Design Practice
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Lecture - 22
Techniques for the Implementation of concurrent engineering environment

Hello and welcome to the design practice module 22. In the last few modules we were looking at a very interesting case study by the cals C electronic system working group about how you set up a concurrent engineering environment, and what kind of diverse, what kind of direct applications of resources you could kind of plans. So, that the level of the concurrent engineering environment moves up one grade. So, when we talk about you know such a system is in place. How do you actually record or measure or how do you actually find out whether the c system is effectively sort of implemented.

So, there are a variety of techniques which are useful for implementing the concurrent engineering environment and I am going to now take case by case some of these techniques which are important for you to understand, how a C E is really practiced for from product design all the way to every part of the lifecycle of a product.

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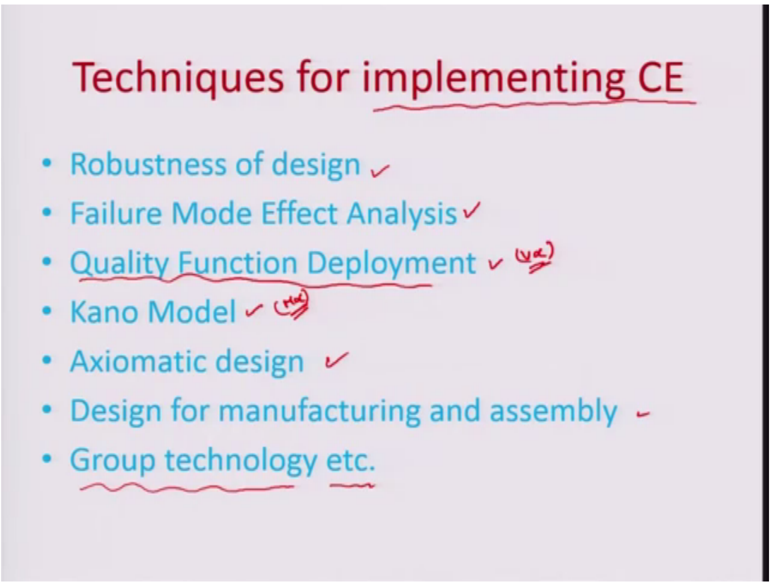

So, we will now discuss some techniques for implementing the concurrent engineering philosophy, or you know for making. So, you exactly know what is it, that needs to be pumped with resources in terms of elements, but we do not know how to implement, and so therefore, it is important that we get an understanding of this process.

So, there are a few of the techniques which are very commonly used in a c environment for implementing concurrent engineering philosophy. One of them is actually adding robustness to the product design, this was proposed by Taguchi which, which really is about learning from mistakes in terms of non compliance to standards or specifications and trying to do some improvement in the design through a organized cost structure. So, that one can in fact, determine you know, or one can in fact, make take decision making regarding or arrive at decision making regarding, whether a certain cost structure needs to be included in a process for ensuring compliance to some specifications or some standards.

In context of that there are a few other techniques which are important for me to discuss; one of them is called the failure mode effect analysis. we will try to look at this aspect and how you know from a systems implementation point of view f m e a can be utilized for eliminating a processed effect through design improvements. Then there is also a very interesting tool called quality function deployment or house of quality, which is used for really mapping the exact need which comes in to directly into the scene environment. In fact, need that exists out there in the market for which there is a product definition.

If you go a little bit further you have this very interesting Carnot model, which talks about mind of the customer quality. Function deployment is really about the voice of the customer, but here this is about how exactly he would be delighted. So, there is a delight factor over and above what basic functionality is this tool right here would serve.

We will also talk about the interesting area of axiomatic design and then design for manufacturing and assembly and some aspects of group technology, which may be needed to understand for thoroughly implementing a concurrent engineering environment. So, let us start with robustness and robustness. The term robustness really comes with the term quality, and so if we look at the product cycle really and if we wanted to see how quality can be improved or what is the purpose of the quality to be improved.

