Riveter Machine Reconditioning for Output Capacity Increase

Edgardo Porcell
Master in Engineering Management
Dr. Héctor J. Cruzado
Graduate School
Polytechnic University of Puerto Rico

Abstract *— The ability to ramp up or down production in order to quickly respond to customers' demand is a necessity in today's competitive lean manufacturing environments. Output capacity bottlenecks forces manufacturing plants to meet customer peaks in demand by stacking up their inventory levels. The production output capacity of the second stage of a 2-stage manufacturing cell was identified as a bottleneck and a plan was devised to double its capacity by reconditioning an unused defective riveter machine. After a multi-disciplinary team was deployed to tackle all identified problems, the riveter was placed in production, effectively doubling the output capacity of the cell. Also, new opportunities were identified for further increasing capacity in the future.*

Key Terms *— flexible flow shop, parallel machines, manufacturing, reliability centered maintenance, scheduling.*

INTRODUCTION

A manufacturing plant assembles a product called "primary contacts assembly". This product is manufactured in two main stages: manufacturing and riveting. The manufacturing stage is a manual operation and can be ramped up or down according to demand. The riveting stage on the other hand, can become a bottleneck for operations because this process is done on a unique riveter machine that is able to process only one assembly at a time. Output capacity of the riveting stage is a fixed rate of 25 parts per hour. The riveting cell has only one operational riveter. However, a second riveter is currently available in the cell, but it is inoperable due to design flaws and programing bugs. There is an opportunity to increase the output capacity of the riveting stage if the second riveter machine gets reconditioned and incorporated into the assembly cell as shown in Figure 1.

The objective of management is to double the output capacity of the riveting cell (50 parts per hour) in order to meet demand peaks by reconditioning the existing inoperable riveter machine in the following two months.

This paper provides a quick introduction to scheduling theory as it relates to parallel machines and its implications for preventive maintenance strategies. Then, the roadblocks for implementing a second riveter are explained along with the solution and plan proposed for execution. Finally, the results and conclusions are discussed along with suggestions for future opportunities in increasing output capacity.

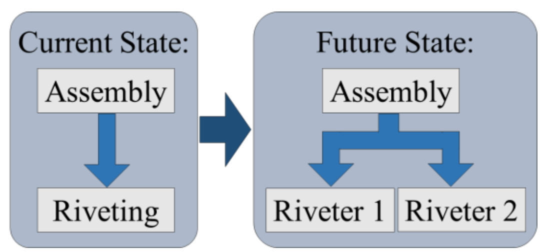

Figure 1
Current and Future State diagram for assembly cell

BACKGROUND

Scheduling Theory

Scheduling is a fundamental activity in any manufacturing plant. "It deals with the allocation of resources to tasks over given time periods and its goal is to optimize one or more objectives" [1]. The existing literature on Scheduling Theory lists multiple machine environments over which the scheduling activities can be performed. For the purpose of this project, the more relevant are: Flow shop (Fm) and Flexible Flow Shop (FFc). The Fm configuration consist of m machines in series and all jobs follow the same sequential route. i.e. they have to be processed first on machine 1, then on machine 2 and so on [1]. The FFc configuration is a generalization of Fm in which there are c serial stages, with one or multiple machines available at each stage [2].

The FFc configuration has an evident advantage to Fm as parallel machines provide the capacity of simultaneous processing. The advantage in Flow Time can range from 25% (for two machines) for a limit of 50% (for many machines). In effect, one could view the m machines working simultaneously on a single job as a single machine with m times the power of the basic machine [3].

Preventive Maintenance

Identical machines running in parallel can also have implications for preventive maintenance strategies. While an in-depth analysis of the maintenance strategies is outside the scope of this project, it is illustrative to examine its implications in a manufacturing environment. Take for example the 'Reliability Centered Maintenance' (RCM) framework, which is a process to evaluate equipment and develop maintenance tasks and frequencies to reduce failures [4]. A single machine providing a critical function would be inevitably classified as "Critical Equipment" and would require a preventive maintenance strategy appropriate for such classification. On the other hand, provided that certain conditions are met, two machines running in parallel can both be classified as "Run to Failure", which would require no preventive maintenance [5].

ANALYSIS AND APPROACH

Riveter Design Problems

The mechanical conditions which prevents the equipment to be used on production can be classified in the following categories:

- **Design Flaw:** During the riveting process, the riveter head presses down on the assembly before the spindle reaches the riveting point in order to minimize vibration, which can cause the product to disassemble before the riveting cycle completes. However, as the surface of the "primary contacts assembly" is uneven by product design, uneven stress gets propagated at the base of the machine's riveter head, causing machine breakage
- **Programing Bug:** Each "primary contact assembly" has 4 riveting points and the machine must rivet one at a time. The riveting sequence is important because the design of the product is asymmetrical and can become unstable due to vibration during the riveting process. The machine program currently starts riveting at a point in which the product is not yet very stable causing it to disassemble during riveting.

