Efforts toward Improving Product Quality (Improvement of Design Process and Human Resource Development for Prevention)

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Mitsubishi Heavy Industries, Ltd. (MHI) delivers a variety of products around the world, and when there is a significant nonconformity, not only will our own company's management be affected, but so will our customers', resulting in the loss of credibility and trust from society. In order to avoid such a situation, it is necessary to steadily continue quality improvement activities in manufacturing, and to improve the quality of work to ensure and improve the quality of products. In this paper, we introduce an overview of efforts for "design process improvement" and "human resource development related to prevention" related to nonconformity prevention activities undertaken by the Value Chain Headquarters.

1. Introduction

To prevent nonconformities beforehand, it is effective to extract risk in advance, to analyze the generated nonconformity, and to take preventive measures so as to avoid similar nonconformities.

Many significant nonconformities are attributed to the design process, and the factors are insufficient risk extraction, review and verification in product development and design change. Section 2 summarizes an outline of the design process improvement activities that we are currently undertaking to eliminate these factors.

Section 3 introduces the human resource development activities presided over by the Value Chain Headquarters that utilize the "failure studies" analysis method focusing on human failure to derive reliable prevention measures.

2. Design process improvement activities

To extract risks in design process, methods such as FTA (Fault Tree Analysis) and FMEA (Failure Mode and Effect Analysis), design review, quality engineering and risk assessment are utilized. It is important to combine these methods well and extract risks without omission. To respond to customers' advanced requirements and complicated systems, MHI developed new approaches as described below in addition to these methods and promote application to products

2.1 Visualization of risks during product development by "functional element - component element system diagram"

Many of our group's products adopt a design method to customize models already on the market or standard models according to customer needs. If partial modification is done in the customization, it is likely that nonconformity will occur after delivery unless how the change affects the system or product is correctly grasped and evaluated.

To suppress the occurrence of this kind of nonconformity, we are trying to utilize and disseminate "functional element - component element system diagram" for logically identifying the influence destination.

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In this method, customer requirements are decomposed into functional elements of the system and relationships with components (parts) are organized to create a system diagram. With this system diagram, it is possible to logically derive functions and parts affected by design changes, failure modes to be considered, etc.

Consequently, it becomes possible even for inexperienced designers to carry out risk assessment of a change, which previously had to rely on experts, without omission. In addition, creating a system diagram is extremely useful for the designer to understand the system, and it is also useful for knowing the structure of products that they did not design such as licensed products.

Figure 1 gives an example of the functional element - component element system diagram.

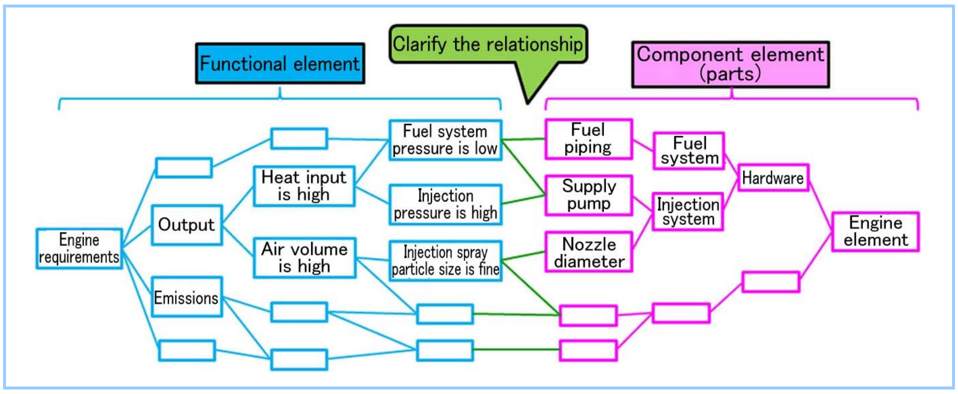

Figure 1 Example of functional element - component element system diagram

2.2 Building FMEA creation support tool and sharing lessons learned based on SSM

To utilize the collection of past nonconformities and lessons learned to prevent recurrence and occurrence, it is necessary to arrange it in a form that can be easily used by anyone, so the building of the "FMEA creation support tool" and disseminating and establishing of the "SSM (Stress Strength Model)" method are promoted.

The FMEA creation support tool is a database of failure factors, nonconformity cases (public cases, in-house cases, etc.), countermeasures, etc., of major machine parts and electrical parts based on the failure mode. This tool is utilized by the business division for the creation of FMEA and design review.

