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PROCESS DESCRIPTION AND PERFORMANCE EVALUATION OF AN AUTOMATION LINE

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AUTOMAATIOLINJAN PROSESSIKUVAUS JA SUORITUSKYVYN ENNAKOINTI

Opinnäytetyön tarkoituksena oli tuottaa prosessikuvaus Cencorp Automation Oy:n suunnittelemasta ja valmistamasta tuotannon testauslinjaston toiminnasta. Aihe on tärkeä muuttuvien volyymien ja sitä kautta tehokkuuden parantamisen kannalta. Työ on ajankohtainen, sillä kyseisen linjaston on määrä olla asiakkaalla kesän aikana.

Linjasto koostuu kolmesta solusta. Työssä esitellään jokainen linjastossa oleva yksikkö/solu erikseen sekä kyseisen solun kuormitus ja volyymit. Testilinjan aikamuuttujat ovat keskeisessä asemassa solujen tarkastelussa.

Tavoitteena oli perehtyä linjastolla testattavan tuotteen läpimenoaikaan ja tahtiaikaan sekä ko. aikojen optimointiin olemassa olevaan dokumentointiin ja laskelmiin perustuen. Sekä linjastolla mahdollisesti muodostuviin pullonkauloihin, kun asetetaan tavoitteeksi tietty määrä kappaleita/ennalta määritelty aika.

ASIASANAT:

Tahtiaika, jaksonaika, läpimenoaika, pullonkaula, linjan tasapainotus

BACHELOR´S THESIS | ABSTRACT

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PROCESS DESCRIPTION AND PERFORMANCE EVALUATION OF AN AUTOMATION LINE

The purpose of this thesis was to produce a process description of the function of a test line that is designed and maintained by Cencorp Automation Oy. It is important subject because of changing volumes and thus from point of view efficiency improvement.

The test line consists of three cells. They are all introduced in this study separately and also the load and volumes of each cell. The test line variables play an important role in the cell review.

The aim was to get familiar with the throughput time and the takt time of the product being tested as well as time optimization and the calculations based on the existing documentation. The bottlenecks that may be formed at the line when setting a certain number of tracks / predetermined time were also examined.

KEYWORDS:

Takt time, cycle time, throughput time, bottleneck, line balancing

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FORMULAS

FIGURES

ABBREVIATIONS

BR	Bottom Router
CIS	Cencorp Intelligence System
Cycle Time	The period required to complete one cycle of an operation
Golden sample	Approved product samples that help minimize product defects
PWB	Printed Wiring Board
PCB	Printed Circuit Board
RFID tag	Radio Frequency Identification label
Takt Time	Adjustable time unit used in lean production to synchronize the rate of production with the rate of demand

1 INTRODUCTION

Production capacity is one important aspect in production system. The capacity has to match in demand that has made. If demand is higher than capacity, to supply for the customer is not possible. On the other hand, if capacity is higher than the demand, then production will have many idle workers and machines, which is not good either. The name is a bit of a misnomer, since capacity is the ability to contain things, whereas for a production system the bigger interest is in the number of parts that are completed. In any case, capacity is important. (Christoph Roser 2015a.)

The purpose of this thesis is to produce a process description of the function of a XPRS test line that is designed and maintained by Cencorp Automation Oy. It is important subject because of changing volumes and thus from point of view of efficiency improvement of the test line. Study is well timed because the designed XPRS test line should be on a customer in summer time.

The XPRS test line consists of three cells. The first cell consists of a Bottom Router, which is designed for depaneling printed circuit boards and panels. After depaneling, items are identified and moved to a numbered palette. The palette enters to the next cell, XPRS Tester, to be tested. XPRS Test have various amount of options how testing can be planned. The amount of test units can be customized based on customer needs. The last unit is the Packing cell. There the task is to split the items according to the test cell result (pass/fail) and after that send the blank palette along the return conveyor belt back to the beginning of the line. The entire XPRS test line is always tailored to meet the customer's needs.

The goal is to introduce each cell individually as well as loads and volumes of that cell. The time variables in the XPRS test line plays an important role in the cell review. Those are, for example, the throughput time, takt time and cycle time.

The aim is to get familiar with the throughput time and the takt time per device under test as well as time optimization and calculations based on existing documentation. A bottleneck that may be formed at the line when setting a certain number of tracks / predetermined time are also under study. The bottlenecks are processes that influence the throughput of the entire system. The larger the influence, the more significant the bottleneck.

2 CENCORP AUTOMATION OY

The foundations of Cencorp can be traced back to 1948, when the Finnish company, Evox Ltd was established. In 1978 Colorado Engineering Corporation (Cencorp Inc.) was established in Longmont Denver, USA. The first assembly cell for odd-form components was manufactures in1986. Since 2014, the company has been owned by FTTK Company Limited, a Chinese investment company.

