Design Practice

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Lecture – 24
Robustness in Design

Hello and welcome to this lecture on design practice module 24. We were talking about how to do robustness of design and the same can in fact, be utilized for studies related to materials exploration or material selection and design. I will give you a case study on an example today, where we will talk about selecting between two different sources of bolts on the basis of the engineering parameter ultimate yield strength of those bolts. So, we will do some material exploration you know example, where we will try to select on the basis of quality costs adding robustness to the system there was in fact, a case which was discussed in the last lecture before the end of the lecture about high tech rotor dynamics.

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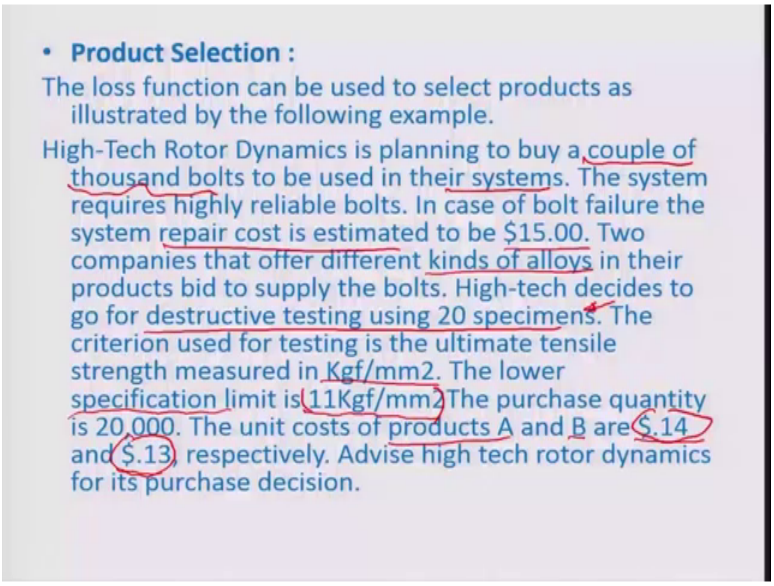

Which are planning to buy and select a couple of thousand bolts to be used in their systems the systems require highly reliable bolts, in case there is a bolt failure the estimated repair cost is given to be about 15 dollars, and there are two different sources from which these different kind of alloys are utilized for supplying the bolts.

So, each bolt is of a different alloy different type and the criteria that high tech decides to use for doing the product selection or the material selection in this case is that it basically does destructive testing using about 20 specimens and try to find out from each source, what is going to be the ultimate tensile strength measured in kg force per millimetre square

Now, in this particular example, the quality parameter that would be used for the robustness is basically the higher the better because; obviously, it is desirable to have the highest possible ultimate yield strength of the bolts in such entering assemblies. The lower specification limit is given to be 11 kg force per millimetre square. So, this is a qualifier if a bowl does not meet this particular specification it is going to be rejected and it will give some kind of a you know if supposing it is selected and used it is going to give some quality cost to the company and based on this cost we have to take a explore the you know material select criteria can be sort of a gauge to based on this quality cost that comes up. Also is given that for these two different products that we are going to make a selection from each of them costs 14 cents and 13 cents respectively and we have to take a decision as to which of these two bolts are good for high tech dynamics.

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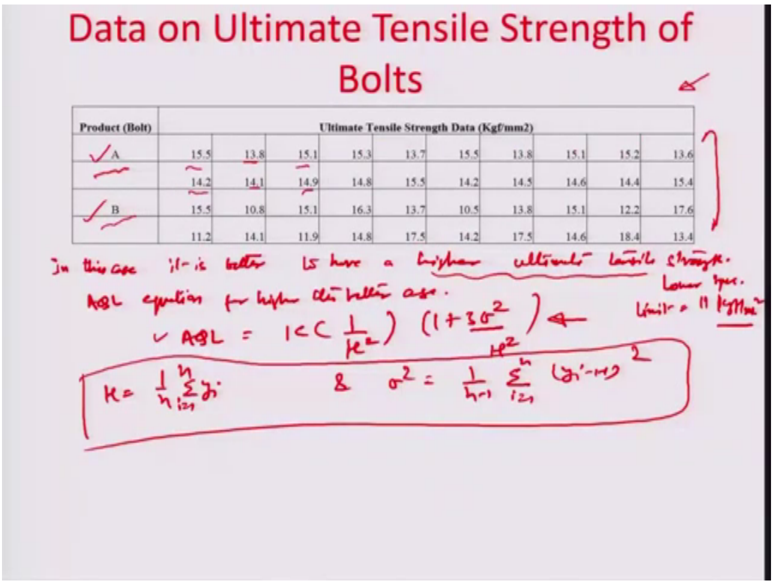

