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RESOURCE UTILISATION IN A PRODUCTION CELL FOR LAMINATED VENEER PRODUCTS

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Abstract:
The concept of productivity is often used to determine how well resources are used in an operation, and it is usually determined as the ratio of what is consumed in the production. Laminated veneer products are considered complicated products often taking complex shapes, using a raw material with high variation, and requiring machining processes that create scrap material that needs to be handled. Therefore, maintaining high productivity in industries producing such products may become challenging. This study reports on productivity measurements in a production cell consisting of an adhesive, pressing and a processing station. The study seeks to increase the understanding of production-related problems in this industry. This research has been based on productivity measurement as well as on interactive discussions between researchers and workers. Measurement of cycle times indicated bottlenecks in the processing cell. The discussion led via cycle times, processing residues and chatter marks to an examination of the foundation and rigidity of the CNC-machine in the processing cell. The study indicated that the performance of the CNC machine did not correspond to expectations. The machine was too weak to handle the required output in an efficient manner. Thus, there is a need to determine the performance expected before a machine or machine group is purchased. An update of the existing purchasing literature and its dissemination will support the crystallization of the purchasing process as a way forward to support the industry.

Key words: *CNC; robot; stiffness; vibration.*

INTRODUCTION

The concept of productivity is often used to determine how well resources are being used in an operation. It is usually determined as the ratio of what is produced to what is consumed in the production (Olhager 2000). Productivity can be given as Overall Equipment Effectiveness (OEE), which is calculated by multiplying the availability, performance, and quality (Bicheno et al. 2011). Laminated veneer products (LVPs) are considered complicated products often taking complex shapes, using a raw material with high variation (Blomqvist 2015) and requiring machining processes that create scrap material that then needs to be handled. Therefore, maintaining high productivity in industries producing such products may become challenging. Flexible automation in the manufacturing of LVPs has been used as a working hypothesis to examine the possibility of developing the wood furniture industry. A production cell that produces LVPs was chosen to carry out these studies, seeking to increase understanding of production-related problems in this industry. The aim of this particular study was to create an understanding of production-obstructive events in this industry, by investigation the potential for improvement in the selected production cell with the help of cycle time (CT) registration and root cause analysis (RCA). RCA is a method of asking the question “why?” until the root cause is discovered (Petersson et al. 2009).

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METHODS

The study has involved a combination of productivity measurement and interactive discussions between researchers and workers regarding its methods (Archibald 2016).

Case description

The production cell contained two robot-automated cells with an intermediate press station that was handled manually. These persons were also engaged in the support and control of the robot-automated cells. In the first robot cell, veneers were taken from different magazines by the robot, adhesive was spread on the veneers via a bead/string application and the veneers were packed in bundles in preparation for moulding. This sub-cell is here called the adhesive station. In the press cell, the staff took the bundles of veneers with adhesive and placed them in form-pressing tools where the laminates were moulded. There were three presses, each with an identical pressing tool. This sub-cell is here called the press station. After the press station, the staff moved the moulded seat shells to a conveyor belt that served as a cooling station and as interim storage prior to the second automated robot cell, where a robot took the seat shell from the conveyor belt and positioned it in the CNC machine for processing. After the CNC-processing, the robot took the shells to different sanding units and finally placed them on a conveyor belt. This sub-cell is here called the processing station. After the processing station, the shell was taken manually and placed in a box for lacquering, as shown in Fig. 1. There were other activities concerning the seat shell before and after its processing in the production cell, but these activities were not investigated in this study.