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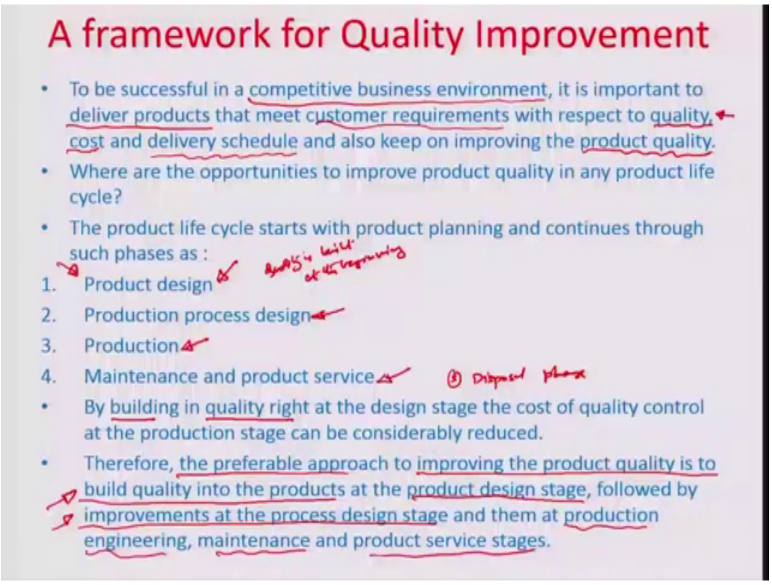

We all know that in today's competitive business environment it is very very important to deliver products that meet exactly the customer requirements and requirements could be in terms of the functionality, the quality of the functionality or quality of the product itself. It could be in terms of cost, overall cost; it could be in terms of maintaining schedules delivery lead times for example. And not only that in today's framework of all enterprises, the management philosophy really aims at how to continuously have a sustained product quality improvement program

So, what are the opportunities which are there to improve product quality in any product lifecycle, let us say if we look at a lifecycle, it really starts from the design stage, product design stage. Then we talk about a process design was the, product design is kind of established. We also talked about production phase. We also talked about maintenance and product service which is after sales phase. And then finally, a very important disposal phase which is not mentioned here, but I will just add it here product disposal phase.

So, these are different aspects of product lifecycle and you know the design should be done at have ensure steps in a manner. So, that it builds the quality right at the very beginning. So, quality is built at the beginning. So, what I mean really is, that can be specifications be set to an extent that it gives any useful know, how about what is the capability of a process; that is already there, where little addition deletion may enable the process to start generating new products ok.

So, you basically learning from the improvements that need to be done in the design. So, that are changes that then need to be done in the design. So, that it suits the process design. So, it is basically adding you know more and more value, I would say to the design the initial stages itself making it more robust in nature. Robust meaning there are hardly any failures along the way of the product cycle from the design to manufacturing to sales to, you know after sales and disposal the product goes smoothly without having to go through any hitches. And so therefore, that is what we know by robustness, we mean by robustness, so adding robustness to the design. So, that it survives the lifecycle.

The preferable approach therefore, would be to improve the product quality by building quality into the products itself at the design stage itself, and this is followed by; obviously, improvements at the process design state. So, that there are certain fits which you can make. You had done that example of how a shaft could be manufactured over a series of you know lathe machines, and we learned how to you know have the right manufacturing option assemble for the right specification. So, that amount of scrap produced is minimalistic

So, that is about how you can improve the process at the design stage itself. And then of course, you can have these improvements from coming from all the different steps; like production, engineering, maintenance product service stages so on so forth, which builds in the necessary amount of robustness.

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So, when we look at a product, you know product design, you know that it is a prime activity in the process of realizing any product, and therefore, you know this design really would have the greatest impact on the quality of the product, and whenever there is a deviation in this quality, there is going to be some kind of loss associated with such deviations. Although this loss does not really come on a balance sheet, but these losses are notional and if this losses come in, it gives you a an idea about how to proceed.

So, that you can do some loss minimization, some numbers are there rather than just qualitative index indices, and therefore, it is a very good strategy to monitor the deviation of all the functional characteristics of products from their target values through adding notional losses to quality. So in fact, Taguchi when he started apply applying this process.

I proposed the philosophy and mythology saying that designing quality into products and processes should be at the very beginning, and he postulates that a process of designing a product or a process should be viewed in terms of a system design phase, parameter design phase and tolerance design phases. So, of course, I will come into the details of all these different techniques. So, just before going there, let us learn little more about the different losses which are there in this aspect of quality degradation, because of deviation from target.

