with little drift on the both side, that is plus minus 3 sigma. So, mu represents the mean and from mu this is plus minus 3 sigma are allowed on both sides. That gives the C p towards or to be equal to 1.33, which is generally acceptable. The C p has two major shortcomings, it cannot be used unless we have upper and lower specification limits and it does not account for process centering.

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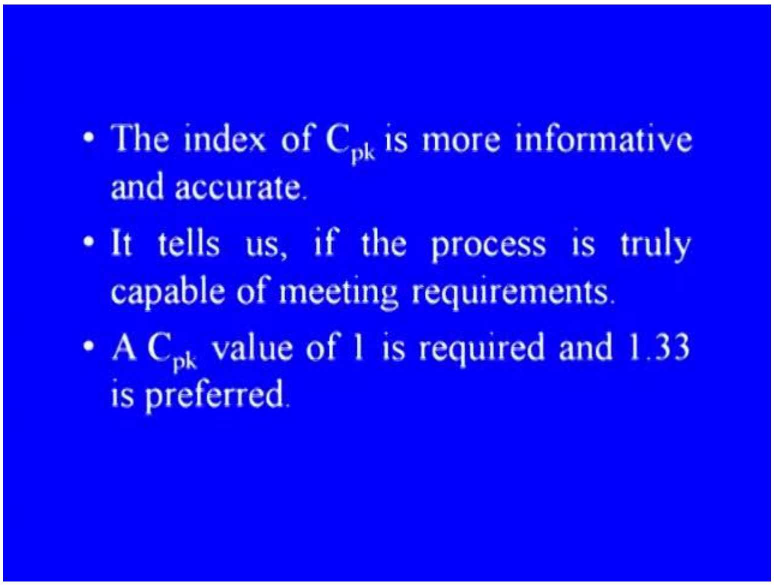

The index of C pk is more informative and accurate. It tells us if the process is truly capable of meeting requirements A C pk value of 1 is required and 1.33 is preferred. C pk is closely related to C p, the difference between C p and C pk represent, the potential gain from centering the process. Let us take an example to explain this importance of C p and C pk.

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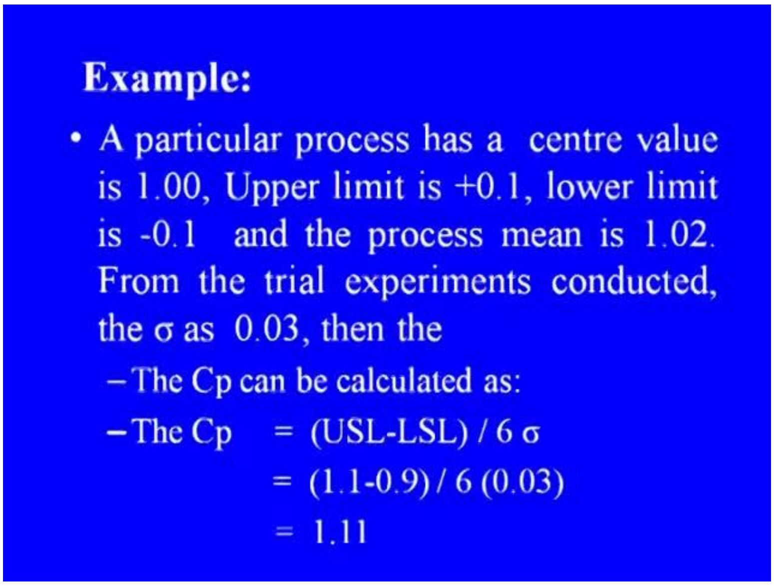

A particular process has a centre value, let us consider to be 1 and the upper limit is plus 0.1 while the lower limit is minus 0.1, and the process mean is 1.02. From the trial experiments conducted the sigma is obtained to be 0.03, then the C p can be calculated as C p equal to upper specification limit minus lower specification limit divided by 6 sigma, which comes out to be using these values just now mentioned, 1.11.

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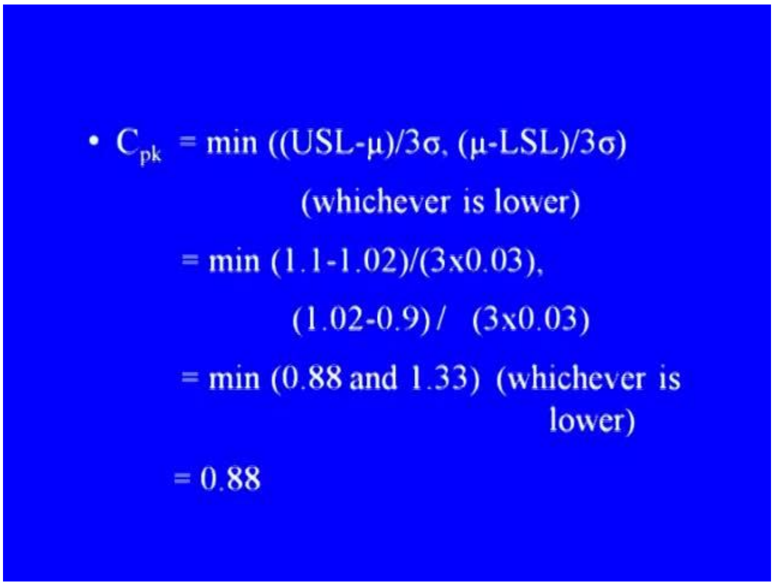

On the other hand C pk for the same situation at the same values given can be calculated as minimum of upper specification limit minus mean by 3 sigma and mean minus lower specification limit by 3 sigma, whichever is lower. And this comes out to be 0.88 with the calculations using those values. Thus the lower one being 0.88 is considered to be the C pk.

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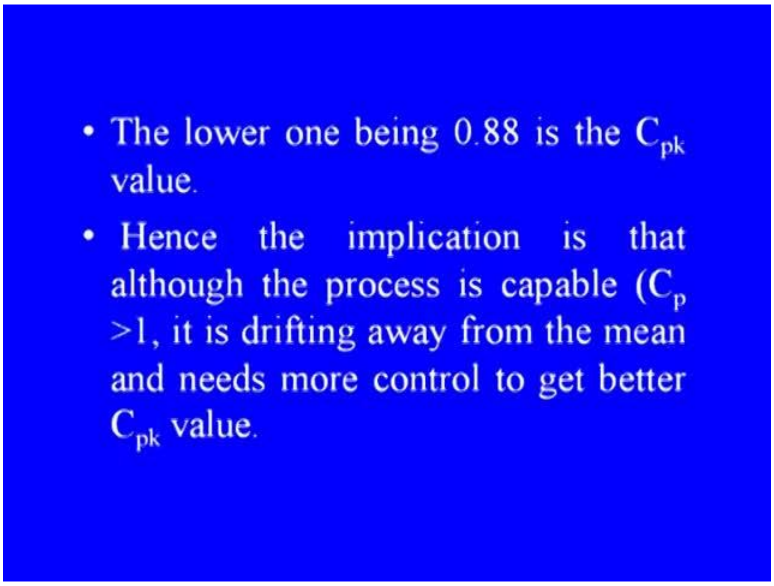

Hence, the implication is that although the process is capable because the C p is greater than 1, it is drafting away however from the mean and needs more control to get better C pk value. This is the interpretation of this analysis. Now, let us summarize what we have studied in this session. In this session, we have discussed about few important terminologies or concepts used in manufacturing processes like; precision, then process capability. We have discussed different classifications of manufacturing have also been introduced. We hope this session was informative and interesting.

Thank you.