Use of Design Structure Matric (DSM) in Engineering Change Analysis

Rameshwor Bista * , Dunbing Tang*
aryav101@gmail.com d.tang@nuaa.edu.cn

*Nanjing University of Aeronautics and Astronautics,
College of Mechanical and Electrical Engineering, Nanjing, china

Abstract -The design and development of complex engineering products require the efforts and collaboration of hundreds of participants from diverse backgrounds resulting in complex relationships among both people and tasks.Many new parts or products of advanced machine are developed through modifications of existing ones. The engineering changes required to modify such modifications may sometimes propagate, extend further changes to the design. This kind of propagation of change is therefore a huge influence on resource allocation when designing new parts or products. Many of the traditional project management tools (PERT, Gantt and CPM methods) do not address problems stemming from this complexity. While these tools allow the modeling of sequential and parallel processes, they fail to address interdependency (feedback and iteration), which is common in complex product development (PD) projects. So, we have introduced a matrix-based tool called the Design Structure Matrix (DSM) here.

This paper represents a design structure method that is designated to manage the effects of change propagation and is applied to the design of a jet engine fan. The method uses a matrix-based approach to model the dependencies between the solution alternatives, the potential change propagation brought about by the solutions, the affected product attributes, and the resources needed to carry out the change work. It allows engineers to trace critical change propagation paths and manage them. The findings suggest that this DSM method is suitable for assessing solution alternatives during preliminary design and can help support engineers to explore the design space in the right direction.

Keywords: Propagation, Engineering propagation, Design structure matrix (DSM), Component based design structure matrix (C-DSM), Dependency. Design Space, Modeling System.

1 INTRODUCTION

The ability to make changes to existing designs or agility in product development and production, has become an important issue for a lot of companies that want to be superior or just want to survive in this dynamic market. One of the most effective ways for companies to stand competitive is by making different changes to existing designs while avoiding time and cost overruns as well as maintaining quality. In order to limit the risk generated by an unknown factor in large complex projects, companies need 'incremental innovation', which gradually introduces new functions, performance characteristics and technologies that rely on existing product designs. As a result, adaptive designs are modified to produce new solutions that satisfy changing needs, new requirements or the desire for better quality, constitutes 75 to 85% of new product development projects [1]. In order to efficiently and effectively deal with the introduction of a new product solution, it is paramount that the impact of engineering change (i.e., effort, span time, technical difficulty, quality, fulfillment of customer requirements, and cost) be identified and assessed as early as possible within the product life cycle. On the other hand, evidence from empirical investigations [2] and from the literature [3] show that 70-80% of total product cost is decided during early design stages where 56% of changes occur after the initial phase, of which 39% are avoidable. That's why Engineering changes have always been fundamental to the development of new products. Instead of designing new products from scratch, it can be more efficient to carry out engineering changes to existing products. Changes in engineering field facilitate the reuse of tested components in future products and cause comparatively less disruption to the supply chain. However, changes to a product can sometimes lead to undesired propagation [2]. This is particularly true for complex technical systems.

In addition, it is possible for changes that were initially thought as simple to propagate uncontrollably, resulting in change Avalanches [4]. Although companies may have a choice to drop further changes and settle with sub-optimal products, they are sometimes bound by legislation to deliver new products that must meet certain product performance. For instance, new engines must satisfy emission legislation before they can be sold. It is thus important to model and predict how engineering changes can propagate in order to better manage the design process. Such sentiment is common among companies. For instance, during the Engineering Change workshop held by the Cambridge-MIT Institute in 2008, many companies expressed their need to effectively manage engineering changes. In a follow-up interview, a staff from an aerospace company highlighted that "… the propagation of change is a concern. That is clear. And it does give us problems as well by not anticipating everything…" It was also added that having a system that can model the impact on the company, and not just the product, can be useful in

ISSN 2229-5518

providing insights. To address this concern, this paper presents a DSM (design structure matrix) method that analyses the effects of change propagation on both the product and the company. The method allows engineers to trace change propagation paths from design requirements to affected product components and design features, and focuses on the design of complex product during preliminary design.

