A&QT-R 2002(THETA 13)
2002 IEEE-TTTC-International Conference on Automation, Quality and Testing, Robotics
May 23-25,2002, Cluj-Napoca, Romania

DESIGN OF A ROBOTIC ASSEMBLY WORKCELL

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ABSTRACT

As there are so many changes regarding to the development of information technology and customer requirement and preference, manufacturing processes have to develop their capability. Manufacturing processes have been forced to cater for both productivity and flexibility. Therefore, automation process is the answer.
Assembly, an important activity in manufacturing, should also be dealt with automation. Boothroyd and Dewhurst [1] categorized three types of assembly. One category of assembly methods which needs automation is robotic assembly or flexible automation.
This research was undertaken to design an assembly process using robotic. Also, the extent that the robotic assembly could be used in manufacturing area was investigated. Case study for this research was assembly design for spark plug. The first step of this research was designing the robotic assembly workcell system.
After designing the system, next step was the simulation process. This step was performed by CATIA to verify performance of the proposed system. Based on this simulation, analysis of workcell system was investigated and technical recommendations were suggested. Based on these recommendations, an improvement made.

Key words: Design for Assembly (DFA), Robotic assembly, Boothroyd and Dewhurst Methodology, Integral Model of Rampersad.

1. INTRODUCTION

Manufacturing processes have developed as the development of information technology and fast changing of customer requirement. Manufacturing processes have been forced to be able to compete through maximize both their productivity and flexibility. The automation process is the answer for both of them.

Assembly process as one important process in manufacturing should also has dealt with automation. Through its development, recently, we can divide the assembly process into three categories, which are [1]:

1. Manual assembly
2. High Speed Automatic Assembly
3. Robotic Assembly or flexible automation.

In this paper, an assembly process using robotic was designed. It was also analyzed, to what extend robotic assembly can be used in manufacturing area. For this case, spark plug type Champion A6YC and N9YC were used.

To perform a controllable system for robotic assembly, during the design process an integral assembly model proposed by Rampersad [2] was developed as a basic procedure and there were some improvements in some steps based on the requirement.

After designing the system, next step which is also important was the simulation process. This step was performed to verify the performance of proposed system[3]. After the system performance was obtained, analysis was performed to check whether there are some improvements are possible to apply.

2. LITERATURE REVIEW

Design for Assembly (DfA) is one method used to reduce cost of manufacturing. Simplifying the design of product is one way to reduce manufacturing cost. Boothroyd and Dewhurst stated that reducing number of part should be assembled and designing parts to be easy to manufacture and assemble is the best way to reduce manufacturing cost.

Boothroyd and Dewhurst Methodology

Boothroyd and Dewhurst methodology is concerned with simplifying design to gain the minimum cost of assembly. In *Product Design for Assembly*[1], they explained that to get a minimum cost of assembly, it is important to keep the most efficient way for the design. Therefore, there should always be reasons for separating parts rather than combining them.

Boothroyd and Dewhurst divided the assembly method into three main methods, which are:

1. Manual assembly.
2. High Speed automatic assembly
3. Robot assembly

Three of them then should be analyzed and improved to get better degree of efficiency.

Rampersad Model

Rampersad [2],[4] introduced a model called concentric design model as can be seen in the Figure 1.

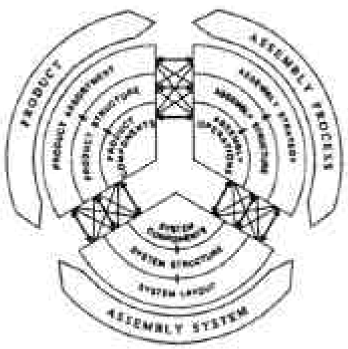


Figure 1 : Concentric Design Model [2]

This model has been summarized three variables of assembly, which are :

1. Product design
2. Assembly process design
3. Assembly system design

3. DESIGN FOR ROBOTIC ASSEMBLY

This research was using spark plug, which consists of 5 parts [5] :

1. Terminal Post (screw)
2. Centre Wire (electrode)
3. Ceramic insulator
4. Side terminal with ground terminal
5. Gasket

3.1. Analysis of Product Design

Comparison between manual assembly and robotic assembly

After defining the product, the writer analyzed the design for both manually assembled and robotic assembled. This step started by calculating theoretical time for both types of assembly.

