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USING AXIOMATIC APPROACH FOR DEVELOPMENT OF NEW CONCEPT DESIGN AND MANUFACTURING

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ABSTRACT

Since the industrial revolution, industries have been growing rapidly in all the fields. With the rapid development economical efficiency has been emphasized, and economical manufacturing method has been researched abroad. One of the economical aspects of manufacturing is satisfying the customer's need with the least production cost. The design of a product is the most important factor in the economical efficiency. A bad design will result in high cost and long production time with low quality. Such result comes from the designer's lack of understanding of the product and subjective design decisions. Design errors are usually occurs in the materialization of the ideas.

Keywords: axioms, design, new-concept, air-compression

1 INTRODUCTION

For centuries, human being has been using air in every day life for a power source in such examples as windmills and sailboats. However, it has not been long since the principles of pressurized air were systematically studied in using the air for engineering purposes. In the modern industrial society, the development of automation has replaced manpower to other sources of power, and one of these sources is the use of the pressurized air. Air is not a cheap source of power since the air has to be pressurized, eliminate moisture, filtered, then cooled. However, it is a useful energy source since machines using compressed air have very high efficiency. Today, a new concept in the use of gas has been utilized for lubrication. Air lubricant bearing is widely used in the industries for high speed machines.

The purpose of this paper is to show a method of reducing the elements that the designer has to consider by integrating various functions into a product or a part in the initial stage of design. The new method uses axiomatic approach in improving production efficiency and development time.

2 AXIOMATIC APPROACH

Design is attained by the interactions between the goal of the designer and the method used to achieve the goal. The goal the design is always proposed in the functional domain, and the method of achieving the goal is proposed in the physical domain. Design process is the mapping or assigning relationship between the domains for all the levels of design.

Design can be defined as the materialization of a product or a process that satisfies the functional requirement of the designer. The process involves the mapping of the functional requirement of the functional domain to the design parameter of the physical domain. Mapping is selecting appropriate design parameter that satisfies the functional requirement. Mapping does not have an absolute and definite solution, so more than one design can be drawn from same set of functional requirement. Axiomatic approach helps the designer choose the best design among infinite number of designs that satisfy the functional requirements by giving objective design axioms that can be used to create or evaluate designs.

As the functional requirements become diverse, satisfying the requirements become more difficult. Therefore, concentrating on the functional requirements for the given stage or level of the design process is necessary. Many designers may feel that a problem with many variables is too complicated. A good and skilled designer can sort the primary and the secondary functional requirements and will handle each functional requirement according to the precedence of importance.

The axiomatic design can be defined as 'the process of designing with a systematic method for a satisfactory product design'. A satisfactory design is a design that satisfies all the requirements. Therefore the role of the designer is to satisfy the design requirements and at the same time appropriately define the design requirements. The requirements of a satisfactory design in the axiomatic approach can be divided into two parts. First is the appropriate selection of FRs(Functional Requirements) and DPs(Design Parameters) and second is the satisfaction of FRs and DPs. FR can simply be defined as the 'object you want to achieve' and DP as the 'means to achieve the object'.

The axiomatic designing process can be defined as the process of defining the relations among several fields-defined as mapping. The designing process can be classified into the following 4 domains depending on the designer's view point; Customer Domain, Functional Domain, Physical Domain and Process Domain. In the designing process the designer first selects the functional requirements to satisfy the requirements of the customer. And secondly the designer selects the design elements that satisfy the functional requirements. And finally the

designer selects the design parameter that composes the design elements that has been selected.

Functional requirement is included in the functional domain. Special methods that satisfy the object of the design should not be defined because the functional requirement is the object to achieve. Therefore the designer should thoroughly understand the problems in the functional domain and should not limit any possible selections without a special reason. Clearly defining the problem is closely related to defining the functional requirements. On the other hand the designer should select the design elements in the physical domain by specifying the functional requirements physically.

The overall aspect of the design-customer requirement, functional requirement, design element and design parameter-should not only be focused on the aspect of designing a product to satisfy the requirement but also be focused on the manufacturing aspect.

Most of the designing methods focus on one or few aspects of the design. But the axiomatic design evaluates the actual quality of the design by helping the designer to make optimum and creative decisions. But in order to take advantages of the axiomatic design the tools and methods should be considered prudently.