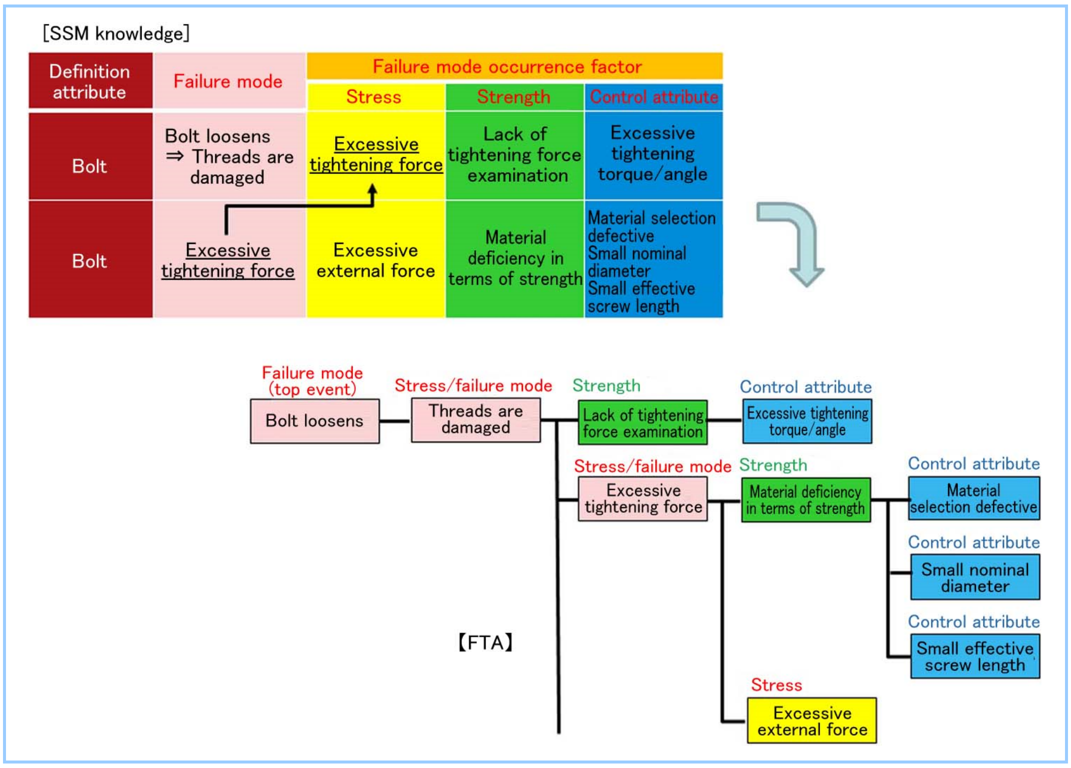

Figure 2 Example of creating FTA from SSM knowledge

In addition, the SSM method organizes the nonconformity occurrence mechanism in terms of stress (external factors such as usage and environmental conditions) and strength (design factors such as a deficiency in strength) and clarifies the causal relationship of events that occurred to enable their utilization in future designs. In the past, the identification of event occurrence factors using FTA depended heavily on the experience and knowledge of the designers. However, by expressing them based on the concept of stress and strength as shown in **Figure 2**, it is possible to suppress the omission of related factors and to create FTA with advanced logic.

2.3 Disseminating systems engineering

In addition to the above, we have been working on the dissemination of systems engineering since this fiscal year.

Systems engineering is a method developed to smoothly proceed with a huge project without problems, which started with the Apollo Space Program and is widely-used in the aerospace and defense industries. In recent years, many industries such as IT, transportation systems and automobiles have adopted systems engineering.

In recent years, customer requirements have become more advanced, and it is also necessary to respond to different environments and regulations depending on the country and user.

Unless a system that reliably captures these requirements is established, unexpected problems may occur in unexpected places.

Against such a background, the number of industries utilizing systems engineering has been increasing.

Systems engineering uses an approach called the "V-shaped process." As can be seen in **Figure 3**, according to the V-shaped process, customer requirements are incorporated in the design in the order of the system, subsystems, and components, and verified in the reverse order. By proceeding with each design stage while checking the validity of the higher-level requirements, rework can be prevented.

In MHI group, a study group by design members has been established, and it is promoting dissemination activities to apply this process in a form suitable for the product.

