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Information Management for Failure Analysis of Fluid Power Systems

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ABSTRACT

As fluid power systems improve their performance, the demand for their safety and reliability increases and so the failure analysis plays an important role. In the product lifecycle, the failure analysis is performed before and after the launch of the product. The former is a kind of conventional risk analysis to prevent system failure in the design process, while the latter identifies the cause of a customer's complaint; why the product cannot work as the customer expects. This paper considers an information management for the latter, which is divided into two processes: one is to answer the customer's complaint, and the other is to improve the product quality. Based on its objective, a different kind of information flow must be organized. Since fluid power systems work in various operating conditions, the clear specification of environmental factors is essential. An illustrative example shows a simplified treatment process of a customer's complaint.

KEY WORDS

Information flow, Task structure, Customer complaints, Organization

INTRODUCTION

As fluid power systems advance their performance, the demand for their safety and reliability also increases; a kind of risk assessment and management [1] becomes required through the lifecycle of fluid power systems. In the first step toward this goal, the failure analysis plays an important role in identifying problems latent in the subject system. Considering the product lifecycle, two types of failure analyses are identified: before and after the launch of the product. Before the launch, the failure analysis is performed as a part of conventional risk analysis to identify all possible causes of system failure to be considered in the design stage. Information necessary for the analysis can be collected and stored inside the organization or company. The object is to minimize the risk caused after the launch of a product. On the other hand, the failure analysis after the launch is mainly performed to identify the cause of a customer complaint; why the product cannot work as the customer expects. The main object is to maximize the customer satisfaction. Compared with the consumer products, the fluid power systems such as cranes are used under various conditions, which make it difficult to identify the cause of a system failure. It is necessary to obtain appropriate information from the customer such

as the condition where the accident occurs or the product fails to meet its requirement. Further, for the identification of possible root causes and the planning of their countermeasures, the cooperation of design, manufacturing, and maintenance parts is as essential as in the failure analysis at the design stage. Since the good cooperation depends on the good communication among members, the management of information flow in the organization is important.

The construction and evaluation of the information flow for the production system is extensively studied in [2-7]. As the quality of information flow depends on the quality of its contents, MIR (maturity of information reliability) concept is proposed for evaluation of information quality [2]. Using MIR, several case studies have been performed (for example, see [3-5]). Further, a guideline is proposed for building field feedback information flows using MIR revised with consideration of the span-of-control affecting the decision [6]. In [7], IDEF0 approach is modified to analyze a manufacturing enterprise.

This paper considers an information management for the failure analysis after the launch of the product. To communicate appropriate information with the relevant parts and store the analysis results for the future reference in its design, manufacture, and maintenance, the overall task structure of the failure analysis is to be identified in analyzing information flow. For each task, necessary information flow is obtained as requirement to achieve its object. Comparing the information requirement with its current condition for each task, problems such as the loss of information flow can be identified. An illustrative example shows a simplified treatment process of a customer's complaint.

FAILURE ANALYSIS OF CUSTOMERS' COMPLAINTS

For the improvement of the product quality, the feedback from customers is very important. Usually, the feedback takes a form of complaint about the product like "this machine did not work as expected or specified in the catalog", but this kind of superficial information is not valuable not only for the product improvement, but also for determination of an appropriate customer treatment. The root cause of the complaint must be identified so that an appropriate measure can be taken. For this purpose, the collection of the right information from the customer is essential.

Classification of Customers' Complaints

From the viewpoint of customer satisfaction, the treatment of a customer complaint should be quick. This quick response requires that the cause of the complaint must be classified as the customer's fault or the company's fault as soon as possible. When complaints of the same type occur frequently, the answer to the complaint is easy. But, when an unexpected event occurs in the product, the failure analysis is necessary to investigate its cause. From the viewpoint of the readiness of response, the following customers' complaints can be answered easily and quickly:

1) Complaints on items listed in the manuals or checklist

The treatment of the complaint is determined based on what item is wrong and its warranty.

2) Complaints with similar cases in the past

The treatment is to follow the past case similar to the present one.

The response of the complaint in either case is (1) a gratuitous or onerous repair/replacement, or (2) an instruction on how to use the product appropriately. Although these quick responses may be satisfactory for the customer, the company or organization obtains no gain from customers' information. The valuable knowledge for the improvement can be obtained from unfamiliar cases such as unexpected result of the product with/without following the user manual. The failure analysis can give the valuable information on the product quality and the customer usage. This process can be considered as a kind of learning process from failure cases to obtain their root causes.

Requirements for Failure Analysis

For the failure analysis to be effective for the improvement of product quality, the following points must be considered:

1) The information on the field use of the product (especially, customer complaints) should be considered from the viewpoints of not only product warranty, but also design improvement.

