Design Practice
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Lecture - 25
Robustness in Design – 2

Hello and welcome to this design practice module 25. We were talking about the robust design approach, where we indicated that any engineering system can be really speed up into signal factors control, controllable factors, where control can depend either on the user or in the designer, depending on what is it the level of control that is needed. And then there are noise factors which are responsible for causing really the variation of the performance.

And so with the signal factor coupled with the noise factors as well as the control factors, engineering system would typically give response, and the response might vary. And so all these factors have to be the twickten, where the only and controllable part is the noise, and somehow something needs to be done through design, so that that noise can be avoided completely. Although is not itself that impossible do that. In real life situation there are many causes for which variations might happen or creepen which are beyond control, but at least the part which is in control of the designer or of the user should be made the manners, so that there is not much variation in the performance measure or performance characteristics.

So, on one hand one aspect is to rule out. So, how do you measure what is the performance variation. So, you have to actually again go back to the target value and then try to see how well deviated you are from the target, or are you within range. And then the Taguchi's approach says that the moment you are of target, you should start attributing a cost, so that you know exactly that your of target and your panelise for that at least virtually, so that you can come back to the target again, and there are hardly and variation which are involved there.

So, today I am going to take this further and try to give you some understanding about the, because I have already told you about the user defined control factors. We should also have a look, very broad look at the designer defines control factors and for that we will just start this lecture by looking into what are the factors which are controlled by the designer himself as regards the engineering design.

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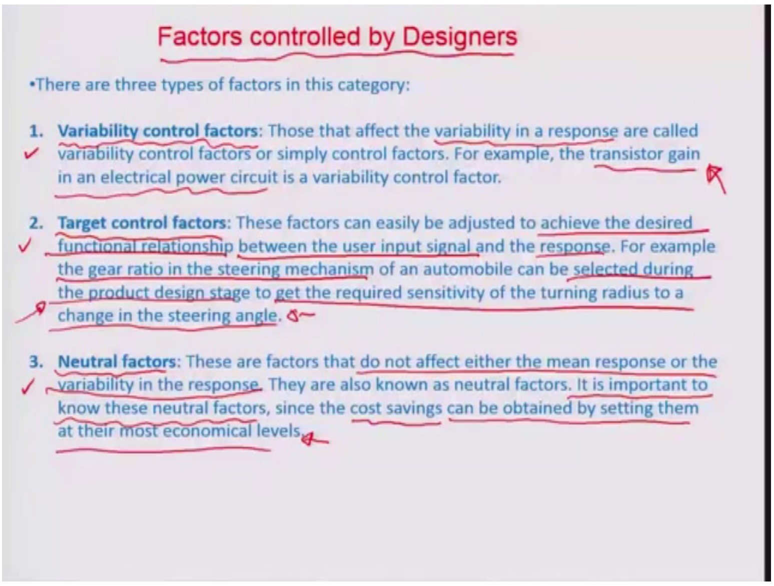

So, if you really split it up into different categories. There are three different categories where we can actually attribute this controllable factors, where control depends more on the designers; one of course, the variability control factors. So, this is about variability of the response of the performance output and you can you can say that if there is some kind of variability in response, it is it is the goal of the designer to somehow strategized in a manner, so that such variability reduces, and there is overall and improvement in the performance being on target rather than off target

So, we will look at the very important example here that which was actually proposed by Taguchi himself about transistor gain in an electrical power circuit, where we will talk on one hand about the response level of a transistor circuit, based on the gain voltage. And on the other hand, because of the non-linear characteristics of the target you would find out that in two different voltage rangers for the gain voltage, there will be different output levels.

One would be much varied in comparison to the other, and it may all be an appropriate idea to go and higher level of voltage, output voltage in put a resistance you know in series to that. So, that there is a drop and voltage and the available voltage that is the available comes down to the desired level for the system, and all your ensuring is control in the variability aspect by doing this job.

So, that example we are going to sort of seen details here, about what really you mean by such variability control factors. We will also talk about target control factors. Target control factors are typically those which can be easily adjusted to achieve the desired functional relationship between the input signal and the response, any engineering system as we know has user signal which is being given by user control and also by a certain response output level and.

