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THE METHOD FOR UNCOUPLING DESIGN BY CONTRADICTION MATRIX OF TRIZ, AND CASE STUDY

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ABSTRACT

This paper shows the method how the coupled design can be changed to uncoupled design by logical and systematic process of TRIZ. The brief concepts of Axiomatic Design and TRIZ are reviewed. The detail process of uncoupling design process is explained and also a case study is showed.

Keywords: Axiomatic Design, TRIZ

1 INTRODUCTION

In Axiomatic Design, axiom 1 is Independence Axiom. It states that smaller interaction among functional requirements is better for final product's performance. Less components' interactions will also reduce the cost of production and A/S.

In many cases, engineers are faced to design problems which violates axiom of independence. Many design parameters usually influences on more than 2 functional requirements (FR). To maintain axiom of independence, engineers have to find suitable design parameter (DP) which only affect given FR.

When changing DPs, engineers use their intuition and experience mostly. It can be time consuming job, and sometimes engineers fail to find exact DP which satisfy axiom of independence.

TRIZ is a theory of inventive problem solving made in Russia 50 years ago. The main idea of TRIZ is that there are special processes of creating new concepts. Some ideas of TRIZ are similar to those of Axiomatic Design in essential parts. TRIZ suggests lots of tools for generating ideas and solving technical problems. Among them, contradiction matrix is one of early tools based on more than 40,000 patents analysis, and it is a strong method for deriving new concepts for products.

To apply contradiction Matrix to Axiomatic Design, it needs a special mapping process. First of all, the design matrix's DPs are changed to standard characteristics to apply it to contradiction matrix. Secondly, suitable inventive principles are selected in the contradiction matrix. Finally uncoupling process is done by new DPs which are derived from the inventive principles.

In this paper, the real example of uncoupling design problem by contradiction matrix will be also discussed; How to prevent material from cracking during pressing process.

2 AXIOMATIC DESIGN

As it is shown in Figure 1, design in the Axiomatic Design is defined as a mapping process that connects the requirements that the 4 areas of design require. The 4 design areas are 1)Customer Requirements: CRs 2)Functional Requirements: FRs that actually realize 3)Design Parameter: DPs that are related to the FRs and lastly 4)Process Variable: PVs, the variable that is needed in the actual process.

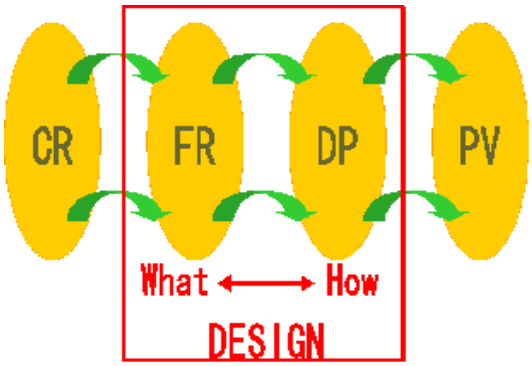

Figure 1. Design process

2.1 DESIGN AXIOMS

The Axiomatic Design was developed to help in selection 'useful' designs. According to professor Suh(1990), two designs of axiom is a helpful tool in creating a new design. Two axioms exist and the first one is the axiom of independence related to the functional requirement's selection and the second one is the axiom of information which provides a standard in evaluating the better design.

Axiom 1 : Axiom of independence
Axiom 2 : Axiom of information

Of the two axioms listed above the axiom of independence is the most useful tool when evaluating the design in its concept process. Knowing, whether the functional requirement's

independence is maintained in the proposed design or not, early can eliminate many needless designs in the early stages. On the other hand the axiom of information is used to compare designs that have already satisfied the independence more minutely.

The best method to clearly show the relation between the functional requirements and the design variables is to use the design matrix. The axiom of independence is considered foremost with the necessity of independence. It means that the functional requirements and the physical requirements correspond to 1:1 and that changes in the physical requirements must bring about changes in the corresponding functional requirements. Functional requirements have a hierarchical structure and the design variables that satisfy it also constructs a similar hierarchical structure. Therefore one FRs has only one DPs.

What this means is that if one design variable is altered on basis of a functional requirement's change it will not make cause any changes to other functional requirements.

