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Concurrent engineering and logistics design process through re-engineering

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Abstract

The basic requirements of Concurrent Engineering, Logistics Design and three interdependency relationships such as uncoupled relationship, coupled relationship and decoupled relationship for the logistic design activities are presented in this paper. The coupled relationship plays an important role in concurrent product design process. To represent the precedence relationships among design activities, a directed graph is used to describe the design process. A Design Structure Matrix (DSM) illustrates the interdependency relationship between activities, which is the transpose of the accessibility matrix of the corresponding graph. Using the DSM, an algorithm of recognizing the coupled activities during the design process is presented. Moreover, an algorithm to figure out the order levels of activities during the logistic design process is proposed. Both algorithms are illustrated with a die design example.

Keywords: Concurrent engineering; Logistics Design; Design structure matrix; Directed graph; Product development process re-engineering

1. Introduction

The difficulties in designing complex engineering products do not arise simply from their technical complexity. The managerial complexity, necessary to manage the interactions between the different engineering disciplines, imposes additional challenges on the design process .In recent years; concurrent engineering (CE) and Logistics Design (LD) has become increasingly important for product development. CE is a philosophy that suggests the need to consider Logistic Design issues simultaneously where they were considered sequentially in the past. The sequential design process has been considered inefficient, since this type of design process typically leads to greater development time, greater cost, and lower overall design quality, all of which lower the overall profit generated by the design. The remaining challenge of managerial complexity is to transform the product design process from a SE (sequential engineering) environment to a CE environment. Logistic design is the strategic planning and optimization of supply chain networks, physical facilities, and operational workflows. The important transformation approach practically relevant to this paper is the product design process re-engineering. When applied to re-engineer the product development process, it is mainly concerned with the rationalization of the product development activities, with the belief that a rationalized product development process is more likely to result in better product design decision. Using management tools that model the interface and dependencies among the decomposed tasks contains the managerial complexity of the design process includes four major steps:

- Model the information and dependency structure of the logistic design process
- Provide a logistic design plan showing the order of execution for the design tasks
- Reduce the risk and magnitude of iteration between design tasks
- Explore opportunities for minimizing the project cycle time.

Further some design process modeling and management tools have been developed. The Project Evaluation and Review Technique (PERT) method is a digraph of a project .In the PERT method, three probabilistic time estimates are given to

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each task. The critical path method (CPM) is a variation of the PERT method. CPM assumes a time-cost tradeoff rather than probabilistic times used in PERT. Both methods improve the process flow only by crashing the critical activities, but they do not consider iterations and feedback loops that are characteristics of logistic engineering designs, and they ignore the concurrency and overlapping of the design process.

A more compact representation of a design process is the Design Structure Matrix (DSM). It overcomes the size and visual complexity of all graph-based techniques. Matrices are amenable to computer manipulation and storage. In this paper, we use DSM representation to describe the product design process. A new method using simple and understandable algorithms is presented to re-engineer the product development process for CE and LD. This paper is organized as follows. In Section 2, the interdependencies among activities during design process are analyzed and summarized into three types: uncoupled relationship, coupled relationship, and decoupled relationship. Section 3 presents and interprets the DSM. CE calls for the simultaneous execution of coupled product development phases. Moreover, the coupled relationship between activities plays an important role in concurrent design process. Thus, Section 4 presents an algorithm to recognize the coupled activities during the product development process. Section 5 proposes an algorithm to figure out the order levels of every design activities. The design process Re-engineering is executed according to the order levels. The algorithms above have been applied to re-engineer the traditional stamping die development process to meet the needs of CE. Section 6 gives the conclusions of this paper.

2. Types of relationship between design activities

The product design process is a set of design activities. There are various interrelations among these activities. The concurrency among design activities corresponds to the interdependencies between activities. According to the degree of interdependency, and making use of Sub classification of design parameters, divide the interdependency relationship among activities into three types:

- Uncoupled relationship,
- Coupled relationship
- Decoupled relationship.

2.1. Uncoupled relationship

Uncoupled relationship means that a design activity is independent from one another or the interdependency degree between them is very low. And there is little information exchange between them. In this situation, two or more activities can be executed in parallel.

