USE OF A PHYSICAL SIMULATION TO TEACH ASSEMBLY LINE AND KAIZEN CONCEPTS

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ABSTRACT

Many students in lower level courses are not familiar with manufacturing or assembly plants and thus have trouble understanding many of the concepts pertaining to production and operations management. Concepts such as scheduling, assembly line balancing, Just-in-time, theory of constraints, etc., are difficult to grasp without some physical demonstration. This paper discusses a simulation exercise used to aid in teaching these concepts in a course on Production Methods and Controls.

INTRODUCTION

The Industrial Engineering Technology Program at the University of Dayton offers a three-semester hour course in Production Methods and Controls. It is an introduction to the principles and current practices of optimizing the production of goods and services. Concepts covered in the course include forecasting, inventory management, bills of material, material requirements planning, scheduling, just-in-time, set-up-reduction, and theory of constraints. The course is taught using lectures and videotapes that explain and demonstrate examples of various concepts. Still many students have trouble grasping the concepts because they have never been in a manufacturing facility. In order to give the students some hands-on experience, a physical simulation exercise was developed. The exercise simulates the assembly of an airplane. As part of the exercise students perform time studies, and experience the effects of different lot sizes, push and pull systems, and performing constraint management. In his "Anniversary Comments," Lawrence J. Wolf indicates that in addition to attending classes, Engineering Technology students participate in experiences that simulate the work environment and require them to use equipment and instruments, record data, compute results, and write reports[1]. Thus, a laboratory-type experience was deemed an important addition to this class.

DESIGN OF THE EXERCISE

The purpose of the exercise is to demonstrate how an assembly line works, to demonstrate the difference between a "push" and a "pull" system, demonstrate the concept of bottlenecks in the context of the theory of constraints, and what is meant by lot sizes. The exercise is designed to simulate assembly of the XF-27 Fighter Aircraft. Students are assigned to workstations to facilitate the assembly process. Other students are assigned to perform time studies of the workers who are performing direct labor activities.

Initially, there are 12 workstations in the assembly process. The finished airplane consists of three component parts: the fuselage, the wing assembly, and the canopy. The parts are drawn on 8 1/2 x 11 sheets of paper. The parts must be cut out, folded, and then glued together to form the airplane.

Assembly Process

The fuselage is one piece that is cut out and folded on premarked lines and then glued together. Figure 1 illustrates the fuselage part. There are two fuselages per sheet of paper. Workstation 1 cuts out the aircraft fuselage, then passes it to Workstation 2. Workstation 2 folds the fuselage according to the fold lines and then passes it to Workstation 3. Workstation 3 cuts out the cavity for the canopy and then passes it to Workstation 4.

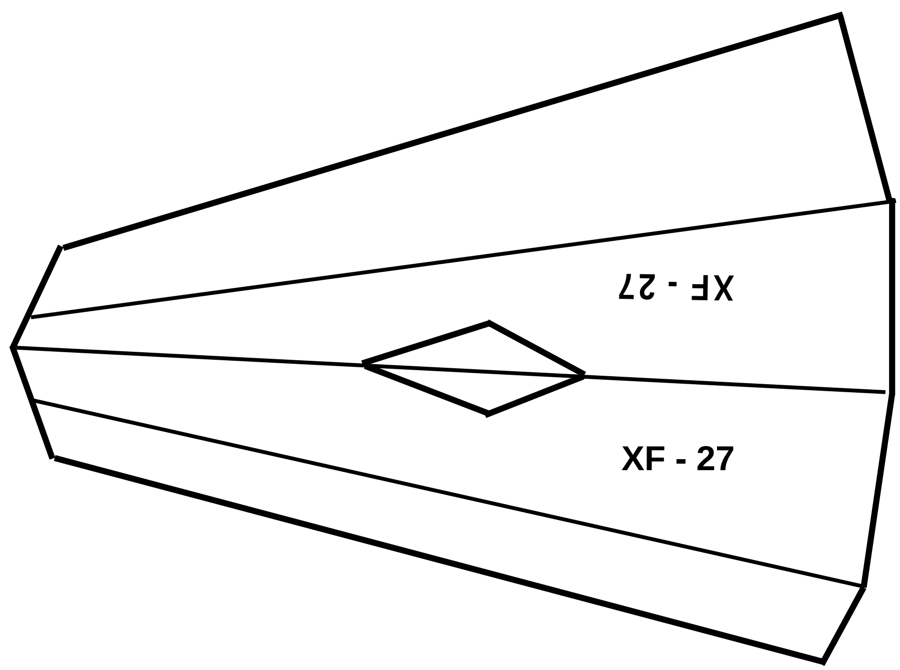

FIGURE 1. Fuselage

The canopy is one piece that is folded over once and glued to the fuselage. Figure 2 illustrates the canopy. Workstation 5 cuts out the canopy and passes it to Workstation 6. Workstation 6 folds the canopy and then passes it to Workstation 4. Workstation 4 assembles the fuselage and canopy and glues them together and then passes them to Workstation 10.