The strength data is given here for the destructive testing done using A and b. So, now, you are not only measuring, but trying to implement robustness of quality through this measurement into delivering a cost parametric. So, on the basis of which you will see whether there is you know A more expensive or B more expensive in terms of selection and a criteria is determined for selecting the same. So, let us say in this case if we try to solve, it is better to have a higher ultimate tensile strength. So, ideally one should go for an infinite tensile strength although it is not practicable, but the loss equation and the average loss that comes out. So, the average quality loss equation that comes out for the higher the better case. If you may remember we had discussed it in one of the last lectures is basically AQL equals K times of 1 by square of the mean times of 1 by 3 times square of sig sigma a standard deviation by mu square.

So mu and sigma has its own connotations mu is 1 by n sigma I varying between 1 to y i and sigma square is 1 by n minus 1, i wearing between 1 to n y i minus mu square. So, that is how you represent the higher the ultimate strength or higher the better quality parametric to be. So, using this as a criteria for selection, we need to find out what kind of average quality loss will incur in these two distributions provided that are lower cut off limit has been given as 11 kg force per millimetre square this is the lower specification limit ok. So, anything below it typically should be rejected. So, anywhere if the distribution starts moving towards you know the lower specification limit that is 11 kg force per millimetre square it will start incurring a loss, which will be a notional loss again and based on that we can make a criterion for selecting between A and B.

So, if I used the statistics which was which came out of the non destructive testing of all these different samples, there are 20 samples of each category A and B, we have accordingly you know we can make the different means and standard deviations for A and B.

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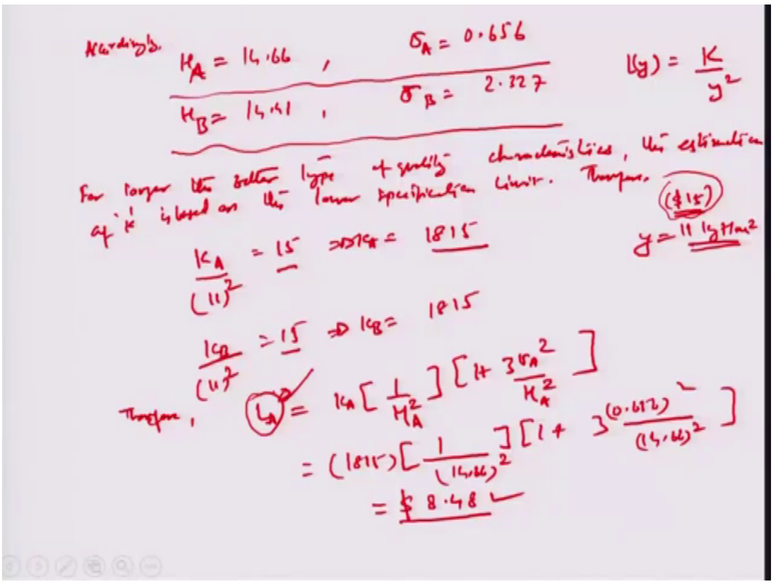

So, let us write the mean for the distribution A or bolt A as 14.66 as is apparent from the numbers, which are listed in the table earlier and the sigma A the standard deviation happens to be 0.656 from again the tabulated data. Similarly for the case B bolt B the mean distribution happens to be 14.41 and this sigma in this particular case comes out to be again 2.327. So, given these and applying the AQL formulation for the higher the better value, we can probably get an estimation first of the K value.

And then proceed with the K to do a selection between A and B just as we did in the case of automatic transmission for setting up a factory specification for what exactly should be the tolerance to set up the cut off r p m, when it you know the 80 goes from first gear to second gear. So, in this particular case again we are trying to develop a similar criterion for doing material selection, this is a very important aspect of designing components or designing systems. So, for larger the better type of quality characteristics, the estimation of k is based on the lower specification limit ; obviously, because anything which is below this is not qualified to be even counted.