However, in real situations it is hard to find one functional requirement being influenced by just one design variable. In this case it is hard to explain and therefore it is necessary, if possible, to make one functional requirement possessing one design variable.

The matrix of the design variables and the functional requirements can be shown in to three types.

2.2 AXIOM OF INDEPENDENCE

The first axiom is about the relationship between the design components. In other words, it means that a component of design had better not affect another component of design. If the design is coupled design, it may cause many trouble after product is made, and it is hard to find the factors.

The relation between the functional requirements and the design variables can be expressed by the method of using design matrix. In a similar way, by using design matrixes the relation between different fields can be shown.

The design matrix that satisfies Independence Axiom can be shown in either diagonal matrix or triangular matrix. The diagonal matrix stands for uncoupled matrix which satisfies complete functional Independence Axiom, is most appropriate. In this case each functional requirement is affected by one design variable and the intended alteration of the design variables is made possible. The triangular matrix is decoupled design matrix and if the design variables are changed according to a specific order, the influences caused by changes in the design does not make trouble very much.

$$\text{FRs}=\begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix}\text{DPs} \qquad \text{FRs}=\begin{bmatrix} X & O & O \\ X & X & O \\ X & X & X \end{bmatrix}\text{DPs}$$

Uncoupled Design Decoupled Design

3 TRIZ

TRIZ stands for Teoriya Reshniya Izobretatelskikg Zadatch in Russian. It means the theory of inventive problem solving. TRIZ is a strong systematic method to achieve innovation and invention. This theory is developed by Genrich Altshuller, Russian inventor and panel of patent judge, who was curious of the possibilities of general methodology for problem solving. When he was engaged in the service related to patents, he saw many people brought the same problems in the different area. Also he noticed that some people were creative and some others were not creative. He decided that it is better to discover a new methodology by conventional solution and structure of problem than the development by conventional methodologies based on psychological view. He started the research on the history of technology and product. Especially He categorized and researched 40,000 patents systematically of the 1,500,000 patents in the world. Then he made a general method for problem solving, which is called TRIZ. It is based on the essence, property, and adaptation. TRIZ says that a problem solving method is not limited in an area. If a invention is occurred, it can be adapted to another inventions. TRIZ is distinguished from other methodologies because it gives many cases based on entire patents

TRIZ suggested that invention has an algorithmic structure (Figure 3). In most cases inventors tell the solution was found by a lot of trial and error process or accidents. And these processes were understood as a slow thinking process.

The innovation is the most important thing for a company to survive at present society, If the company fail to innovate, it will be weeded out. Therefore the modern companies try to find a method for inventive problem solving.

Until now the methodologies as brain storming (Figure 2) as brain lighting have been introduced. They just suggest what the problem is, not how the problem is solved. A new methodology is required to solve problems fundamentally.

Suppose mathematics is a quantitative method which can be adapted to all technical area, Because TRIZ is a method for developing technology, which can be adapted to all the area that possess problems, it can be used for improving the conventional system, proving a causal relationship, and developing new concept products, process, strategy of R&D.

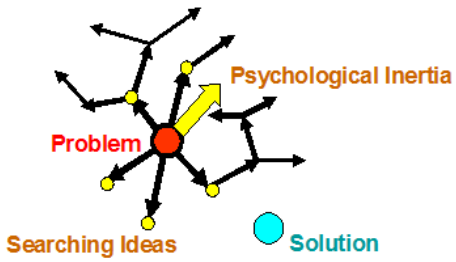

Figure 2. Brainstorming method

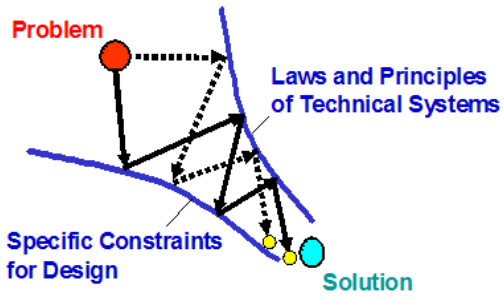

Figure 3. Main idea of TRIZ

3.1 CONTRADICTIONS

Contradiction is one of the main concepts of TRIZ. In TRIZ view, there are more than one contradiction in engineering problem. To solve problem, the contradiction must be resolved

The concept of contradictions is very similar to the coupling in axiomatic approach. There are technical contradiction, physical contradiction, and administrative contradiction in it. Contradiction is also one of the most important concept of TRIZ.