So, if there is the variability in the response output level due to different causes; obviously, the function relationship between the signal and that response would change, because user would typically wanted to be to the desired level, and so therefore, he has to do for a example you think about the case of the steering wheel. If suppose in the user finds out that he is turned the steering wheel by let us say ten degrees, and the automotive takes a turn by very small amount, let us say five degrees. User has to do little more of the steering turning so that the automotive could desired take the desirable turned ok

So, the response level actually gives your feedback, particularly when your user for a system to somehow change your signal level so that you know, the response can happen according to your wishes and. So, this is about that target that you are achieving are. If there is a factor which actually helps you to achieve the target faster in between; that is called a target control factor. You can you can think about the gear ratio for example, in such a steering mechanism of an automotive, and you can be selected during in the product design stage itself, where you can get the required sensitivity so that the user is happy always.

So, if you are able to gauge of the user has a general habit of turning the steering x degrees, which will allow the automotive to turn y degrees, and he is in the comfort zone saying that if it is turned x degrees, if finds automotive exactly turn according to his aspirations on needs. Then you can say that it is a rightly defined gear ratio, and this can be one of the target control factors, which you the, which are designer can put in place. So, that with the input signal which is being generally given by the user the, there is no variability to the response signal.

So, we can get the required sensitivity of turning radius to change in the steering angle in this particular basis. However, this can be controlled only once, because at the design stage when your actually planning the product, you have to be very careful about such factors. There is also third different kind of factor which is also otherwise known as a neutral factor.

These are factors which will do not affect either the mean response or the variability in the response, but still are existing. Why they are important is that, there may be sometimes. There may be sometimes useful to know that they exist so that modifications in those where the response or the input signal level, response of the variability does not get affected, can easily we taken off so that there is cost saving ok

So, you have to identify those factors which are essential and which exists so that you know if they are, if the system is unaffected by their presence, although there highly required by the system to support the system. So, they may as well be gotten rid of, or sometimes may be connected to a level where, there are probably excessively designed and you can get savings out of changing those level to the normal values. So, you can say that typically neutral factors are to be identified for cost saving aspects related to the overall design ok.

So, you can set them at their most economical levels ok, so that such factors do not happen. So, such factor do not affect the response of the target control. For example, in this case of, let us say the gear ratio, and if it is the manual steering system. So; obviously, the amount of effort that you are doing on the steering wheel, is going to get translated in terms of gear ratio, in terms of the final turning radius of the for bar steering mechanism of an automobile.

But if you are introducing something like a lubricant ok, and the rate at which the lubricant is being infused into the system to perform, you know for satisfactory improve or satisfactory performance of the system, is being controlled to a lower level, while still being you know useful to so there is no relation between the response level or the, let us say the signal level or let us say the variability aspect, related to this automotive steering mechanism, because of the oil ok.

The oil always helps you to get some other desirable characteristics; like necessary lifetime for example, or the product, or maybe a little bit of more user comfort to some extent you know, because of the lubricating capacity. So, unless we are jeopardizing that user comfort level, and we can still reduce the neutral factor to a level where oil uses is minimum, you may be able to do a better job with the lower cost. Although the presence of oil is very important, because that will give you some sense of lubricity while you trying to do, you know trying to change directions in case of this automotive.

So, such factors are then known as neutral factors. So, having said that let us look into this two vary important aspects that how we can change the variable control variable t v control factors and the target control factors, in a real life problem, but before doing that, I would also like to emphasise a little more on the, the little more different kind of aspect which is about the noise.

Noise which is an essentially evil in all engineering systems, and somehow the question is can noise also be classified into several different types, where there can be probably some strategies to remove the noise or even like mediate the noise to lower level. So, if you look at the noise factors. The noise factors are general generally responsible for the functional characteristics of a product ok, deviating from the target value.

