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TRW/TED ACCELEROMETER WAFER PROCESS PRODUCTION FACILITY: MANUFACTURING SIMULATION

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ABSTRACT

Simulation is a cost affective way to analyze and make improvements to dynamic complex manufacturing systems, such as semi conductor processing. The TRW/TED Accelerometer Wafer Process Production Facility is a semi conductor processing facility which makes automotive air bag sensors. A manufacturing simulation of the facility was developed to determine what changes could be made to the facility and/or personnel to maximize production of the sensor chips. A simulation model of the existing facility was developed and validated. Eight experiment models were built. The models included adding: lot starts, a second shift, personnel to the first shift, equipment, personnel and equipment, personnel and a second shift, changing process times, and eliminating process steps. Throughput was chosen as the performance criteria to determine the alternatives effectiveness.

The model for the existing conditions indicated a production throughput of 825,552 chips per year. Experiment model which added personnel and a second shift produced the greatest increase in throughput, 2,555,280 chips per year. This is an increase of 210% over the existing conditions. The conclusion is to add personnel to the first shift and add a second shift.

The conclusion was based on operational, technical and physical data, it did not take into consideration financial objectives. Using cost information in the analysis will give a more accurate solution.

1 MANUFACTURING SIMULATION

1.1 Why Simulation Is Needed In Manufacturing

Three key words indicate why simulation is an essential tool when attempting to analyze and improve a manufacturing system: complexity, uncertainty and cost.

Suppose we wish to determine the production capacity of a factory. The factory is defined as follows: produces a single product, has a straight line product flow, no machine breakdowns, no product rework, no operator interface, and no variation in process times. Using this definition a mathematical formula or spreadsheet program can be used to determine production capacity. Now suppose we want to add a second product to the factory leaving all other assumptions the same. We could use linear programming to optimize the production capacity of the factory. These models are static (not influenced by time) and deterministic (contains no random variables) mathematical models.

The problem with this scenario is most manufacturing systems are dynamic and stochastic in nature. Gogg and Mott (1992) state, "A dynamic system implies action. Factors which influence a system can change as time progresses (a manufacturing system is subject to part scheduling changes, equipment breakdowns, part defects, etc.). Stochastic suggests that these changes can vary indiscriminately."

Simulation models are excellent imitators of dynamic/stochastic systems because they are able to account for the affects of changes occurring within a system. They can analyze complex systems with nonlinear product flows and operator interface with machines. They can account for uncertainty by handling product rework, machine breakdowns, and variable process times.

Organizations must be able to react quickly to changes from the market place, changes in technology, and changes on the factory floor. Using a validated simulation model, developed with the proper software, a company can make decisions on the computer before implementing them on the factory floor. This is a very cost effective way of determining a course of action.

1.2 Simulation Software

There are numerous simulation software packages currently available. In choosing a package the user should look for three characteristics: speed, flexibility and animation. Taylor II software was chosen because it excels in all three characteristics.

Speed: Taylor II uses an optimized simulation algorithm that guarantees fast simulation runs. Simulations can be run for a fixed time or until a certain condition is reached.

Flexibility: Taylor II is a menu driven package that allows the user to graphically build models by positioning resources like machines, buffers, conveyors, reservoirs, warehouses, transports and labor on the screen. Details are added to the model by using pre defined parameters, distributions and Taylor interface language. Information on model runs is collected through several pre defined reports or through user created reports.

Animation: Animation servers two purposes: model verification (does the model behave as intended?) and presentation of the model and results. Because the animation is integrated into Taylor II and can be used instantly, it will verify (or refute) the model immediately.

Taylor II's combination of these three characteristics gives the experienced simulation user the flexibility and performance to model the most complex systems and present the results in a timely manner with as much detail as the project requires.

2 ACCELEROMETER FACILITY MODEL

2.1 Problem Definition

The production of the air bag sensors (semi conductor chips) developed by the accelerometer facility has been a success. Requests for the sensor by the automotive industry is increasing. To determine if these requests can be met, the maximum capacity of the facility must be established.

There area four methods of maximizing the capacity of the existing facility: add employees, add process equipment, add employees and process equipment, and change or eliminate process steps.

Changing the physical layout will not be considered since the original layout was developed taking into consideration process flow, cleanliness requirements, and air flow dynamics of the clean rooms.

Adding employees is restricted floor space in the clean rooms, the skill level required to operate the equipment, and machine cycle times. The machine cycle times prevent an employee from being assigned to only one machine or work station.

Equipment should be added at the bottleneck points. These points were determined through interviews with the accelerometer personnel and by observation. The bottlenecks occur at the Ultratech 1000 and the Dektak in lithography and the VWR ovens in metals.

Through experiments being conducted the accelerometer personnel feel the process can be changed as follows: the process time for the VWR oven can be reduced, the process time for the Dektak can be reduced, and the process steps for the sensor stops can be eliminated. With more experience and training the set up times for the Ultratech 1000 and the Dektak can be reduced.