Cencorp Automation is one of the leading process automation solution providers in the world. The product portfolio includes equipment solutions for depaneling, odd-form assembly, test handling, laser marking, laser welding and final assembly to tailor-made solutions substantially improving the productivity and quality of the customers' production. Innovative automation solutions increase customer production process efficiency significantly. Cencorp customers include e.g. the leading companies in car electronics, telecommunications and industrial electronics.

All sites in Cencorp Automation follow the principles of ISO 9001 quality management. Cencorp Automation Finland management system is ISO 9001 certified by DNV GL. It covers all the company processes from sales, design and manufacturing to customer care of production automation and test solutions for the electronics industry. Cencorp Automation Finland management system conforms to the Quality Management System standard ISO 9001:2015. To ensure continuous improvement, the processes are regularly assessed by performing both internal and external audits. Moreover, Customer satisfaction surveys and effective feedback handling processes are used to further develop quality and operations. (Cencorp Automation 2018a.)

3 AUTOMATED XPRS TEST LINE

3.1 Structure of The Automation Line

The XPRS Test line is a fully automated three machine production line (Figure 1). It consists of three operation machines, Bottom router, XPRS Test and Packing. A conveyor belt between the cells and return conveyor belt from Packing cell back to the BR cell provides a transfer system to allow products to move in system. The conveyors also function as a buffer in the system. The product moves from one station to the next and at each station a specific process is performed on it.

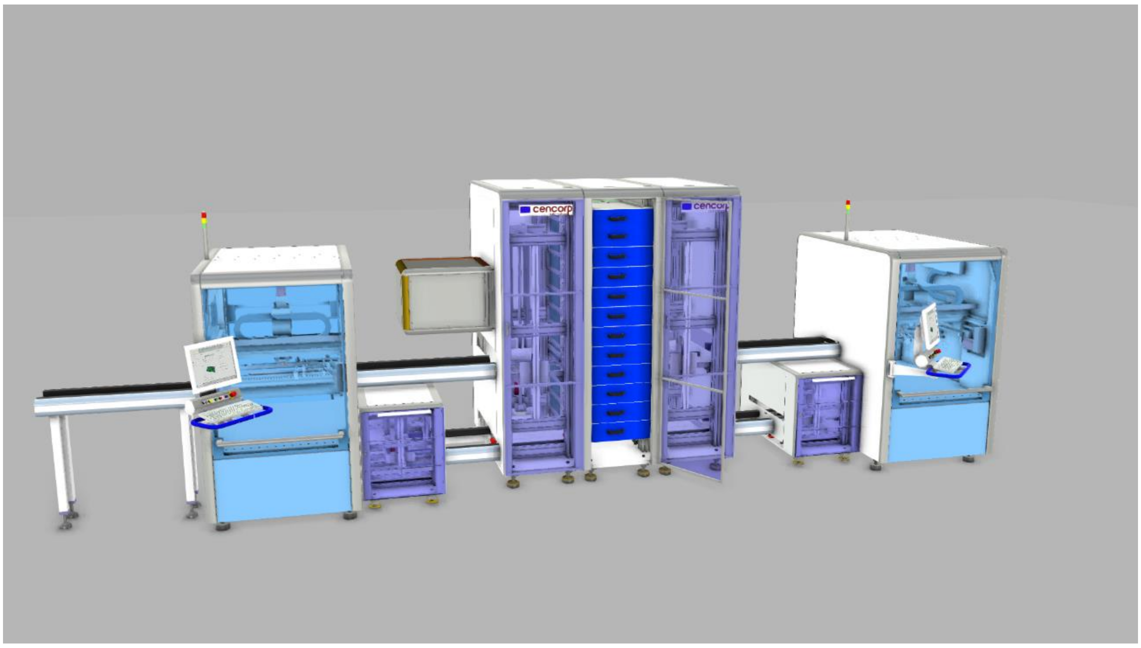

Figure 1. XPRS Test Line (Cencorp Automation 2018a.)

3.1.1 Cencorp 1000 BR EVO

The Cencorp 1000 Bottom Router Evolution is designed for depaneling printed PCB panels. A panel enters the cell along a panel conveyor. The lower robot (router unit) is equipped with a stopper unit which stops the incoming panel. The conveyor is equipped with locking pins and clamps, which lock the panel in its place the time of routing.

The routing unit moves under the conveyor on servo driven X-Y table. The routing unit carries out the depanelling according to a product-specific run program. In addition to the routing unit, the cell is also equipped with a gripping tool installed in the upper robot, which can be used e.g. for taking the routed boards to a pallet. The gripper can be equipped with different gripper fingers, which the cell automatically changes according to the work cycle.