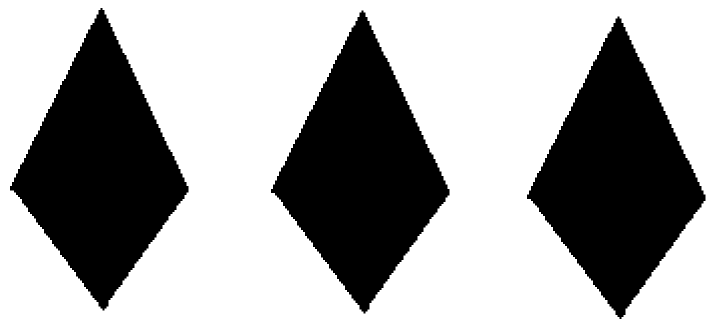

FIGURE 2. Canopy

The wing consists of one piece that is folded over to form the upper and lower components of the wing that are glued together for stability. The wing is illustrated in figure 3. Workstation 7 cuts out the wing and passes it to Workstation 8 who folds the wing and passes it to Workstation 9 to glue the top and bottom of the wing together.

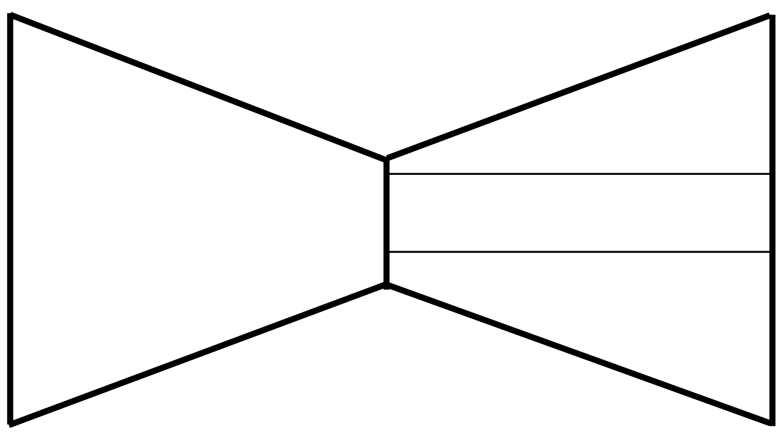

FIGURE 3. Wing

Workstation 9 then passes the wing to Workstation 10 who assembles the fuselage and the wing to form the finished airplane. The assembled airplane then goes to Workstation 11 for final inspection. Workstation 11 has an inspection list of items to be checked such as cutting outside of tolerances, not folding within the tolerances on the fold lines, gluing not properly performed, etc. Defective airplanes are then passed to Workstation 12 to be reworked. Figure 4 shows the workflow for the assembly process.