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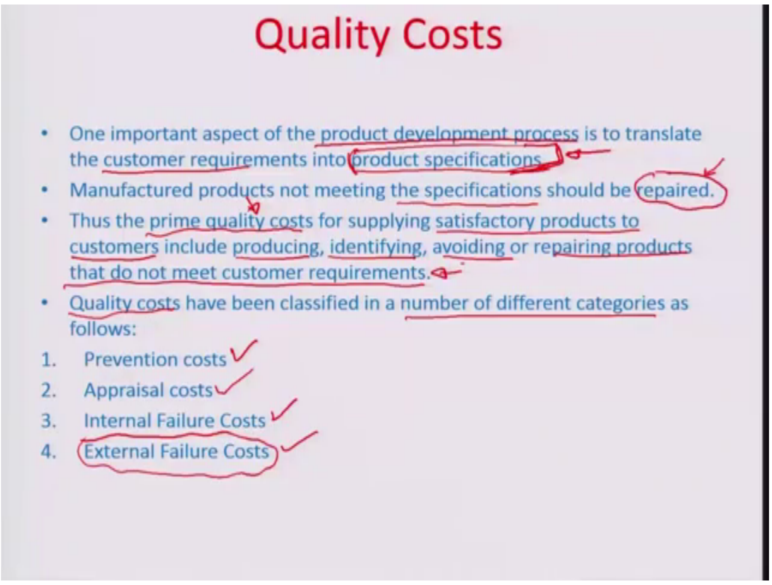

So, one of the most important aspects of the product development process, is to translate the customer requirements into product specifications and; obviously, the main goal here is this one term right. Here the product specifications which are arrived at through a meticulous you know process of product design, and; obviously, the manufactured products which are there and not meeting specifications should either have to be repaired or they have to be completely rejected or the market kind of does not accept them, and their losses.

So, the prime quality costs for supplying satisfactory products to customers include sort of producing, identifying, avoiding or repairing the products which do not meet such customer expectations or requirements. So, if there are certain preliminary issues which have cropped up in the products, which have made them non compliant to what exactly is specified as to how a product should be produced.

Then; obviously, that is not acceptable for the end user who is the customer, and therefore, one can livi. Some of these notional costs onto the system in of different categories, where these costs would kind of guide you through giving you a lead into what has to be improved at every stage, either the design or the product itself or the process itself, or you know anything related to the different phases of the life cycle. So, that this end user satisfaction index goes up, and you are compliant to what is needed ok.

And so it is it is basically about what you need and how do you satisfy the need. Are you satisfying the need accurately or not?

So, we are giving you sort of a quantitative basis to do that, and so if I looked at different kind of costs which are available in different categories for describing the quality, there would be costs related to prevention for these non specified, or for this deviation from targets to happen. There can be costs needed for sort of appraisal. For example, measurement costs there are parameters to be measured of produced items, where you know after measurement you find there is a deviation.

So, that a Brazil has to be done in a continuity. There is also something called an internal failure cost which has to be absorbed once a system has been already partially built. let us for example, look at a car making facility, if you have already produced a weld body just up to the final stages, and then you realize that you have a spot dent then the whole body is lost, and it is an internal failure cost which happens, which comes to the business since in fact, and then either you have to somehow repair it offline or if repairing is not possible. Then scrapping, it would mean a humongous amount of metal has already been wasted into the which goes into the car body

Similarly, there are external failure costs and these are in fact, more prestige issues, when such failures happen in the market which is related to giving a lot of you know poor visibility for the company's quality or also maybe in terms of some losses of market share etcetera. So, what has to be done in order to levy the costs at the right time, so that these costs do not drop up really a lot, and they get controlled at the very outset you know by complying the standards which are sort of made. So, let us look at some of the details about such costs, and how it can be prevented from happening.

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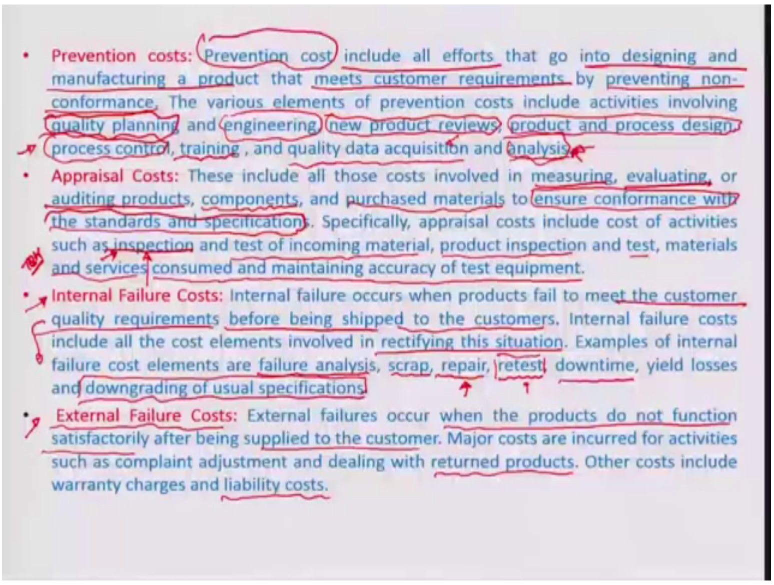

