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Development of Web-based Design Review System for Reliability and Safety Knowledge Management

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Abstract : This paper describes a web-based design review system as a knowledge management system relating reliability and safety system design. Since people's consciousness for safety and security become sensitive and increases the need of establishing a proactive prevention method for internal failures and relating risks in products. It also means that prevailing tacit knowledge in retired workers, in order to transform them to be easily used to support new system development, become more important. When considering safety and reliability design, at least two data sheet are necessary; Failure Modes and Effects Analyses (FMEA) and Risk Assessment (RA). These two data are practically made separately. However, it includes the concerns that a risk by failures during long-term use may not be noticed. To overcome this insufficiency, a support tool for integrating reliability evaluation and risk assessment data simultaneously is expected to be revealed. The authors have then developed a web-based design review system for reliability and safety system design. The system include various profitable functions; making FMEA and RA sheet, retrieving past data sheet for engineering change management and new product development and web-based discussion to increase the efficiency of discussion. The system is applied to one practical development works in order to demonstrate its effectiveness that is to be made clear by interviewing user's qualitative comment.

Key words: design review, FMEA, risk management, knowledge management

1. Introduction

In Japan, consciousness of people for safety and security has recently become sensitive. In a product development stage, checking the safety of a product in advance is then required. When it comes to consider reliability and safety design, Failure Modes and Effects Analysis (FMEA) [1]) and Risk Assessment (RA) [2]) are normally used to identify latent hazards in products and evaluate their degrees of risks for customers. In long time use of products, a concern of risk that a fracture of structure harms users may increase, e.g., a broken cable in an electric circuit causes fire by electric shorts. According to ISO code for RA, a hazard of fracture during service is listed. However, it does not contain the way of predicting a specified content of the fracture that is necessary to consider its countermeasure. On the other hand, FMEA data sheet contains Fault Tree Analysis (FTA) to link a failure mode between its causes but not includes a hazard list to discuss effect of the failure mode for users. To support for predicting these hazards by failure modes, it is necessary to make FMEA and RA sheet at the same time with ease.

Conventional data for reliability or safety assessment is stored by papers. This preservation system is easier to be operated. However, it also has difficulty in searching specific data from plenty of papers by human efforts. To overcome this problem, a web-based system is suitable. Huang investigated the Hong Kong industrial company for its situation of using engineering change management system [3-4]. Though ISO guideline of engineering change management has already published, the company only introduced paper based system using their original forms, which has difficulty in searching a

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specific related document to concern potential errors in a current change. Huang also developed a web-based design review system [5-7] to discuss effects of engineering changes, which is helpful to preserving the detailed contents of the reviews. Peng and Trappey [8] proposed a data model of a product compatible to ISO. Bouikni also developed a design review system based on the concept of Product Features Evolution Validation Model (PFEV) [9] to discuss the effect of changes in design stage. However, they discussed little in defining engineering changes and in finding errors involved in the changes through a design review process. These systems scopes for normal design reviews, which includes concept design, functional design or component design etc. However, these systems did not consider the process of detecting failures in their design concepts and connections of results of reviews to a specific form of data sheet for FMEA or RA. Furthermore, little discussions have been conducted to predict latent failures in current design concepts by using past data effectively.

One of the authors proposed the Design Review Based on Failure Mode (DRBFM) to predict latent failures by focusing the engineering changes or environmental changes that was visualized by comparisons design features with past reliable one [10-11]. This method is applicable for the complex products which has hierarchical structures [11]. The DRBFM method can be helpful in detecting much amounts of failures more than the one taken by using conventional FMEA [12]. This kind of design reviews can also be useful in On-the-job training by means of transporting know-how from veterans to younger workers [13]. Combining the DRBFM method and ISO based RA is useful and necessary to simultaneously discuss the reliability and safety of products designing. The stored data will be helpful in discussing the failures in next products. The web-based design review system based on the DRBFM and RA is then necessary in order to manage the framework of design reviews in workplaces.