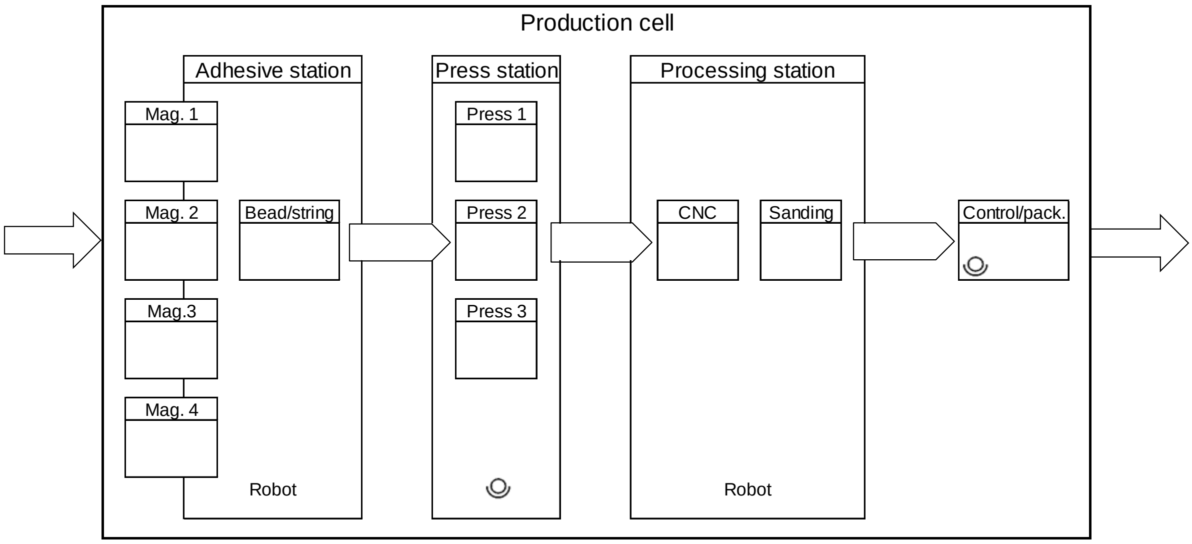

Fig. 1.
The different stages in the production cell where the seat shells were moulded and processed.

Data collection

The resource utilisation was controlled in various parts of the production cell by recording the cycling times (CTs), which were used to calculate the maximum possible production and effects of various improvements. The researcher observed and asked questions on several occasions to gain an understanding of the production cell. A workshop was arranged in which all employees at the production cell participated, together with management and researchers. The discussion processed CT causes with RCA. This resulted in further measurements and analysis of the machine setup regarding stiffness of the floor and machine head.

EMPERICAL FINDINGS AND ANALYSIS

The CNC machine was recognized as the production cell's limiting factor, i.e. the bottleneck, in the production of the seat shells. The CT for a seat shell was 172 seconds in the CNC-machine compared with 128 seconds in the adhesive station, 137 seconds in the press station (calculated as: [349+62]/3=137), and 158 seconds for robot handling in the processing station (20+138=158) (Table 1).

Table 1

Cycling times of different production steps

Place	**CT (sec)**
Adhesive station	128
Press station	
• Correcting a bundle of veneers	27
• Loading of press and pressing time	349
• Movement from press to conveyer belt	62
Processing station	
• Robot gripping and positioning	20
• CNC-milling	172
• Sanding	138

CNC-milling

The CNC-milling was divided into two steps: a rough machining to remove unnecessary material and rough mill the contour with a feeding speed of 9,000–12,000 mm per minute, and a fine milling of the contour with a fine milling cutter, with a feeding speed of 2,000–5,000 mm per minute, depending on the severity of the processing.

The rough contour milling gave a lot of residual material. Optimization of the first step of the CNC-milling in conjunction with a new rough milling cutter with greater length and diameter could shorten the time and reduce the amount of residual material. Calculations indicated that this could shorten the CT by 15 seconds, so that the CT of the CNC-milling could be shortened from 172 seconds to 157 seconds (Table 2).

The feed rate of the fine milling cutter was low, due to chatter marks after the contour milling (Fig. 2). The chatter marks became larger with faster feeding and complicated the sanding of the milled contour.

Fig. 2.
Chatter marks on the contour milled edge after fine milling.

An increase in the feed rate of the fine milling would lead to a further shortening of the CT of up to approximately 12 seconds in the CNC-milling. Together with the previously mentioned improvement this could mean a reduction in CT to 145 seconds. The bottleneck would then be shifted to the other two cycles of the process station which together took 158 seconds. The time for sanding could, however, be reduced if the seat shell edge had a better surface after the CNC-milling. It was, therefore, reasonable to expect a CT of 158 seconds as the limiting factor if the CNC-program were optimized regarding rough milling and a further reduction down to 145 seconds if the chatter marks could be radically reduced (Table 2).

Table 2

Cycling times in different productions steps with capacity calculations related to various alternatives for improvement

Place	**Alt.**	**CT (sec)**
Adhesive station		128
Press station		137
Processing station – robot		158
Processing station – CNC	1	172
Processing station – CNC	2	157
Processing station – CNC	3	145

Vibration in relation to chatter marks

It appeared that the CNC machine vibrated and that such vibrations increased in amplitude with increasing feed rate, which could explain the chatter marks and with the effect of feed rate on the chatter marks. It also emerged that the vibrations had been reported and were to be addressed during service of the CNC-machine when a linear bearing had to be replaced.

A poor foundation was suggested to be the probable cause of the vibration. However, the manufacturer of the examined CNC-machine had not specified any special requirements of the floor on which the machine would be set up. Nevertheless, a manufacturer of a similar CNC-machine (6 ton) advocates floors to withstand a "*minimum unit load capacity of 20 000N/m^2 over the machining centre-bearing surface"* to withstand load and stress (Venus 2007). Examination of the floor resulted in an estimate that the concrete thickness was 100mm with unknown material underneath.

Investigation of floor and machine stiffness

The floor's dynamic stiffness and the natural frequency of the mounting of the tool in the machine were measured, using a hammer equipped with a built-in force sensor that excited the test points. An accelerometer was used to measure the response in the same direction as the excitation with the hammer, i.e. perpendicular to the floor (Fig. 3). Measurements of the natural frequency of the machine head were made in its X, Y and Z directions (Fig. 4).

