Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 57 (2016) 764 – 768

www.elsevier.com/locate/procedia

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

The influence of raw material on the wood product manufacturing

Roaa Salim[a]*, Jimmy Johansson[b]

[a]*Jönköping University, Gjuterigatan 5, Jönköping 551 11, Sweden*
[b] *Linnæus University,Universitetsplatsen 1, Växjö 351 95, Sweden*

* Corresponding author. Tel.: +476 279 9364; *E-mail address:* roaa.salim@ju.se

Abstract

This paper focuses on the later part of the wood processing chain in wood industry: the wood product manufacturing. Wood product manufacturers are facing many challenges e.g. due to the high variability of the raw material. Waste and rework are prevalent, resulting in high manufacturing costs. Each processing step in the manufacturing affects material utilization and cost efficiency. The proportion of the material cost and waste in most wood products are high. The challenge for wood product manufacturers is to make profit and remain competitive when on one side they need to execute the processes at the lowest cost and within shortest time and on the other side deal with a highly variable raw material. Therefore, wood product manufacturers need to consider their manufacturing process with emphasizes on the raw material consumed. The purpose of this paper is to examine the direct –and indirect influences of the material on the wood product manufacturing process in terms of productivity and efficiency. The direct influences aims at examining the impact of consuming raw material with different properties on the manufacturing process, while the indirect influences examine process-related aspects affecting the material's influence on the manufacturing process. This paper is based on a case study at a Swedish interior wood product manufacturer. The first phase of the study compares between two wooden panels with different material properties. Results show that solid, knotty raw material with higher moisture content results in lower efficiency than finger-jointed, knot free material with lower moisture content. The second phase of the study examines the indirect influences and shows that material handling is one of the key process-related aspects that need to be considered.

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

Keywords: efficiency; influence; material utilization; productivity; product yield; wood product manufacturing

1. Introduction

The wood industry is divided in two main branches [1]; forest industry and wood product industry. The forest industry consists of: forestry sawmills, board industry, energy conversion, and pulp and paper. The wood product industry adds higher manufacturing value to the sawn timber in order to produce different wooden products, (figure 1). The wood product industry is also a great user of materials from other parts of the wood industry such as board materials. This paper focuses on the later part of the wood processing chain, thus, the wood product industry, and in particular its manufacturing system.

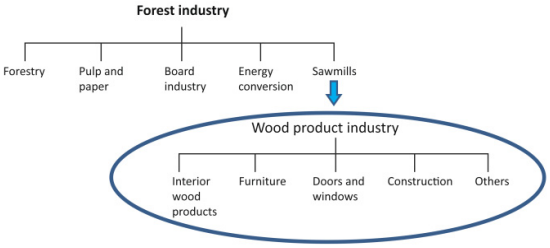

Fig. 1. The wood industry.

Wood is a heterogeneous material, which means that its appearance is dependents on different biological factors that affect the raw material's properties [2]. Due to the highly variable nature of wood, wood product manufacturers are struggling with issues related to quality and material

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2016.11.132

utilization aspects [3]. The wood material has several natural "defects", such as: knots, streaks and discolorations. Further, variable moisture content can cause splits and cracks [3]. All these aspects affect the raw material, and thus the final product quality. More on, raw material quality has a great impact on manufacturing productivity [4] and efficiency. Each step of the wood processing chain affects material utilization and product cost [5]. Raw material with less than the expected quality can have a great impact on the manufacturing process [4]. The challenge for wood product manufacturers is to make profit and remain competitive when on one side they need to execute the processes at the lowest cost and within shortest time and on the other side deal with a variable raw material. In order to achieve this, wood product manufacturers need to consider their manufacturing process productivity and efficiency with emphasizes on the influence of the raw material consumed.

Large amount of available research focuses on the first part of the wood processing chain, the forest industry [5]. Fewer studies examines the challenges occurring in the later part of the wood processing chain regarding the influence of the raw material on the manufacturing process. Sofuoglu et al. [6] state that in order to reduce the high scrap rate accruing in the wood product manufacturing, factors that lead to higher loss must be determined. Therefore, this study applies a holistic perspective to examine the material influence on the wood product manufacturing in terms of productivity and efficiency. The influence of the material is examines in direct – and indirect influences. The direct influences examine the impact of material properties on the manufacturing process and the indirect influences examine the impact of process-related aspects on the material's influence on manufacturing. The process-related aspects will be examined at a manufacturing level, analyzing elements involved affecting the material's influence on the manufacturing process. In this paper, the production system is defined as superior to the manufacturing system. Further, the manufacturing system is viewed at a factory level and consists of machinery, tools, and labor [7].