This paper describes a framework of web based design review system as a knowledge management system relating reliability and safety system design. The developed system is applied in development case of one pressure vessel system for food processing. The effectiveness of the system is investigated.

2. Web-based Design Review System

2.1 Role of participants

A design review system normally needs the following participants in order to fulfill a FMEA or a RA data sheet.

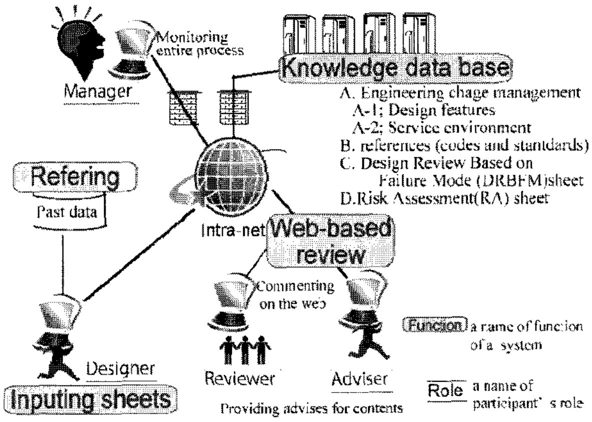

Fig. 1. Entire structure of design review system.

- Manager

A person who decides participants in design review, monitors a process of making data sheets and manages a schedule of review.

- Designer

A person who makes a DRBFM and a RA sheet for a composite of his /her charge.

- Reviewer

A person who checks whether enough causes of failure modes and risks are predicted based on his / her profession.

- Adviser

A person who checks whether all of failure modes or risks are treated by appropriate solutions and the contents of solutions are fulfilled explicitly in data sheets

2.2 Structure of the design review system

Fig. 1 Entire structure of design review system shows an entire structure of a developed web-based design review system. The system is composed of the following functions.

- Inputting data sheet

A designer can make data sheets for engineering change management, reference codes, standards, Design Review Based on Failure Modes (DRBFM) [13] sheets and Risk Assessment (RA) sheets.

- Web-based review

A reviewer and an adviser can check input data sheet using web-browser and give a designer comments for a revision or a recommendation.

- Referring past data

All participants can search past data in order to check past identifications for failure modes or risks and their

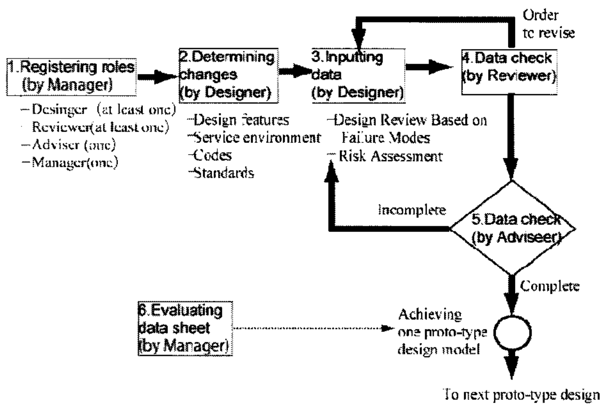

Fig. 2. Work flow of making DRBFM and RA data sheets in one proto-type design model.

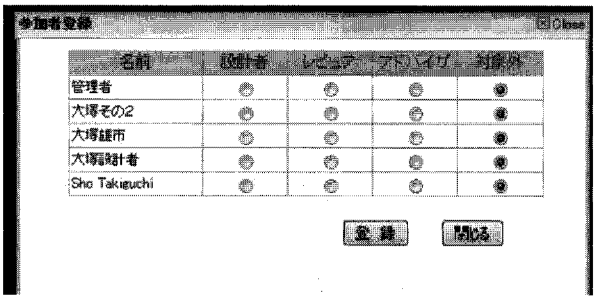

Fig. 3. Example of selecting roles of participants.