2.2. Coupled relationship

Coupled relationship means that the decision of one activity will affect one another or more activities, and vice versa. The interdependency degree between them is very high, and there are information exchanges among the coupled activities. Such interdependency needs many iteration loops to set all design information in a consistent way. The coupled activities need to be performed concurrently.

2.3. Decoupled relationship

Decoupled relationship means that decisions of early design activities affect downstream activities, but no repercussions, generating a sequence of decisions that results in a straightforward process without iteration. By analogy with electrical circuits, three relationship types above are described in Fig. 1. The design requirements are represented by a voltage source, whereas the resistors stand for the design activities. As the requirements flow through the activities they induce design information similar to a voltage across a resistor. In the left circuitry, the activities are connected in a parallel manner, and they are mutually independent. In the center, the circuitry couples all activities, so that every change on one activity affects all others. The circuitry on the right resembles a cascade of voltage dividers.

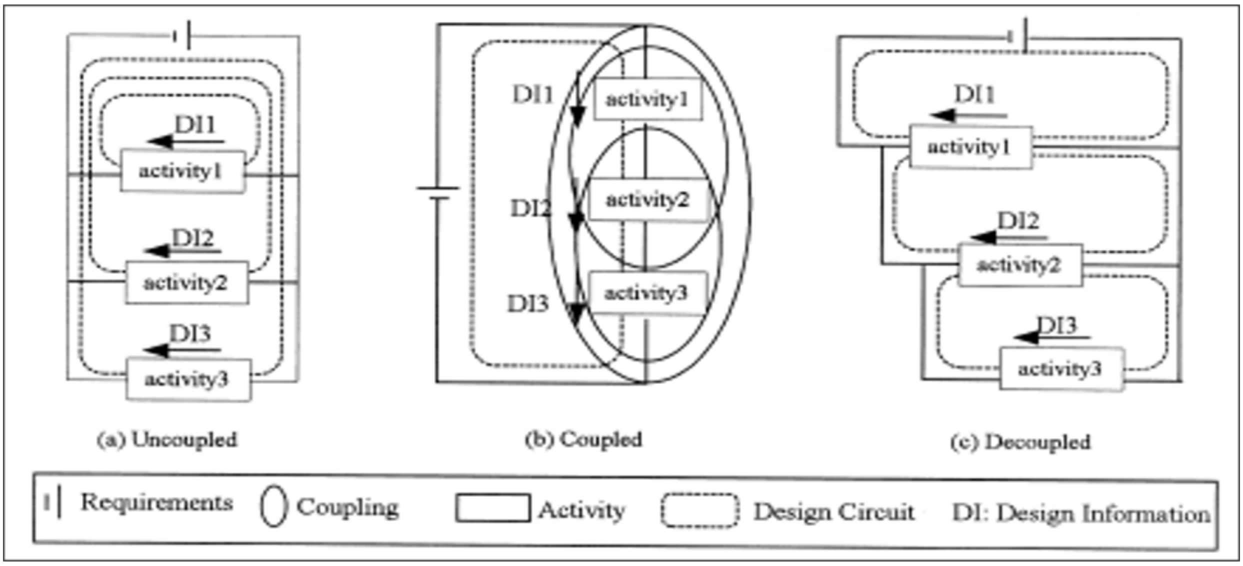

Figure 1 Three types of relationship between design activities.

3. Design Structure Matrix

A DSM can illustrate the interdependency relationship between the activities. Given that a design process consists of n activities A_i (i=1,2…n), the DSM is described in Fig. 2. The rows and columns of the matrix are corresponding to the activities A_i. The dimensions of the matrix represent the number of the activities. The elements on the diagonal represent the activities themselves, and $a_{ii} = 0$. The other elements of the matrix express the interdependencies between the activities. If the activity $A_j$provides information to the activity A_i, then a_{ij}= 1: While $a_{ij} = 0$ ($i \neq j$) means there are no information exchange between the activity Ai and the activity A_j.

An important challenge of CE can be defined as how to make sound decisions at early stages of product development where committed costs are low and by that obtain a lower total cost, which means all factors on the downstream development should be considered at early stages, so that the potential problems can be found as early as possible. In fact, to achieve its aim, concurrent design is through the small local iterations to avoid the large scope iterations of the traditional sequential design process. From a microcosmic view, the early stages of concurrent design are focused on coupled phases, which often arise the small local iterations and can be expressed by the coupled relationship model.