So, particularly prevention costs it includes all the efforts that go into designing and manufacturing a product that meets some customer requirements and. So, prevention costs is the cost you add on to the system to prevent the non compliance or the non conformance. There may be various elements of prevention costs, which may include activities involving. Let us say quality planning at different phases of the production or production engineering. There can be something related to the new product reviews which gives you an idea about you know how a product is doing in the market, or what are the expectations of the customer which way the market goes in terms of liability aspirations develop by the customer so on so forth.

There can be also some kind of you know cost put in to do product design or process design an appropriate manner in a robust manner. So, that failures do not happen, and automatically there is the right mapping of the right capability that you have in terms of manufacturing options to the right designs, that you are going to manufactured. There could also be prevention in terms of accurate process control, this needs for a strategical a strategic way of monitoring measuring recording and then trying to statistically analyse whether we are in control or out of control,or whether it is needed to do something to the process.

So, that it comes back into control. So, all those costs which are levied, because of such activities fall in the category of prevention cost. There could also be components related to training of individuals or new to the system, so that they do not do any non conformance, or let us say when things related to quality data acquisition, either automated or in a manual manner or some kind of an analysis from trench which leads us to believe that and this is also known as prognosis that something will happen at a futuristic point of time related to a product ah

So, you are preventing a failure much early to actually the failure started happening this, than Lauren aerospace industries these days for you know meeting up health monitoring aspirations, engineering aspirations, related to such products and they are also appraisal costs. Appraisal costs are typically inclusive of those costs which are involved in measuring evaluating you know of whatever we are producing, or even sometimes auditing the products to see if they are as per the norms, they are as per the specified requirements.

They could be cost involved in again inspection of auditing of the individual components or sometimes purchase material from vendors which directly go into the assemblies, and to ensure the conformance with standards and specifications; that is always going to be this essential measuring recording and sort of using this for policing purpose. So, the process design control

So, that is called appraisal cost. You know it typically includes cost of activities such as inspection for example. This is of course, non value added component. In fact, in the latest process designs from particularly Japanese manufacturers inspection has been almost combined with the process itself. So, that the idea is that outside the assembly line or outside the final product line, there should not be any unit which goes in an uninspected manner or in an undetected manner.

So, this is a part of so called total quality management T Q M that people perform ok. So, then you also have tests of incoming materials, you have product inspection and other tests, you have materials and services consumed and maintaining accuracy of test equipments. All these levy costs and they are just, because you want to appraise the system of what is the quality level. So, that is why appraisal costs internal failure cost, as I told occurs when the product fails to meet customer requirements before being shipped.

So, something has failed within the domain of the production itself. So, there is still a control of the processes and still there is a scope of improvement quickly. So, these are not that serious in you know terms of putting a lot of bad name and you know affecting the prestige, but yes internal failure cost sometimes are very very critical and how you handle them, and how, what kind of awareness level you create is definitely the most important management strategy which enables 1 to 0 down the failures within the ambits of the production facility

So, internal failure costs include all costs involved in rectifying the failure which has happened. You can have examples of for example, internal failure cost elements could be out of failure analysis out of the scrap generated, you know what are the kind of repairs that are being met a product; like anise automotive is made and there are twenty thirty defects in that automobile after it rolls out of an assembly line. So, it is; obviously, an additional cost that you are putting in terms of repair time. So, that all these card different difference could be successfully repaired. So, it is non value added, and therefore, levies the cost again and there may be a failure if left unrepaired and sent to the customer.

So, there are costs related to for example, retesting of something which has happened. For example, there is a door noise or an instrument panel noise. So, you might have to just go through a process of iterative testing and repair. So, that you finally, arrest and these problems failures could be related to downtime of equipments which causes major problems in schedule issues related to you. Remember schedule is also a very important part of customer expectation or requirement. There are also yield losses sometimes and downgrading of usual specifications, because just because the specification spray we had to tight for under the, under the existing manufacturing environment, and unless you downgrade them there is a possibility of almost all failures happening to whatever is produced.