1.1 Objectives

The purpose of this study is to examine the influence of the raw material on manufacturing process in terms of productivity and efficiency in the later part of the wood processing chain: wood product manufacturing and especially the manufacturing of interior panel products from sawn wood. For this purpose, the following research objectives were established:

- Compare between solid and finger-jointed interior wood panels production in terms of manufacturing process productivity and efficiency
- Identify process-related aspects affecting the material's influence on the manufacturing process

Therefore, the influence of the material is examined in direct – and indirect influences. The direct influence aims at examining the impact of using raw material with different properties on the manufacturing process, while the indirect influence aims at examining process-related aspects affecting the material's influence on the manufacturing process. The process-related aspects include all elements within the "walls" of the manufacturing.

2. Method

This paper examines the influence of the raw material on the wood product manufacturing in terms of productivity and efficiency. The factors influencing the manufacturing are examined in: direct – and indirect influences. The direct influences of the raw material refer to the influences of material properties on the manufacturing process. Besides the material properties there are several factors within the manufacturing system that can affect the influence of the raw material on the manufacturing process, these factors are referred to as the indirect influences in this paper.

The unit of analysis is the manufacturing system, which here is defined as: part of the production system and includes activities and facilities needed to transform raw material into finished products [7]. This study was performed at a Swedish wood interior manufacturing company. The paper is based on a case study [8] that consists of document analysis and multiple interviews performed with production engineers, operators, production scheduler, and site manager. Document analysis was performed to investigate the impact of material properties on manufacturing productivity and efficiency. Two products (wood panels) were chosen. These products were chosen due to the difference of the demand put on the incoming material properties between them. Both products are processed by the same machines. The aim was to investigate the influence material properties have on the manufacturing process. The following two wooden panels were therefore selected and analyzed:

- Finger-joint – Panels delivered to the customer with moisture content of 8-10%, finger-jointed, knot free, and only cover painted
- Solid – Panels delivered to the customer with moisture content of 16-18%, solid, knotty, and not surfaced finished

The company documentations consisted of historical data that described process productivity and efficiency through stop time, product yield and production/machine hour. Stop time provides information about reasons for stop in the manufacturing, how many times the stops occur for each reason and time for each stop. Product yield divides the finished product in two qualities and scrap material (A, B, and C) and provides information on percentage of each quality that is achieved from each order. Quality A represents the best quality achieved and quality C represent scrap. Therefore, the study only analyzes products with A and B qualities. Machine hour category provides the number of running meters of A, B and C produced each machine hour. Both panels analyzed sum up to the same amount of produced products expressed in running meters. There were respectively 13 and 7 analyzed orders when finger-joint and solid-wood panels were produced both accounting to the same amount of 343 000 rm. Descriptive statistics were calculated in order to describe the productivity and efficiency variations of produced orders in

terms of yield and machine hours for both finger-joint and solid wood panels.

Further, interviews were conducted with the aim to investigate process-related factors affecting the influence of raw material on manufacturing process. These factors are referred to as the "indirect influences".

3. Empirical findings

The empirical studies were performed at a Swedish interior wood product company. The company is producing among others panels, flooring, and moldings. The manufacturing unit studied is part of a large business area with over 1500 employees and consists of approximately 50 employees. The findings are presented in two sub-headings: direct -and indirect influences.

3.1 Direct influences

The productivity and efficiency variations for both types of panels are shown in table 1 and 2. The productivity and efficiency variations are in all categories expressed with a mean value and standard error.

By producing finger-joint panels, higher yield of quality A is gained than in the case of solid-wood panels. Also there is less scrap material when finger-joint panels are produced. As it can be observed from table 1 and 2 the sum of machine hours required to produce the same amount of panels is higher for finger-joint panels.

Table 1. Descriptive statistics of yield and total machine hour for finger-joint panel.

Descriptive statistics	Finger-joint panels		
	Yield (%)		Machine hour (rm/h)
	Quality A	Quality B	
Mean value	83.2	14.5	7311.9
Standard error	3	61.5	61.5

Table 2. Descriptive statistics of yield and total machine hour for solid panel.