2 RELETED WORKS

There are lots of papers that discuss the engineering change and effects of engineering changes. Using different analyzing methods, they have analyze this change.To analyze the change propagation in the complex technical systems, Monica Giffin Olivier De Weck and Gergana Bounova [4] uses the DSM method. Clarkson et al. [2] introduce the Change Prediction Method (CPM) which predicts potential component change propagation through the modelling of component dependencies. Hauser and Clausing [10] describe the use of the House of Quality (HoQ) 'roof' matrix to examine the interactions between design-features if changes do propagate. Fricke and Schulz [5cc] propose the principles of Design for Changeability (DfC) and highlighted the four main aspects as Robustness, Flexibility, Agility, and Adaptation to improve the changeability of products. Other literature suggests ways to model how the product attributes can be affected when parts of the product are changed. For instance, to assess probable behavioral side effects during a design change, Ollinger and Stahovich [6cc] introduce the RedesignIT tool.

Weber et al. [7] and Conrad et al. [8cc] describe a Property-Driven Development approach to assess the effects of changes by analyzing the relationship between product behavior and component characteristics given a set of internal dependencies and external conditions. Cohen et al. [9cc] propose a methodology called Change Favorable Representation (C-F AR) to capture possible change consequences using existing product data information. Koh et al. [11] subsequently extended the CPM application to consider the 'knock-on' effects on the product attributes.Change propagation can affect various aspects of the organization. For instance, the effect on company documentation resulting from engineering changes was discussed by Pikosz and Malmqvist [12]. Cost analysis is also affected as described by Rios et al. [13]. Furthermore, the emergence of unplanned change propagation can result in project delays and disruptions in design resources. Beshoy Morkos, Prabhu Shankar and Joshua D. Summers [14] have used the higher order DSMs for an industry case study.

3 MODLEING A SYSTEM

Introduction of the DSM:The DSM method is an information exchange model that allows the representation of complex task (or team) relationships in order to determine a sensible sequence (or grouping) for the tasks (or teams) being modeled. DSM has been an effective way to get relation between different components or aspects.

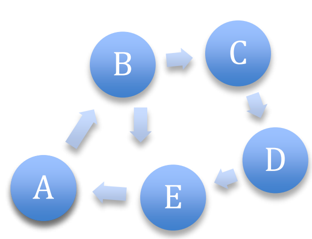

Fig 1:Components relation diagram

The relation can be shown in the simple square matrix. As we can see in Fig 1, the relation on the different components in a system. In this diagram we can see B gets some information from A and so on. But E has taken information from B and D. for the simple diagram we can find it out easily from diagram. But if we have lots of components then it's hard to express it through this diagram.

In this form of matrix (shown in fig2), it's clear that the column component A is propagated from the row component E. The maximum propagating component is E and maximum propagated component is B. By using this matric form, we can easily find the relation of the different components. It's more convenient and clear in case of analysis.
DSM for the above diagram can be expressed as:

	A	B	C	D	E
A		X			
B			X		X
C				X	
D					X
E	X				

Fig 2: Component based DSM

Development of DSM for the jet engine:In the similar way we have the jet engine with different components like fan blade, fan disc, nose cone , LP shaft etc.

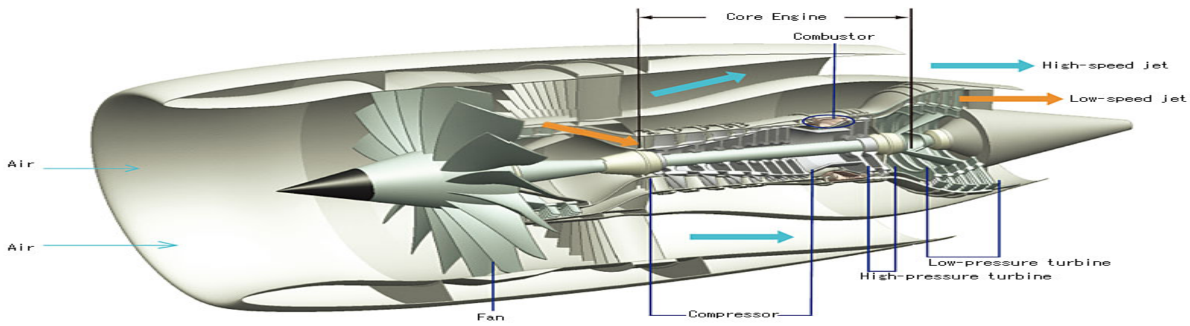

Fig 3:Jet engine internal mechanism

We know that fan blade depends on fan disc, nose cone and LP shaft, again fan disc depends on fan blade, nose cone and LP shaft as we can see in the Fig 3.