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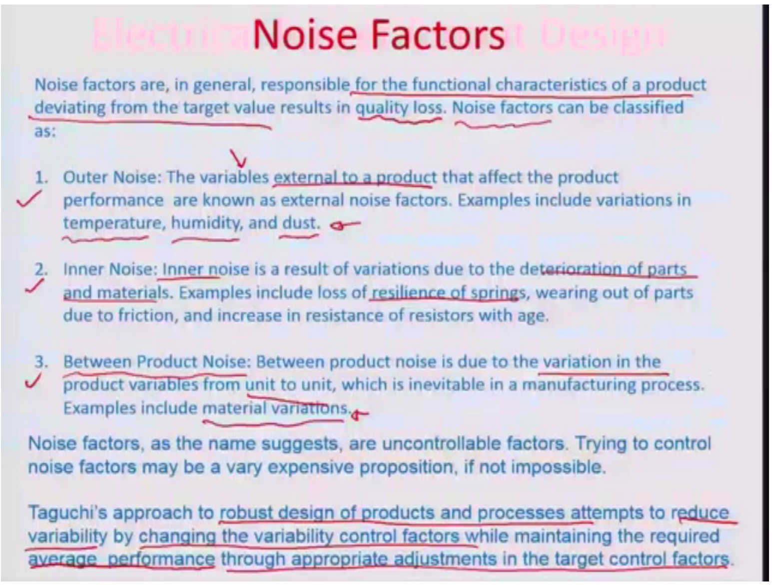

And; obviously, even such a such a such a functionality deviation happens, it results in loss; emotional loss and; obviously, if you looked at large variety of this noise factors, we could categorize them into many different types based on what they coming from. For example there can be outer noise ok. So, outer noise is typically due to the variables which are not really within the product, but external to the product, but they do affect the performance of the product.

For example, let us say if we talked about oil film for lubrication within the gear box, typically would depend on, you know the flow rate of the oil would typically depend on also other factors like temperature, humidity and dust levels, which are otherwise not controllable, but based on this temperature levels, you know you may have a thinner version of the oil or slightly thicker version of the oil, and you might have different application aspect to the to the product which is being considered, because of a factor which is probably there, and is essential annual factor which has no other way to control ok

So, temperature in which your automotive your operating your steering mechanism for example, as laid out earlier, is not in your control. So, but still there is some noise, because of the variability in the film thickness, related to the lubricity that is being provided by the oil in between. So, those are outer noise. Then there a noise inner noise. Inner noise mostly come as a result of variations due to deterioration of parts, parts and materials. For example, let us say when we talked about springs, with time there is a loss and resilience of a springs or maybe you can wear out parts due to essential component of friction. There may also be an increase in resistors, let us say with age and use of all the different resistances, and circuitry.

And with the as a function of time, such parameters keep on changing and contributing to some uncontrollable factors which are present in the design and you can treat them, because the noise is resulting, because of variation from within the component. Resistor for example, in place and working for twenty four hours for the next about ten days, may slightly vary in their resistance, because of such long working hours, and because of the fact that it is a piece of such a kind of change in the resistance all the product with age, could be considered to be an inner noise to the resistance itself, for to the product itself

So, there are there is a third different kind of noise which we commonly known as between product noise, which basically would mean that there is a lot of variation from unit to unit of manufacture what is happening in a process. Obviously, there is no control on only one aspect which will lead to such variation. No controlling of one aspect with lead to such variation, there are many aspects associated with the manufacturing process.

There are aspect related to materials for example, which is coming going to come in there is aspect related to the skill set of a person, who is go to work in the particular, you know whatever contribution is making to the whole work system which may vary, because of it such noise may come.

So, there is going to be between the products from one material to the other, from one you know let us say batch to the other batch of the same products for the same process and for the same material supply system, that are noise may generate. And so this is inevitable, you cannot help to prevent it, metal variation for example, is one of the major cause of such a noise. If you could control it would have been very useful, but you cannot help to control this between product noise which would keep coming

So, as the name suggest, the noise is a noise, because its some controllable, you cannot give a definite of strategy to control such noise, and sometimes even controlling such noise maybe a very very expensive proposition, because you may have to think out of the box, change the whole process all together or sometimes create you know more or add or build more robustness by designs, so that such noises may eliminate for example,. Let us say look at the bolt example of an upper lower limit of let us say 11 k g force per millimetre square which we considered in some of the earlier lectures, for the selection criteria of a bolt ok

So, if this level world do in increase to lecture 15 or 20 k g force for millimetres square; of course, the overall cost would be higher in that case, but then, because of the over development of the design the, definitely would add robustness, and so there may be less possibility of overall variation because of between product noise, or let us say even like inner noise so on and so forth. So, because your over designing on. At the same time there is the cost aspect involved in over designing products, and so there really has to be a trade of, which has to be the basic theme for all designers, particularly in engineering design of a products.