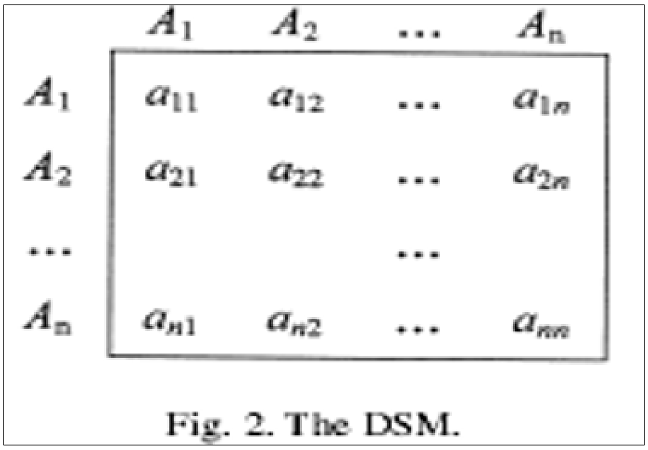

Figure 2 The DSM

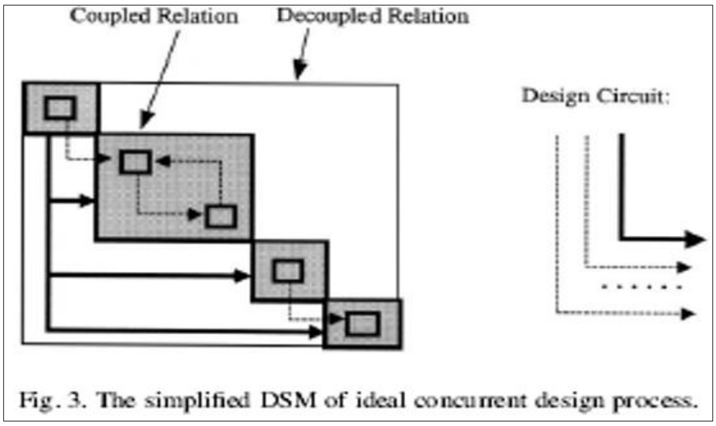

Figure 3 The simplified DSM of ideal concurrent design process

While from a macroscopical view, the structure of the decoupled circuitry serves as an ideal model of the concurrent design process that emphasizes no rework and "do it right first". If one interprets the activity ordering in the DSM as the execution sequence, the elements a_{ij} =1 (i> j) below the diagonal represent the forward information transfer to later activities. The elements a_{ij} =1 (i< j) above the diagonal depict information fed back to earlier activities. Thus, the DSM of the ideal concurrent design process is simplified in Fig. 3.

4. An algorithm of recognizing coupled activities

CE calls for the simultaneous execution of coupled product development phases. The coupled relationship is the main factor that increases the complexity of concurrent design. Before re-engineering the design process, we should find out the activities having coupled relationship. In this paper, a new algorithm of recognizing coupled activities is proposed as follows. Once decomposed, the design process can be described as a directed graph. It consists of a set of nodes, representing the design activities, and a set of directed lines connecting these nodes. The directed lines or linkage reflect a dependency or a relationship between the connected activities. The DSM can be considered as the transpose of the incidence matrix of the corresponding directed graph. The problem of recognizing coupled activities set is translated into the problem of seeking strongly connected component in a directed graph. Given that G =< V, E > is a directed graph, where V = $\{v_1, v_2, \ldots, v_n\}$; and A is the incidence matrix of G, P is the accessibility matrix of G. Then

$$P = A^{(1)} \vee A^{(2)} \vee A^{(3)} \vee \cdots \vee A^{(n)} = \overset{n}{\underset{j=1}{\vee}} A^{(i)} \qquad (1 \le j \le n,\ \ 1 \le i \le n),$$

Where

$$A^{(i)} = \underbrace{A^{(1)} \wedge \cdots \wedge A^{(1)} \wedge A^{(1)}}_{i}$$

"Λ" is called the Boolean Sum operator, and "V" is called the Boolean Product operator. And both operations are defined as follows.