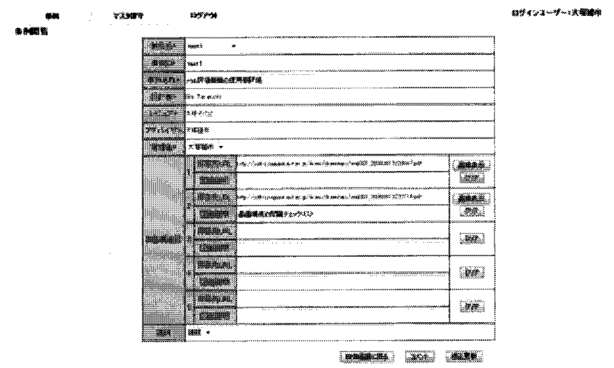

Fig. 4. Example of one registered case.

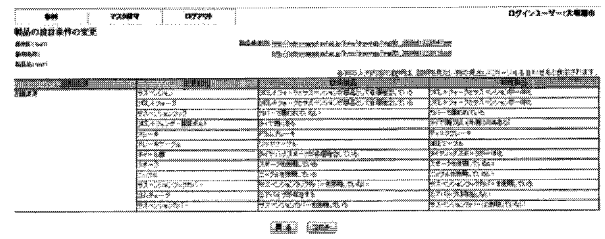

Fig. 5. Example of engineering change management; comparing differences in design features of a current model from a previous one.

measures.

- Knowledge data base

This design review system can stock four data sheets; engineering change management data, codes and standards, DRBFM sheets and RA sheet. This function will help manager to monitor a process of discussion and analyze contents of these sheets.

2.3 Flow chart of design review

Fig. 5 shows a flow chart of design review in making one proto-type design model.

1. Registering roles

Manager decides participating designer, reviewer and adviser from a registered list (Fig. 2). When all the participants are determined, a case that is an unit data set including four data sheets and explanations for a model is made (Fig. 4).

2. Determining changes from a past design model

Fig. 5 Example of engineering change management; comparing differences in design features of a current model from a previous one

Fig. 2 Work flow of making DRBFM and RA data sheets in one proto-type design model

At first, a designer makes a list of engineering changes in his design from previous one and also checks an environmental change in service condition. Fig. 5 is an example of comparing list of engineering changes in design features. A designer can predict failure modes in a current model with ease by using the comparing list because differences shown in the list mean new points on a past reliable design condition that may cause a new failure mode. The list helps a designer to focus on the differences in his complex model to identify reliability problems. If a service environment has also changed, its content should also be listed, as shown in Fig. 5 Example of engineering change management; comparing differences in design features of a current model from a previous one. Because there are so many accident reports caused by not considering an environmental change, e.g., temperature, roughness of road etc.

3. Inputting data sheets

A designer subsequently makes a DRBFM work sheet and a RA work sheet. Fig. 6 illustrates an example of a DRBFM work sheet. In normal, these sheets are made by paper or an office soft. However, such kind of data form has difficulty in searching contents of failure modes in order to use a past data in checking whether sufficient failure modes can be predicted in a current

