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The Development of Manufacturing Process Design Tool

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Abstract. Designing a design process is a crucial activity in concurrent product design environment. Though, there are several tools to design and visualize manufacturing process, e.g. Outline Process Chart, Process Flow Chart or IDEF0; the necessary information, e.g. standard, to manage processes, still can make the chart too complicate to realize. In addition, the evidence from field studies reveal that the required input variables from a considered process are not necessary to be similar output variables from the immediately predecessor process. These two findings and Control Plan as well as TQM lead to develop the novel manufacturing process design tool called the Material Alternation Product (MAP) chart. The major step forward of the new tool is accounted of which it has the capability to illustrate the important information for a considered manufacturing process, e.g. material in put requirements, variable to be controlled etc., within one chart. A hub-flange from a car is used as a case to validate the tool, moreover the validation square method is a mean to capture expert opinion on the developed tool. The results that the MAP tool is valid from the expert viewpoints.

Keywords. Concurrent Engineering, manufacturing process, design

Introduction

A process is a transformation of inputs to be a desired output, as a result each process comprises of information from required material inputs, operations as well as controlled variables and output specifications [1].

From field studies, it is found that the designing a manufacturing process is a complex activities [2][3]. Representing all required information in manufacturing processes to design team needs huge amount of document which is not in the same source. As a result, the researchers aim to develop a tool in which all necessary information can be encapsulated within one chart.

The next section reveals the available process visualisation tools each of which is examined and then research gaps are addressed [4]. Section two presents results from field studies which influence the tool developing in section three. Section three, four and five are tool validation and discussion of the results consecutively.

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1. State of the art in Manufacturing Process Visualization and Design Tools

To review the state of the art for process visualization and design tools, the researchers focus on three keywords as process flow, manufacturing process and Total Quality Management (TQM). The last keyword is necessary in industrial environment because most manufacturing entities follow the TQM philosophy especially those obey either ISO 9000 [5] or AS9000 [6] (aerospace manufacturers). From literature, IDEF0, Outline Process Chart, Flow Process Chart and Process Flow Chart are investigated. There are two aspects for analyzing the existing tools which are the capability of the tool and the capability to encapsulated information. In each manufacturing process, material inputs must be transformed to be a product output by sets of actions. In addition, both material inputs and product outputs are described by specifications, while each action is controlled by standard. The results from analyzing four existing tools are shown in Table 1.

IDEF0 represents each action in a manufacturing process as a function name each of which receives inputs and delivers outputs. At the same time, each action has to be controlled by mechanism. However, specifications of input and output are not attached in the diagram.

Table 1. The comparison of encapsulated information for charts representing manufacturing process.

Tools	Encapsulated Information
IDEF0 [7]	- Input and Output
	- Operation (function name)
	- Control
	- Mechanism
Outline Process Chart [8]	-Operation name
	-Inspections
	-Time for each Inspection or Operation
	-Material input specifications
Flow Process Chart [9]	-Operation (name)
	-Transport (location)
	-Delay
	-Storage
Process Flowchart [10]	-Start and end
	-Operation
	-Decision
	-Input and Output
	-Annotation
	-Predefined Process
	-Preparation

The Outline Process Chart and Flow Process Chart come together as a package to describe assembly process rather than explaining a single part manufacturing. The Outline Process Chart shows the overview of assembly processes and how to manufacture each part, moreover it shows each operation name and period as well as inspection time. In addition, the specifications of material input for each part are given, but the specifications for either each part or a complete product are not considered as important information. The Flow Process Chart provides the detailed operation of the Outline Process Chart by which includes additional information on transportation, delay and storage [11]. However, the input and output specifications are still missing. Whereas the detailed information for operation getting from both tools is describes in another document.

The existing process visualization tools can be able to explain manufacturing process [12]. Though, they are tools for improving manufacturing process, the application for monitoring and control needs more discussion. For corrective action purpose, process visualization tool should ideally navigate to the locale of each problem. The researchers conduct further investigation in field studies in the adjacent section.

2. Industrial Field Studies

Data collection is conducted in two automotive tier 1 suppliers in Thailand, and the Case Study Research approach is applied.

In order to avoid bias, two questions are asked as follows:

- What kind of tools or charts do you use for designing manufacturing process?
- Apart from designing manufacturing process, do you use the mentioned tools or charts for other purposes? Please clarify.

There are three interviewees. Two from company W the other works for company X, and all of them have more than 25 years of experiences. Company W supplies stamping parts, moreover, production tools are design in-house. Company X delivers machining parts; furthermore, production lines are designed in-house.

ISO9000 and TS16949 are applicable for both companies [13]. Both companies have never experienced IDEF0 for designing process. The Outline Process Chart and Process Flow Chart are realized in manufacturing process design. In addition, the Outline Process Chart appears in Control Plan, which is crucial during production. It is assumed if all variables in a manufacturing process are in control, each final product should be in an acceptable range.