4.1. Definition 1.

- The matrix R = $(r_{ij})_{nXn}$is a Boolean matrix, if the values of r_{ij}(i,j=1,2,….,n)can only be 0 or 1.
- The matrix W = $(w_{ij})_{nXn}$is a Boolean Sum of R and S, if $w_{ij} = r_{ij} \vee s_{ij}$; where
- R =$(r_{ij})_{nXn}$and S = $(s_{ij})_{nXn}$are Boolean matrixes.
- The matrix U =$(u_{ij})_{nXn}$is a Boolean Product of R and S, if $u_{ij} = \vee^{n}_{k=1}(r_{jk} \wedge s_{kj})$
- where R =$(r_{ij})_{nXn}$and S = $(s_{ij})_{nXn}$are Boolean matrixes.
- The algorithms of Λ and V are explained in Tables 1 and 2.
- For example, given that

$$S = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}, \quad R = \begin{bmatrix} 0 & 1 \\ 1 & 1 \end{bmatrix}.$$

Then Boolean Sum W and Boolean Product U are computed as follows

$$W = R \vee S = \begin{bmatrix} 0 & 1 \\ 1 & 1 \end{bmatrix} \vee \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 \vee 0 & 1 \vee 0 \\ 1 \vee 0 & 1 \vee 1 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 1 \end{bmatrix},$$

$$U = R \wedge S = \begin{bmatrix} 0 & 1 \\ 1 & 1 \end{bmatrix} \wedge \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 \wedge 0 & 1 \wedge 0 \\ 1 \wedge 0 & 1 \wedge 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}.$$

Now define $P \cap P^{\mathrm{T}}$ as follows:

$$P \cap P^{\mathrm{T}} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix} \cap \begin{bmatrix} p_{11} & p_{21} & \cdots & p_{n1} \\ p_{12} & p_{22} & \cdots & p_{n2} \\ \cdots & \cdots & \cdots & \cdots \\ p_{1n} & p_{2n} & \cdots & p_{nn} \end{bmatrix} = \begin{bmatrix} p_{11}^2 & p_{12} \cdot p_{21} & \cdots & p_{1n} \cdot p_{n1} \\ p_{21} \cdot p_{12} & p_{22}^2 & \cdots & p_{2n} \cdot p_{n2} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n1} \cdot p_{1n} & p_{n2} \cdot p_{2n} & \cdots & p_{nn}^2 \end{bmatrix},$$

where the matrix $P = (p_{ij})_{nXn}$ is an accessibility one, and P^T is the transpose of P.

If it is accessible from node v_i to node v_j, then $p_{ij} = 1$. If it is accessible from node v_j to node v_i, then $p_{ji}=1$. Thus, the nodes v_i and v_j are accessible from each other, if and only if $p_{ij}.p_{ji} = 1$. As to the matrix $P \cap P^T$; if the non-zero elements of the ith row are in the j_1th, j_2th….,j_kth columns, then, the nodes $v_i, v_{j1}, v_{j2}….v_{jk}$ form a strong connected component. And the activities corresponding to these nodes are in a coupled set.

	Stamping process planning team					Die design team				Analysis & simulation team			
	A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9	A 10	A 11	A 12	A 13
Blank layout design A1	0	0	0	0	0	0	0	0	0	0	0	0	0
Rough process planning A2	1	0	0	0	0	0	0	0	0	1	0	0	0
Detail stamping process planning A3	0	1	0	0	0	0	0	0	0	0	0	0	0
Stamping resource election A4	0	0	0	0	0	1	0	0	0	0	0	0	0
Generation of process sheets A5	0	0	1	1	0	0	0	0	0	0	0	0	0
Determination of die structure A6	0	1	1	0	0	0	0	0	0	0	0	0	0
Working parts design A7	0	0	1	0	0	1	0	0	0	0	1	0	1
Auxiliary parts design A8	0	0	0	0	0	1	1	1	0	0	0	0	0
Drafting of parts and the assembly A9	0	0	1	0	0	1	0	0	0	0	0	0	0
Stamping capability evaluation A10	0	1	0	0	0	0	0	0	0	0	0	0	0
Stamping process simulation A11	0	0	1	0	0	1	0	0	0	0	0	0	0
Technological data analysis A12	0	0	0	0	0	0	0	0	0	0	1	0	1
Analysis of the flaws in simulation A13	0	0	0	0	0	0	0	0	0	0	0	1	0