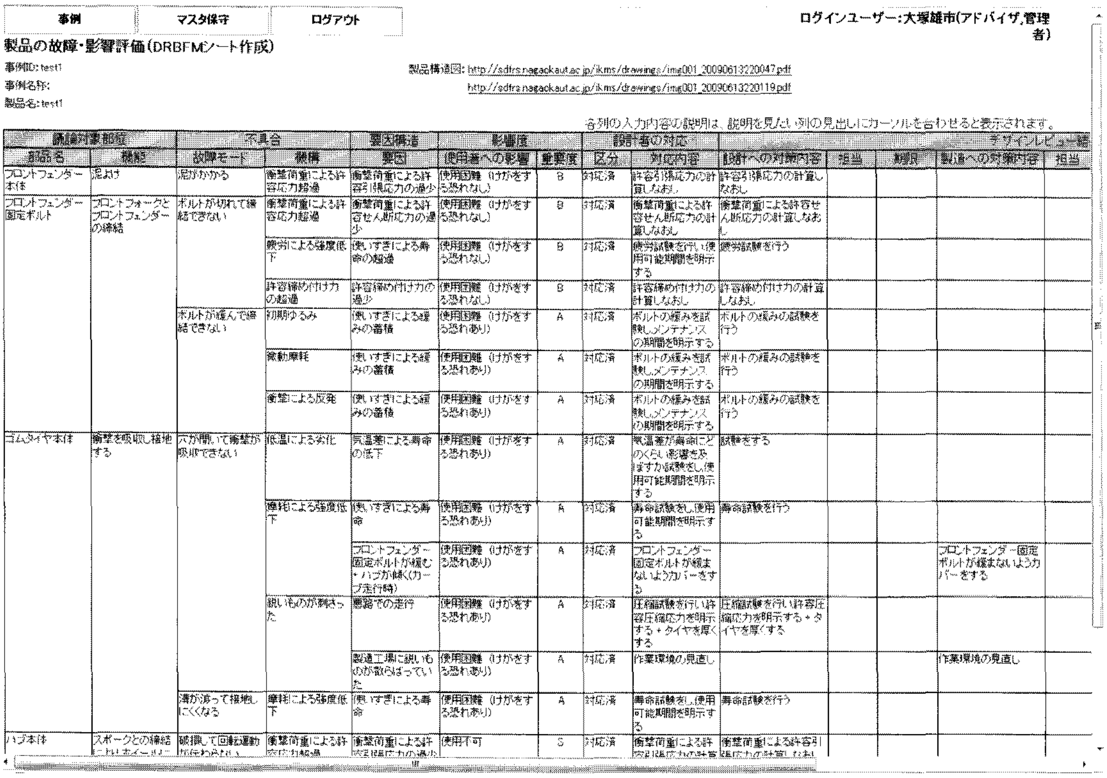

Fig. 6. Example of Design Review Based on Failure Modes work sheets.

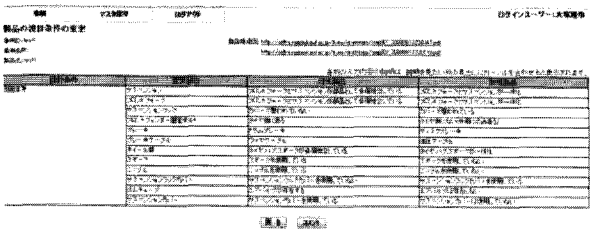

Fig. 7. Example of engineering change management; comparing differences in service environment.

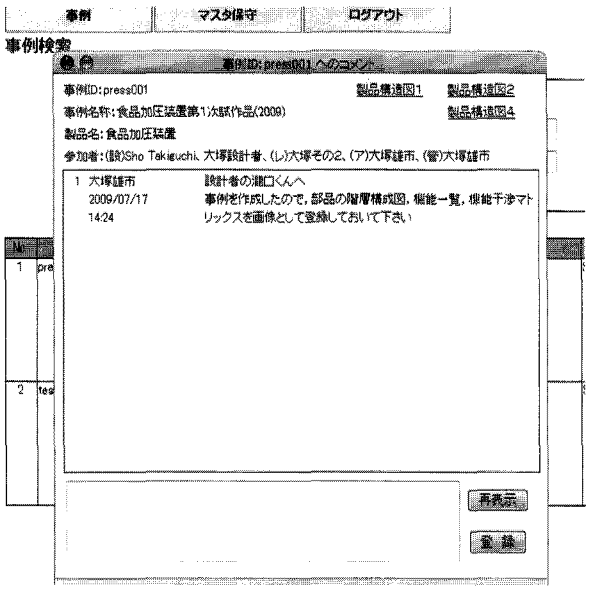

Fig. 8. Example of design review board on web-browser.

design. By using data base management system, such problem can easily be solved.

4. Data check by a reviewer

A reviewer can check all of the contents in data sheets by using a web-browser. If he wants to give a message to a designer, a communicating board is useful to send a comment and stock a process of discussion, as shown in Fig. 9.