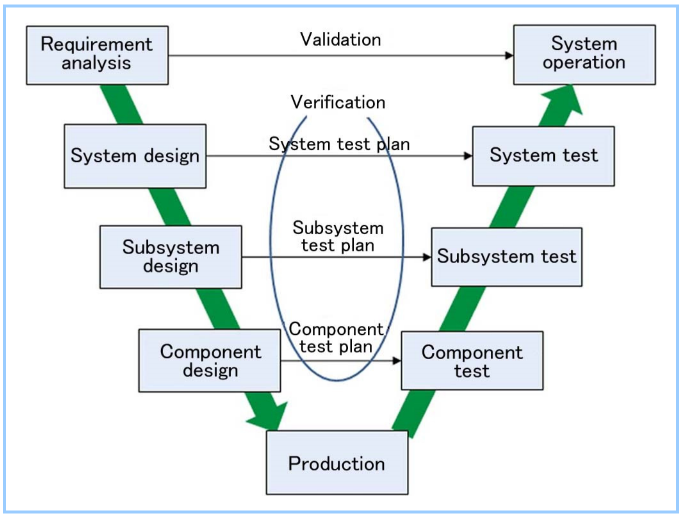

Figure 3 V-shaped process

3. Training for the improvement of human cause analysis utilizing study of failure

Although cause analysis and countermeasure study are performed to prevent the recurrence and occurrence of nonconformities, it is possible that countermeasures will be misdirected unless analysis is properly performed.

The causes of nonconformities include physical and human causes. A physical cause is something that was the starting point of the mechanism leading to deterioration, damage, destruction etc., of the product (such as the shape, structure, system, etc.). A human cause is a human error that led to a nonconformity such as an erroneous decisions and action, etc.

A physical cause is due to a physical phenomenon, but the materials and parts did not naturally cause such nonconformity phenomenon, and it was a human who chose the materials and parts. Therefore, since in all cases human causes are involved, the cause of a nonconformity is always a human cause.

In analyzing human causes, it is necessary to analyze why the failure behavior was taken, including circumstances and psychological aspects and take countermeasures. This section presents activities aimed at improving the practical ability of analysis and countermeasures of failure behavior utilizing the concept of "the study of failure," which we are working on.

3.1 Concept of study of failure

Many human causes of nonconformities are common across products and departments. If the event and countermeasure are conveyed as information unique to the department in which the issue occurred, it is difficult to recognize the information as a nonconformity risk of the information-receiving department itself, and therefore the information may not lead to prevention of the nonconformity. When the human cause of the nonconformity is analyzed, generalized by excluding unique information limited to products and departments, and expressed as a lessons learned (dominant concept), it can be easily recognized as a risk for different products and sectors, and effective nonconformity prevention measures can be developed (**Figure 4**).

Table 1 details the method of proceeding with analysis according to the concept of the study of failure. This flow is summarized in "Essence framework of study of failure" advocated by Hamaguchi (the former professor of the University of Tokyo) (**Figure 5**).

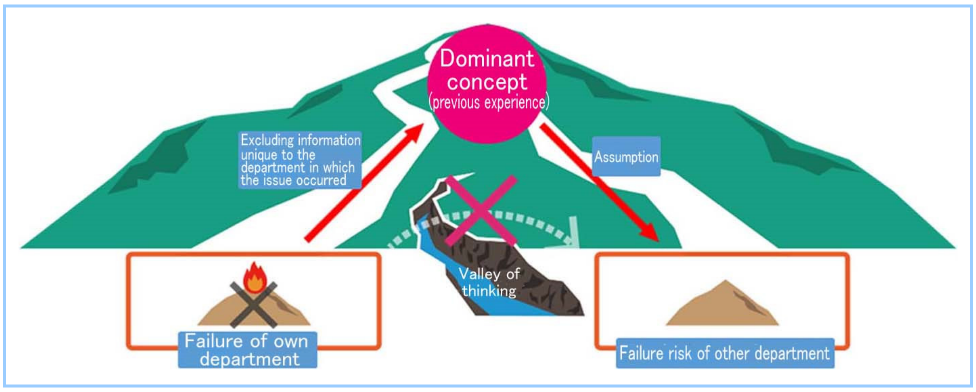

Figure 4 Concept of study of failure: picture of mountain climbing
Source: Tetsuya Hamaguchi, Takayuki Hirayama, Practice of Study of failure, JUSE Press, Ltd. (2017), Figure 2.1

Table 1 Procedure of failure analysis

(1) Identify the failure behavior of the human that led to the nonconformity.

(2) Consider the motivating information and surrounding environment/situation (motivational cause) that caused the failure behavior believed to be "correct."

* Although the behavior of the related person is ultimately regarded as a failure behavior, at that time he or she believed that the behavior was "correct." It is important to imagine the situation at that time and to think about what was the motivational cause that made him or her think so. Considering an "excuse" to justify the behavior such as "it was inevitable to choose that behavior," or "anyone would do so in that situation," it is easy to find the motivational cause.