So, these are all, because there is improper planning, because of which some of these failure costs would come external failures. On the other hand are very very serious in nature and consequences. It is basically something related to directly when the products do not function satisfactorily at all after being supplied to the customers. So, there are many activities to do these compliance adjustments. For example, sometimes products are returned back under warranty and there are warranty claims issued to the company. It actually goes into the balance sheet of the company. There are the costs which are liability costs. For example, some accidental casualty has happened because of use of a product, because of its failure.

So, that is levied on the particular manufacturer. So, one has to be very careful about these external failure costs as well, when you talk about maintaining a general regular system of quality. So, when we talk about the other issue; that is the Taguchi's approach for building robustness in a manner. We want to specify the design steps in a manner so that we have a system level design, we have a design of parameters and then of course, the third level which talks about the tolerance design. And here we would like to use system design as a process of applying scientific knowledge to produce a basic functional prototype.

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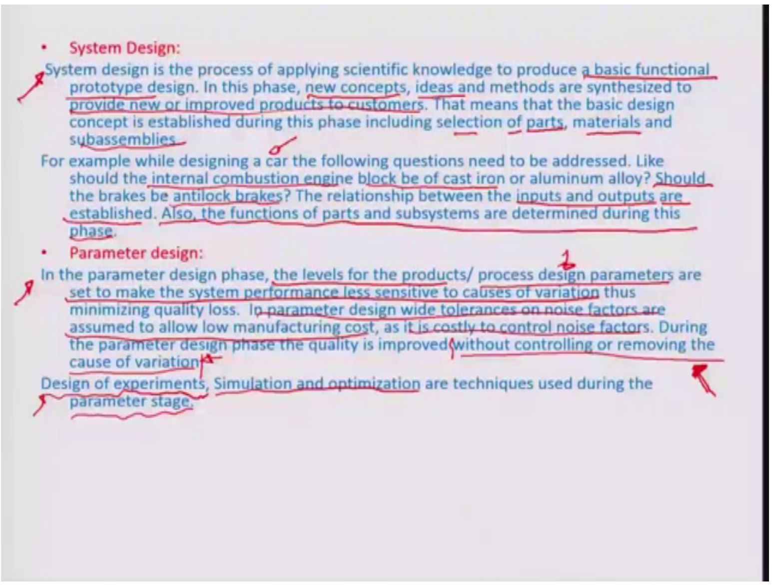

This can be typically a face at the very beginning of the, let us say product designing process, where new concepts, new ideas methods are synthesized, and they provide new or improved products to the customer. This means that the basic design concept is established during this phase including selection of the parts which are involved in the design or the materials or the sub assemblies. let us give a small example that you are designing a car and the following questions need to be addressed; like should the internal combustion engine block be made out of a material cast iron or aluminum alloy, depending on what is the weight requirements should the brakes be anti lock type. That is another you know question that we need to address while doing the system level planning or designing

So, we are talking about a functional system layout, maybe just decomposing the various functions in terms of subsystems, and then using these subsystems to sort of connect to each other to create a functional map. So, that is the first phase of any sort of design activity. And it you know really a yield into the overall layout of the integrity is behind a system, which is planned to be designed. So, the relationships between inputs and outputs also are established in such subsystem level, as well as the overall system, level and functions of parts and subsystems are determined during this phase. So, you have already done some mapping related to wagons and carts earlier in the first few lectures, when you talk about just laying out functionally decomposing the system into various subsystems level information.

So, once this level is crossed we go to the next level which is the parameter design phase. So, where the levels of the products or process design parameters are set to make the system performance less sensitive to causes of variation. Here is an aspect of non conformance which is being embedded in this statement; obviously, causes of variations are deviation from the target. And if you want to create design parameters which would randomly yield a variety of such noise or deviation from targets.

Then; obviously, it is a low quality design, it is a less robust design, but the idea here or the goal here, is to introduce as less variation as possible to the performance of the system that has been planned in the last step by setting the parameters related to processes or related to the products at the right levels. So, in parameter design, maybe white tolerances or noise factors are assumed to allow low manufacturing cost. It is it is quite costly to control noise factors as you know, but during the parametric design phase the quality is improved without controlling or removing the causes of variations

So, you are talking about setting up the right specification, which will be producible. I will I will show you some problem examples later with costs you could actually try to determine, what is the tolerance level or the specification, related to a certain in you know engineering product just, because you would have a living of greater cost while the component goes out in the market. So, a of, sort of a permanent cost put in the process for carrying out a small check or and that inspection might just change the paradigm and create the system or make a system, which is this lower you know in terms of its sensitivity to variation, and you could address the problem right. There in the process itself

So there are a lot of methods which are used in this particular parameter design phase. For example, D O E design of experiments are very widely used to set up what is going to be the right set of parameters, which would help you to operate at an no noise level, low noise level. There are also simulations and optimization packages which are used as techniques at the parameter stage to set up some parameters related to a system. And then of course, the third phase that Taguchi suggests in order to build robustness into the design are the tolerance design phases, where it usually follows the parameter design phase.