According to the axiomatic principles, the essence of design process lies in the hierarchies. The designer starts the design from comprehensive functional requirements or comprehensive requirements. And because of the different priorities of all the functional requirements, the designer can assemble all the functional requirements into different hierarchies. The important point in this process is that it must be done with the design parameters. As it goes to the lower level more details should be considered. This can be a very effective way to consider all the details of the design. The functional requirements of the higher level must be satisfied through the appropriate design parameters in order for the lower level functional requirements to be satisfied.

Additional creativity in the design can be induced when going through these procedures. The design process can be evaluated properly when started from the most basic function requirements-the highest level of functional requirements. This is because through this procedure a better design can be derived and also the design parameters can be considered in a wide variety. The first step in choosing the most important functional requirement starts from selecting the design parameter. And then the functional requirement of the next level can be determined after the design parameter is properly selected. Zigzagging among function requirements and design parameters is also necessary because two sets of each level are not only connected but also dependent on each other. By using axiomatic approach the ideas in the initial stages of design can be materialized in a scientific way. First, the functional requirement has to be defined. Then, design parameters that satisfy the functional requirement must be selected. The resulting set must be evaluated by using the design matrix to see if they satisfy the independence axiom.

The relation between functional requirement and design parameters can be representing symbolically using design matrix [A].

$$\{FRs\}=[A]\{DPs\}$$

$$[A]=\begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ A_{n1} & A_{n2} & \cdots & A_{nn} \end{bmatrix}$$

Each matrix disposition A_{ij} represents the relation between DP_j and FR_i. Design matrix has symbol X which has strong relation between elements, O which has few or no relation between elements. Observing the state of A_{ij} of the design matrix is a simple method to check the independence axiom.

To maintain independence of functional requirement, the functional requirement should be controlled. If the functional requirement is not independent, this design is called coupled design.

Figure 1 shows how to develop solution from proposed new concept idea.

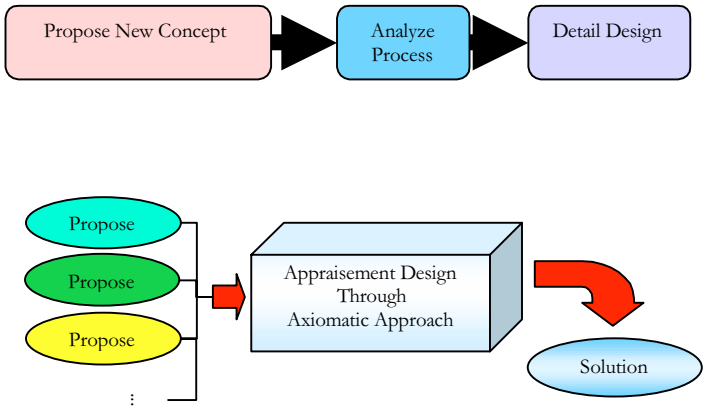

Figure 1. Process of development new concept idea by using Axiomatic Approach

3 DEVELOPMENT OF NEW CONCEPT IDEA

Next is a case study of the development of a new transportation means that uses compresses air. Axiomatic approach will be used in the development of the new concept.

The functional requirement of the new transportation is shown in the following

FR_1 : high speed transportation method
FR_2 : no environmental pollution
FR_3 : wide range of operation

The design parameters for satisfying the functional requirement is as follows

DP_1 : no contact operation
DP_2 : use of non-fossil fuel
DP_3 : use of chemically and physically stable substance

The relationship between the functional requirement and the design parameter can be evaluated through the use of design matrix.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & X \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix}$$

Therefore, the development of the initial idea can be done without violating the independence axiom

The next step is deriving a specific plan to materialize the initial ideas. Currently, one of the key researches on the super conductivity system is the magnetic train by using super conductivity magnetic. This train satisfies functional requirements 1 and 2, but it cannot satisfy the third functional requirement. The super conductivity system is very sensitive to the temperature which poses as the biggest obstacle for the system to be practical enough for commercial use. Therefore, a general and practical idea for a new transportation concept is needed. The main focus in the development of the new idea is in the sensitivity of the operation conditions.

The new method of transportation that satisfies the third functional requirement is air lubricant bearing. Air lubricant bearing has the following advantages. First, the air lubricant bearing is safe to the environment since no lubricating oil is used. Second, the bearing is chemically safe because the viscosity of air does not change due to temperature changes allowing wide range of operating conditions. The low viscosity of air as lubricant makes the viscous friction close to 0 resulting in low power loss, and no contact between surfaces prevents wear and vibration. Finally, the air can be a power source of high efficiency that can operate at high speed.

In the next step, prototype of the air shift train using air lubricant bearing was designed and tested. The following elements must be considered in the design of the prototype.