- Administrative Contradiction : In this situation that people recognize problem, but don't know the reason.

- Technical Contradiction : It means there are two properties A and B. When improving A, the B get worse. For example, to thicken the steel plate of car to make the car safer, the weight of car increases.

- Physical Contradiction : It is a situation that two properties A and B is controlled by the same parameter C. For example, alarm clock, has to be turned off, but it can't easily be turned off to wake up person. The wheels of airplane needs when landing, but doesn't need when flying.

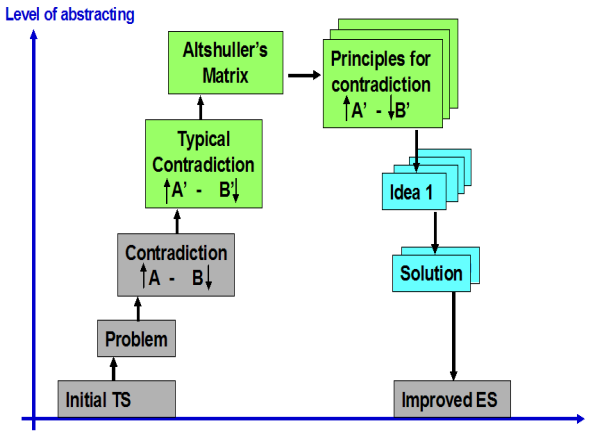

Figure 4. The process of problem solving by contradiction matrix

3.2 CONTRADICTION MATRIX

Technical contradiction is that more than two requirements are related to each other. It makes impossible to solve problem because one situation get worse when improving another.

TRIZ gives contradiction matrix and 39 standard characteristics, and 40 invention principles. By matching the characteristics to contradiction matrix, the solution of problem is found in 40 inventive principles. The standard characteristics and inventive principles are shown in Figure 5 and Figure 6, and Figure 7 is contradiction matrix.

The process resolving technical contradiction follows the process of Figure 4.

At first, the parameter to be improved and the parameter to be worsened are found in the 39 characteristics. After that, inventive principles at the intersection area of contradiction matrix are found. Usually contradiction matrix recommends 1~4 principles.

After selecting proper inventive principle, apply the principle to the engineering system and develop new concept.

1	weight of moving object	11	pressure	21	power	31	harmful side effect
2	weight of fixed object	12	shape	22	waste of energy	32	manufacturabi lity
3	length of moving object	13	stability	23	waste of substance	33	convenience of use
4	length of fixed object	14	stiffness	24	waste of information	34	repairability
5	area of moving object	15	durability of moving object	25	loss of time	35	adaptability
6	area of fixed object	16	durability of fixed object	26	amount of substance	36	complexity of device
7	volume of moving object	17	temperature	27	reliability	37	complexity of control
8	volume of fixed object	18	brightness	28	accuracy of measurement	38	level of automation
9	speed	19	energy consumed by moving object	29	accuracy of manufacturing	39	productivity
10	force	20	energy consumed by fixed object	30	harmful factor acting on object		

Figure 5. 39 Standard characteristics

1	extension	11	beforehand cushioning	21	skipping	31	Porous materials
2	extraction	12	equipotentiality	22	convert harm into benefit	32	color changes
3	local quality	13	inversion	23	feedback	33	homogeneosity
4	asymmetry	14	sphroidality	24	intermidiary	34	discarding and recovering
5	merging	15	flexibility	25	self service	35	parameter change
6	universality	16	partial or excessive action	26	copying	36	phase transition
7	nesting	17	another dimension	27	cheap short living object	37	thermal expansion
8	counterweight	18	mechanical vibration	28	replace a mechanical system	38	use strong oxidizers
9	preliminary anti-action	19	periodic action	29	pneumatics and hydraulics	39	inert environment
10	prior action	20	continuity of useful action	30	flexible shells and thin films	40	composite materials