Descriptive statistics	Solid-wood panels		
	Yield (%)		Machine hour (rm/h)
	Quality A	Quality B	
Mean value	70.7	24.7	7507.3
Standard error	1.8	1.4	112.4

The reasons for non-adding value times in the manufacturing of both types of panels are shown in figure 2 and 3. It must be observed that only most occurring stop tines in terms of accumulated minutes are displayed in figure 2 and 3.

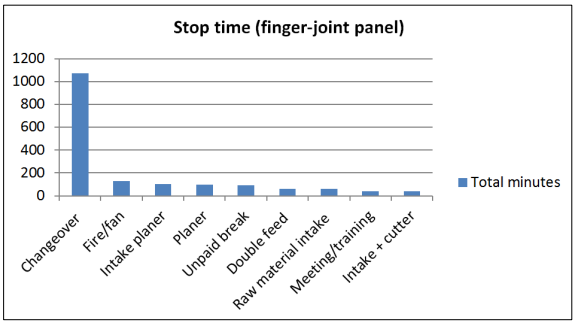

Figure 2. Stop time for finger-joint panels.

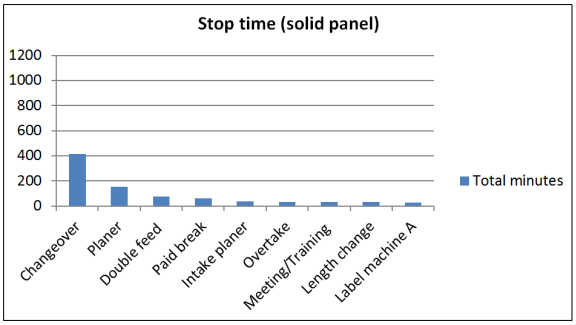

Figure 3. Stop time for solid panel.

Changeover is the biggest reason for non-adding value times in the manufacturing of both types of panels. The accumulated idle times were more than double for finger-joint wood panels than for solid wood panels which is in line with the aforementioned required machine hours difference. The total time of processing the finger-joint panels is 1755 minutes, while the total time to process the solid panels is 909 minutes. The meaning of the different stop causes presented in figure 2 and 3 are defined in table 3.

Table 3. The meaning of stop causes

Stop causes	Meaning
Changeover	The time it takes to change machine equipment from running one product to another. In this case, changing equipment for different profiles.
Planer	Error in planer causing stop time
Fire/fan	Time spend on accidents causing fire /heated machines
Intake planer	Intake error
Unpaid/paid break	Break time for operators
Meeting/training	Meetings in the manufacturing for different purposes

Intake + cutter	Errors in intake and cutter
Overtake	If one station is not on time to deliver to the next station other orders will be handled in the meantime, thus when the material is handed over to the next station delay can occur as there is already an order to process, this refers to the overtake time
Length change	The time it take to adjust the processes to change from one panel length to another
Label machine A	Error in label machine A
Raw material intake	Error in material refills (material missing)
Double feed	The machine is being fed with several wood pieces at the same time.

3.2 Indirect influences

Besides the high variability of the raw material being the largest challenge, the company was facing other challenges related to the material, such as logistics. The material or product is transported a great many times between the inventory and different processing stations. Every time the material is transported there is a high risk of material damage, which increases the scrap rate and defects. The inefficient transportation of the material in the manufacturing was found to be due to poor manufacturing flow. Another challenge the company dealt with that caused high material defects and high scrap rate was due to packaging. The raw material that arrived to the manufacturing inventory were packaged in large batches, when the trucks picked up smaller batches of the raw material to deliver to the different processing station, which often was the case, some material were damaged.

Further, the machines were perceived as being not flexible enough to handle a heterogeneous material. A great part of the manufacturing processes currently consists of visual quality control. However, when transferring this activity to the machine this means that the machine should be able to handle a great variation of quality; otherwise the material scrap will increase. A similar observation was made by Broman and Fredriksson [5]. Another aspect concerning the machines is the change-over time. Material properties could affect the need of tool change due to tool wear. Tool change increased stop time and downtime and thus decreased productivity. Same problem was observed by Ratnasingam [9]. Lastly, a great part of the manufacturing processes currently consists of visual quality control. Thus, dependent on the operator, material quality is defined differently and while some operators might choose to pass the material other might scrap it.