Figure 4 The DSM of sequential die design process

$$A=\begin{bmatrix}0&0&0&0&0&0&0&0&0&0&0&0&0\\1&0&0&0&0&0&0&0&0&1&0&0&0\\0&1&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&1&0&0&0&0&0&0&0&0\\0&0&1&1&0&0&0&0&0&0&0&0&0\\0&1&1&0&0&0&0&0&0&0&0&0&0\\0&0&1&0&0&1&0&0&0&0&1&0&1\\0&0&0&0&0&0&1&1&1&0&0&0&0\\0&0&1&0&0&1&0&0&0&0&0&0&0\\0&1&0&0&0&0&0&0&0&0&0&0&0\\0&0&1&0&0&1&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&0&0&1&0&1\\0&0&0&0&0&0&0&0&0&0&0&1&0\end{bmatrix}, P=A^{(1)}\vee A^{(2)}\vee\cdots A^{(13)}$$

$$=\begin{bmatrix}1&1&1&1&1&1&1&1&1&1&1&1&1\\0&1&1&1&1&1&1&1&1&1&1&1&1\\0&0&1&1&1&1&1&1&1&0&1&1&1\\0&0&0&1&1&0&0&0&0&0&0&0&0\\0&0&0&0&1&0&0&0&0&0&0&0&0\\0&0&0&1&1&1&1&1&1&0&1&1&1\\0&0&0&0&0&0&1&1&1&0&1&1&1\\0&0&0&0&0&0&0&1&1&0&0&0&0\\0&0&0&0&0&0&0&0&1&0&0&0&0\\0&1&1&1&1&1&1&1&1&1&1&1&1\\0&0&0&0&0&0&1&1&1&0&1&1&1\\0&0&0&0&0&0&1&1&1&0&1&1&1\\0&0&0&0&0&0&1&1&1&0&1&1&1\end{bmatrix}.$$

$$P\cap P^{\mathrm{T}}=P\cap P^{T}=\begin{bmatrix}1&&&&&&&&&&&&\\&1&&&&&&&&1&&&\\&&1&&&&&&&&&&\\&&&1&&&&&&&&&\\&&&&1&&&&&&&&\\&&&&&1&&&&&&&\\&&&&&&1&&&&1&1&1\\&&&&&&&1&&&&&\\&&&&&&&&1&&&&\\&1&&&&&&&&1&&&\\&&&&&&1&&&&1&1&1\\&&&&&&1&&&&1&1&1\\&&&&&&1&&&&1&1&1\end{bmatrix}.$$

As an example, a DSM in Fig. 4 is used to represent the traditional sequential stamping die design process. To build this DSM, an exhaustive list of all the activities that collectively define the whole die design process is established by a group of experts or representative from all functional areas including stamping process planning, die design, and analysis and simulation. After the teams agree on this list, make up the DSM by asking the engineer responsible for each activity for the minimum set of other activities (taken from the list) that need to be performed before his/her activity can start. These activities are his/her predecessor and are marked in the DSM by a "1" mark.

Using a directed graph G to represent the die design process above, the corresponding incidence matrix A, accessibility matrix P, and the result of $P \cap P^T$ are figured out as the following:

From the result of $P \cap P^T$, we find that the strong connected components of the directed graph G include {A1}, {A2, A10}, {A3}, {A4} {A5}, {A7, A11, A12, A13}, {A8}, {A9}, {A10}. Of course, the coupled activity sets are {A2, A10} and {A7, A11, A12, A13}.

5. An algorithm of re-engineering the design process

The aim of re-engineering the design process is to enhance concurrency among design activities for reduction of the product development time and cost. And the re-engineering principles can be summarized as the follows:

- According to a DSM, if all the elements of a column are zero, the design activity responding to this column should be executed as early as possible, because it does not need any information of other activities.
- According to a DSM, if all the elements of a row are zero, the design activity responding to this row should be executed behind other activities, because it provides no information to the others.
- The coupled activities would be looked as one activity in the re-engineering process.
- According to the order levels of all activities, the objective of the re-engineering is to schedule rows and columns of the DSM into a below triangular form.