Figure 6. 40 Inventive principles

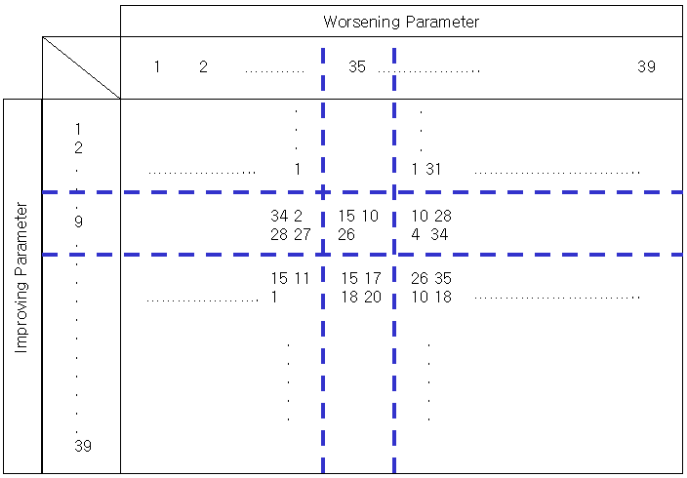

Figure 7. Contradiction matrix

4 UNCOUPLING DESINE METHOD BY CONTRADICTION MATRIX

Most of engineers are faced to many design problems that violates Independence Axiom. Designers try to change the coupled design to uncoupled design or decoupled design. It is a similar concept to contradiction in TRIZ.

Coupled design means that one of the DPs has an effect on more than two FRs. It has same characteristic as contradiction in TRIZ.

There are mainly two kinds of contradiction solving methods in TRIZ. In this paper, only uncoupling method by contradiction matrix is introduced.

To apply contradiction matrix in TRIZ to uncoupling process in Axiomatic Design, the process follows these steps;

STEP 1 : Formulating designing problem

Most of customers notice the problem, but usually it is hard for them to find the true reason. First of all, to find the true problem the designer makes hierarchical structure and set relation between FRs using design matrix.

STEP 2 : Determine the type of contradiction

Before applying TRIZ methodology, the type of contradiction must be analyzed. For example if one FR requires high temperature and the other FR needs low temperature at the same time, it is a physical contradiction problem, and Separation Principles must be used to solve problem in this case. But if the type of coupled FRs is different, it is technical contradiction problem and the contradiction matrix is used to make uncoupled design.

STEP 3 : Change coupled FRs to standard characteristics

In order to use contradiction matrix, each coupled FR should be converted to one of the 39 standard characteristics. Proper characteristic which stand for FRs is selected. Most of the cases the FRs can be converged to the proper standard characteristics.

STEP 4 : Find inventive principles in the contradiction matrix

By using the characteristics developed in Step 3, the inventive principle can be found in the contradiction matrix in Figure 7.

Usually 3~4 inventive principles is suggested from the node in the contradiction matrix.

STEP 5 : Generating new DPs which make design uncoupled

To generate detailed design concepts, the process shown in Figure 4 is performed. Because of the preliminary ideas from contradiction matrix are very abstractive.

Each inventive principle has a lot of real cases based on patents. From time to time, solutions can be derived by adapting the examples of the inventive principles to the design problems. By using these processes, the proper DPs are set and they substitute the conventional DPs.

After all, new DPs which satisfy Independence Axiom, are found. And the design problem can be solved.

