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A SIMULATION CASE STUDY OF PRODUCTION PLANNING AND CONTROL IN PRINTED WIRING BOARD MANUFACTURING

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ABSTRACT

Production planning and control in printed wiring board (PWB) manufacturing is becoming more difficult as PWB's technology is developing and the production routings become more complex. Simultaneously, the strategic importance of delivery accuracy, short delivery times, and production flexibility is increasing with the highly fluctuating demand and short product life cycles of end products. New principles, that minimize throughput time while guaranteeing excellent customer service and adequate capacity utilization, are needed for production planning and control. Simulation is needed in order to develop the new principles and test their superiority. This paper presents an ongoing simulation project that aims at developing the production planning and control of a PWB manufacturer. In the project, a discrete event simulation model is built of a pilot case factory. The model is used for comparing the effect of scheduling, queuing rules, buffer policies, and lot sizes on customer service and cost efficiency.

1 INTRODUCTION

Printed wiring boards (PWB), also called printed circuit boards (PCB), are an essential part of virtually all electronic devices. They work as a physical base on which electronic components are attached and they provide the electrical interconnection between the components. A picture of a PWB can be seen in Figure 1.

As PWB's have an important effect on the size, cost, and performance of electronic products, there is strong and rapid development going on in PWB technology. This is reflected as changes and challenges in the manufacturing process.

PWB's are nearly always product specific. This means that the same PWB can not be used for different products or even different versions of the same product. Therefore, as the final electronic products' life cycles are getting shorter, also the life cycles of PWB's are getting shorter. Some consequences of this are that: a larger part of orders are orders of new products, it is more difficult to forecast demand, and risk of obsolete stock grows. Factories need to adjust to rapid changes in both the amount of orders and the type of products ordered. Production lead times must be reduced in order to achieve this kind of flexibility.

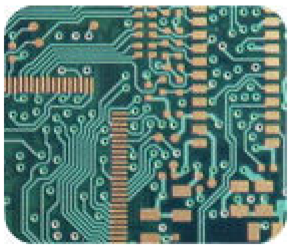

Figure 1: Printed Wiring Board

At the moment lead times in PWB manufacturing are long all over the world, typically several weeks depending on the type of PWB in question. There is a strong drive to shorten the lead times. In a roadmap study that's been made on microelectronics packaging and assembly industry for Hong Kong and the Pearl River Delta region (EPA Centre 2000), the goal for PWB delivery time for mass production in year 2000 was 3-4 weeks. The corresponding goal for year 2001 was 2-3 weeks and for year 2002 it was 2 weeks. The roadmap of Japan Printed Circuit Association (1998) expected the circuit board manufacturing lead times to fall from 12-40 days to 4-25 days between 1997 and 2002.

Even though reducing lead times is clearly important for the PWB industry, only little is written about how to reach this goal. In comparison, there is a vast amount of studies on how to reduce lead times in the PWB assembly process, where components are mounted on PWB's.

2 OBJECTIVES

TAI Research Centre has started a simulation study that aims at developing the production planning and control of PWB's in a case company in order to achieve better customer satisfaction and cost efficiency. Especially reduction of lead times is seen as a potential development target that would lead to these goals.

The case company has several PWB factories around the world. A pilot factory has been chosen for the simulation study. If the project is successful, resulting methods can be implemented in the other factories as well.

The primary method of attaining project goals is development of production planning and control principles. Others, like changes in capacity or lay-out, come secondary to this. This stems from several reasons. First there is a strong belief that the planning and control methods have great improvement potential. Secondly, if the ground of production planning and control isn't laid properly, adding capacity only moves the problems to some other place. Thirdly, planning and control principles can be transferred to other factories.

As customer service level and cost efficiency are partly contradictory goals in the short time frame, it is difficult to set strict numerical objectives for them. Optimizing one easily compromises the other. There are no perfect methods for production planning and control. Each method is always a compromise that sets different values to different goals. Therefore the simulation project must aim at presenting the results in a way that gives the case company a better insight of the pros and cons of the principles under consideration. This way the case company can make its own judgements of the merits of each method.

The main measures used for judging are lead time, delivery time, delivery accuracy, output, and capacity utilization. At the moment lead time is seen as the most important one of them. This is because shorter lead times can have several direct and indirect favorable implications for both customer satisfaction and cost efficiency. The goal for lead time has been set to 1 to 2 weeks compared to the present 4 to 5 weeks.