(3) Based on the motivational cause, derive the "trap" (unique to that case) in which he or she was caught.

(4) Eliminate information unique to the product or department of that case from the trap to generalize the cause of the failure and derive the dominant concept of the failure, that is, a trap by which everyone may be caught.

(5) Based on the dominant concept of the failure, or the "trap," consider prevention measures against being caught by the "trap," that is, the dominant concept of success.

(6) Apply the dominant concepts of failure and success to other products or departments and consider possible failures and preventive measures.

Source: Tetsuya Hamaguchi, Takayuki Hirayama, Practice of Study of Failure, JUSE Press, Ltd. (2017)

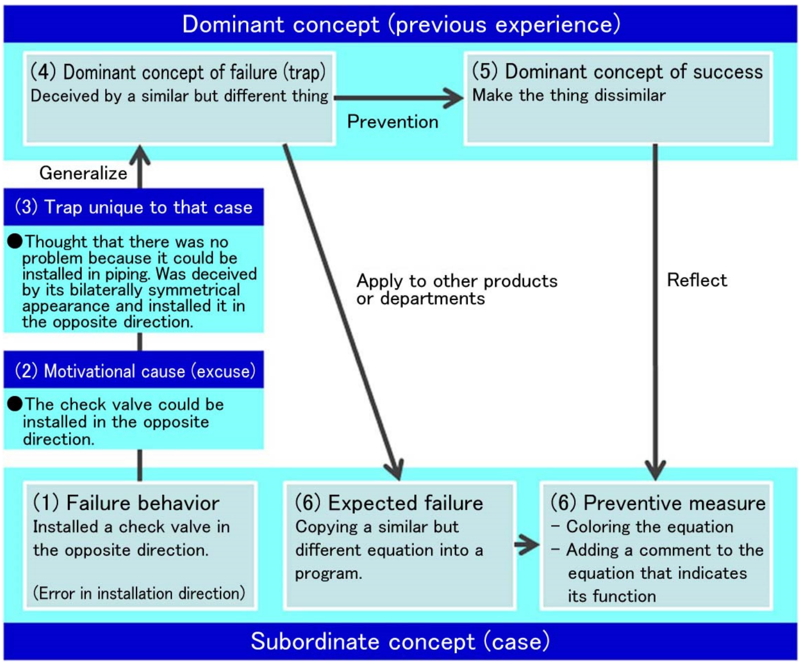

Figure 5 Framework of failure analysis
Source: Tetsuya Hamaguchi, Takayuki Hirayama, Practice of Study of Failure, JUSE Press, Ltd. (2017), Figure 3.2

3.2 Training for improvement of human cause analysis

With only learning the failure analysis procedure, it is difficult to actually identify the failure behavior and derive the motivational cause based on factual confirmation of a nonconformity event and interview results. Our company has been inviting professor Hamaguchi to hold workshops for human cause analysis for several years.

The workshop proceeds with step (1) Lecture (learning the way of thinking), (2) Training (practicing how to use), and (3) Guidance (analyzing nonconformities of one’s own department and receiving guidance for correction) and intends to improve practical skills through repeated training in the same organization.

In addition, ergonomic knowledge is also necessary to perform analysis after a thorough understanding of human characteristics. Therefore, we are developing human factor training and analysis manuals.

Furthermore, to utilize nonconformity cases for prevention in other departments, case studies and presentations are also being conducted, using the case study analysis examples from the workshop. With regard to these deployment methods, we have also devised an approach based on the concept of human factors to more effectively extract risks.

4. Conclusion

To prevent nonconformities, MHI is promoting design process improvement activities, training for the improvement of human cause analysis, etc. As examples of this, this paper presented the visualization of risks in product development using the "functional element - component element system diagram," the establishment of the FMEA creation support tool, the sharing of lessons learned based on SSM, and the application of systems engineering for design process improvement activities, and the framework of failure analysis based on the concept of the study of failure and the workshop using the framework for the training for the improvement of human cause analysis. In the future, we will combine these activities to improve the practical ability for extracting nonconformity risks and implementing prevention measures, while promoting improvement activities that can contribute to the reduction of nonconformities in various products of our group.

References

1. Tetsuya Hamaguchi, Study of Failure & Study of Creation, JUSE Press, Ltd. (2009)
2. Tetsuya Hamaguchi, Practice of Study of Failure, JUSE Press, Ltd. (2017)