Ok. So, therefore, I could find out the K A value here to be equal to you know the last equation in this particular case L y happens to be. So, the L y happens to be equal to K by y square, y being the quality characteristics or parameter in this case y tends to infinity means that you have almost zero loss and so, higher the better of y is a valuable strategy for planning out the average quality loss to be at its minimum level. So, in this particular case let us again go back to our problem example, we have a 15 dollars loss as being suggested, if the specifications of 11 kg force per millimetre square is not met. So, if y is somehow less than 11 kg force per millimetre square, you will incur less than or equal to you will incur a loss of about 15 dollars and any where higher than 11 kg force per millimetre square will not incur this loss.

So, we get K A by you know y square is the total amount of loss which is 15 or K A happens to be equal to 1815 and similarly if I looked at bolt b also similar characteristics are obeyed similar cost distribution is there for repairing of the rotor if such a bold failure happens and the K B in this case also comes out to be 1815. So, therefore, given all these issues together the L A or the loss incurred the quality loss that is incurred given the bolt A characteristics happens to be equal to K A times of 1 by square of mu A times of 1 plus 3 sigma A square by mu A square.

So it is actually 1815 times of 1 by 14.66 square times of 1 plus 30.656 square by 14.66 square respectively and this happens to be an average quality loss in case of bolt a stationed at about 8 dollars and 48 cents. So, this is how loss in case of component a is defined, I would have a similar definition for the loss in case of component b. So, you know that in case of b again we have a separate mu b and sigma b value.

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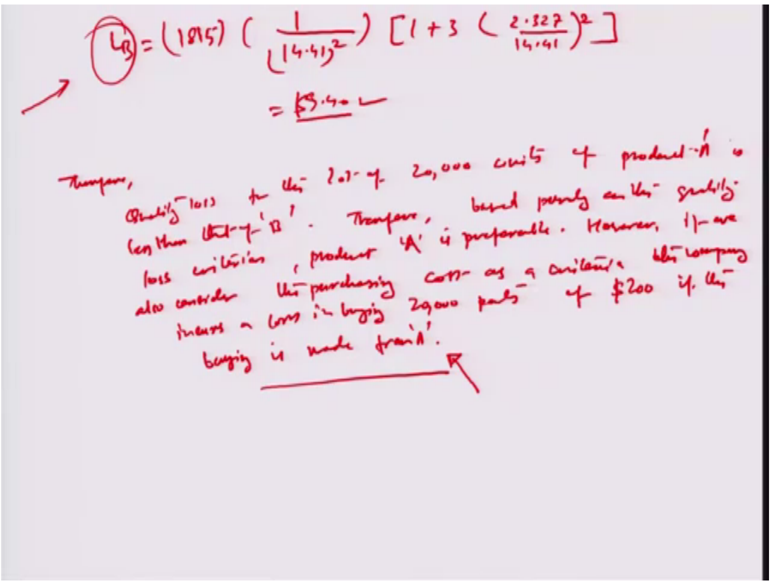

So, the L B in this case would be defined as 1815 times of 1 by the mean of b square times of 1 plus 3 times of the standard deviation 2.372 in the case of second distribution that is related to b by 14.41 square.

And this happens to be about 9 dollars and 40 cents. So, which has a higher loss average quality loss is visible here. So, in case of b for the selected samples with the certain amount of you know distribution related to ultimate tensile strength, the loss happens to be bigger number if you are selecting from b in comparison to if you are selecting from a. So obviously, this is on one of the factors, the other issue is that supposing you are going for getting a purchase made on A and B there are two different numbers related to their unit cost we are typically wanting to buy a couple of 1000 bolts for our systems.

So let us say we make a number about 5000 volts. So, we can look at what is going to be the incremental difference. So, product A is definitely expensive than B and B has a better obvious a higher quality loss in comparison to A. So, therefore, a trade off has to be made between B and A based on the unit price, that was there for the particular agency high tech dynamics and also the loss that they would incur in case there is a failure within the system, quality loss that would be incurred. So, it again depends on what is your strategy at the time, if quality is over imposing and if quality is one of the strictest guidelines, which are needed in this case maybe this rotor is a part of an assembly which otherwise a failure of a rotor would mean a lot of damage to the assembly. So, you might have to stick with higher priced component, just because of the fact that it has a lower quality loss level.

So, you are seeing that how robustness is being added at every step of the design including material selection, in the earlier one you saw how you draw specifications. So, in this way you have to build up the robustness of the system and finalize your design before giving it out. So, in this particular case quality loss for the lot of let us say 20000 units or product A is less than that of B and therefore, based purely on the quality loss criterion. Product A is preferable ; however, if we also consider the purchasing cost as a criteria, the company incurs loss in buying 20000 parts of 200 dollars, if the buying is made from A. So, one has to really decide now what would be a more realistic approach to consider if we are talking about very large number of units.

