Event-driven Modelling Method for Sub-assembly Intelligent Production Line

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Abstract. Focusing on the design of sub-assemble intelligent production line, an event-driven design method for production line was proposed. With the method, the manufacturing activity was defined as event, and then the relationships among events are analysed to define the input-output and execution behaviours digitally in each stage. Furthermore, the event-driven execution mechanism for multi-stage process was built to describe the production line in digital. The digital model of production line was conducted to explore the event behaviours, which will support the research about data-driven production line simulation in future work.

1 Introduction

Shipbuilding is a discrete type manufacturing, so the sub-assemble manufacturing is not conducted in the form of flow production like auto-industry. Recently, with the development of intelligent manufacturing, the new technical change will come into shipbuilding, and intelligent production line become the important direction for shipbuilding transformation and upgrading.

Sub-assemble is the typical structure in modern shipbuilding mode, which has the characteristics of large demands and variable types. Generally, the sub-assemble production contains many processes, including assemble, weld, repair, polish and back burning. In many enterprises, the production mode of sub-assemble is the combination of manual operation and robot operation. Some shipyards have developed the production line for sub-assemble.

Depending on the manufacturing technique of sub-assemble to improve the intelligent level, the production line of sub-assemble is designed. The digital model is established to support the data-driven simulation of production line.

2 The mechanism of event-driven process control

The mentioned event in this paper is defined as the series of job activity, including material transportation, material waiting, and job execution. With the concept, the event in manufacturing process can be described. First, the relevant events in process are defined listed in the Table 1.

| Concept          | Ico    | Symbol | Descriptions                      |
|------------------|--------|--------|-----------------------------------|
| Event waiting    | $\square$ | $BP_i$ | The waiting behaviour in one process |
| Keep waiting     | $\bigtriangleup$ | $BS_i$ | The waiting behaviour in next process |
| Event execution  | $\bigcirc$ | $FP_i$ | The execution behaviour in one process |
| Interval         | $PI_i$ |        | The time between two execution behaviours of events |
| Event time       | $MP_i$ |        | The time for one event to be executed |

It is noted that the behaviours out of execution are all treated as waiting behaviours, including the transportation behaviours. A case with three stations is analysed to describe the proposed method shown in Fig.1.

In Fig.1 (a), the waiting behavior occurred after $(i-1)$ station and before $i$ station, which included 3 event behaviors, written as $E_i$. The mathematical model can be described as follows.

\begin{equation}
E_i^o = \{BS_i, FP_i, BP_i\}
\end{equation}

In addition, the waiting stage included material transportation and machining waiting. The machining stage included machining arrangement and machining execution. The waiting after machining included post-processing after machining and transportation waiting.
3 The event behaviour analysis of sub-assembly production line

3.1 The process flow of sub-assembly manufacturing

The manufacturing of sub-assembly generally contained 6 stations, which were loading, assembling, welding, repairing, back burning and baiting etc. The function of each station was listed as follows.

(1) Loading. It was used to place the sheets of all workpieces for sub-assembly. The execution event was to transport the workpiece to assembly station by electromagnetic lifter. The involved equipment was electromagnetic lifter.

(2) Assembly. It was used to group, spot weld and transport. Firstly, the baseplate and rib plate were grouped to conduct spot weld. After assembly, the workpieces were transported to welding area. The involved equipment was roller bed and plot weld equipment.

(3) Weld. The weld robots were used to complete welding. The execution process was that the visual identity was utilized to scan the structure of workpiece. Then the process parameters were selected depending on the scanned structure. Following, the welding work was conducted. The involved equipment was roller bed, crane, robots, visual system and welding devices etc.

(4) Repair. The assisted job (welding slag clear, welding check, polish) were conducted to support welded sub-assemble structure. The involved equipment was roller bed, polish device.

(5) Back burn. The process was to amend the deformation for sub-assemble and release the stress. The involved equipment was back burning device.

(6) Bait. The manufactured sub-assemble was baited in the process. The involved equipment was electromagnetic lifter.

3.2 The event behaviour analysis of sub-assembly production line

The 6 working areas mentioned above are treated as the production station and the extracted event-behaviors in each station are listed.

The operating mechanism between event and behavior are displayed in Fig. 3. In addition, the simulation are conducted to verify the proposed method shown in Fig 4.

In Fig 3, the proposed method can describe the sub-assembly production line digitally. With the development of CPS, the ‘digital twin’ becomes the important issue in shipbuilding. A digital environment with virtually and reality is the basis of popularization and application of intelligent manufacturing technology. Therefore, the proposed modeling method can provide an appropriate solution for building a data-driven digital environment for sub-assembly production line.
Table 2 Event behavior of sub-assemble production line

| Station   | Behavior                          | Symbol | Set | Description                                                                 |
|-----------|-----------------------------------|--------|-----|-----------------------------------------------------------------------------|
| load      | Waiting before load               | BP₁    | E₁  | Depending production requirement, the required materials were transported to load station and waiting. Then the loading arrangement and execution were conducted to complete loading. |
|           | Loading execution                  | FP₁    |     |                                                                             |
| assembly  | Waiting before assembly           | BP₂    | E₂  | After loading, the materials were transported to assembly station and waiting. Then the assembly arrangement and execution were conducted to complete assembly. |
|           | Assembly execution                 | FP₂    |     |                                                                             |
|           | Waiting after assembly             | BS₃    |     |                                                                             |
| weld      | Waiting before weld               | BP₃    | E₃  | After assembly, the materials were transported to welding station. With the welding waiting, welding arrangement and welding execution operations, the welding job was completed. |
|           | Welding execution                  | FP₃    |     |                                                                             |
| repair    | Waiting before repair              | BP₄    | E₄  | After welding, the materials were transported to repair station. With the repairing waiting, repairing execution operations, the repairing job was completed. |
|           | Repair execution                   | FP₄    |     |                                                                             |
| back burn | Waiting before back burning       | BP₅    | E₅  | After repairing, the materials were transported to back burning station. The back burning waiting and execution were conducted to complete back burning. |
|           | Back burning execution             | FP₅    |     |                                                                             |
| bait      | Waiting before baiting            | BP₆    | E₆  | Finally, the machined workpiece was baited in this station.                 |
|           | Baiting execution                  | FP₆    |     |                                                                             |

Figure 3 The event behaviour relationships in sub-assemble production line
4. Conclusions

On the basis of production technology, an intelligent manufacturing-oriented digital modeling method for production line was proposed, which could provide a new solution for constructing simulation environment of sub-assembly production line. With the method, the sub-assembly manufacturing process could be described digitally. Then the practical production data were used to simulate production line, and the results showed that the established digital model was appropriate.

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