Definition 2. The accessibility matrix P becomes a reduced matrix P0, if every coupled activity set is merged into one activity, and the rows and columns responding to the coupled activity set have been merged into one row and column.

	A 1	A 2	A 10	A 3	A 6	A 7	A 11	A 12	A 13	A 4	A 8	A 5	A 9
Blank layout design A1	0	0	0	0	0	0	0	0	0	0	0	0	0
Rough process planning A2	1	1	0	0	0	0	0	0	0	0	0	0	0
Stamping capability evaluation A10	0	0	1	0	0	0	0	0	0	0	0	0	0
Detail stamping process planning A3	0	0	0	0	0	0	0	0	0	0	0	0	0
Determination of die structure A6	0	0	0	0	0	0	0	0	0	0	0	0	0
Working parts design A7	0	0	0	1	1	0	1	0	1	0	0	0	0
Stamping process simulation A11	0	0	0	1	0	1	0	0	0	0	0	0	0
Technological data analysis A12	0	0	0	1	0	0	0	1	1	0	0	0	0
Analysis of the flaws in simulation A13	0	0	0	0	0	1	0	0	0	0	0	0	0
Stamping resource election A4	0	0	0	0	1	0	0	0	0	0	0	0	0
Auxiliary parts design A8	0	0	0	0	0	1	0	0	0	0	0	0	0
Generation of process sheets A5	0	0	0	1	0	0	0	0	0	1	0	0	0
Drafting of parts and the assembly A9	0	0	0	0	1	1	0	0	0	0	1	0	0