2) Loss of information on accident and customer complaints as time passes yields the reoccurrence of the past accident and the reduction of the opportunities of the technology transfer from a veteran to a freshman. To prevent this kind of problem, the transfer and retention of safety knowledge are essential.

3) For the share of common information and exact informational transfer in an organization, it is necessary to investigate what knowledge should be stored from users' viewpoint and how to coordinate the information flow in an organization.

Considering these points, the information flow must be designed for the root-cause analysis of customers' complaints.

Overview of Treatment Process

A conventional organization in the product industry has the following divisions for the treatment of customers' complaints as shown in Figure 1, where an arrow indicates a communication flow.

1) Service Division (SD): A customer always contacts with SD about his complaint.

2) Sales Division (SaD): SaD informs a customer on the current state of his treatment.

3) Quality Assurance Division (QAD): QAD performs the main role in the root cause analysis of the customer

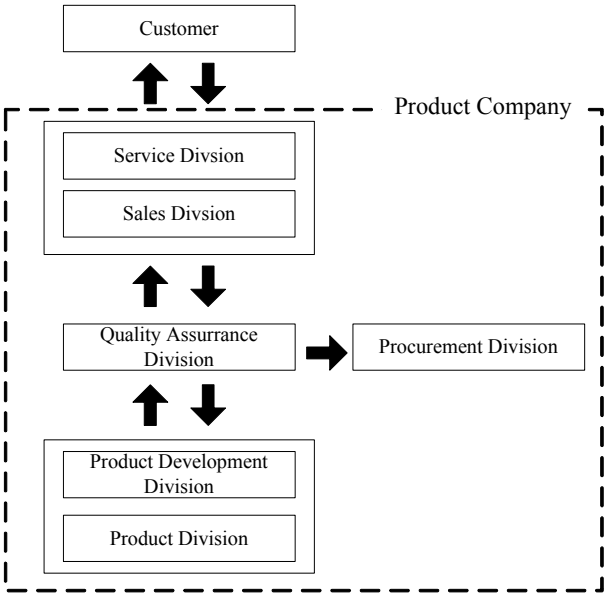

Figure 1 Organizational Structure

complaint.

4) Product Development Division (PDD): PDD is further divided into three subdivisions: design, experiment, and control. They deal with the research and development of the product.

5) Product Division (PD): PD deals with production engineering.

6) Procurement Division (PrD): PrD contacts with the suppliers.

At the first step, a customer submits his complaint to SD, which tries to answer it based on its experience. If SD cannot, SD asks QAD to deal with the root cause analysis of his complaints in cooperation with PDD, PD and PrD. Finally, the customer gets the answer from SD.

Detailed Failure Analysis

The situations where the detailed failure analysis is necessary are classified into the following four cases:

Case 1: SD and SaD cannot deal with a customer's complaint.

Case 2: The product is broken, but its cause (failure) cannot be identified.

Case 3: A component has a lot of customers' complaints, which implies a quality problem.

Case 4: A lot of cases with onerous repair occur, which implies that the revision of customer treatment may be necessary.

The common feature among these cases is that the root cause of the complaint or failure cannot be identified and an appropriate measure should be taken immediately. The main object in cases 1 & 4 is to establish a new decision criterion about the treatment, while the object in cases 2 & 3 is to improve the product quality by understanding the abnormal phenomena.

TREATMENT PROCESS OF CUSTOMERS' COMPLAINTS

To perform the detailed failure analysis to obtain the root cause of a customer's complaint, a wide range of information on the use of a product is necessary. For example, how the product was used? Under what condition was the product? What was the product quality? Different parts of the organization must cooperate with one another to collect the information. For this purpose, a good communication is necessary so that the right person can get the right information. Since the object or output of a task can specify necessary information, the task structure or procedure for failure analysis of customers' complaints must be understood first to design a good communication.

Task Analysis

To identify the task structure present in the organization, the overall task is analyzed as follows:

Step 1: For each task component composing the subject task, identify its input information or material, its performer, and its output information or product. If additional requirements or conditions are necessary to perform the task component, they must be attached to it.

Step 2: Based on the information obtained at step 1, the overall task structure can be easily obtained by connecting input and output with the same content.

The task structure shows the relation between task components as well as the flow of information and material among task components. When some information is utilized, it is an output from some task component and inputs to other task components. Thus, unnecessary or useless information can be identified as one being no input to task components.

Even if all the information is utilized, the overall task structure is not necessarily complete. This structure may have missing information. To complete the information structure, the following step must be supplemented.

Step 3: For each task component to achieve its task objective or output, examine whether any additional information or material is necessary. If necessary, supplement it.

Since an identified task corresponds to an information source, how to obtain necessary information can be determined easily. For the future reference to improve the design or the manufacture, additional information can be supplemented to the information management system based on how the information is used in the design, manufacture and maintenance of the subject system.