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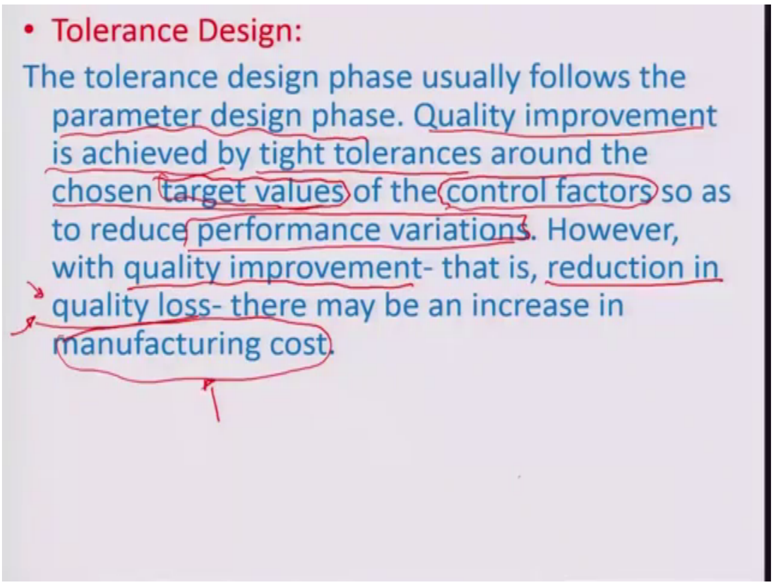

But here the basic purpose is an improvement in the quality by tightening tolerances around the chosen target value. So, whenever there is a huge deviation you might be able to design the process or maybe the specification in a manner. So, that these tight tolerances around the target values, may help guide the right quality to be produced, and choose the control factors which are available to the designers in a manner, so that it reduce the performance variations. I will come to this when I exemplify a case of you know, let us say steering control on a on a car, and I will show you how these different factors would influence the overall design.

So, overall the quality improvement must happen in terms of reduction in quality loss, which is a notional loss, again levied upon the system. And although there may be a increase in the manufacturing cost, the lessening of quality loss in the way would be helping you to guide in the right manner, so that your variation or deviation from the targets are as less as possible. And so this is where the aspect of robustness builds in the design, that if your variation of you know a system matching to the right process is minimized, you are successful to add robustness to the design.

There is not going to be any kind of non conformance. These are all linked usually the customer is the one who judges and so the customer does not get any non compliance is happy. And that is the goal of everybody working in the business, including the designers, as well as for the for the product, as well as the system in the process

So, let us now look at the approach of how we penalize in terms of giving some notional losses, as there is a deviation from the target, because this would be the basic tool used to set up these specifications ok, are the designs later, on the designs later or maybe doing tolerance design based on the quality loss. So, we will do that in the next step. So, in this particular case let us start defining the loss function now.

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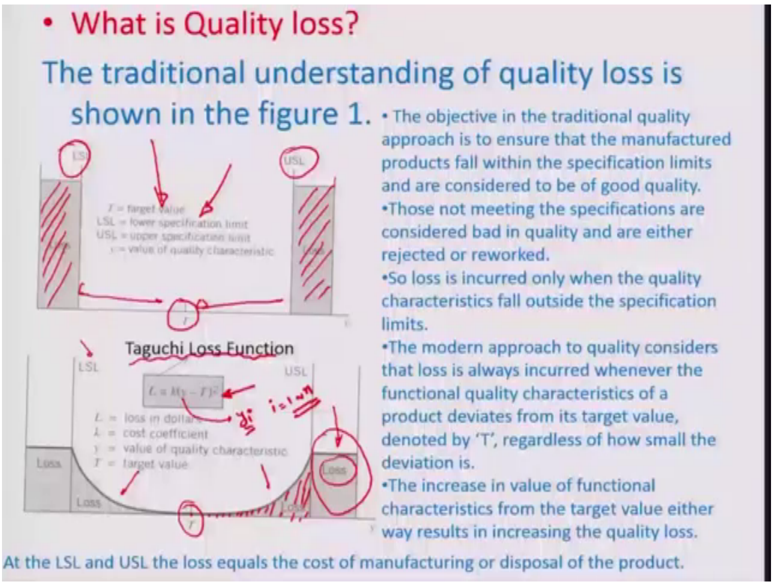