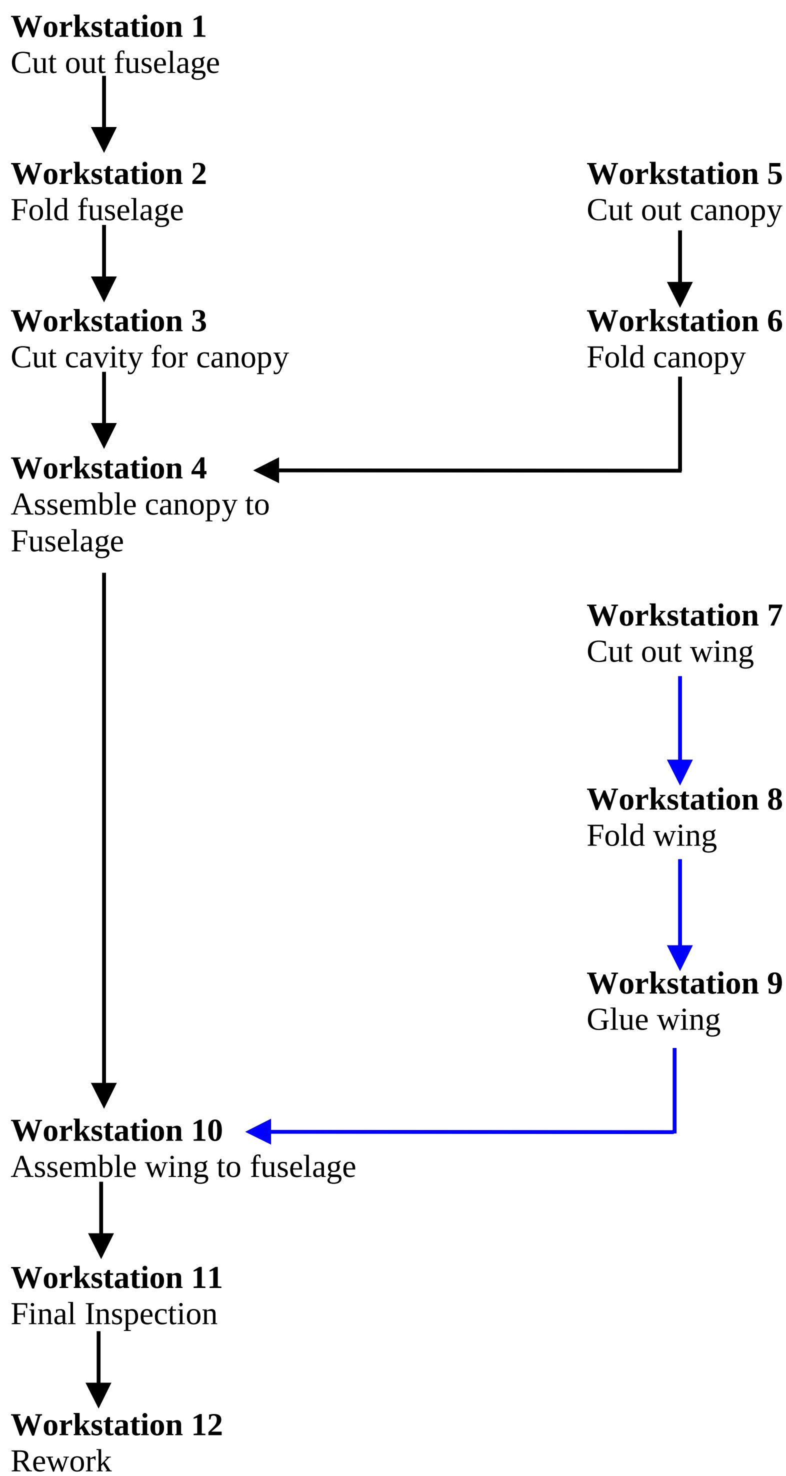

FIGURE 4. Assembly Process Work Flow

Exercise Methodology

The exercise is performed similar to an exercise used by the University of Dayton Center for Competitive Change in their "Hand-on, How-to" training for executives of major corporations[2]. The exercise starts by using a "push" system with a lot size of three. To generate some work-in-process to the start the exercise; each worker initially produces three parts. The plant works 10-minute shifts. When the shift begins the workers cut out parts in lots of three and pass them to the next workstation without regard to whether the workstation needs more parts or not. Each worker produces and forwards to the next workstation as many parts as they can within the 10-minute shift. As a result, some workstations become starved and some become blocked. As the workers are producing the parts, a student with a stopwatch times each operation to determine the cycle time for each workstation. At the end of the shift, data is collected to compute average cycle time per worker, total output of finished airplanes, average output per worker, number of defects, and total work-in-process inventory. The shifts are performed several times to allow for learning curve effects. The lot size is then reduced to two and the exercise is performed for several more shifts and then performed again with lot size of one. The exercise is then repeated using the "pull" system with a lot size of one. After each shift certain data are collected. Cycle times for each workstation are displayed in a bar chart similar to Figure 5. Only Workstations 4-9 are shown in Figure 5, although all workstations are shown on the blackboard during the exercise.