When all the work phases programmed in the run program have been accomplished, the panel frame is released and the conveyor moves it out of the cell. At the same time a new panel is taken in. The barcode reader verifies that the panel that is taken in and the product program loaded in the software are compatible.

The cell may be programmed to carry out prehandling and checking by using different accessories, e.g. tools, manipulators and a Vision System. (Cencorp Automation 2017.)

3.1.2 Customized Router

A 2-Segment base PCB board conveyor with a clamping and PCB board location system, including automatic centring pin adjustment on a fixed conveyor edge. Panel identification is handled with 2D/Barcode reader. The module is routed out from the panel and gripped with gripper fingers. The palette handling conveyor system will be installed partly inside the router. The maximum dimensions of the panel are limited when the palette handler is installed. Palette is aligned and locked to loading position and modules are loaded to palette slots 1-4. Conveyor direction from right to left and Beckhoff industrial PC act as a controller (Figure 2). (Cencorp Automation 2018d.)

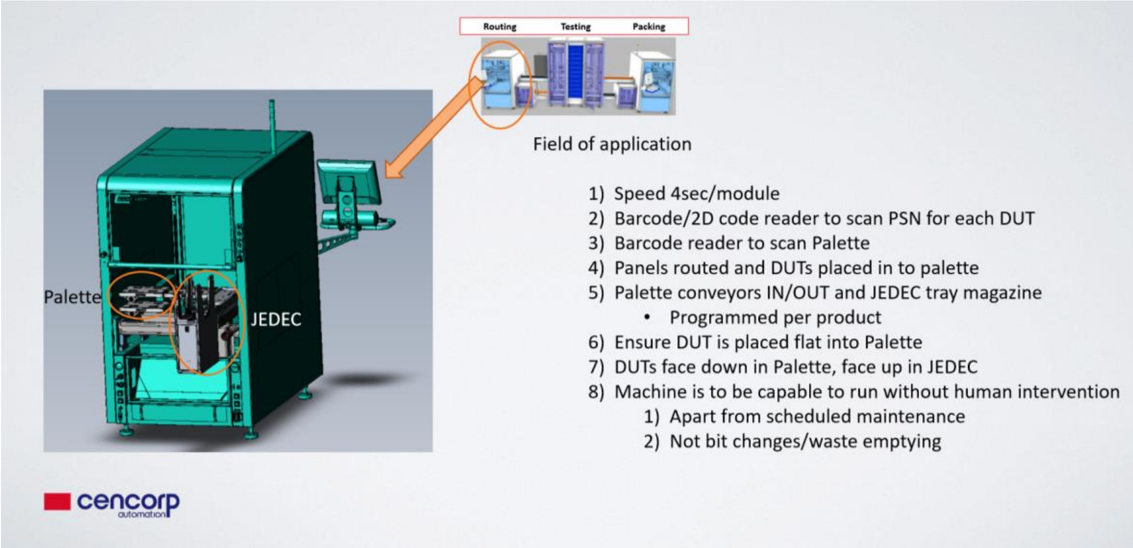

Figure 2. Bottom Router (Cencorp Automation 2018a.)

3.1.3 Cencorp XPRS Test

The XPRS Test is having various amount of options by how customers can plan their process control testing. The XPRS Test can be equipped with one or two lifted units to optimize the use. XPRS Test supports two different test box sizes 145mm and 290mm and can be customized based on customer needs. Test applications can cover from ICT Flash testing to complex RF testing and many other possibilities. XPRS Test has places for 12 pcs of 145 mm test boxes and 6 pcs of 290mm test boxes.

In PWB panel testing the supported panel sizes are from 30mm to 350mm (depth) and 50mm to 400mm (width). Machine support also Carrier Frame Technology which brings new opportunities to testing. One-piece flow with single test at a time can be changed to multi execution testing with parallel handing. Carrier frames are cycled from beginning to the end of testing process. Carrier frame can be equipped with RFID tag to enable multiple different products under test in one production testing line.

Inside one XPRS Test can be multiple different test phases. The machine can be equipped with centre pass through conveyor to enable multiple XPRS Test handlers connected in high volume production lines.

XPRS Test does not need a failed product marking device since it can co-operate with depanelling cell directly.

The XPRS Test has plenty of room for the test instrumentation. No separated test rack is required. All are integrated inside the machine. The XPRS Test has temperature controlled environment for the test instrumentation. (Cencorp Automation. 2018b.)