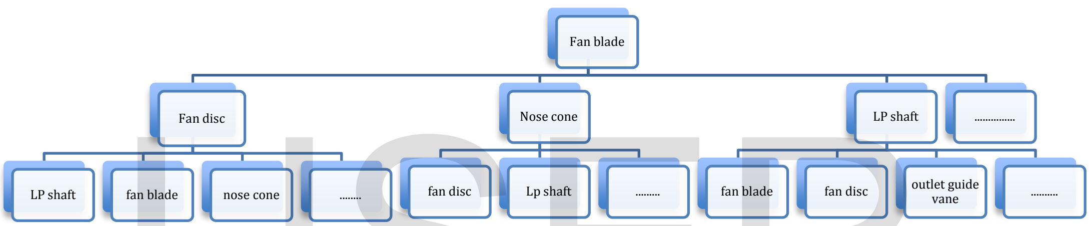

Fig 4: Information Flow in the Jet Engine Components

So, the chart relation of the different componentscan be represented as in Fig4. In this figure, we can see that fan blade is considered as the propagating component and the affects of the propagation is shown through this chart.

4 PROPAGATION ANALYSIS

All components have the different level of propagation relation, some of them are strong and some of them are weak. The components on the row are the changing components and the components on the column are the propagation-effected components. The propagation effects of change in different components have been discussed below:

Change in Fan Blade:Fan blade is directly connected to the disc as we can see in Fig 7, so it affects the fan disc a lot. For example, if the thickness of blade is made smaller the size of the disc should be reduced too. As we can see in the Fig 7, t1 and t2 are the thickness of the blade and T is the thickness of the disc. As we increase the size of t1 and t2, the size of T should be increased too. But if we increased the size of T that won't affects the size of t1 and t2. Similarly, blade has high dependencies with nose cone and LP shaft. When the size of disc is reduced, the size of LP shaft and nose cone also get affected. DSM makes it so easier to analyze the information.

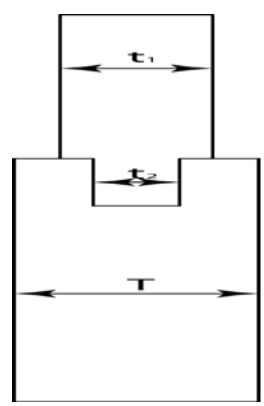

Fig 7: Blade on Disc Attachment

Change in Disc:Disc plays the vital role in the jet engine design. This component is connected to many other components. So, small change in this component can affect other components. As we see in Fig 8 disc has the direct with the fan blade. As we mentioned above, when the blade changes the disc get affected. Similarly, when disc get smaller the size of blade should be reduced too. Since disc is connected to the nose

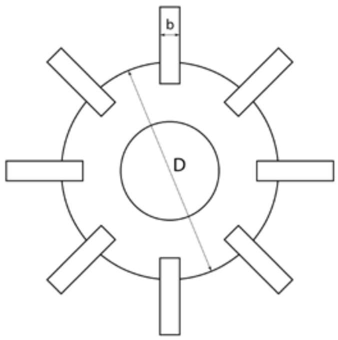

Fig 8: blades on disc attachment

Cone and shaft, it has also dependency with these two components. In figure 8, D is the diameter of the disc and the b is the thickness of the blade. As we increased the value of D, the perimeter of the disc will be increased too (P=πD). If the perimeter changed that affects the thickness or the number of the blade.

Change in nose cone: Nose cone has the direct relation with the disc and LP shaft. If we change the size of nose cone that will propagates the diameter of disc and LP shaft. Nose cone decides the diameter of the disc and diameter of the disc directly depends on the size of disc. So, fan blade has also incredible dependency on nose cone. The highest dependency of nose cone in with fan disc and as a result change in nose cone will highly propagate the size of disc.

Change in LP shaft: LP shaft holds lots of components together. It holds the major components like disc. So the change in LP shaft will affect the many components. The major propagation that occurs with LP shaft is on the Disc. As we can see in below Fig 10, d is the diameter and T* is the length of shaft that hold the disc which affect the D(diameter) and T(thickness) of the disc respectively. As we increased the size of T* the thickness of the disc also should be increased and vice-versa.

