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CONTROLLING DEGRADATION TO ENJOY FEELING OF BEST FIT: A POSITION PAPER

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1. Introduction

This is a position paper to point out that if we control degradation appropriately, we can keep the feeling of best fit and enjoy using our products for much longer time, because it permits us to use our machines and products in the best working condition in spite of the widely and frequently changes of situations and environments. In addition, we can avoid producing too many wide variety of products. Then, we can focus our attention more to each product and we can avoid build up a complicated and high expertise demanding high mix, low volume production system, thereby reducing energy, time and cost considerably.

2. Diversification

When operating conditions did not change appreciably, we could foresee them so that we could design machines and products that worked best in their actual operating conditions. But situations and environements change extensively and very often these days and product requirements are diversifying very quickly. Therefore, we cannot predict the operating conditions any more.

2.1 Space diversification: Diversification of products

Thus, what we did was to prepare a wide variety of products to cope with the diversifying customer requirements. Since we cannot predict their operating conditions, we thought we coulc serve our customers better if we produce products in a wide variety as much as possible. Then, customers would choose what they need. That was what we thought. But to realize this, we had to build up sophisticated high mix low volume production system and it takes not only cost and time, but needs high expertise to run such a system. And to be competitive, we had to make our product lifecycle shorter and shorter so that customers always feel a new product is coming up. These actions are focused upon space diversification. i.e, diversification of customer requirements for a final product at the time of delivery. Indeed, requirements vary extensively from customer to customer these days.

But if we look at what caused such diversification, we realize that it comes from the diversification of their use conditions. The situations and environments of operating conditions vary extensively and very frequently change these days. Therefore, high mix low volume production is not the final answer to diversification. We should focus our attention to time diversification as well.

2.2 Time diversification: Diversification of processes

If we note that diversification comes from the diversification and variations of operating conditions, it would be better to focus our attention more to customization. If we can make our products easy to

customize, then even if we producte our products in much smaller variety, we could satify our customers more, because our products respond to their needs and preferences more adequately.
User Experience (UX) is getting wide attention these days [Hassenzahl 2001], [Norman 2005], UX is nothing other than customization.
The same kind of product can generate different value through different experience. That is what UX means. In fact, the word customer comes from "customize". Customers are not mere consumers. They would like to customize our products to their needs and preferences [Fukuda 2010]. In other words, customization is nothing other than adaption. If our products adapt to the needs and preferences of our customers, they will certainly satisfy our customers much more. The response to time diversification is how we can make our products adaptable and flexible enough to varying conditions.
However, researches on how we can make our products adaptive and flexible enough are very few. This is because our engineering value is still based on final product at the time of delivery and we focus our main attention to whether our products comply with the design requirements, not to the operations. In other words, our engineering has been verification-oriented. We should change it to validation-oriented. We should make more efforts to meet the real expectations of our customers.

3. Degradation

When we talk about adaption, we should not forget that it is closely associated with degradation.
Let us take shoes for example. When we buy new shoes, we do not enjoy walking, because they do not fit us perfectly. But as we wear them, they break in and adapt to our walking style and to our feet. Then, we enjoy walking.
Tremendous amount of research has been carried out on degradation such as wear, fatigue, etc. But these studies are aimed mainly at how we can prevent them. They were considered to be devaluating phenomena. This is because the value of a product has been evaluated at the time of delivery and a product which meets the design specifications has been considered to be most satisfactory.
But if we look at our daily life, we would immediately realize that this is not true. We enjoy using our products when they break in and come to fit us best in our environments and under our situations. In other words, we enjoy using our products when they adapt to our conditions. Shoes, for example, are such typical products in our daily life. But this holds true to all machines and products.
We should start pursuing how we can control degradation so that we can maintain the feeling of best fit as long as possible.
It should be pointed out that development of sports shoes are very much associated with degradation. We often assumes the problem of degradation isa long term phenomenon. But in the case of development of sports shoes, it is a challenge against short term degradation and it should also be stressed that it is a problem of short term break-in or adaptation. Although the importance of these issues are well recognized by such industries as sport shoes developers, etc, there are very few, if ever, papers relating to these issues. These shoes industries are developing their products by trials and errors.

3.1 Fatigue

Most typical degradation research that focuses only on its prevention is fatigue. Fatigue is studied only from the standpoint of failure. S-N Curves only represents lstress vs number of cycles to failures.
But this curve represents the response of material to stress so if we can establish another curve that describes relation between adaptability and number of cycles, we can estimate the necessary time for breaking in and if we can maintain that condition as long as possible, we can maintain the feeling of best fit for a long time.
We should pursue such degradation as fatigue from completely different standpoint, i.e., the standpoint of adaptability. This is the problem of long term adaptation.

3.2 Traditional maintenance and adaptive maintanance

Maintenance in the traditional sense has been to restore the degrading function back to its design level (Figure 1).