So, traditional understanding of quality loss is given in this particular figure that you have two different limits. Let us say the upper specification and the lower specification image. And whatever is beyond these for example, some particular component or system which crosses the U S L or the L S R are considered to be hundred percent loss they are rejects

So, basically you are rejecting the whole cross overs and accepting all this, which is in this white area right. Here at the target or beyond the target by a distance of whatever specified tolerances have been given in the system, but Taguchis loss function is slightly different is basically postulates that the loss starts not at the crossover of the U S L L S L, but right at the deviation state itself. So, anything which gets deviated from the target, levies sort of a loss.

Although this is not an actual loss, because you are not going to waste the component, but there is a notional loss which comes to you, which helps you to sort of go ahead and modify yourself at an early stage. So, that this situation does not come over at all ok. So, you can see that the overall loss level is reduced, because you have a tightness of control. So, this is more about a management practice I guess which you are going to follow

So, this is what we are going to use for our studies and we will try to find out based on this loss equation, what is going to be the kind of average quality loss. So, let us suppose there are you know different measurements. let us say I measurements of this quality characteristic which is there and these I measurements vary between, let us say some 1 2 n different measurements this y i shows the i th measurement. So, in that event, what would be the kind of average loss which will be levied on the system? Let us look at that and then let us try to tweak that in terms of what are the desirables, and what are the undesirables of characteristics.

There are some characteristics in products which you might need to retain. For example, ultimate yield strength the higher the better or there are some, where it is are completely undesirable and you typically envision to operate at a value which is close to zero for example. They should not be friction or wear and tear in components; they should be kept at a level of zero. So, the loss equation might vary, it is not that there is a target friction value which is there, friction needs to be at target zero. So, loss equation might slightly vary and so does the average quality loss

So, let us actually have an understanding of all this from a standpoint that whenever such a loss is levied to the system, it will help you to improvise your design specifications and you will get an emergent design, which is actually robust enough to handle you know a situation like a failure situation like that. So, it goes without having a failure, because the right specification could be imparted just after it crossed the target at the right time. So, that it did not cross over a maximum threshold or something

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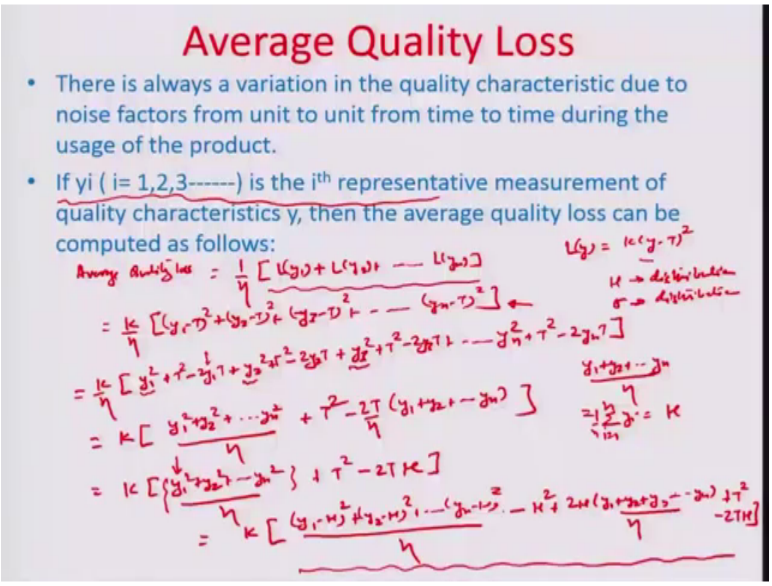

So, let us look at average quality loss. So, in you know you know the i measurements that I have been talking about the average quality loss would be defined as loss due to y 1 characteristics plus y 2 plus so on up to loss due to y n characteristics averaged out with respect to n measurements. And if I wanted to just use the Taguchi's loss equation about l y equals k times of y minus T square here. So; obviously, for the average quality loss we are going to represent this in terms of k by n times of y 1 minus T square plus y 2 minus T square plus y 3 minus T square plus so on so forth up to y n minus T square.