Task Structure of Treatment Process

Using the task analysis in the previous section, the treatment process of a customer complaint can be summarized as follows:

(0) The customer makes a complaint against SD.

(1) Can SD make the judgment based on the manual and the stored knowledge?

Yes: SD replies to the customer. [End]
No: SD asks QAD for the judgment. Go to (2).

(2) QAD performs the investigation & analysis with additional information from the customer through SD. Can QAD decide using the database of past analysis records?
Yes: QAD makes a report to SD. [End]
No: QAD asks PDD for Investigation and analysis of uncertain items in the database. Go to (3)

(3) With the answer from PDD and additional information from the customer, can QAD decide whether the problem is due to a design error or a customer problem?
No: QAD requests Quality Measure Meeting (QMM) consisting of QAD, PDD, PrD (Production Div), SD, and SaD to solve the problem.
Yes: Due to a customer problem:
QAD makes a report with onerous result to SD. [End]
Due to a design error:
(a) If the cause is known, the appropriate measure is verified by QAD and Experiment of PD. [End]
(b) If a cause is unknown, QAD request QMM. Go to (4)-(b).

(4) QMM discusses countermeasures for the problem with the additional from the customer and decides whether the problem is due to a design error or a customer problem?
(a) Due to a customer problem:
QMM makes a report with onerous result to SD. [End]
(b) Due to a design error:
QMM determines an appropriate measure, and asks QAD and Experiment of PD for its verification and validation. Go to (5)

(5). PDD and PrD take the measures for quality (such as design revision and improvement of production process) to prevent the recurrence of the same problem, and planning for the next production. Verification and validation are also required for the measures. Go to (6)

(6) PDV and PrD make the final report to QAD. Go to (7)

(7) QAD reports the final result to SD and SrD reports to the customer. [End]

Here, [End] indicates that the problem is solved or the process finishes.

Evaluation of Treatment Process

Although the business process is developed according to ISO9000, the information flow seems not necessarily effective as general comments in [2]. Since the task process is sequential as well as hierarchical, the information exchange among different divisions is restricted so that the response to the customer cannot be quick. Since QAD plays the central role in transferring information as well as analyzing the cause of a customer complaint, the failure analysis fails if QAD does not work appropriately. Further, the current object of QMM seems ambiguous because the duties of each member in QMM seem to be decided in advance by QAD. The role of QMM seems to be to confirm and transfer the statement. For the improvement of both product quality and information flow, QMM on customers' complaints should be held regularly instead of the initiative of QAD so that all the divisions related to the product quality can share and understand the feedback from the customers as well as the background information on the objective of their own role and duties. This will also facilitate the interactions between the customer and SD in obtaining the appropriate information. Since the task analysis result shown above focuses on the treatment process of a customer's complaint, the information flow should be also considered from the viewpoint of the retention of valuable information for future reference.

ILLUSTRATIVE EXAMPLE

This chapter discusses the first part of the treatment process of customers' complaints in detail, which determines whether the problem is due to a design error or a customer problem. Compared with conventional failure analysis, this part considered as a kind of diagnosis decision based on the observational data. The second part which identifies the root cause of a customer complaint corresponds to a conventional failure analysis.

Task Description

Consider a system failure "The arm of a hydraulic crane fell down by itself". Figure 2 shows the schematic diagram of the crane related to this example. A customer calls up SD about this accident. SD inquire the customer about the overall condition. The first concrete information is:

(C1) There was an oil leak from the holding side of the derrick cylinder.

Then, the process of question & answer continues between the customer and SD according to the task analysis shown in Task Structure.

The parts related to the system failure are (P1) hose, (P2) joint at the holding side, (P3) holding valve, and (P4) cylinder. The failure analysis in this step is to identify the failed part and examine its condition. The failed conditions to be considered for each part can be summarized as below.

(P1) Hose:
1. The hose at holding side of the derrick cylinder was cut.
2. The hose at the holding side of the derrick cylinder was burst.
3. The hose at the holding side of the derrick cylinder was torn loose.
4. The joint of hose at holding side of the derrick cylinder loosened.

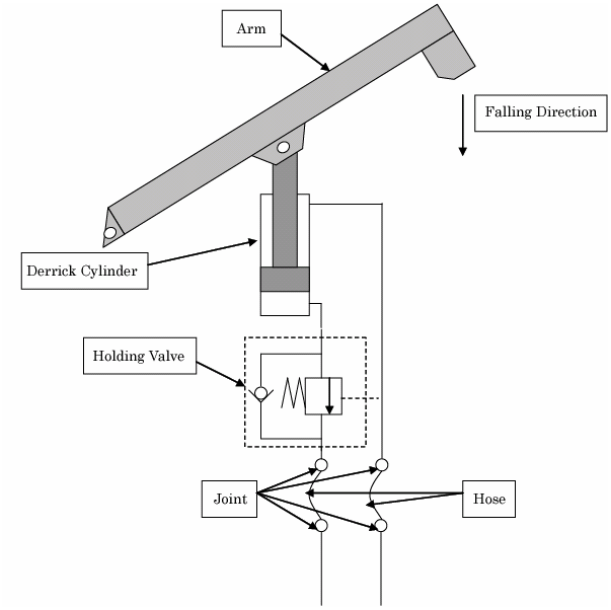

Figure 2. Schematic Diagram of Crane

(P2) Joint:
1. The joint at the holding side of the derrick cylinder loosened.
2. The joint at the holding side of the derrick cylinder was damaged.