The case company has traditionally tried to optimize capacity utilization. This is because the PWB industry has been seen as capacity intensive and the customers' main buying criteria has been cost. There is a change of attitudes as the strategic importance of flexibility is growing. The level of final demand of electronic products is unstable and difficult to forecast. Also the type of products needed changes unpredictably. The level and type of demand has great influence on both the overall level of capacity usage and the spread of capacity usage in the different phases of production.

3 THE MANUFACTURING PROCESS

The PWB's manufactured in the case factory are rigid multilayer boards. The number of layers differs in different products. Each layer has a unique wiring design. The layers of wiring are separated from each other by nonconductive substrate. In the "normal" plated-through-hole (PTH) boards there are copper-plated holes that go through all the layers and connect them. In 'blind' boards some of the holes don't go all the way through the board. They connect only part of the layers. The two types of holes can be seen in Figure 2.

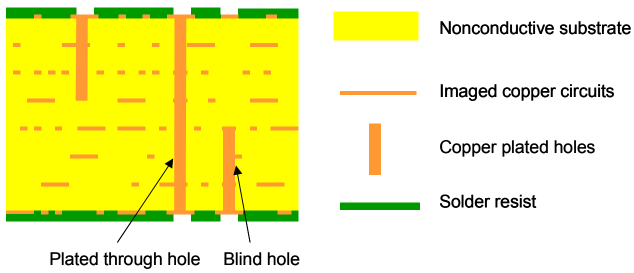

Figure 2: Cross Section of a Printed Wiring Board with PTH Holes and Blind Holes

A simplified description of the manufacturing process is shown in Figure 3. Each inner layer is made by transferring a circuit image to a copper-coated base laminate and removing excess copper in an etching process. When making normal PTH-boards, different inner layers and copper foil for outer layers are compressed together under heat and pressure. Then connections are made between the layers by drilling holes into the board and by growing a layer of copper into the sides of the holes. Then a circuit image is transferred to the outer layers and excess copper is removed. Finally the board is given a solder resist, the connection surfaces are finished and the board is cut to its final shape.

When making blind boards one first compresses together and drills those layers through which the blind holes go. After this one compresses together all the layers, makes the PTH-holes and continues the manufacturing process as for normal PTH-boards.

In practice there is a vast amount of different product routings in the factory. They change often as the production processes are improved. 8 most common and representative routings are included in the simulation model.

The number of layers and whether the board is a blind board or a normal PTH-board are the two main parameters that define how capacity usage is proportioned in different phases of production. The more there are layers in a PWB, the more capacity is needed in the very first phases of production that come before pressing. Blind boards make loops and therefore need proportionately more capacity in these phases. Other variables that have an effect on capacity usage are e.g., type of surface finish, number of holes, level of difficulty of the circuit image, copper thickness, and size of the panel.