3.1.4 Customized Tester

The Cencorp XPRS Tester cell enables automated parallel testing of a variety of products. The XPRS Tester cell can be used as a standalone with manual feeding or as an inline cell in the factory production line. The cell is setup for the product before testing. The required actions are product program loading and conveyor width adjustment according to PCB or pallet width (Figure 3).

A PCB or the pallet with products arrives along a conveyor and stops before the tester cell. The pallet has a barcode and the products has QR codes which are read by the system. The cell identifies the pallet and takes it into the cell along a conveyor into the lifter conveyor. Lifter transfers the pallet to the correct test box according to read code. Standard platform includes 12 slots for 145mm test boxes. Testing is done in the current test box and the CIS (Cencorp Intelligent System) got the specific information of tested products.

All test boxes are individual testers and works parallel with all test boxes. The major benefit of the XPRS Tester is that it enables parallel testing in a multiple piece flow process. The XPRS Tester takes simultaneously new products in when the other test boxes are testing products.

The tester is equipped with an extra lifter unit, return conveyor for empty pallets and with a pallet magazine for golden sample.

After the test has been done in the test box, the conveyor can release the pallet to the extra lifter and the pallet is transferred further eg. to the Cencorp Packing cell where the pallet is emptied automatically and then returned with the Tester return conveyor back to the loading place. (Cencorp Automation. 2018c.)

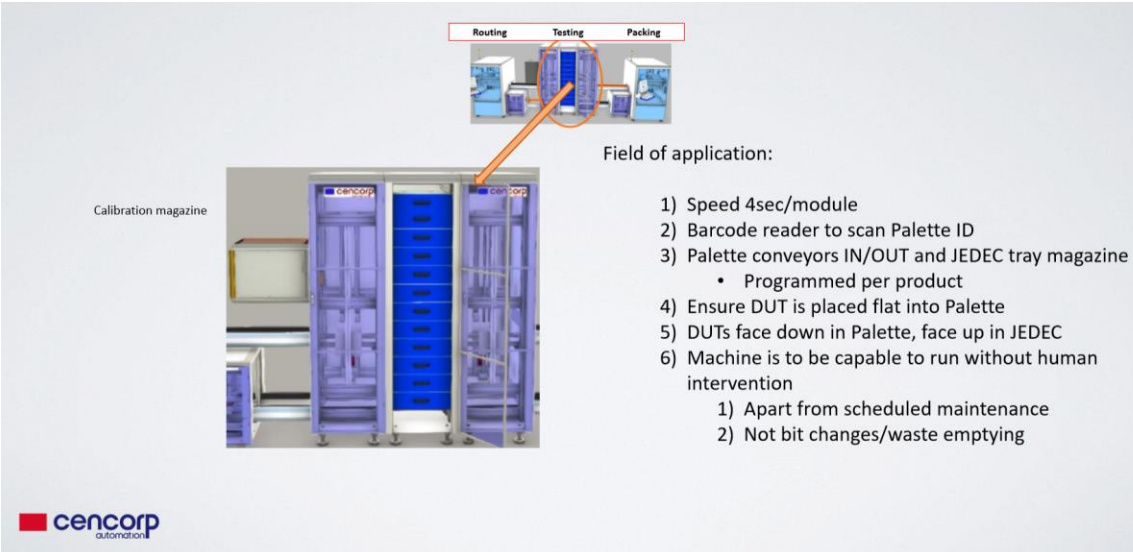

Figure 3. XPRS Tester (Cencorp Automation 2018a.)

3.1.5 Packing

A palette enters the packing cell along a conveyor belt (Figure 4). In Flip unit 4-up multi-gripper with two gripper fingers, all 4 modules are picked up from palette so they can be flipped up. After flipping, each module is gripped with a servo gripper and placed to palette and then exported to correct packing location. Either to Jedec Feeder for pass modules or Fixed Jedec tray for separate the failed products. Inside the packing cell there is a palette lifting unit where the empty pallets are moved and taken down to return conveyor level.