1. The body must be lightweight to lower the momentum resulting in lower requirement of propulsion energy.

2. The system must be modularized and independent. For economical purposes, there should be no outside facilities required and must be independent for operations.

Under these requirements, the prototype was produced and tested by the following steps. First, aluminum was used in making the base of the body. The area of the base must be kept at minimum because of the weight and because larger surface area of the base will require larger amount of air required. 6 holes were drilled into the base where pressurized air will be injected. A pocket for the air was made through milling at the end of the hole. After the processing of the base a compressor was put on the base.

Solenoid valve was used for control by opening and closing the airflow. Solenoid valve has lower poser consumption, short switching time, and high performance. Another solenoid valve was used right next to the compressor. On/Off switch is used to control the valves as a brake system.

Figure 2 and 3 show that schematic design of air shift system.

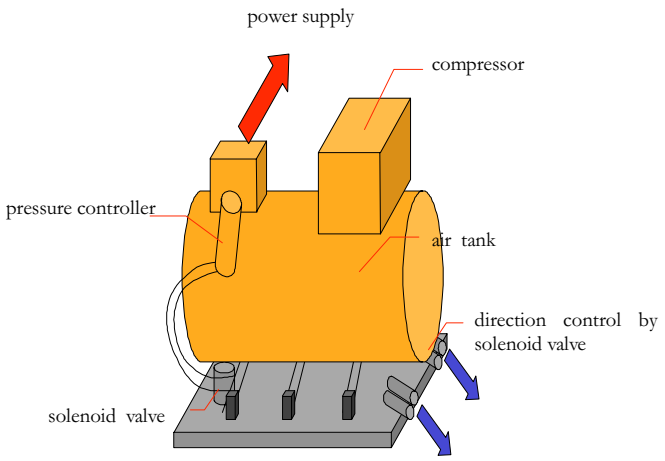

Figure 2. Schematic of base and injection hole

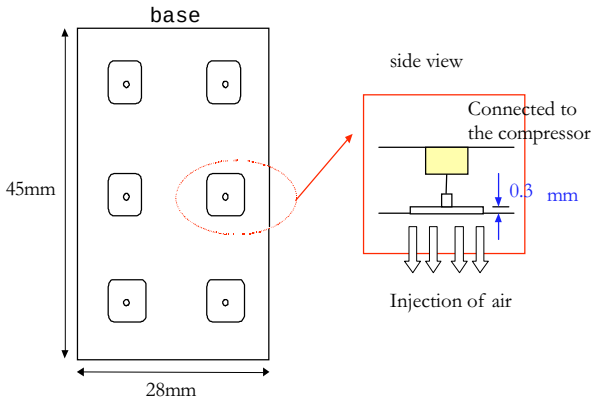

Figure 3. Schematic of system composition

The figure 4 and 5 show that photographs of prototype model.

In figure 4, there are many tubes and solenoid those parts control moving direction and speed.

Figure 4. Photograph of prototype base

Figure 5. Photograph of whole prototype model

4 RESULT

The development of a air shift transportation system has the following advantages. The biggest advantage is the energy requirement. A little power is required for lifting the system above the ground, but once the system is lifted low frictional loss makes even a slightest push to make the system to move almost forever. The low frictional loss also allows the system to move at a very high speed. Another advantage is that the system induces almost no pollution to the environment. The system uses small amount of electricity rather than fossil fuel for energy and no lubrication oil. Other advantages include reduction of vibration, a safer system, and the simplification of the structure.

The air shift transport system can also be applied to airplanes. When the plane takes off, low friction will allow faster acceleration shortening the length of the runway. The air shift system can be also used for moving very heavy objects. Heavy containers or machines can be moved easily with relatively small force. Today, the system is used to move buildings or roof of a stadium.

5 CONCLUSION

Design has been known to be subjective and rely on experience. Axiomatic design gives the basis for the development of products or processes by systematic and analytical approach. By defining the problem and using the design matrix to evaluate the design gives the basis of design process. By using this problem solving method of axiomatic approach the problem can be analyzed and a specific design can be obtained.

In the case study of this paper, the unspecific ideas in the initial stages of design were evaluated, and using the axiomatic approach materialized the idea. Such development of ideas by using axiomatic approach brings a systematic and scientific method to the subjective and unscientific process of design. The use of the design matrix can greatly help in making the design a scientific process.

The idea of integrating two independent functions into one module does not violate the independence axiom and can be said to be legitimate design.

6 ACKNOWLEDGMENTS

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