The analysis was performed using Boothroyd and Dewhurst Method. The comparison between manual and robotic assembly resulted this calculation :

- Time required for manual assembly : 27.85 seconds
- Time required for robotic assembly : 24.42 seconds

This calculation was resulted based on assumption, that the machining process required for both assembly processes is excluded (special press process).

3.2. Assembly Process Design

Before defining the process design, there are some criteria should be fulfilled for robotic assembly workcell [6]. All of these criteria were fulfilled by the robot used for this workcell, ASEA 2100, which has 6 degree of freedom and an additional move of the 7^{th} degree of freedom.

Assembly Strategy

There are several points should be explained related to assembly strategies, such as :

(1) Feeding strategy
(2) Gripper strategy
(3) Transport strategy

These will be discussed more in the Table 1.

Assembly Structure

Assembly structure was defined based on the Bill of Material of the product. The assembly structure chosen is described in Figure 2.

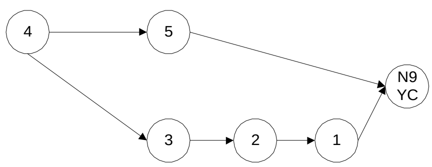


Figure 2 : Assembly Chart of Spark Plug

Assembly Operation

Operation for assembling spark plug can be divided into four different operations, which are feeding, handling, adjusting and special process, such as screw driving and special press [7], [8].

3.3. Assembly System Design

System Component

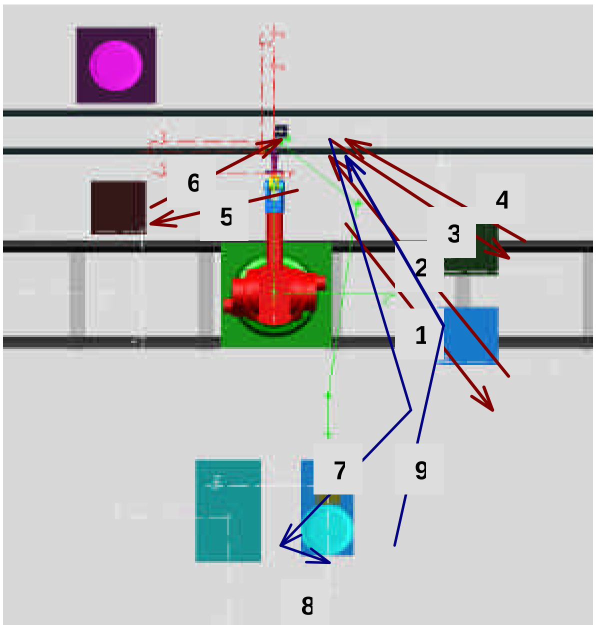
Based on product structure and assembly structure and supporting by assembly operations, system component was designed using morphological chart [2].

Table 1 : System component

No.	Function	System Component
1.	Transport	Free and power transfer machine
2.	Handling - Robot type - Gripper	 Industrial robot (7 d..o.f) Multi-gripper
3.	Feeding Part 1 : Gasket	Vibratory bowl feeder
4.	Feeding Part 2 : Side Terminal	Pallet
5.	Feeding Part 3 : Ceramic insulator	Pallet
6.	Feeding Part 4 :Centre wire	Pallet
7.	Composing	Special Press machine
8.	Feeding Part 5 : Screw	Vibratory bowl feeder
9.	Checking	Manual (at next workstation)
10.	Composing	Automatic Screwdriver
11.	Transport	Conveyor belt

System Structure and Layout

To get detail dimension, the layout was designed directly in the CATIA software, parallel with simulation. The workcell, material flow and layout can be seen in the Figure 3 below.