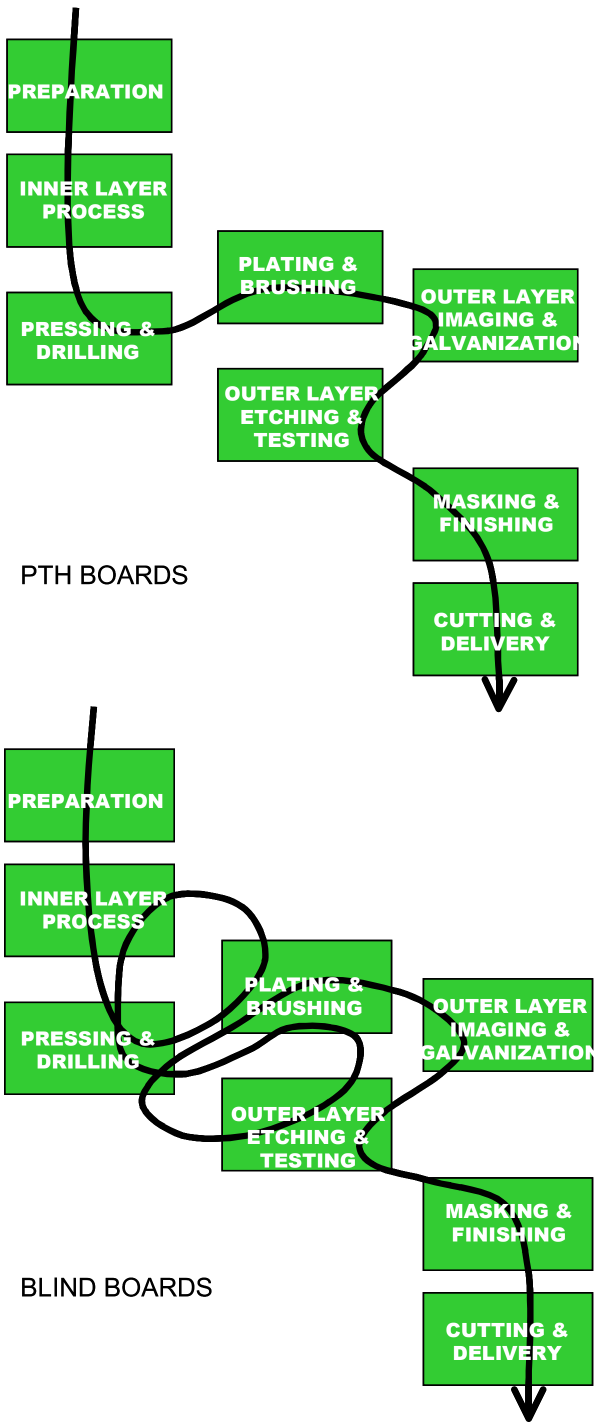

Figure 3: The Manufacturing Process

A feature particular for PWB manufacturing is that the final product is fixed in the very beginning of the production process. A product specific circuit image is transferred permanently to the board in the first stages of production. Once processing has started the product can not be changed.

4 PRODUCTION PLANNING AND CONTROL

Presently the case factory starts production of normal PTH-boards 4 weeks before the planned completion date and production of blind boards 5 weeks before the planned completion date. In case of low demand orders are started earlier. The time span is divided evenly to the different phases of production.

Each lot is given a priority between 1 and 5. Top priority is given to express deliveries, which have a higher margin than normal deliveries. Second priority is given to additional lots that replace scrapped production. Normal orders start with the lowest priority and their priority is raised if they seem to be very late. The more the customer needs the boards, the higher the priority is raised.

The instructions concerning queuing rules are partly contradictory. The main rule is that the lot that has the highest priority and the earliest due date within that priority should be started first. Workers are also told that they should start lots in a sequence that maximizes capacity usage. Also there is a rule that each lot of blind boards should progress a certain amount of process steps every day.

The exact principles for production planning and control used in PWB manufacturing differ in each company and each factory. However, to our knowledge the basic ideas behind the planning and control are quite similar in companies where similar types of PWB's are produced. Also, it seems that the outcome in the case factory represents the normal industry level.

The basic control problem in the case factory is that the capacity need in different phases of production changes abruptly as demand fluctuates. The operators try to solve the problem by maximizing capacity in all production phases by shuffling the queue in order to minimize setups. Lot size is kept rather large for the same reason. Shuffling causes variation in queuing times to grow and therefore throughput times grow. Prioritizing is used amply for late jobs. The effect is that lots progress through production quite randomly and lead times are long. There is a large amount of work in process and the need for capacity fluctuates a lot.

Ideally, the planning and control method should level the need for capacity in a way that allows for quick and predictable completion of each work phase and simultaneously results in adequate capacity utilization. The case company has developed buffering, ordering, and forecasting methods together with its customers in order to level demand. However, the demand for electronic products is highly variable and difficult to forecast and therefore also buffering is risky.

5 EXPECTED RESULTS

In order to reach the goals set for the project, production should be made more predictable at the case factory. The proposed remedies are:

- After the initial queue arrangement in the beginning of production, the queue order should only be reorganized in one well thought control point. In other places prioritizing or shuffling orders should be avoided.
- Stock should be used in order to level capacity need and provide fast service. Instead of the current practice of having lots of work in process everywhere in production, stock should be kept as final stock or as buffer stock of half-made products just before the queue reorganizing point.
- Smaller batches or transfer batches should be used in order to level capacity need. Small transfer batches also allow concurrent processing and therefore shorten throughput time.

Even though there is a general consensus of the above points within the project group, the details are not as clear to anyone. The main expected results of the simulation study are comparisons of more precise solution suggestions. The simulation model will be used for answering questions like:

- Which one of the alternative points should be chosen as the queue reorganizing point?
- How well do the alternative scheduling and queuing logics work in this case?
- What is the effect of the proposed stock policies on production?
- What is the effect of smaller batch sizes or transfer batches and how small can the batches be?

In addition to helping make the solution proposal more precise, the simulation study is expected to answer the overall question of whether the proposed solution works and whether something else is needed in addition. The factory has a long history and there are reasons for the way things are being done. Were the solution self-evident, it would have been implemented already.

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