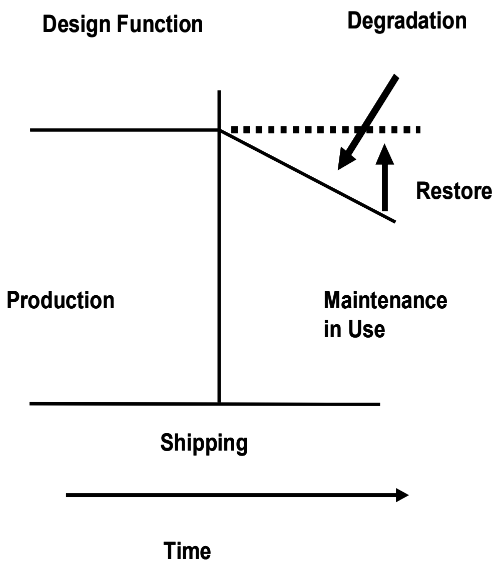

Figure 1. Traditional maintenance

But maintanence proposed here means to keep the best fit condition as long as possible (Figure 2).

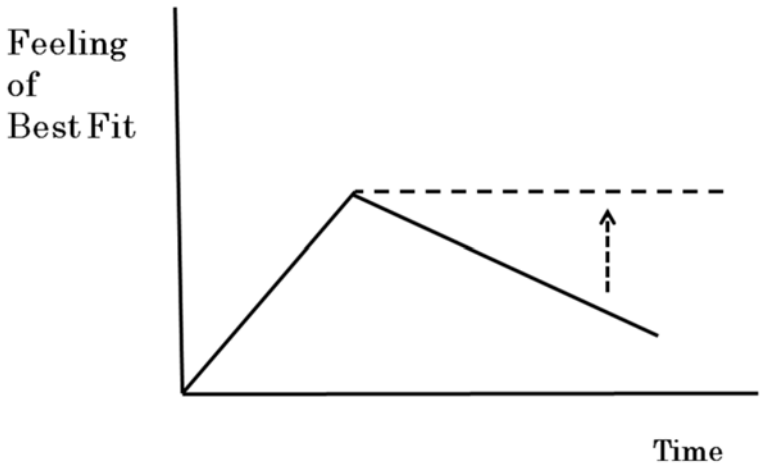

Figure 2. Adaptive maintenance

Then, how can we achieve adaptive maintenance?
One possible solution would be to monitor the product deformation and the material changes and to feed them back. The monitoring of material change is not easy, but to monitor the product deformation is not so difficult. Then, the deformation vs. Number of cycles can be established. This is in a sense cycle-to-cycle reverser engineering. If the best fit deformation can be identified, then the next challenge is to keep that shape as long as possible. It might be difficult to achieve this goal with current materials. The emerging new manufacturing technology such as additive manufacturing would provide a solution to this problem.

4. One time value and lifetime value (LTV)

Thus, we realize that it would be more benefitial and profitable, if we take the other way. That is, instead of increasing a variety of products, we focus on one product and make it as much adaptable as possible. Such design and production policy has several benefits, such as follows,

1. No need to build up a complex production system. We can make production with much simpler processes. Thus, we can reduce energy, cost and time and we do not have to worry about set-up.

2. We can change our business from one time to lifetime value one. We can keep our customers much longer because they feel attached to our products and would like to use it longer, because they best fit their requirements.
3. Since such actions to make our products as adaptable as possible is to sell service rather than to sell products alone. Thus, customers would be more attached to our products and are willing to pay more because they feel more satisfied and besides there is no standard to compare the costs in terms of products. The products they are enjoying to use are "their products" and customers are willing to pay more for such products that really satisfy them emotionally. They are paying for emotional satisfaction, not for product functions.

5. New manufacturing

Hod Lipson [Lipson 2013], [Lipson and Kurman 2013] predicts that the future manufacturing will change the whole scene of design and manufacturing, where materials are no more analog but will be digittal. Materials may be developed from the needs of design and manufacturing, completely in an integrated ammaner, very much different from the current one way flow from material to design and to manufacturing. Currently materials are developed by material engineers and they pursue new applications of such newly developed materials. The linkage between material properties and final design and manufacturing is very weak. But new digital design and manufacturing will integrae te our material development together with design and manufacturing because material development can accommodate much more flexibly the needs from design and manufacturing. In short, materials will be developed in response to the final needs. Up to now, material testing has been to verify the strength, deformation, etc. These properties are not specificied by the needs of design and manufacturing. Design is carried out based on these material data.

Indeed, stronger materials have been developed from design requirements, but these improvements are material property improvements. They are not directly associated with design attributes. As design followed after material selection, the properties of materials have been decisive factors in design.

But material research in the upcoming digital design and manufacturing is more flexible. You can make your material stronger or weaker or make it more flexible as you require in your design. In short, materials in the next generation will be more adaptive to the design and manufacturing needs.