4. Discussion and conclusions

The purpose of this study was to examine the influence of the raw material on manufacturing process of wood product industry in terms of productivity and efficiency. This is done by studying the effect of the material at the final wood processing chain at a Swedish interior wood product manufacturer. The empirical study was conducted in two phases with the aim of examining the direct influences of the material, which in this paper is related to the material properties, as well as the indirect influences which are concerned with process-related aspects that affects the materials influence on manufacturing productivity and efficiency. The first phase was conducted through document analysis comparing key indicators between two wooden panels with different material properties to observe any differences in terms of productivity and efficiency.

The first phase of the empirical studies shows that there are pros and cons with both types of observed panels. Finger-joint raw material provides more “A quality” products. The reason for this might be due to the fact that finger-joint is a knot-free material. Further, the dimensional stability of finger-joint panels is more constant than that of solid-wood panels during the service time. Higher moisture content of solid wood panels could be a reason for lower amount of quality A. The reason for this might be how the company in itself handles the product or how the supplier handles the product. The finger-jointed product is processed to a large extent by the supplier through careful drying and processing, and the product is delivered by a limited number of suppliers. The raw material to the solid wood panel is to be seen to be more of a commodity product and is most likely treated in another way. To study the process at the supplier is, however, out of the scope of this study.

On the other hand solid-wood raw material requires less machine hours for the manufacturing of the same amount of products. The stop times in the manufacturing shows that the changeover between products is the largest reason for non-adding value times of both types of wooden panels. However, the accumulated idle times were more than double in finger-joint panels then in solid-wood panels which is in the line with the aforementioned required machine hours difference. In this case, the reason for this could be that even though a fixed volume were chosen for both wooden panels when comparing, different amount of orders were observed. There were respectively 13 orders for finger-jointed panels and 7 orders for solid wood panels analyzed. Thus, the change-over time for 13 orders compared to 7 orders might have been higher.

The second phase of the empirical studies, which deal with the indirect influences of the raw material on the manufacturing process show that the impact of others aspects within the manufacturing can affect the material’s influence on the process in terms of productivity and efficiency as well. This phase shows that material handling is one of the key process-related aspects that affect the material’s influence on manufacturing process. These findings were mainly based on

experienced shop floor workers during interviews. Most shop floor workers had the same opinion concerning material waste and defects. Further, the main issue lying behind material handling was explained to be due to the manufacturing flow. Other process-related issues mentioned were among others technical errors and human errors.

The limitations of this study are that it has limited numbers of wooden panels to compare between, further, the comparison between these two panels are hard to make since it is unknown how comparable quality A is between finger-joint panels and solid-wood panels. However, the main purpose was to analyze and observe differences of the influence of raw material with different properties on the wood product manufacturing process. Further, the indirect influences examined are based on interviews and thus are not measureable. The empirical findings showed that material handlings were one of the main problems based on the interviewees experience, but which and how much each indirect influences affect the manufacturing process are not examined in this study.

Acknowledgements

The authors wish to express their sincere gratitude for financial support from The Knowledge Foundation (www.kks.se) through ProWood, the doctoral school on wood manufacturing, Linnæus University and Jönköping University. We also owe much gratitude to the participating company and the respondents.

References

[1] Sandberg D, Vasiri M, Trischler J, Öhman M. The role of the wood mechanical industry in the Swedish forest industry cluster. Scandinavian Journal of Forest Research. 2014: 4.

[2] Wodzicki T J. Natural factors affecting wood structure. Wood Science and Technology. 2001: 1-2, 5-26.

[3] Korhonen S, Niemelä J. A conceptual analysis of capabilities: Identifying and classifying sources of competitive advantage in the wood industry. University of Helsinki. 2005.

[4] Eliasson L. Ställ krav på virket. Linnaeus University. 2011.

[5] Broman O, Fredriksson M. Wood material features and technical defects that affect yield in a finger joint production process. Wood material science and engineering. 2012, 167-175.

[6] Sofuoglu S, Kurtoglu A. A survey for determination of wastage rates at massive wood materials processing. Wood research. 2010: 12, 297-308.

[7] Groover M. Automation, Production systems and Computer Integrated Manufacturing. Prentice Hall. 2014.

[8] Yin R. Case study research: Design and methods. Sage publications, 2009.

[9] Ratnasingam J, Ma T, Perkins M. Productivity in wood machining processes - a question of simple economics? Holz als Roh - und Werkstoff. 1999: 57, 51-56.