And we would like to iterate this oracle second manipulated this equation in a manner so that known quantities which are measurable related to, let us say the mean for the distribution of these measurements or the sigma standard deviation for the distribution, they are utilized, to describe what you call the average quality loss

So, it just as empirically trying to solve this, we have y 1 square plus T square minus twice y 1 T plus y 2 square plus T square minus twice T 2 T y 3 square plus T square minus thrice y 3 T [noise so on so forth up to y n square plus T square minus twice y and T is what the average quality loss equation is going to be like.

And if I try to group these squares together, for example, all the y i squares together or for example, all the twice y i T terms together or the ts together, we are left with three different terms here. So, it is y 1 square plus y 2 square plus 1 up to y n square divided by n plus n T square by n. So, n it goes off. So, you have only T squared minus twice T by n times of y 1 plus y 2 plus 1 up to y n

So, we all know that you know the y 1 plus y 2 plus. So, on up to y n by n also written as 1 by n i wearing from 1 to n y i is the average mu for the particular distribution. And we have here a case where I can write this equation as y 1 square plus y 2 square plus. So, on up to y n square by n plus T square minus twice T times of mu and let us suppose we try to convert this a little further by bringing in slight modification to this first term right here and recording this as y 1 minus mu square plus y 2 minus mu square so on up to y n minus mu square, all divided by n minus off, because there are exactly n mu squares which are involved.

I will just subtract minus mu square and also add further twice mu times of y 1 plus y 2 plus y 3 plus so on up to y n divided by n to this whole equation plus T square minus twice T mu. So, that is how I am going to represent this whole equation, which is finally, going to change into k times of n minus 1 by n times of sigma y i minus mu square i wearing between 1 to n, 1 by n minus 1 minus off a plus of mu minus T whole square this right

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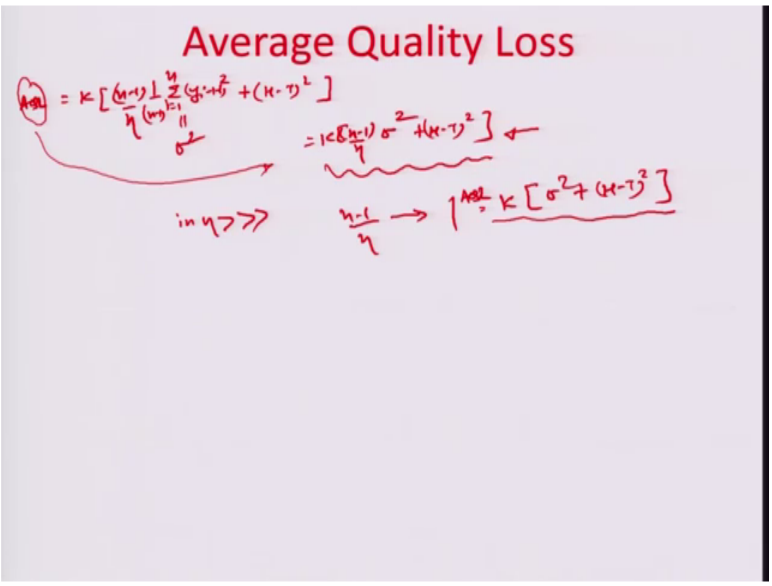

Here is sigma standard deviation ok; that is how the standard deviation for in distribution would be, and so we are left with an actual value which equals to k times of n minus 1 by n times of sigma square. I am sorry this is sigma square square of standard deviation plus mu minus T whole square. So, that is how we will record the average quality loss of a situation where a target value T is not achieved, because of a certain mean and variance of recorded values around the target.

So, this is exactly where the Taguchi's average quality loss or how the Taguchi's average quality loss is calculated. We do record that in case n is quite large then n minus 1 by n could be recorded as converging to 1. And so noise] we have the loss equation in that case to be simply a summation of sigma square and mu minus T square times of k. So, the AQL will change once the n value or the subset of observations are quite large.

So, I think I will bring my lecture, this lecture to, but in the next lecture I will take it up and try to analyse the situation more from a practical standpoint, where we will see that based on the different quality characteristics that we are considering this loss function will also vary, the equation will also vary and we will start applying this for calculating specifications which would be important for the product design stage itself. So, thank you very much for this into me.

Thank you again.