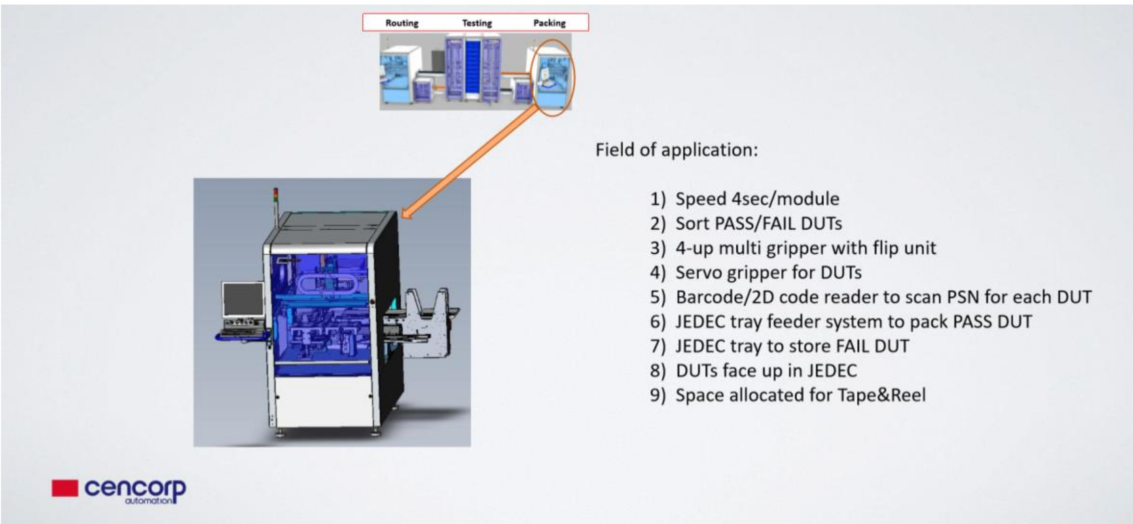

Figure 4. Packing cell (Cencorp Automation 2018a.)

3.1.6 Conveyor Belt System

System require parts to be fitted onto palettes before they can enter forward after panel routing. A conveyor between each cell consists of two segments and is also used as a buffer of next machine. Input palette handlers purpose is to feed the product palettes from the Bottom router to the XPRS test handler and return empty product palettes from the XPRS test handlers return channel to the router. Output palette handler's purpose is to feed product palettes from the XPRS tester to the packing cell and return empty product palettes from the packing cell to the XPRS handlers return channel. (Figure 5)

A return conveyor consists of 13 segments. After the packing cell palettes are moved to the lifter which takes palettes down to the return conveyor level. At end of the return conveyor there is a second lifter that lifts palettes up to the router table level. From the point of view of the palettes, such system is closed loop. Beckhoff Panel PC controls the movements of the lifters and lower conveyors. (Cencorp Automation. 2018d.)

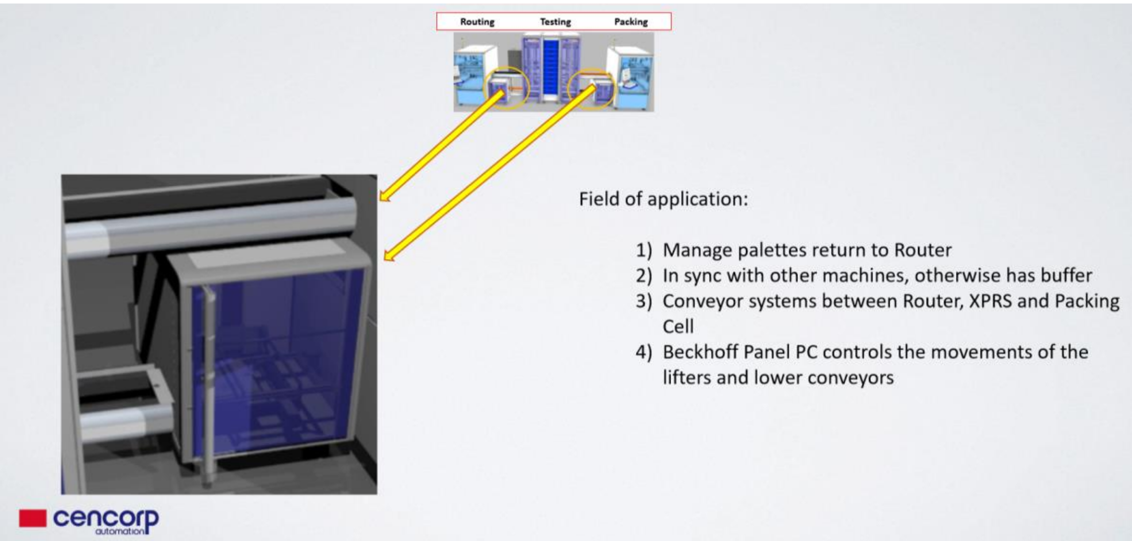

Figure 5. Conveyor System (Cencorp Automation 2018a.)

3.2 Cencorp Intelligence System – CIS

CIS is a software with an integrated set of tools working in real-time to feedback every aspect of manufacturing. It is a mass customized production control system. It includes a customer product definition for each product, that allows infinite amount of product variations. Enables centralized product definitions downloaded to line servers when starting a new batch and maximum performance and productivity. Production control with CIS, like machine utilization and line balancing enables higher production throughput. (Cencorp Automation. 2018h.)