(P3) Holding Valve:
1. Attachment bolt of valve of the derrick cylinder was loosened.
2. The seal of the valve of the derrick cylinder was lost.
3. The seal of the valve of the derrick cylinder was damaged.
4. The valve armor of the derrick cylinder was damaged.

(P4) Cylinder:
1. The cylinder of the derrick cylinder had a crack in an externally damaged part.
2. The cylinder of the derrick cylinder had a crack in a welding part.
3. The seal at the cylinder of the derrick cylinder was damaged.

Depending on the customer's information on the failed part, SD must determine whether the failure is due to the customer's fault or design fault. For this purpose, SD performs a field check to confirm the customer's information and collects additional information from the customer.

If the failed condition is different from the above list, SD asks QAD for their help to identify how the system failure occurred.

Onerous Service vs. Gratuitous Service

After the failed part and its condition are identified, the problem is to determine whether the customer has to pay the repair cost or not. For this purpose, the additional information must be checked as follows:

(P1)-1:
Is the externally caused damage is expected?
If no, onerous service. Otherwise, gratuitous one.

(P1)-2, 3, & 4:
Is the damage caused in its normal use?
With excessive load, beyond the temperature boundary, over the service life: onerous service.
With hose joints loosened: depending on the warranty period.

(P2)-1 & 2:
Is the damage caused in its normal use?
With excessive load: onerous service.
With joints loosened: depending on the warranty period.

(P3)-1:
Depending on the warranty period.

(P3)-2 & 3:
Decomposition examination of the valve is necessary.
With excessive load: onerous service.
Attachment error of the seal, or manufacturing error of the valve: gratuitous service.

(P3)-4: Onerous service.

(P4)-1: Onerous service.

(P4)-2:
With excessive load: onerous service.
Over the service life: depending on the warranty period.

(P4)-3:
Decomposition examination of cylinder is necessary.
With excessive load: onerous service.
Over the service life: depending on the warranty period.

Even if the situation does not fit any case in the above, the detailed examination must be performed by QAD. This corresponds to the start of the second stage or the conventional failure analysis procedure.

CONCLUSIONS

This paper considers the failure analysis to identify the root cause of a customer complaint. Compared with the failure analysis in the design process, the detailed information on the failure is uncertain. Thus, the cooperation among different divisions in a company is essential to collect the right information, which requires their good communication. Based on the task structure of treatment of a customer complaint, the communication or information flow can be evaluated. Task analysis of a simplified process in the illustrative example points out the redundant information flow structure. One is to satisfy the customer satisfaction, and the other is to improve the product quality for the prevention. Since this paper focuses only on the task structure or information flow structure, the evaluation of consistency of required information with provided information must be checked. Thus, the evaluation of contents and quality of information as well as the effective use of documentations obtained from the

analysis is our next step toward the design of information management for the failure analysis of a customer complaint.

REFERENCES

1. Kumamoto, H., and Henley, E. J., Probabilistic Risk Assessment and Management for Engineers and Scientists, IEEE Press, 1996.
2. Sander, P. C. and Brombacher, A. C., MIR: The Use of Reliability Information Flows as a Maturity Index for Quality Management, Qual. Reliab. Engng. Int., 1999, 15, pp. 439-447.
3. Brombacher, A. C., Maturity Index on Reliability: Covering Non-Technical Aspects of IEC61508 Reliability Certification, Reliability Engineering and Systems Safety, 1999, 66, pp. 109-120.
4. Petkova, V. T., Sander, P. C., and Brombacher, A. C., The Role of the Service Centre in Improvement Processes, Qual. Reliab., Engng. Int., 1999, 15, 431-437.
5. Berden, T. P. J., Brombacher, A. C., and Sander, P.C., The Building Block of Product Quality: An Overview of Some Basic Concepts and Principles, Int. J. Production Economics, 2000, 67, pp. 3-15.
6. Petkova, V. T., Yuan, L., Ion, R. A., and Sander P. C., Designing Reliability Information Flows, Reliability Engineering and Systems Safety, 2005, 88, 147-155.
7. Kim S., and Jang K., Designing Performance Analysis and IDEF0 for Enterprise Modelling in BPR, Int. J. Production Economics, 2002, 76, pp. 121-131.