Thus, it is certainly a challenge, but not a dream to develop materials which deform and keep the feeling of best fit as lons as a user likes.

For example, such a solution could be developed. We develop porous material, then we inject liquid first into pores to indentify what shape works best for the user and once identified, we solidify the liquid to keep the shape as long as possible.

6. Feature parts-emotional modularization

Although [Hassenzahl 2001] and [Norman 2005] emphasized the importance of user experience and emotional design, they did not point out the importance of modularization with attention paid to emotional feature parts.

It is mportant that we distinguish parts which affect emotional satisfaction very much from those which do not. Those parts which do not affect emotion so much can be separated from such emotion affecting parts and can be produced as a common platform. Then, we can focus our attention more to feature parts which affect emotion and make our products much more adaptable and meet the needs and preferences of our customers.

This is in a sense modular design and production. But these modules are emotional modules, not functional modules.

7. Open loop to closed loop

As the fact that Big Data is attracting wide attention these days demonstrates our design and production is quickly changing from our traditional open loop system to closed loop system.

In an open loop system, our models are fixed so that we have no other choice than to prepare a wide variety of products to respond to the quickly increasing diversification. But such actions can only take care of space diversification and cannot accommodate such emotional satisfaction as feeling of best fit, attachment or experience design.

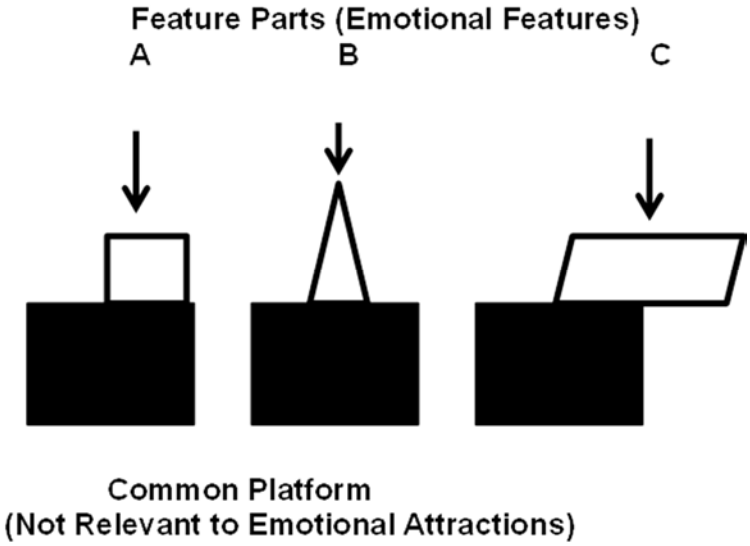

Figure 3. Feature parts

The quickly progressing sensoring technonology and emerging new manufacturing technology will make it possible to feedback user's conditions directly to us. Thus, although we cannot predict the widely diversifying and varying operating conditions of our customers, we can utilize feedback information for adaptation and make them best fit for the condition.
In order to achieve this goal, we have to re-study degradation such as fatigue, wear, etc from the standpoint of providing emotional satisfaction, not from the standpoint of preventing failures.

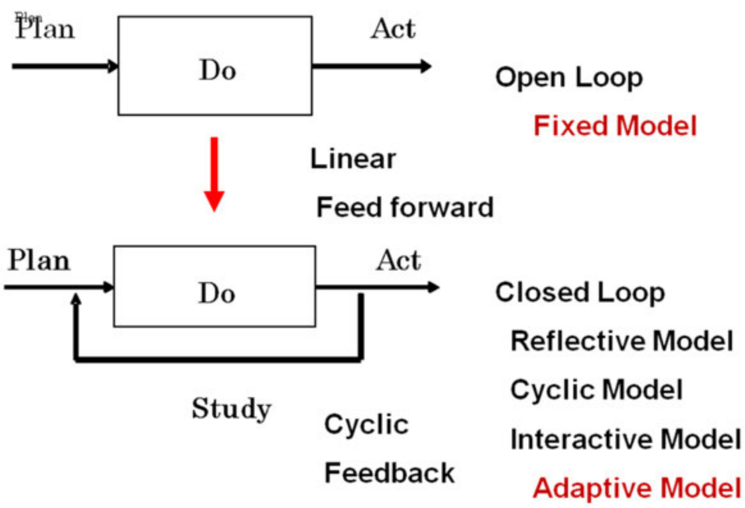

Figure 4. Open loop and closed loop system

8. Summary

This paper points out that in order to satisfy our customers more and to let them enjoy using our products, we have to change our maintenance from traditional design specification based to adaptive maintenance to keep the feeling of best fit for a long time. To achieve this goal, we have to re-study the phenomena of degradation and we have to utilize the progressing sensor technology as well as emergying new manufacturing technology.

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