Statistics key features provides real-time visibility of all processes. Reporting system to show trends and machine errors. Improves line balancing with reports for balancing optimization. Reporting also non-value add operations like waiting time, up-stream busy etc.

From a maintenance point of view, the line includes counters that make it easy to set the service interval for specific parts. The customer can determine the service interval and the CIS will perform the calculation and indicate when the service time is approaching. (Cencorp Automation. 2018g.)

4 EFFECT OF PROCESS VARIABLES

4.1 Manufacturing Speed Measurements

The speed of production system is a key aspect of manufacturing system and controlling it is important. There are many ways to measure manufacturing speed. To short out different measurements there are few questions to help figure out differences. Do you measure time/part or part/time? Does the measure include losses, i.e. delays like break-downs, defects, speed losses etc.? And do you look at a single system or the entire system? In Figure 6 is an overview of different manufacturing speed measurement op-tions.

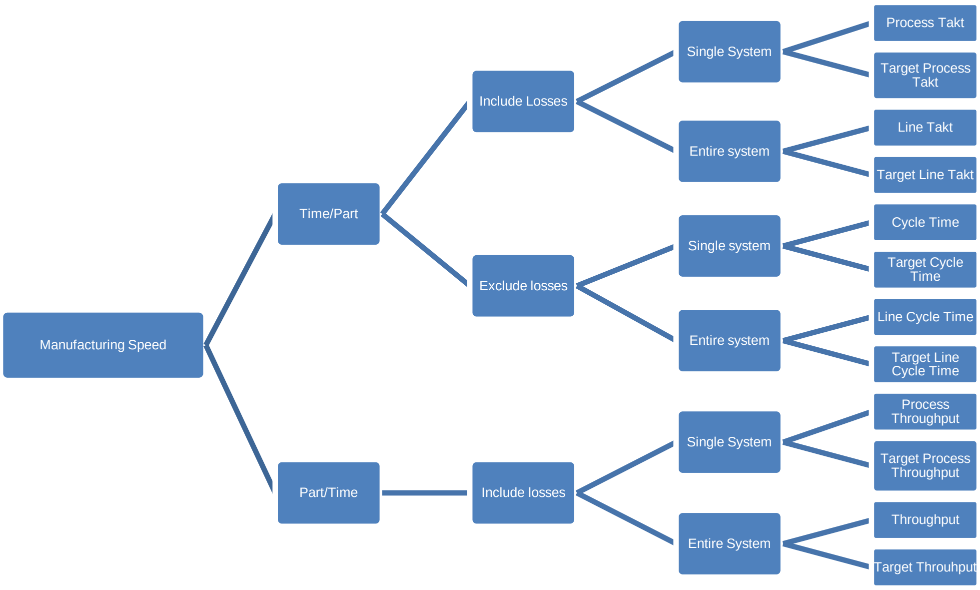

Figure 6. Manufacturing speed measurement options (Christoph Roser 2015c.)

The most commonly used measures are presented above to express the speed of the system. The way of measuring depends of course on what is wanted to do with the measurement. (Christoph Roser 2015c.)

4.2 Takt Time and Cycle Time

The customer takt, or takt time, is one of the central principles for determining the speed of a production system. It represents the average demand of the customer during a period of time. Every time designing a new production system or change an existing system, one of the early data inputs needed is the customer takt. The customer takt can be calculated by dividing the demand by the time available for production, simple as that. But there many more details needed to fully understand it.

$$Customer\ Takt = \frac{Available\ Work\ Time}{Customer\ Demand\ during\ available\ Work\ Time}$$

Formula 1. Takt time (Christoph Roser 2015c.)

The takt time gives us a measure of the customer demand over time. There are two main reasons why customer takt is needed. One is the production speed. If it is known how fast customer requires parts, it is known how fast processes should run in average. Or, by dividing the customer takt by the OEE (Overall Equipment Effectiveness). It can be known how fast processes should be before the usual break downs and other problems slow it down. The customer takt helps to determine how fast processes must be.

The cycle time of a process is a key to match the supply with the demand in lean manufacturing. The cycle time is the fastest repeatable time in which you can produce one part. The cycle time is like the takt measured in time/part. The important and often confused difference, however, is that the cycle time does not include losses. The cycle time is the fastest repeatable time in which one part can be produced. I.e. it is an idealized time that it is needed per part if everything goes perfect, having no breakdowns, quality defects, or other problems.

Cycle times are usually measured for individual processes, where having both, a cycle time for the current state and a target cycle time for the speed that is wanted. (Christoph Roser 2015c.)