5. Data check by an adviser

An adviser also checks the contents of data sheets, especially in contents of solutions for predicted failure modes or risks. Because error might also be involved in a contents of the solutions and it's difficult in finding them without enough profession on product's behavior.

6. Evaluating quality of data sheets

A manager can evaluate a quality of data sheets in views of finding errors, causes and enough solutions. These evaluating data can indicate a good data sheet for

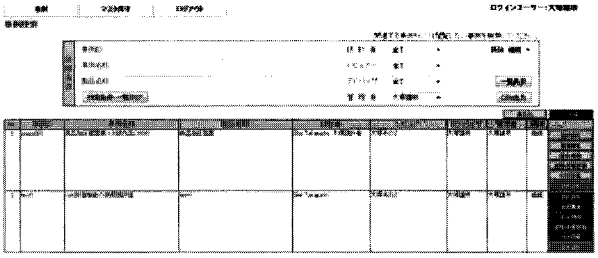

Fig. 9. Example of searching box. Only cases in process are shown in a search result. A manager can monitor a schedule of making data tables.

next users.

2.4 Management functions

A manager can search each case by using a searching table, as shown in Fig. 6. By using this monitor function, a manager can easily see which cases are finished on schedule. If he notices a delayed case, he contacts an adviser of the case whether a help is needed. The manager also arranges contents of items in each column of data sheet by using sheet masters.

If a next design stage starts, a new case, which succeeds to all contents in a previous type model, can be updated. This function helps managers to store a history of design changes through a development stage.

3. Case Studey: Risk Assessment of Pressure Vesses System

3.1 Target of the application

The target of the case study is a pressure vessel system for food-processing. Figure 11 shows the specification of the prototype model of the pressure vessel system. This vessel system can operate suppresses inner water at the maximum pressure of 200 MPa. Inserted food-packs are then pressured. Complex structures of proteins in the foods are changed during pressurizing. The high pressure process can reduce the hardness of meats that can improve their taste and can also reduce the allergen in the foods, which is expected to make less-allergy foods for patients.

However, the vessels are subjected to such the high pressure, designers should be sensitive for the structural reliability and related risk of the vessel. Once the walls of the vessels were broken in operating, the flying pieces of the broken walls will be critical hazard for surrounding users. We applied DRBFM and RA for the vessel system with the help of the developed web-based design review system.

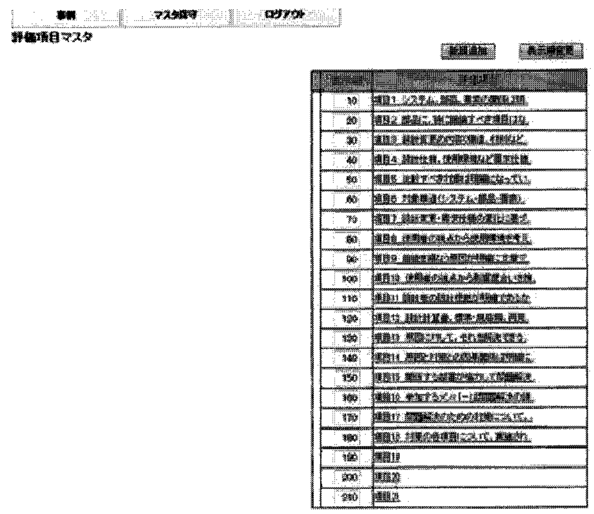

Fig. 10. Example of a master table. A manager can easily change a name of each item.