Showing material movement within a considered manufacturing process is the main purpose of the Flow Process Chart. As a result, this chart is suitable for process improvement, e.g. Kaizen, than designing a new process from scratch.

Both companies work in international environment, because they accredit ISO9000 and TS16949. It is found that the existing manufacturing process design tools are realized in automotive industries except IDEF0. In addition, the Outline Process Chart and Process Flow Chart can be able to visualize process for process design purpose, but for managing process (monitoring and control as well as analyzing manufacturing defective) the Flow Process chart is applied.

For the researchers, it is a challenge to create a tool for multi purposes of usages. There are a lot of tools which implement in product design and development. If the newly developed tools can be used for designing and managing a process, this will be beneficial for industries than separating tools as found from field studies.

3. The Development of MAP chart

The newly developed tool must show the details of how each process transform material inputs to a final output. Specifications of material inputs and outputs for each sub-process should be explicitly revealed, however, the tool must not be too complicate and overload with information. In brief, designing a new manufacturing process will be a benefit from the tool and it should simple enough for managing process during production.

The researchers develop a novel tool called Material Alternation Product (MAP) chart [14]. The critical assumption for this tool is manufacturing process is sequentially proceeded. The example of MAP chart is shown in Figure 1. Obviously, there are several sub-process in a certain manufacturing process. A rectangle is represented as an action or sub-process. Within each action, there are two rectangles, one circle and two arrows. Those two rectangles in each action contain a Planned Input (PI) and a Planned Output (PO) consecutively, these two terms specify a material input and an output conditions. Whereas the circle represents the focused action or Process Characteristics (PC). Both arrows show inflow and outflow from the PC.

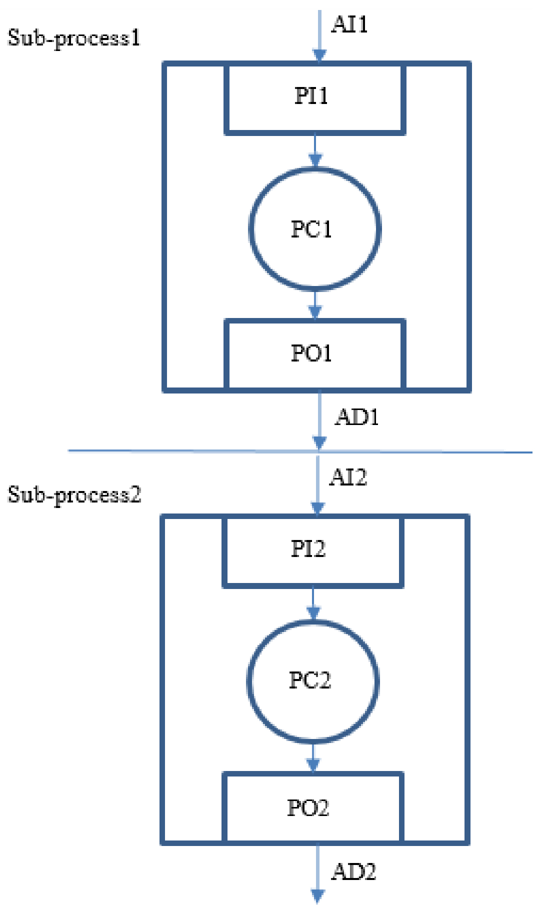


Figure 1. Schematic of the MAP Chart.

An input arrow on the top of the MAP chart explains input characteristics from which are accumulated actions upon material since upfront sub-process. As a result, it is called as an Accumulated Input (AI). PI and AI are not necessary to be alike. PI describes the needed condition of a material or a semi-finish good before receiving an action in the considered sub-process. Similarly, the output arrow at the bottom most denotes the characteristics of the physical product called an Accumulated Deliverable (AD). Again, PO defines the target conditions of the physical product as resulted by PC, while AD states the result of adding on actions to product since upfront until a current sub-process. Again, AD from the current sub-process is not necessary to be similar to AI for the adjacent sub-process.

4. The Validation of MAP chart

The MAP chart is validated with an automotive hub-flange (Figure 2). Raw material is made by hot forging, and then sends to company X for machining. Apart from receiving raw material and inspection, there are two turning processes. The critical parameters to be controlled are the surface roughness as well as parallel and dimensions. Surface S1 is at the hub while S3 is the back surface, both of which need to be parallel. Moreover, the diameter of the hub-flange is restricted as D1 while the thickness measured between surface S1 and S3 is maintained as T1.

Figure 2. Hub-flange.