4.3 Throughput

The throughput is simply the inverse of the takt time. The throughput is the average number of parts completed in a given time. The throughput is also rather easy to measure. It can be checked how many parts is produced during a period of time. Dividing the number of parts by the total time gives the throughput.

$$Throughput = \frac{Parts\ Produced\ during\ available\ Work\ Time}{Available\ Work\ Time}$$

Formula 2. Throughput (Christoph Roser 2015c.)

It must include losses. Hence, it is also possible to have a system or line throughput, a target system/line throughput, a machine or process throughput, or a target machine/process throughput. This naturally must be measured in parts/time. (Christoph Roser 2015b.)

4.4 Line Balancing

Balancing the workload at each piece of equipment across all processes in a manufacturing system helps in improving performance. Most importantly, it reduces unevenness due to different workloads and achieving a homogeneous quality is easier. In balancing the equipment attempt is to ensure that each piece of the equipment in the cell has the same amount of work. This in turn will reduce wasted waiting time and overburden. It usually be one of the easier aspects of lean manufacturing, since the new standard can simply be enforced through the layout of the machines. Product layout requires line balancing. If any production line is unbalanced, then machinery utilization may be ineffective. A balanced layout eliminates bottleneck operations and prevents the unnecessary duplication of equipment capacity. Balancing the workload among the different processes of a manufacturing system is usually straightforward. It is easiest with a flow line where all products are quite similar and go through the same sequence of processes. Getting an overview of the products, tasks, and the customer takt is the first step in line balancing. The objective is to match the production rate after all wastes have been removed to the takt time at each process. The next step is to determine the duration of tasks. This is relatively easy if all products have the same steps and the same time for each step. The time should be excluding all losses. Interesting are different strategies on how to balance a line if the tasks have different durations for different products. If it is a machine you already have, it would be the cycle time (i.e., the time between completion of a part excluding all losses and disturbances). Getting this time usually is not too difficult, but there are a number of hidden difficulties. (Christoph Roser 2015b.)

The Line balancing problem is normally associated with design of manual assembly lines. Very few people have investigated the problem for automated production lines or transfer lines. Known methods of assembly line balancing optimisation problems cannot be used directly for transfer lines because the operations at each workstation are executed simultaneously and the cycle time is equal to the longest process time and not the sum of process times. (Syed Masood, 2006)

Balancing automated and mechanized production line is more difficult since finding equipment with identical cycle times is rarely possible. Perhaps the most challenging problem of inherent balance in the production line comes from variation from cycle time at some processes.

5 IMPROVEMENT OF PROCESS EFFICIENCY

When the manufacturing process involves complicated machines to complete production, a temporary malfunction or a breakdown in a complex equipment may affect the manufacturing process. Methods for improving the process efficiency of all working parts of production promotes a continual and more efficient operation. The goal is to make company's processes more efficient. Constantly evaluating each step in the process to ensure it adds to the value chain (A., Vicki. 2018.)

5.1 Bottleneck

Identifying bottlenecks is critical for improving efficiency and stability in order to improve capacity in any production system. The machine or process that accumulates the longest queue is usually a bottleneck. Only the improvement of the throughput of a bottleneck process will lead to an improvement of the throughput of the overall system. This is complicated by the trends of bottlenecks in industry to shift between different processes. The bottlenecks are processes that influence the throughput of the entire system. The larger the influence, the more significant the bottleneck.

An accurate way to detect the bottleneck in manufacturing systems based on monitor the down times or waiting times for machines. The method is highly accurate, not only giving the likelihoods of different processes being the bottleneck, but also estimating the improvement of the entire system capacity if the bottlenecks are improved. It is also possible to observe the shifting of these bottlenecks over time.

Dynamic systems have one major impact on bottlenecks: In dynamic systems, bottlenecks shift. Shifting bottlenecks are a result of inevitable unexpected events for which no planning is possible. The bottleneck may change over time. For example, if a process has a breakdown, then the bottleneck may change to this process. Depending on the buffer between the processes, bottlenecks may change quicker or slower. The main performance parameter of interest when designing such a system is the production capacity, i.e. the maximal production rate that can be obtained. It is a function of the processing times at the different machines, the buffer sizes, as well as the total number of pallets that are available. A conveyor can also be used a as buffer. A buffer is provided in order to cope with unexpected failures of the machines, which may cause interruptions of the production process.

Assessing the degree of the bottleneck is crucial for determining how to manage the bottleneck. Managing the bottlenecks requires finding bottlenecks first. This is difficult, especially because the bottlenecks in most production systems can shift. Finding the bottleneck should also give clues for the root cause of the bottleneck. For example, if the process always becomes the bottleneck during a breakdown, it may be part of the root cause. If afterward the bottleneck shifts to another bottleneck that is working normally, its cycle time may be part of a bottleneck root cause. (Christoph Roser 2014.)