2.2 Simulation Goal

Determine the maximum output of accelerometer parts (chips) from the TED Accelerometer Wafer Processing Facility at Space Park in Redondo Beach.

2.3 Criteria

This is the performance index of how the alternative's effectiveness will be evaluated. The performance criteria will be throughput (number of wafers processed per week).

2.4 Assumptions

1. The set up and process time values supplied by the accelerometer facility personnel accurately describe the operation of the facility.
2. One shift is 8 hours.
3. Each employee is considered proficient at operating all equipment in their area.
4. No personal fatigue or delays are considered for the employees.
5. There are 12 wafers in each lot, 2,100 chips on each wafer.
6. There is no scrap.
7. The equipment breakdown (MTBF) and repair time (MTTR) will use the Weibull distribution. Times are estimated by accelerometer facility personnel.
8. There is no starting WIP.

2.5 Input Parameters.

1. Quantity of equipment.
2. Quantity of labor.
3. Machine cycle times (with distributions).
4. Machine set up times.
5. Machine breakdown and repair times (with distributions).

2.6 Model Descriptions

Model 0 - Existing conditions: 12 lots in the system, one shift, two employees in lithography, two employees in metal, one employee in final assembly.

Model 1 - Increase lot starts from 12 to 16. All other conditions remain the same.

Model 2 - Add a second shift. Duplicate the first shift conditions.

Model 3 - Add a third employee to the lithography area and a third employee to the metal area. Assume the added employees have the same skill levels and are proficient at operating equipment as the existing employees. All other conditions remain the same.

Model 4 - Add one Ultratech 1000, one Dektak, and one VWR oven. All other conditions remain the same.

Model 5 - Combine models 3 and 4.

Model 6 - Combine models 2 and 3.

Model 7 - Change the process time for the VWR oven from 65 hours to 8 hours. Change the set up time for the Ultratech 1000 from 30 minutes to 15 minutes. Change the Dektak set up time from 10 minutes to 0 minutes and the run time from 68 minutes to 30 minutes. All other conditions remain the same.

Model 8 - Remove the process step for the sensor stops. All other conditions remain the same.

"Multiple model replications are always required when stochastic are involved. A general rule of thumb is to always perform at least three to five replications for each experiment." (Gogg & Mott 1992) Four simulation runs of 2000 hours each were performed for each experiment.

2.7 Results

The results of the simulation runs are ranked in descending order based on throughput.

Table 1: Wafer and Chips Throughput

Model	Ave. Wafer/Week	Ave. Chips/Year
6	23.40	2,555,280
2	15.96	1,742,832
8	12.18	1,330,056
5	9.90	1,081,080
3	9.87	1,077,804
7	9.60	1,048,320
4	8.34	910,728
1	8.02	875,784
0	7.56	825,552

2.8 Analysis

When stochastic are used statistical analysis should be performed to determine if there is a difference in the means of the simulation results. Comparisons will be made between models where the mean values in the results are "close" to each other. As an example, the average difference between model 2 and model 3 is approximately 6 wafers per week. These models will not be compared because from observation there is a significant difference between the two means. Statistical analysis is not required to conclude that model 2's throughput is superior to model 3's throughput.

A paired-t test will be used to compare close alternatives. The paired-t test uses the statistic for small sample test concerning mean, the one-sample t-test. The mean and standard deviation used in the calculations are found by using the difference between the two means being tested. The t value calculated is used to test the hypothesis that the two means are equal. The confidence level is 90%. The test requires the number of model replications performed for each alternative be equal. Common random number streams must be used with model replications.

If $t>2.353$, there is a statistical difference between the means and the model with the larger mean is superior. If $t<2.353$, there is no statistical difference between the means and one model is not superior to the other.

Comparisons will be made between: (1) model 0 and model 1, (2) model 0 and model 4, (3) model 3 and model 4, (4) model 3 and model 5, (5) model 3 and model 7, (6) model 4 and Model 5, (7) Model 4 and Model 7, (8) model 5 and model 7.

Table 2: t Value Comparison

Comparison	t value	Choice
1) model 0 and model 1	1.0395	none
2) model 0 and model 4	3.8060	model 4
3) model 3 and model 4	7.0952	model 3
4) model 3 and model 5	0.1901	none
5) model 3 and model 7	2.1828	none
6) model 4 and model 5	10.069	model 5
7) model 4 and model 7	8.3446	model 7
8) model 5 and model 7	5.0000	model 5

2.9 Conclusions

Simulation is intended to provide a reasonable estimate of the systems behavior. There are hundreds of scenarios (experiments) which can be simulated using the model. The scenarios chosen were determined by estimating which conditions could most likely be changed.

The goal of the simulation study was to determine the maximum output of accelerometer parts from the facility. The models are listed in order, from most desirable to least desirable, based on the selected performance criteria. (1) model 6, (2) model 2, (3) model 8, (4) model 5 or model 3, (5) model 3 or model 7, (6) model 4, (7) model 1.

The to maximize production based on throughput one employee should be added to both lithography and metals and a second shift should be added.