Legend :

1 : Picking side terminal
2 : Placing side terminal
3 : Picking ceramic insulator
4 : Placing ceramic insulator
5 : Picking center wire
6 : Placing center wire
7 : Move assembly pallet to the press machine
8 : Move assembly pallet from press machine to automatic screwdriver
9 : Move assembly pallet to free and transfer machine

Figure 3 : Layout and material flow workcell

4. SIMULATION

Simulation was performed in CATIA software based on the design explained in the previous chapter. Simulation was done using ROBUSE function. In this function, workcell is designed and ROBOT in existing database is used. Robot used was ASEA 2000, it has been drawn and programmed in CATIA using ROBOT function.

Based on the steps had been defined above, there were 6 tracks which were assigned in one task, which is assembling a spark plug. This task required time of 30.80 seconds.

5. ANALYSIS

Design Product Analysis

The assembly designed was still using existing design. Based on the product design analysis, all 5 parts are needed or important. Therefore, it is difficult to reduce number of parts. In addition, 5 parts for a product is relatively few, assembly process is quite simple, and it is simpler because there is only one orientation of assembly (from top to bottom).

Starting form this condition, redesign was to be performed based on the process. There are several weakness of design which can be improved:

1. Threaded operation is one of the most important thing to be avoided in automated assembly.
2. Reducing adjusting operation wherever it is exist by redesign product.

Robot System Analysis

From the joint value analysis, it was concluded that robotic programming designed was acceptable. From the Joint Value Analysis resulted that all 6 joints in the robot are moved in the acceptable working range.

From the simulation itself (generating from CATIA software) it was proved that there was not any warning from the monitor of this simulation. The warning would appear as a red chart if one or some joints of robot nearly reach their maximum working range.

Layout Analysis

Current layout was designed based on these considerations:

1. This layout was designed based on the “successive assembly system” configuration in layout [9].
2. Existing layout design needed more space and robot had to reach further to pick the parts.

This design caused that the system did not give the best performance. It was also proved by the high difference of time requirement between the theoretical and the result of simulation.

6. RECOMMENDATION

Recommendation was made after analyzing several weakness and opportunity that can make better performance for this workcell system design.

Product Design

Two recommendations of design for spark plug were :

1. Change threaded operation with snap fitting. Material used was still the same. This operation gave 2.5 seconds less than threaded operation. The 2.5 second reduction is almost 10% of total assembly time in the previous simulation.
2. Make a tangle to ceramic insulator to ease center wire to be inserted. It reduced time for aligning or adjusting. It is significantly affect for repetitive tasks.

Layout Analysis

Layout change was changed into the one line configuration; which put the entire pallet in one power and transfer machine in front of robot and separate loading and unloading pallet station; and put automatic screwdriver and press machine closer.

Another Improvement

The assembly tasks completing by robot generally can be divided into two types of operation which are general operation : pick and place; and special operation : automatic screwdriver and pressing

Using the GT concept and batch size consideration, another improvement was proposed. This improvement considered that special operations are performed for a group of assembled parts, not only one. Therefore, robot does not need to travel as many as general operations.

Simulation

These recommendations then was simulated again using CATIA. Based on time required for one assembly task, the improvement design gave less time to complete assembling. For 2 spark plugs, it needed 43.2 seconds instead of 30.8 for 1 spark plug in the previous design.

7. CONCLUSIONS

Design of existing spark plug can be used for robotic assembly, although this design needs special processes as threaded operation because of the use of screw and special press process to fit parts each other. The previous design, testing by CATIA, resulted that one task of assembling spark plug need 30.80 seconds.

A technical analysis was undertaken; then an improvement was designed based on Group Technology concept, product design analysis and layout analysis. Assembly time for 2 spark plug in one task is 43.20, which is shorter than the previous simulation (30.80 per spark plug).

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