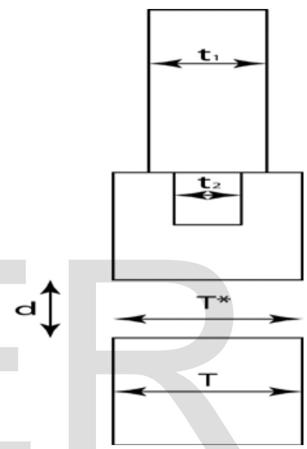

Fig 10: Disc on Shaft

	Fan blade	Fan disc	Outlet guide vane	Nose cone	Fan disc rear seal	LP shaft
Fan blade	■	X		X		X
Fan disc	X	■		X	X	X
Outlet guide vane			■	X		X
Nose cone	X	X		■		
Fan disc rear seal				X	■	
LP shaft	X	X		X	X	■

Fig 5: component design structure matrix

The components on the row are propagating components and the components on the column are propagated components.

ISSN 2229-5518

5 CONCLUSION

So, DSM method is really useful in the modern age to manage undesired change propagation and support resource planning during the early stages of the design process. The method can support the assessment of solution alternatives in an engineering change. It focuses on the preliminary design of complex products and allows engineers to trace change propagation paths from design requirements to affected product components and design personnel. The method was applied to the design of a jet engine fan to assess the feasibility of using such a modeling approach in industry. DSM method is suitable for simplifying and analyzing different alternatives during preliminary design and can help support engineers to explore the design space in the right direction. It can give engineers overview on information supply and is more effective than other method. Future work in this area includes the consideration of change propagation on other aspects of the organization such as the supply chain.

REFERENCES

[1] Jarratt, T., Clarkson, P. J. and Eckert, C. M. Engineering change. In Design Process Improvement: A review of current practice (Clarkson, P. J. and Eckert, C. M., Eds.), 2005, pp. 262-285, Springer London, UK.

[2] Clarkson, P. J., Simons, C. and Eckert, C. M. Predicting change propagation in complex design. Journal of Mechanical Design, 2004, 126 (5), 765-797.

[3] Giffin, M. L., de Weck, O. L., Buonova, G., Keller, R., Eckert, C. M. and Clarkson, P. J. Change propagation analysis in complex technical systems. In ASME International Design Engineering Technical Conference, IDETC/CIE'07, Las Vegas, Nevada, USA, 2007.

[4] Monica Giffin Olivier De Weck and Gergana Bounova, change propagation analysis in the complex technical systems, Engineering System Division, MIT, Cambridge MA02139

[5] Fricke, E. and Schulz, A. P. Design for Changeability (DFC): Principles to enable changes in systems throughout their entire lifecycle. System Engineering, 2005, 8 (4), 342-359.

[6] Ollinger, G. A. and Stahovich, T. F. RedesignIT- A model-based tool for managing design changes. Journal of Mechanical Design, 2004, 126 (2), 208-216.

[7] Weber, C., Werner, H. and Deubel, T. A different view on product data management/product life-cycle management and its future potentials. Journal of Engineering Design, 2003, 14 (4), 447-464.

[8] Conrad, J., Deubel, T., Kohler, C., Wanke, S. and Weber, C. Change impact and risk analysis (CIRA) – Combining the CPM/PDD theory and FMEA methodology for an improved engineering change management. In International Conference on Engineering Design, ICED'07, Paris, France, 2007.

[9] Cohen, T., Navathe, S. B. and Fulton, R. E. C-FAR, change favourable representation. Computer-

[10] Hauser, J. R. and Clausing, D. The House of Quality. Harvard Business Review, 1988, 66 (3), 63- 73.

[11] Koh, E. C. Y., Keller, R., Eckert, C. M. and Clarkson, P. J. Influence of feature change propagation on product attributes in concept selection. In International Design Conference, DESIGN 2008, Dubrovnik, Croatia, 2008.

[12] Pikosz, P. and Malmqvist, J. A comparative study of engineering change management in three , Swedish engineering companies. In ASME Design Engineering Technical Conference, DETC'98, Atlanta, Georgia, USA, 1998.

[13] Rios, J., Roy, R. and Lopez, A. Design requirements change and cost impact analysis in airplane structures. International Journal of Production Economics, 2007, 109 (1-2), 65-80

[14] Beshoy Morkos, Prabhu Shankar and Joshua D. Summers* Predicting requirement change propagation, using higher order design structure matrices: an industry case study, Department of Mechanical Engineering, Clemson University, Clemson, SC 29634, USA

[15] Edwin CY Koh and P John Clarkson, a modeling method to manage change propagation, internation conference on engineering design, ICED'09, Stanford University, Stanford, CA, USA