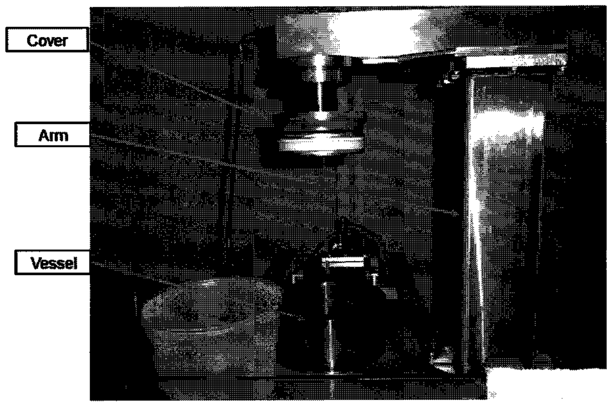

Fig. 11. Entire structure of the pressure vessel system for food processing. The cover is moved down by hydraulic forces and fixed by arm guides in pressurizing.

3.2 Result of DRBFM

Fig. 12 shows the result of DRBFM for the pressure vessel system shown in Fig. 11. Original data was stored according to the form shown in Fig. 6 and was written in Japanese. We then translated it to English form in order to demonstrate the specific result clearly. Ranks in the figure mean the extents of possible damage for both the function of the considering parts and the users. The failure modes of higher ranks involve serious hazards for the users. In this case, cracks on the wall of vessels or arms can have the hazards of abnormally high pressure or breaking the wall. Table 1 shows the result of risk assessment. We could predict 23 risk scenarios from the failure modes shown in Figure 12.

The data shown in Fig. 12 and Table 1 is beneficial

Parts	Function	Failure Mode	Rank
Pressure vessel	The pressure vessel endures inner pressure	A crack penetrates through thickness. → Impossible to keep internal pressure.	S
Water compressor main body	The water compressor main body increases the pressure of the pressure container.	A crack penetrates through thickness in the cylinder. → Impossible to send the water.	B
		An increase in pressure by false operation. →Cylinder break down→Increasing pressure abnormaly by misuse.	SS
Gland	The gland sticks fast with the cylinder and prevents the water leak	Thickness decreases. →Impossible to prevent the water leak.	B
		A crack penetrates through thickness. →Impossible to prevent the water leak.	B
		The gland harden and the space open. →Impossible to prevent the water leak.	B
Pressure meter	The pressure meter make person confirm the pressure in the pressure tube.	The pressure meter break down. → Impossible to confirm the pressure.	C
		The pressure meter jounce. → Impossible to confirm the pressure.	C

Fig. 12. A part of DRBFM work sheets for the pressure vessel system. Original data was stored in the form shown in figure 6 and was translated to English.

Table 1. Number of total failure modes and related risk scenarios for the pressure vessel system

	Failure modes (Partly shown in Fig.12)	Related Risk Scenarios (Using hazards in ISO 14120)
Number of predictions	53	23

for the designers in making the countermeasures for the risks related to failure modes. Designers should give failure modes a specific rank that is the basis of determining the needs of countermeasures for them. However, ranking was highly based on the designers past experiences that is not easy for discuss its rationality. In the case of RA, designers also consider countermeasures for higher risks. They may have difficulties in the consideration that the cause of risks is unknown when the target of risks related to failure modes. The data is stored in DRBFM data sheets, not in RA sheets. By combining both the method, the designers can decide rational ranking for failure modes with specific evidence of risks using RA data and also determine profound measures for the causes of failure modes, which can also reduce the extent of risks inherently.

In this process, the adviser and the designer of the DRBFM and RA work sheet had only a few meeting for discussions in order to check the process of using the system and the quality of final data sheet. During the process, the adviser ordered the designed to change or revise the contents using the design review board shown in Fig. 8. The system can help the workloads of the design review process, which will be effective in improving the quality and cost-competiveness of the reliability and safety design by reducing the cost of management processes.

4. Summary

This paper introduced a web-based design review system for reliability and safety design for a product, which can contain both FMEA and RA data sheets. A designer can identify a risk in using a product with looking a result of FMEA, which is expected to focus on predicting hazards by failures. Furthermore, these failure modes are recorded in risk assessment sheet. The developed system will improve a quality of design review by decreasing a managing load (making data sheets, stocking them in a regulated form and making a meeting time for discussion frequently) and by preventing participants from overlooking possible failure modes or hazards.

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