A test model with two employees added to both lithography and metal was run. The additional employees did not add to the throughput of the facility due to the dynamics of the product, equipment, and employees.

3 RECOMMENDATIONS

3.1 Financial Considerations

This simulation project used operational, technical and physical data. The conclusions were based on this data and did not take into consideration financial objectives. Therefore, it is important that potential solutions be evaluated using financial data. It is necessary to determine what financial data should be included in the simulation analysis. Generally, manufacturing simulations will impact operational costs (direct material, direct labor, and overhead). However, they may also impact general and administrative costs, capital costs, and depreciation.

An important objective for any organization is to reduce wait time and inventory carrying costs. Wait time is non-value added time and can dramatically add to the cost of production. Carrying costs have traditionally been hidden costs and are usually not included in the production decision making process. Simulation is the most effective tool for measuring and substantially reducing wait times and carrying costs.

Gogg & Mott (1992) state that costs can be integrated with simulation projects in three ways: full integration, partial integration, and external integration. Full integration requires all cost information be processed within the simulation. No additional data processing is required to obtain the cost results used for analysis and determining a course of action. Partial integration means some cost information is processed within the simulation. Other costs are processed externally and the results are added to the simulation cost results for analysis and action. External integration means all cost information is processed outside the simulation. The cost information is integrated with the simulation results for analysis and course of action.

Taylor II software is capable of allowing full integration of cost data by using fixed, variable and interest cost parameters for all elements in the model. Fixed costs represent the amount of money per time interval. The fixed costs are always counted, whether a machine is busy or not. A negative value can be entered to accumulate depreciation costs. Variable costs represent the amount of money per busy time interval. The variable costs are only counted over the period of time the element was busy. This can be utility costs and consumable material costs. Interest cost values represent an amount of money per time interval per product. The more products in the system and the longer they are stored, the higher the total interest cost. This parameter is used to accumulate wait time and carrying costs.

Since Taylor II software is able to perform full integration of costs, it is recommended that cost information be accumulated and added to the simulation models. The models should be run again and the results analyzed using throughput and cost data. This analysis will give a more accurate and complete solution of the problem of maximizing throughput by keeping the costs at a minimum. It will be counter productive to increase the throughput of the facility if the cost per part produced is increased in the process.

3.2 Increase Model Accuracy

In addition to output analysis, design of experiment and equipment justification analysis; the accelerometer facility model can be used for process control, shop scheduling, raw material scheduling and product cost analysis. If the model is to be used for additional analysis it is recommended that more accurate empirical data be gathered.

Two sets of data must be collected: employee data and machine data. Employee data consist of machine set up times and employee process times (attended machine cycle times). This data can be collected manually or semi-automatically. Machine data consists of machine process time (unattended machine cycle times), mean time between failure (MTBF) and mean time to repair (MTTR) or "down time". This data can be collected manually, semi-automatically or automatically. The cost and accuracy of data collection increases moving from manual to automatic.

Manual data collection is accomplished by using log sheets. The operator uses a watch and enters start and stop times on the log sheet for employee data and machine data. The problem with this form of data collection is reduced accuracy. The operator may be too busy to enter the time on the log sheet when the operation is finished or, in the case of an unattended machine, the operator may not be present when the machine cycle is finished. In these cases, a guess is made for the stop time. The MTBF is usually an estimate (if any information is recorded at all). The MTTR is usually recorded in a log. The majority of the information supplied by the accelerometer personnel was from log sheets.

Semi-automatic data collection can be accomplished using bar code readers to record employee data and machine data. The operator does not require a watch or writing instruments to record stop and start times. The start and stop times are recorded by using a bar code reader which uses the computers internal clock to record the time values. The MTBF must still be estimated.

Automatic data collection is used for machine data only. This is accomplished by using direct connection of the equipment to a computer. Many pieces of semiconductor process equipment have some form of computer connection (usually RS232). An interface program must be written to collect the information supplied by the equipment. If no computer connection is available, data collection devices can be retrofitted to the equipment. However, the expense for hardware and software development may be high.

3.3 Irwindale Facility

The simulation project evaluated the manufacturing process through the facility at Space Park. The simulation should include the process of component placement, bonding, final packaging and final inspection performed at TRW Irwindale. Incorporating the Irwindale operation into this model would allow an analysis of the total process for producing the air bag sensor device. It is recommended data be collected from the Irwindale facility and added to the current manufacturing simulation.

4 UPDATE

The model and original report were completed in the third quarter of 1994. The model is currently being used to make production related decisions as described in the first paragraph of section 3.2.

A bar code data gathering system and automatic data collection from process equipment have been implemented. The accelerometer management have indicated they will continue to modify and update the model as conditions change in the facility. The model will be used as a tool to help make production related decisions.

REFERENCES

Gogg, Thomas J. and Jack R.A. Mott. 1992. Improve Quality and Productivity with Simulation. Library of Congress Catalog Card Number:92-85591. ISBN 1-882229-0307.

AUTHOR BIOGRAPHY

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