Technical Solutions (Methodology)

For each condition identified in the previous section, the following solutions can be pursued:

- **Design Solution:** Remove the pressure pad on the riveter head and provide an alternative method to hold down the assembly in place during the riveting process. The proposed solution will excerpt force vertically instead of horizontally and will have no interaction with the riveter head.
- **Programing Solution:** Re-program the riveter sequence such that the first two riveting steps are made at the points where the product is most stable. That way, the least stable riveting steps can be performed with a high probability of success as riveting points 1 and 2 bring stability to the assembly.

Project Planning and Schedule

The project's milestones can now be identified as the completion of each solution described in the previous section, namely: (1) Resolve design flaws and (2) Resolve programing bugs. Each milestone can be subdivided into a sequence of tasks, and each task assigned to one or more internal resources as shown in Table 1.

Table 1
Tasks and resources per milestone

Milestone	Task	Resource
1	Replace Pressure Pad	Maintenance
1	Design holder	Tool Room / Manufacturing
1	Fabricate holder	Tool Room
1	Install / Validate Holder	Maintenance / Manufacturing
2	Re-program	Manufacturing
2	Final Validation	Manufacturing

Based on the tasks' dependencies and availability of team members, a project's plan and schedule per week was devised to minimize the project's time to completion as shown in Figure 2.

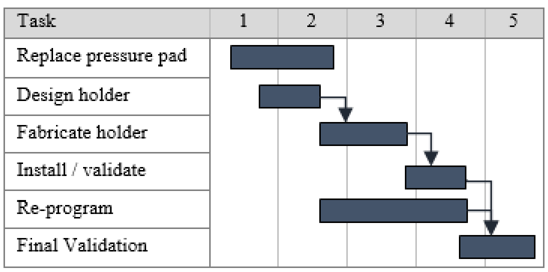

Figure 2
Gantt Chart for project planning

RESULTS

Project Timely Completion

Task and milestones were completed in time. Progress moved steadily according to the planned schedule. The multidisciplinary team engagement and cohesion played a crucial part in the completion of the project. As an example, the collaboration between the manufacturing and tool room teams in the design of the holder proved to be key for timely completion of the project by preventing the need for redesigning.

Fast reaction to unplanned events was also crucial to keep the pace of the project development. During execution of task #1 (Pressure Pad Replacement) it was found that additional parts were required for the machine to perform its function once the pressure pad was removed. The parts were not in stock, so they were purchased and expedited immediately.

Output Capacity Increase

As expected, the output capacity of the cell was increased by 100% by the addition of a new riveter. A mock 4-hour session was performed with the production personnel to validate that the project's goals had been reached while the manufacturing team monitored production.

As can be seen in Figure 3, the average output obtained during the 4-hour session was 50.5. During the first hour, an output of 48 parts was obtained. The lower output during the initial hour can be explained by the operators setting up the equipment while the manufacturing team provided instructions for using the new equipment.

Once the equipment was setup, production did not fall behind the 50 parts per hour mark. A maximum output of 52 parts was obtained during hour # 3.

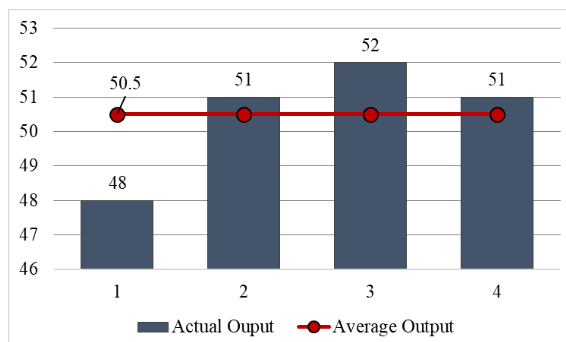

Figure 3
Assembly Cell's Production Output per Hour

CONCLUSION

Adding an identical machine to run in parallel to an existing equipment is an effective way to double output capacity in a manufacturing line or cell, provided that production bottlenecks do not exist in the previous stages. In our case, the effectiveness of this strategy depended on the ability of the assembly stage to ramp up or down as needed. If the assembly stage was unable to meet a demand of 50 parts per hour at a minimum, then additional actions items should have been identified to tackle opportunities in the assembly stage.

For future consideration, it might be possible to further increase output capacity in excess of 50 parts per hour by fine-tuning the riveters' speed parameters. This opportunity was identified during the re-programing task by the manufacturing team. This opportunity was not pursued at the time of this project as it was outside of its scope and it was esteemed that pursing this goal might have jeopardized meeting the deadline.

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