So in that event probably it may be a better idea to go for purchasing decision with the cost criteria, but almost seldom it is that people overlook the robustness aspect and go to the next step. Particularly because in an assembly where the rotor is probably one important part, if a failure of rotor chains up line of failures related to an overall system I think it is always a better idea and the management always wants to go ahead with the decision made based on the quality loss, and still goes for a higher cost product in the market. So, that is how you characterize some of these material exploration issues or material selection issues by defining certain quality parametrics or quality criterion.

So, having said that now, let us go to sort of a approach that we regard board as robust design of products and processes.

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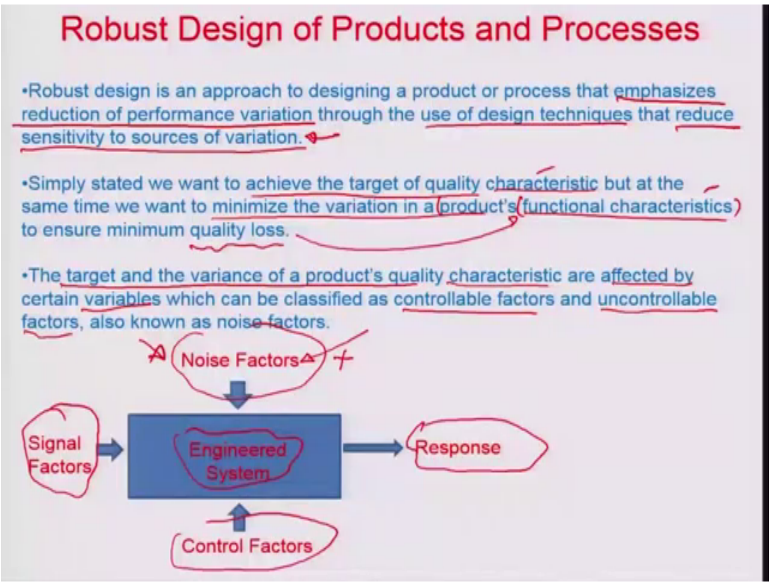

And you know it is an approach to design of products or processes that emphasizes reduction in performance variation and this reduction in performance variation is mostly used by design techniques that would reduce overall sensitivity to the sources of the variation. So, it is very important to identify what are the sources, what are the sources from which there are variations coming into product lines or by various processes by various material quality issues by various you know challenges related to out of time supply of the products so on so forth. So, in order to do robust designing, we want to really achieve the target of quality characteristic, but at the same time we want to minimize the variation in the products functional characteristics. So, that is what the whole approaches of adding robustness to the design and you know that how I give you actually numerical examples also in case if you have products functional characteristics.

You have an option to gauge it using some notional losses which are otherwise not a part of the balance sheet, but it is important to figure out, how this function loss can be quantified somehow. So, that there is minimization of the variation and variation is in terms of what your target value is and how you are performing in comparison to your target value and what is the distribution of you know information related to quality characteristics or any other measurements related to the product either physical dimensions or physical properties so on so forth. And we considered various example problems in that for looking at what you call robust approach of designing. So, typically the target and the variants of products quality characteristics are affected by variables you can look at this from an engineered system point of view.

So, in engineering systems of course, have certain variables which are classified as controllable factors, certain which are uncontrollable factors or noise factors and so, combination of these noise factors and control factors along with the signal that you are giving as a user of this particular engineering system gives out response ok. So, the response is coupled through several different sources and noise factors are really not in your control. So, therefore, you have start avoiding as much noise factors as possible in your design, when we are looking at from a systems point of view and understanding robust designing of products and processes.

So, the target here is of course, how to reduce this noise and that is why all these different examples of motional losses you know deviation from the target etcetera on the is to sort of avoid that variation, which is not in your control or it is because of randomness. So, you design the pro the system in the manner so that at least that randomness is not scaled up, it is always mellowed down as regards the noise factors in systems that. In fact, I am going to show you some examples about how you can control an engineering system from a standpoint of signal factors control factors noise factors so on so forth.