In this case, the hub-flange manufacturing process is visualized in a MAP chart as shown in Figure 3. Due to intellectual prosperity, detailed information related to product are covered. Each hub-flange is produced by hot forging process. The hub position is curved out one side but the other is curved in. Supplier provide products together with mill sheet to confirm specifications as denoted AI1. Shop floor workers check the mill sheet before put each work-piece into CNC lathe machine to start turning process 1. Before clamping the specimen, workers must make sure that there are no crack, no burr and no rust (PI1). Later, the clamp position and other turning conditions must be satisfied (PC3). Clamp positions are located at the center hole and the circumference of the hub-flange. The diameter of the hub-flange (D1) is satisfied as one outcome from PC3. Remember that the D1 is not completed at the location of clamping. Apart from D1, other elements in PO1 are conserved by visual checked whereas the measurement is taken place for AD1. Surface hardness at S1 and S2 is checked whether both surfaces are removed too much or not. Once all variables are checked, AD1 is completed. The mill sheet is developed for each manufacturing batch, while the physical products are kept in store.

To start turning process 2, shop floor workers take semi-finished products from store and check mill sheet (AI2). The surface S1 and D1 must be checked and the work-piece must have no crack, no burr and no rust. After turning process (PO2) the dimension D1 throughout the edge is satisfied visually. Surface S3 is finished and all six holes are drilled through. After checking for parallel between S1 and S3 as well as measuring all variables, AD2 is completed and mill sheet is delivered for the considered batch. Apart from deburr as visual checked, characteristics in AD1, and AD2 are sampling one from five working piece as suggested by TS 16949.

The MAP chart for manufacturing is developed by the researchers and later it is shown to process designers in company X for checking its validity. The experts accept that the method is easy and it has high ability to communicate among team members. All validation activities are supported by validation square method [15].

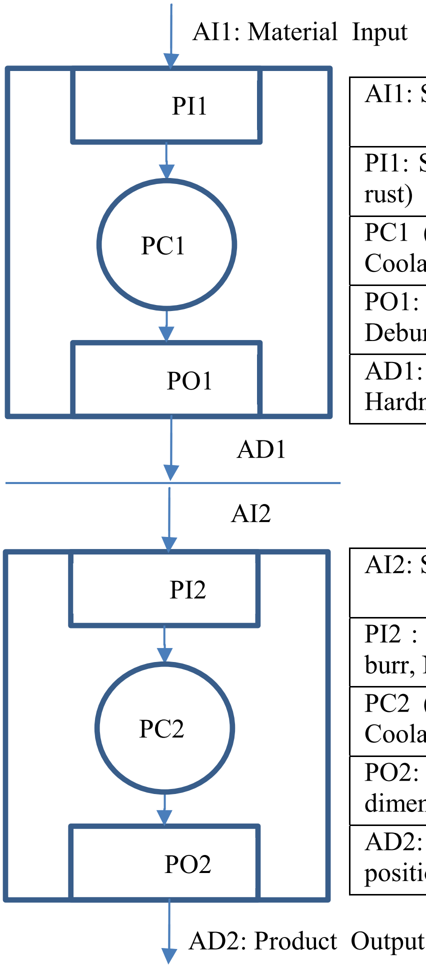
5. Discussion of the result

The MAP chart has capability to visualize manufacturing process as well as represent critical information. From last section, this is the evidence to proof that the input before receive action (PI) and accumulated input (AI) is not necessary to be similar. For output of sub-process 1, the outcome of PC1 are D1, Roughness of S1 and S2 but these three variable cannot be mearsured while turning process 1 and 2 (PC1 and 2). Once surface hardness of S3 is tested and parallel between S1 and S3 is confirmed, AD2 is commpleted. It is interesting that variables in AD2 are the result of PC1 and PC3 whereas PO2 is solely from PC2.

6. Conclusion

The MAP chart can visualize manufacturing process and represent necessary information. Moreover, the process designers from company X support the validity of the newly developed tool. As a result, the researchers claim for the success at this stage.

However, the researchers suggest to validate the tool with other complex manufacturing processes. The assumption of the MAP tool is the manufacturing process is always sequentially completed in detailed. Any processes concurrently executed are still a challenge at the moment.



AI1: Specifications (Mill Sheet)
PI1: Speciment Condition (No crack, No burr, No rust)
PC1 (Turning1): Clamp position, Spindle Speed, Coolant setup, Tool life
PO1: Visual check (D1, Roughness of S1 and S2, Deburr)
AD1: D1, Roughness of S1 and S2, Deburr, Hardness

AI2: Specifications (Mill Sheet)
PI2 : D1, S1, Speciment Condition (No crack, No burr, No rust)
PC2 (Turning2): Clamp position, Spindle Speed, Coolant setup, Tool life
PO2: Visual Check (D1, Roughness of S3, Hole dimensions and positions (6 holes), Deburr)
AD2: D1, Roughness of S3, Hole dimensions and positions (6 holes), Deburr,T1, Paralell S1 and S3

Figure 3. MAP chart for Hub-flange manufacturing process in company X.

It is found during the development that control plans are the tool for representing manufacturing process and key controlled variable, but it is a lengthly document for shop floor workers. The researchers aim to further develop MAP chart to be a handy tool.

In addition, the researchers try to apply the MAP chart for other applications such as for finding root causes of manufacturing problem. Other applications beyond manufacturing process are also future research targets.

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