So, when we talk about the Taguchi’s approach to robust design a products and processes. We attempts to typically reduce the variability and that is that is approached by changing the all the variability control factors through good design, maintaining required average performance. So, it does not go outside the target range for the response of a system. There is of course, targets set of for the response of such engineering systems. And this average performance can be through appropriate adjustments in the target control factors so on so forth, and that basically gives you an idea of how robust design can be carried out

So, let us look at little more details now as I talked earlier about what is, so different about variability control factor and target control factor. And in this case I would look at an example given by Taguchi's itself about.

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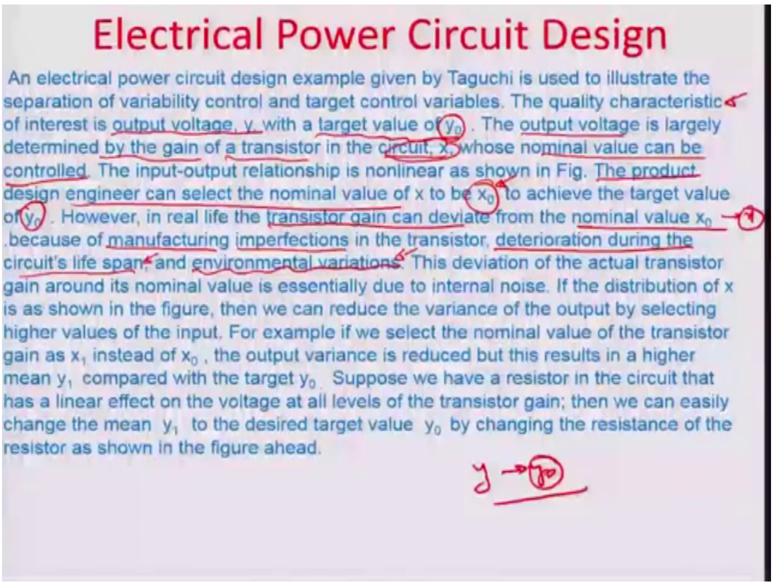

A transistor gain let us say when we talk about an electrical power circuit design. You know the quality characteristic that may be have interest to the production personal, is in one case it could be something related to the output voltage, output voltage of the product. Let us call the output voltage y as in this particular case, and there may be a target value for this output voltage, and this is what we are referring to is the transistor output voltage ok. The target value of y 0 is set in for a output voltage of particularly y, and y could be away from y 0 as you know, because of process variability.

So, there always deviated and typically when we look at the transistor setup in the circuit, as this output voltage of the transistor is also very inherently connected to something called the gain, gain of the transistor. So, gain is sort of factor which is an amplification factor used for multiplying the input response, so that the output response can be multiple folds and so typically in this case, let us consider the gain of the transistor circuit to be about x ok, whose nominal value can be controlled.

And because of such control you, as well see that the responsible transistor is such that its highly non-linear in fact,, that it results into a situation where by intelligent designing we can reduce the variability somehow in the output voltage y ok. So; obviously, when will look at x which is gain, the product design engineer can select the nominal value of x to be about x 0, which is the target gain factor of the circuit.

And to achieve the target value of y 0 this is sufficient ok. So, at gain x 0 you can say that the transistor circuit ideally given output voltage of y 0. However, as you know in real life situations the transistor gain deviate quite a bit from the nominal value x 0. So, there would be a range of values, let us say x across which this deviates from gain x 0 to any other x, which is greater or lesser than 0. And these are typically because of many reasons like, let us say variation in manufacturing, there may be imperfections of defects, particularly in the purity are the silicon crystals, which have been used to make transistors or even some other polymers which are used sometimes to make transistors.

You can also have deterioration during the circuits lifespan, change of resistance elements, related to the interconnects which may lead to such response variation. You may also have some variations related to temperatures at which these a circuits are operated, not every transistor circuit is setup on to operate at a constant temperature. So, there is going to be is selective. There is going to be a certain amount of deviation, definitively on the gain value x and because of that there is also going to be change in the output voltage, and so there is the question of variability which comes.

So, how much away from y 0 is y, at what level of gain x from x 0 which is the target level. So, let us look at this that in fact, if we select the or if you look at the non-linear response of the output voltage y versus the x, as you can see here.