5.2 Common Bottleneck Detection Methods

The Bottleneck detection in manufacturing is the key to improving production efficiency and stability. Common bottleneck detection methods are conducted by the observation of processes and inventories. Blocked processes and full inventories indicate a downstream bottleneck. Starved processes and empty inventories indicate an upstream bottleneck.

Even if stations are equipped with data-monitoring equipment, the information gathered is usually insufficient for the bottleneck detection and lacks key information. The direct observation of the bottleneck gives additional information about the underlying causes of the bottlenecks which simplifying the improvement of the system capacity.

5.3 Influence of a Single Process on The Entire System

Although the automated line significantly improves productivity, it is also vulnerable to random disruptions caused by the equipment failure. It is critical to challenge the customer to understand the importance of flexibility in the XPRS Line operations. Too tightly time-dimensioned line will not withstand any fails, the risk of the bottleneck increases.

Since bottlenecks shift, more than one process is likely to be a bottleneck using the bottleneck definition. The larger bottleneck causes the larger influence on the system throughput. If sensitivity required is difficult to obtain analytically, it can be obtained experimentally by comparing the system behaviour for different cycle times.

The influence of the process on the overall system performance depends on the speed of the process. Change in the process speed has no influence on the system speed if the maximum speed of the system process is slower than the process. If the process becomes slower and its time between parts increases, it will start to have an influence on the system speed. The slower the process gets, the more impact it has. The slowdown of the process affects the entire system to a slowdown of equal magnitude. (Christoph Roser 2015.)

5.4 Simulation

Simulation is a procedure for modelling a system and its dynamic processes in a software model. Simulation models allow evaluate different variants of production and effectiveness. This information can then be transferred back to reality. A simulation enables the user to model a system, even if it has not been built yet. Afterward, the user can test the system under different conditions.

A simulation allows locate bottlenecks in the flow materials. It increases productivity while reducing the cost of the implemented changes. The ability of the simulation software to visualize material flow design increases the system's acceptance within the management. (Christoph Roser 2015.)

5.5 Buffering

Buffering is a method used to ensure the production continues to run smoothly and doesn't reach a standstill. This is important because a bottleneck is one of the longer steps in production cycle.

A buffer ensures bottleneck doesn't suddenly run out of work and sits idle for too long. This is important since, as identified earlier, a bottleneck is already one of the longer steps in the production cycle. It is not wanted to feed its cycle time by not having enough tasks on hand to continue moving forward in the process. If buffer of additional materials does not exist, the production could slow down.

Placing such a buffer immediately before a bottleneck and implement correctly, it can ensure the entire workflow continues to run smoothly and keep costs low. Having extra inventory on hand is a solution to ensure that bottleneck is constantly fed. (Roser C, Nakano M, Tanaka M. 2005.)

In the XPRS Test Line the performance is adjusted by allocating buffers, conveyors, between the cells and the return conveyor which manages palettes return to the Bottom router. A conveyor between Bottom router, XPRS Test and Packing cell consists of two segments and return conveyor consists of 13 segments. Placing such buffers immediately before and after cell can ensure the entire workflow continues to run smoothly.

6 CONCLUSIONS

The objective of the thesis was to understand the requirements of the XPRS Test Line to decrease or maintain the process throughput time. The customer is the one that will provide the guidelines for the production rate and the desired delivery of products. It is essential to understand the customer needs, quality features and throughput time. It is also essential to understand the different time variables and their impact to the throughput.

There are many different terms used to study the variables affecting processes and the speed of the XPRS Test Line: cycle time, takt time, process time, line takt and many more. Often in literature the Lean experts mean different things using the same term or mean the same thing but use different terms. Most attention in literature is paid for the balancing problems concerning the assembly systems. The approaches and formulations of flow line balancing in machining environment are much less analysed.

The aim of this thesis was to map and analyse the production process at the XPRS Test Line. The goal has been achieved by going through the theory of automated production line process and process variables and calculating the effect of time variables. The theoretically calculated results were also used to analyse the direction of the possible bottleneck. For the systems with identical cycle times, it is valid to assume that the buffer inventory is a good indicator of the possible bottleneck.

The understanding between production rate and different variables that affect the line functionality could be improved by process simulation and measuring the time variables in practise and compared it to the theoretically expected results when the XPRS Test Line is ready.

The subject of the thesis was interesting and challenging. It would have been interesting to continue to the practical level and study if a simulated result replicate in a practical situation. The schedule of the XPRS Test Line was delayed because of the modifications required by the customer and therefore there was no possibility of further research.

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