Figure 5 The DSM of re-engineered die design process

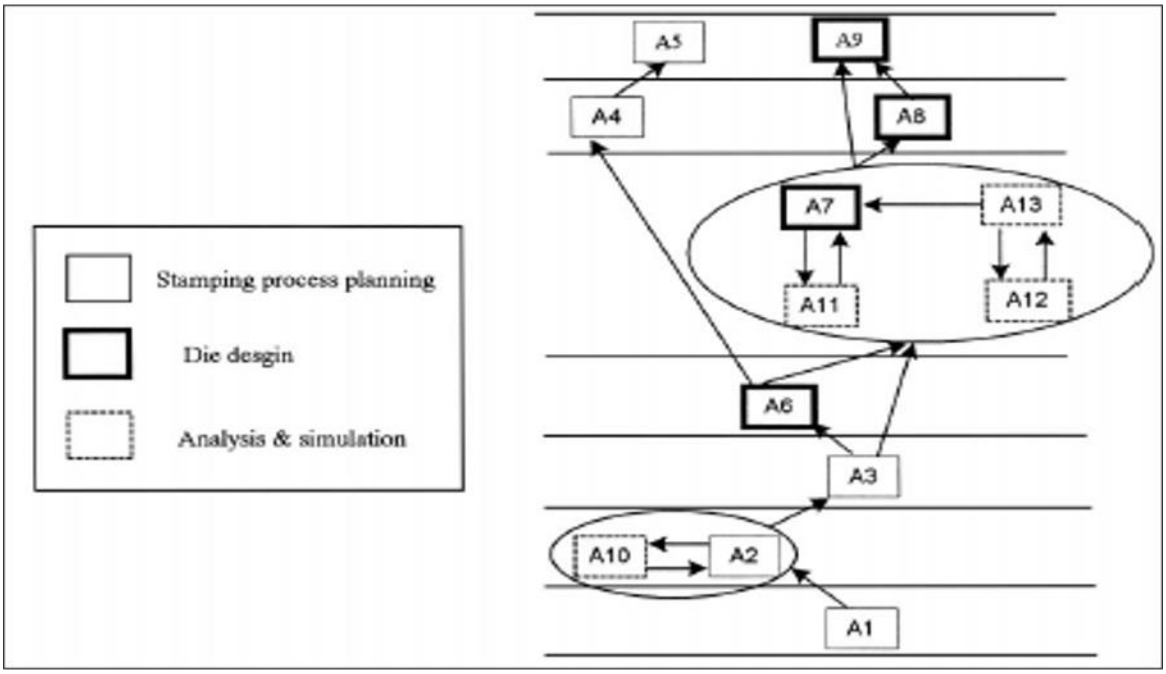

Figure 6 Concurrent die design process

According to the activity levels above, the traditional die design process can be re-engineered, and the new DSM of the re-engineered process is expressed in Fig. 5. Conventionally, die development is performed separately from stamping process planning, die design and analysis and simulation. If there are some problems with the result of analysis and simulation, usually only minor changes can be made to the design to try to accommodate the process. The lack of communication among teams performing these activities results in long die development time and incompatibility problems. As to the re-engineered concurrent die design process (shown in Fig. 6), multidisciplinary personnel workstogether to consider various issues in die development, and the potential problems can be found as early as possible. The rework is reduced to the minimum. Thus, the cooperative and concurrent die design process can lead to less development time, lower cost and higher quality.

6. Conclusion

The first task of implementing CE is to schedule the logistic design process rationally. Hence, the methodology to analyze design process to enhance the concurrency among design activities is very important. And how to re-engineer the traditional design process is a key problem in CE context. In this paper, the relationships between logistic design activities are divided into three types: uncoupled relationship coupled relationship and decoupled relationship. Directed graph is used to represent the design process. Based on DSM, an algorithm of recognizing the coupled activities during the design process is presented. Moreover, an algorithm to figure out the order levels of activities during the design process is proposed. These two algorithms are applied to re-engineer the stamping die design process to illustrate the contributions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Gnanasekaran J.S. & Dr. S.Shanmugasundaram,Concurrent Engineering Model (CEM) Analysis on Logistics Design Parameters- A Case Study, South African Journalof Industrial Engineering ISSN: 1012-277X, SA ePublications. Centurion, 0046, South Africa, May 2009, Vol 20 (1), pp.109-118,

[2] Gnanasekaran J.S. & Dr. S.Shanmugasundaram, Concurrent Engineering Design Process Through Re-Engineering, Proceedings of NationalConference on Development and challenges in Manufacturing Engineering, NCDCM 2004, Manipal,India, March 18-20,2004,pp 743-751

[3] T. Dunbing et al., Computers & Industrial Engineering, 2000, vol 38, pp 479-491

[4] Assine, A., Falkenburg, D., &Chelst, K. Engineering design management: an information structure approach, International Journal of Product Research, 1999, vol 37, pp 2957-2975.

[5] Malmstrom, J., Pikosa, P., & Malmqvist, J. Complementary roles of IDEF and DSM for the modeling of information management process. Concurrent Engineering: Research and Applications, 1999, vol 7,issue 2, 95-103.

[6] Huang, G. Q., & Mak, K. L.Re-engineering the product development process with `design for X'. Proceedings of the Institution of Mechanical Engineers, Part B, vol 212, pp259-268. 1998

[7] Seliger, G., Karl, H., & Weber, H. Cooperative design, manufacturing and assembly of complex products. Annals of the CIRP,1997,vol 46 issue1, pp 67-70.

[8] Krishnan, V. Managing the simultaneous execution of coupled phases in concurrent product development. IEEE Transaction on Management, vol 43, issue 2, pp 210-217,1996

[9] Albano, L. D., & Suh, N. P. Axiomatic design and concurrent engineering Computer-Aided Design, 1994, vol 26 issue7, pp 499-504.

[10] Kusiak, A., Larson, T. N., & Wang, J.Reengineering of design and manufacturing process. Computers and Industrial Engineering, 1994,vol26,issue3, pp 521-536.

[11] Kusiak, A., & Park, K. Concurrent engineering: decomposition and scheduling of design activities. International Journal of Product Research, 1990.vol 28, pp 1883-1900.

[12] Spinner, M. Improving project management skills and techniques, Englewood Cliffs, NJ: Prentice Hall.1989

[13] Ross, D. T. Structured analysis (SA): a language for communicating ideas. IEEE Transaction on Software Engineering, 1977, vol-SE-3, issue1,pp 16-34.