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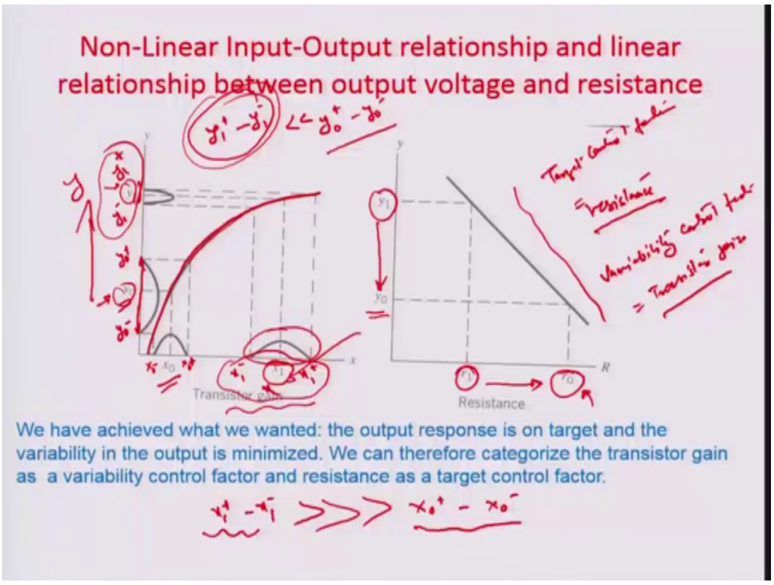

One can recall that let us say it gain value over at x 0 earlier; that means, the gain is setup at x 0, and there is sudden variation here in x 0. This variation is with x 0 centred as a mean value. So, obviously, at x 0 as you know, as we have discussed earlier, there is going to be a output voltage y 0, but because the x 0 is varying between let us say some level x 0 minus 2 x 0 plus ok.

There is going to be some variation in the output voltage also, let us call it y 0 plus and y 0 minus ok. And you seeing that the range of variation here is quite high, but because the resistance or the output is actually a non-linear function of the gain at a higher gain voltage, let us say if you operated x 1, where the variability here is accommodated more ok. So, you can really go up to a greater amount of x 1 plus. I am sorry x 1 minus and x 1 plus range. Excuse me. So, x 1 plus minus x 1 minus as you know is definitely much much greater than x 0 plus minus x 0 minus

So, you are accommodating a higher amount of gain range, but the overall effective variation here between y 1 plus and y 1 minus, let us say is much lesser ok. So, y 1 plus minus y 1 minus, which are the two extremities with mean round y 1,is much lesser in comparison to y 0 plus minus y 0 minus ok. Yeah I am sorry this see a sign needs to change much much lesser here. So, but then the question that comes out here, is that y 1; obviously, is a much higher voltage, which is away from the target y 0. It should have been operating at a output voltage of y 0, but now it is y 1. So; obviously, you have to add a resistance and circuit

So, let us suppose that if supposing the resistance r 1 at the you know series level. The voltages some around y 1 and it can reduced y 0 if you could change or increase the resistance from r 1 to r 0. So, you add certain resistance component to the output voltage. So, that because of the drop, the y 1 changes to the target value y 0. So, in this case, the, target control factor is the resistance ok. So, the resistance is actually allowing the output voltage to change back to the target value. So, you can call this to be a target control factor ok, target control factor, and the variability control factor is the transistor gain ok

So, you seeing that for a larger amount of gain, you are getting a small amount of output range of the voltage ok. So, variability control factor is transistor gain. So, its very very appropriate example to understand what pers means pi target control for factor an a variability control factor, as for as engineering systems or concerned, or engineering system design is concerned.

So, I would like to probably migrate to new topic about you know carrying out strategies a processes industry with respect to the implementation of concurrent engineering as well as giving you a methodology to understand where a deviation is coming and what are the reasons for such deviation to happen. And there is a technique very useful technique call failure mode effect analysis, which is used in most of the industries for looking at some engineering design performances and recording as to what would be the appropriate causes of variation.

So, in the next module when I start next week, I would like to probably go ahead and give introductory session on this F M E A and try to ca do it from a process point of view, that if the reason existing process how F M E A can be done to improve the process where we are essentially again improving the variability as a, you know as an approach to the robust design at the behest of controlling some important factors and not a whole lot of factors. And F M E A kind of gives you a roadmap of privatization, as to what needs to be addressed more priority in comparison to the other factors, so that the overall variability can reduce effectively.

So, with this I like to end the lecture module here, and will do F M E A in the next lecture.

Thank you very much.