Fig. 3.
Measuring point at the upper rear machine foot of the CNC machine.

Fig. 4.
Measurements of the machine head in the CNC machine. Excitation took place with the hammer on the opposite side of the spindle in which accelerometers were placed in the X and Y plane (horizontal). The vertical excitation took place together with the accelerometer in the Z-direction (vertical).

The floor's mobility was at its highest, -110dB (ref. 1m/Ns) in the low frequency ranges (around 10Hz) where the machine was located. The machine head stiffness was different in different directions, being weakest in the X-direction. The spindle mobility was at its lowest, -90dB. There was thus a difference of at least 20dB between the floor and the machine head. Converted to static stiffness, this means that the floor was about 10 times stiffer than the machine head, and that the greatest reason for the machine head's pliancy at low frequencies was the machine's own weakness, and, to a smaller extent, the weakness of the floor (Olsson 2016).

DISCUSSION AND CONCLUSIONS

The need to fix the bundles of veneer after the adhesive station can be considered to be an unnecessary step because it adds no value to the flow of the production of the seat shell. That step ought to be eliminated by ensuring correct bundles. Two suggestions emerged during the study: to include a vibrating tray that shakes the pack into the correct position, or to ensure the correct position by refining the handling of the veneers from the different veneer magazines together with a vision system that ensured the final positioning. The productivity in the production cell would not be affected by this extra step. The same applies to the other two steps in the press station, although, these two steps add value to the process. There is generally a need to study the value of the flow in and out of the production cell to create a better basis for decisions.

Optimisation of the milling in the CNC-machine would mean less processing residue, less vibration and shorter CTs. If the vibrations were minimised to give fewer and smaller chatter marks, then the sanding would also be easier and the total capacity would increase.

Knowledge of the machine performance is obviously important when purchasing, but it is also significant during usage. Although the condition of the floor was found to have less impact than the machine's own pliancy, it is important to consider a possible relocation of the machine to ensure the optimal performance of the foundation.

One way to reduce vibrations would be to optimize the CNC-program. To reduce the forces during acceleration and deceleration through smoother transitions would help to avoid sudden jerks and stops. This is applicable especially in the machine head's X-direction in which the machine head was weakest. This would help to reduce the out-swings occurring after, for example, an abrupt stop.

To handle a machine with lower performance than desired it is important to understand its limitations. Requirements of, for example, surface finish could control various levels of processing, but if the limits are exceeded, the service needs are affected.

When purchasing, it is important to have an understanding of the forces to which the machine will be exposed. Therefore, it should be natural that prospective buyers require an inspection protocol and definition of the machine's optimal performance conditions to ensure purchase of the right machine. It is important to have a clear criterion in the procurement of processes that affect surface finish. For example, an understanding of how the natural frequencies (maximum and minimum resonance frequency in the different directions in relation to the position of the machining tool affect its own frequency) and the specific type of processing makes it possible to determine the maximum feed rate for a particular surface finish, which could ultimately be a type of productivity measurement for the machine.

Sjöberg and Höglund (1997) developed a guideline with a focus on the wood product industries for the purchase of complex machinery. Their handbook covers, among others topics, pilot studies, requirement specifications, quotations, delivery and investment cost calculations. However, there are reasons to update and process the handbook to reflect the needs of new business models and technologies. The findings in the present study give an indication of the parameters which should be included in an updated handbook.

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REFERENCES

Archibald M (2016) Investigator triangulation: A collaborative strategy with potential for mixed methods research. Journal of mixed methods research, 10(3):228–250.

Bicheno J, Holweg M, Anhede P, Hillberg J (2011) Ny verktygslåda för lean - Filosofi, transformation, metoder och verktyg, 4:e upplagan (New toolbox of lean - philosophy, transformation, methods and tools, 4th Edition). Lean Forum (in Swedish).

Blomqvist L (2015) Shape stability of laminated veneer products - a review - defining and achieving shape stability. International Wood Products Journal, 6(2):89–95.

Olhager J (2000) Produktionsekonomi (Production economics). Studentlitteratur (in Swedish).

Olsson J (2016) SP Rapport Beteckning 6P07848 SP Sveriges Tekniska Forskningsinstitut Hållbar Samhällsbyggnad - Träbyggande och boende (in Swedish).

Petersson P, Johansson O, Broman M, Blücher D, Alsterman H (2009) Lean-Gör avvikelser till en framgång (Lean-Turn deviations into success). Part Development AB (in Swedish).

Sjöberg L, Höglund M (1997) Handbok i inköp av komplicerad utrustning (Handbook for purchasing sophisticated equipment). Linköping: Konsortiet Träindustri Kalmar (in Swedish).

Venus (2007) Venus - Installaton, operating and maintenance manual. Zogno, Italy: C.M.S. SpA Construzioni Macchine Speciall.