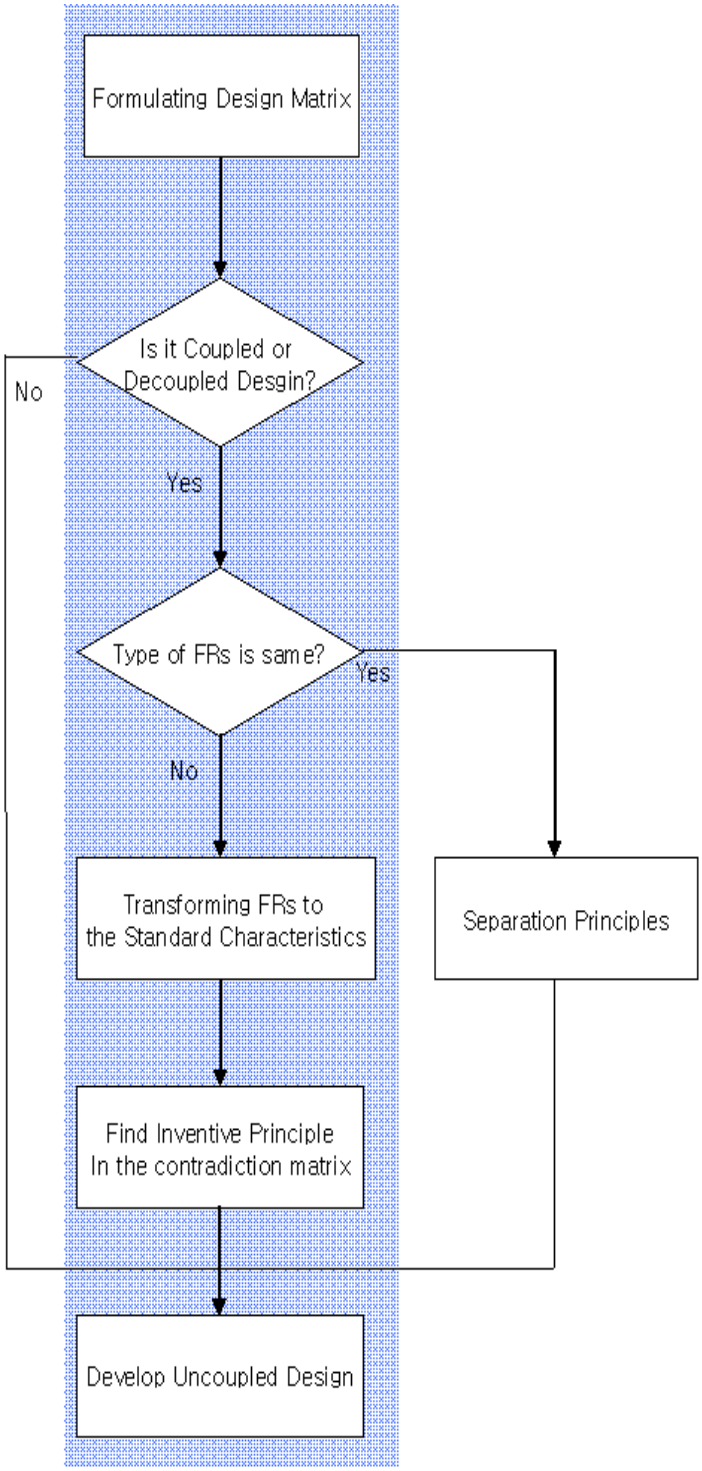

Figure 8. Flow chart of uncoupling process

5 CASE STUDY: DRIVING PILE INTO GROUND WITHOUT BREAKING THE HEAD OF PILE

In the construction yard, several piles are drived into the ground. Figure 9 shows the process of driving piles into the ground. Hammer hits the head of pile to transfer force to the pile. Sometimes the head of pile is broken because of fatigue. The new design which satisfies the safety of pile is required.

Figure 9. Driving pile into ground

Follow above steps to develop new design

STEP 1 : . Formulating designing problem
The design matrix can be formulated as follows
FR1 : Driving pile into the ground
FR2 : Preventing the breakage of head of pile

DP1: The force applied to the head of pile
DP2: The hardness of the head of pile

$$\begin{bmatrix} FR1 \\ FR2 \end{bmatrix} = \begin{pmatrix} X & X \\ O & X \end{pmatrix} \begin{bmatrix} DP1 \\ DP2 \end{bmatrix}$$

If strong force is applied at the head of pile to drive the pile into ground, it will also destroy the head of pile. If the force is reduced in order to protect the head of pile, the efficiency of the construction will be decreased.

STEP 2 : Determine the type of contradiction
The force and the safety of head of pile are different from each other. The design problem has a technical contradiction in it. The contradiction matrix is applied to resolve that kind of contradiction.

STEP 3 : Change coupled FRs to standard characteristics
The FRs of this design matrix is now converted to standard characteristics for applying contradiction matrix.

FR1 : Driving pile into the ground
➔ 10. Force

FR2 : Preventing the breakage of head of pile
➔ 30. Object-affected Harmful Factor

STEP 4 : Find inventive principles in the contradiction matrix

In the contradiction matrix in Figure 10, 4 inventive principles are found as follows.