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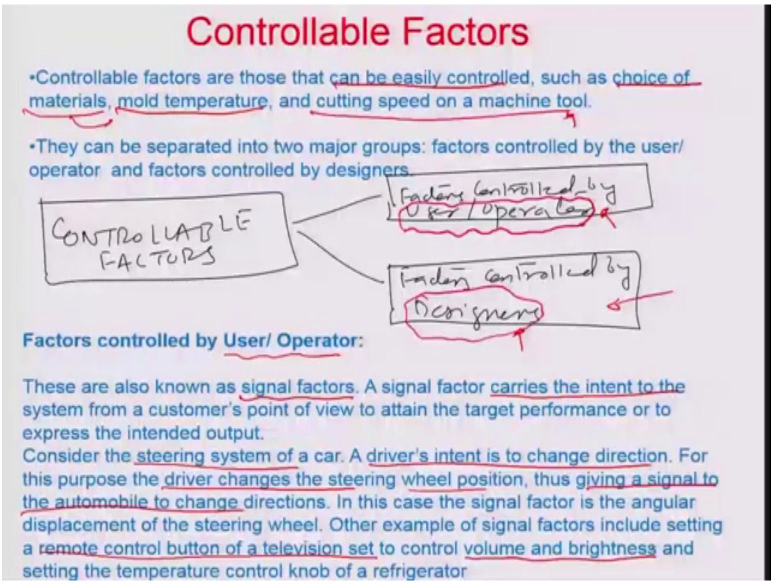

So, if we looked at all the for example, controllable factors which are there, they are basically defined as those which can be easily controlled you know this can be things related to choice of material for example, at the design stage or even the mold temperature depends quite a bit on the material that you are using maybe a cutting speed on a machine tool these are some of the aspects which you could really control very easily and if you looked at again a bunch of these controllable factors they are different aspects of even controlling one is controlled by the user or the operator.

which is something which is related to the users you know a spirit every users way of handling the product users way of lets say if he is creating a signal to control a product how effective he is in generating the similar signal at all points of time or is there a variability in the way that he is generating that signal. So, this is something dependent on the operator or the user and then again all controllable factors which are defined dependent on the designer said those where it is at the outset you have made certain interventions of the design at the product architecture level itself so that you know the factors can get controlled ok. So, these are the two broad groups in which you can put all the controllable factors are.

Let us look at some examples. So, for the user operator factor we also call this or regard this as a signal factor you had seen that how the signal factor is routed in the cartoon earlier which comes from one side into the engineering system. So, what is a signal factor or what is a user dependent or operator dependent control factor, it carries the intent to you know for a required performance of a system a signal needs to be generated. For example, if you are let us say looking at an automotive and you are trying to steer the automotive and you are trying to take a right turn.

So you will basically take the steering and then rotate it on the right so, that the automotive turns on the on the right side. So, you are a user you are a driver for these automotive and you are basically generating a signal factor by rotating to the right. So, that the automotive also takes a right turn now from between the input that you have given and the actual turning of the automotives there is a cycle of events which are happening a chain of events which are happening, many of which are controlled by the designers ok. For example, let us say the kind of gear ratios that would be involved in transmission of your effort may be very high and that may lead to a small amount of effort on the part of the user getting magnified several folds ok. So, that the automotive takes a huge turn. Now you have to sensitize the user to generate a signal which is good enough for creating a certain engineered performance of a system. So, that is a signal factor.

So just as I said that you if you consider the steering of a car and a drivers intent is to change the direction, and for this purpose the driver changes the steering wheel position and it gives a signal to the automotive to change directions but; obviously, there are certain issues involved in the chain, where you can probably put a better gear ratio or you can put just the sensitive gear ratio, where too much of turn is also not very desirable that if you have just miniscule turned the steering wheel it requires you automotive to suddenly go into one direction, that is also something that the user will not want.

So, the right level of the user judgement corresponding to the actual turning is what a designer would have in his hand while designing this particular system, and those are called the factors controlled by the designers. So, you very well know that what is signal, what is the intent which is given to a system and what is what happens after the intent has been given is something which the system does and that is dependent on how the system is being designed. So, the other examples of signal factors for example, if we considered the remote control of a button of a television set, that is also going to control either the volume or the overall brightness level or for example, if you have a temperature control of a refrigerator, it controls the overall cabin temperature, but what you are generally changing by turning the dial gauge or maybe in this case of television by setting up a remote button is to give a certain level of intent to the television and remaining what electronics is there within would take up that signal and try to perform something in terms of functionality so that you can get a list necessary output or response of the system.

And this response chain from the intent is what is in the hand of the designer. So, I will like to talk a lot more on you know factors, which can be controlled by the designers as well as factors which are completely uncontrollable and how to minimize it, but I will probably wait for the next module to do that, in the interest of time I am going to finish this particular module.

Thank you very much for being within.