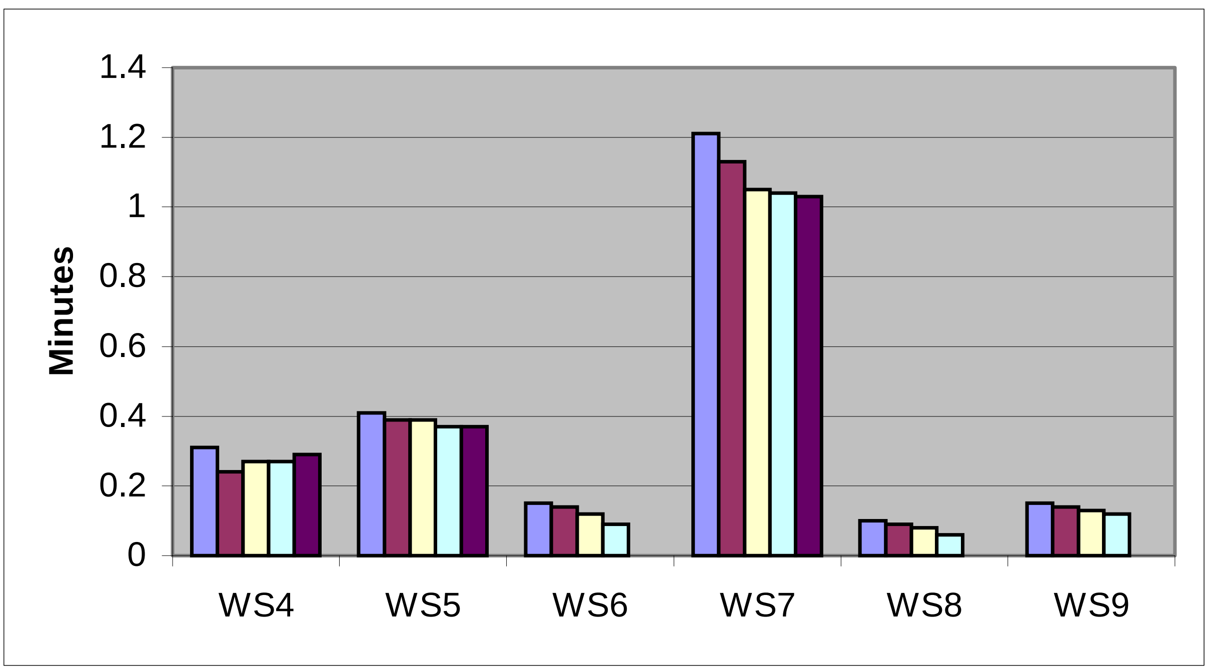

FIGURE 5. Cycle Time/Worker

No attempt had been made to balance the assembly line until after the first cycle of using the pull system. At this time students were asked how could the assembly line process be improved. The students identified the obvious constraint as Workstation 7, cutting out the wings. They suggested combining Workstation 6 with Workstation 4, combining Workstation 8 with

Workstation 9 and having workers from Workstations 6 and 8 help Workstation 7 cut out the wings. This produced a dramatic increase in throughput since Workstation 10 had been held up waiting for wings to assemble to the fuselage.

A discussion of Takt time was initiated at the conclusion of the exercise. Takt time is the amount of time it take to produce one item, that is, the time it takes between successive units of output from a process[3]. Another definition is the flow rate as set by the customer, which is expressed in terms of the time between the production of each unit as set by sales, or expressed in JIT terms, how hard the customer is pulling[4]. If additional class time was available, a Takt time expressing the customers' demand for the aircraft could have been established and the students could have continued to make changes to the process to try to get the workers cycle times to approximate the Takt time and also to eliminate unnecessary workers.

Student Suggestions for Improvement of the Exercise

At the conclusion of the exercise students were asked to write a report summarizing the exercise, assessing what could have been done differently, and how did the exercise increase their understanding of the various concepts explored in the exercise. All students said that the exercise increased their understanding of the concepts, even those who had some previous exposure through other courses or work experience. Students' suggestions for improvement were summarized and discussed in a later class. Some of the suggestions follow:

1. Incorporate a schedule from customers to "pull" the airplane off the production line.
2. Have a water spider to transport the parts from one Workstation to another. This comment was because initially the worker cutting out the canopy had to walk about ten feet to deliver canopies to the worker assembling canopies to the fuselage. This was one of the suggestions that was incorporated when the work was redistributed.
3. Balance the push to compare balanced push to balanced pull. Had this been done, it would have more effectively shown the difference between the push and pull systems. There was not enough time allowed to do this, but this will be done for future semesters.
4. Continuously balance the pull system to see how efficient the system could become. Again, there was not enough time to do this but will be done to some extent the next time.
5. Consider switching employees around - some people may be better suited for another job.
6. Better "tools." The cheap scissors that are used by small children were given to the students to emphasize the importance of ergonomics and having the right tools.

CONCLUSION

Experiential exercises aid students in understanding production control concepts and should be incorporated when feasible. All students expressed an increased understanding of production control concepts as a result of the hands-on simulation exercise. Students suggested several ways that the exercise could be improved. Three class hours were used for this exercise. Six class hours would allow more time to properly explore the concepts and compare the push and pull systems.

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BIOGRAPHICAL INFORMATION

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Charlie P. Edmonson is an Associate Professor and Program Coordinator of Industrial Engineering Technology at the University of Dayton. Prior to joining the faculty at UD, he retired from the U.S. Air Force civil service after 30 years engineering and management experience.