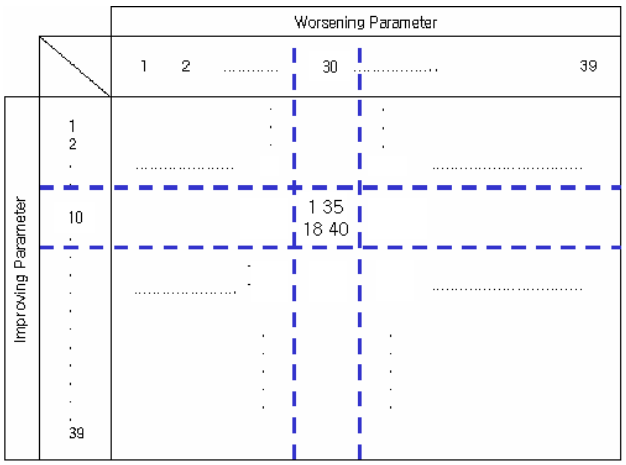

Figure 10. Selecting inventive principles

N1 - Segmentation
N35 – Parameter Changes
N40 – Composite materials
N18 – Mechanical Vibration

STEP 5 : Generating new DPs which make design uncoupled

Not all the inventive principles can be used, and only some of these inventive principles are applied to develop new concept of design. In this case, the inventive principle 1 (Separation) is selected.

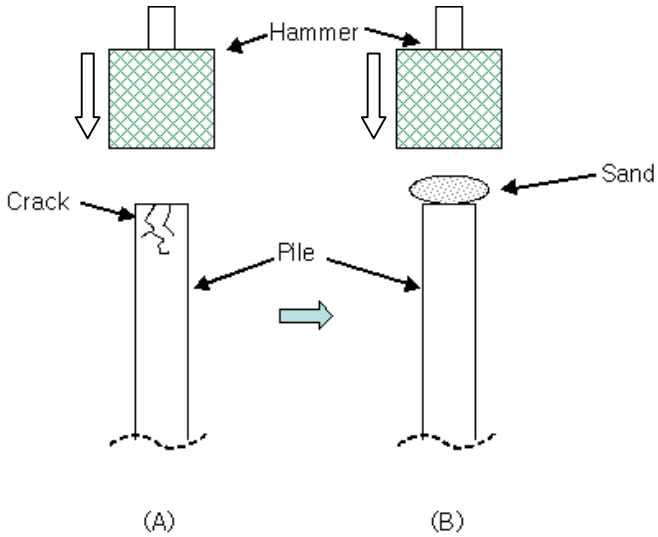

Figure 11. Dividing the head of pile into granules

Figure 11(A) shows conventional pile driving system. To drive pile into the ground, the hammer hit the head of pile, and the hammer also destroys the pile's head.

To distribute the force applied to the head of pile, the head of pile should be divided into many small pieces. The sand pouch is put on the head of pile as shown in Figure 11(B). The sand granules distribute the force to the whole area of the head. The sand pouch transfers the force to the pile efficiently and also it protects the piles head.

Finally the new FRs and DPs are selected and the design matrix becomes uncoupled.

FR1 : Driving pile into the ground
FR2 : Preventing the breakage of head of pile

DP1: The force applied to the head of pile
DP2: The sand pouch on the head of pile

$$\begin{bmatrix} FR1 \\ FR2 \end{bmatrix} = \begin{pmatrix} X & O \\ O & X \end{pmatrix} \begin{bmatrix} DP1 \\ DP2 \end{bmatrix}$$

6 CONCLUSION

To reduce final product's cost and failure, satisfying Independence Axiom in design process is very important, and the design matrix should become uncoupled. In order to change coupled design to uncoupled design, intuition and inspiration is not enough, and more logical and algorithmic process is needed to develop the new concept of design. The main idea of coupled design is similar to the concept of contradiction of TRIZ. Through the contradiction matrix, the uncoupling process can be done more effectively without time loss or trial-error.

There are several steps to apply contradiction solving process to Axiomatic Design;

1. Formulating problem
2. Determining the type of contradiction
3. Changing FRs to standard characteristics
4. Finding inventive principles in the contradiction matrix
5. Generating new DPs which make design uncoupled

As an example, the process of driving pile is analyzed according to these steps. An inventive principle, "separation" is applied to the system. And the new design which satisfies both driving pile efficiency and keeping safety of the pile, is generated by putting sand pouch on the top of pile.

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