ENERGY REDUCTION BY OPTIMIZING SHARPNESS ANGLE AND FEED PER KNIFE IN WOOD PLANING OPERATION

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ABSTRACT

Wood planing operation is one of the widely used processes in value-adding technology of wood products in the wood based industry in Sarawak. The machines and knives used for wood planing process should be properly deliberated and operated in order to achieve high productivity and lower operation cost. Over the years, energy efficiency has become more a function of processing and machine innovation. In the light of growing national interest and desire to develop forest plantations amongst the tropical countries, it is deemed timely and pertinent to evaluate potential plantation species before planting decisions are made. Knowledge on the effect of wood planing parameters on power consumption would improve energy efficiency, thus reduce operating costs and enhance profitability. The evaluation of power consumption is one of the essentials and decisive parts of the required evaluation. This paper is in the proposal stage through literature review with the objectives to determine the optimum knife sharpness angle and feed per knife during the wood planing operation while to obtain the best surface quality and the lowest energy consumption, thus to reduce energy consumption in wood planing process. The study is intended to test on major planted Acacia mangium species in Sarawak. In the evaluation of power consumption and surface roughness results, correlation analysis, analysis of variance (ANOVA), and also a t-test will be employed to investigate whether there is a significant difference between the power consumption and surface roughness values with respect to the tested sharpness angles and feed per knife. As a relationship at the $P \leq 0.05$ level to make available between the factors, Duncan's multiple mean comparison test will be applied and homogenous groups to be detected. The analysis will be performed using SPSS 11.5 (Statistical Package for the Social Sciences).

Key words: Sharpness angle, feed per knife, wood planing, energy efficiency, surface quality.

INTRODUCTION

For the well-being of any timber industry, downstream processing is vital for generating value-adding revenue, providing employment and sustaining other relevant aspects of economic development. The wood based industry in Sarawak continues to strive to reduce production costs and increase productivity to maintain competitiveness. Hence, knowledge on the effect of wood machining parameters on power consumption would improve energy efficiency, thus reduce operating costs and enhance profitability. Measuring power consumption also provides information about other variables, such as tool edge wear, occurrence of catastrophic failures, and other parameters that affect the quality of the timber products and the momentary efficiency of the wood machining process. As a prerequisite for optimizing energy efficiency on the machine level, it is crucial to understand the energy consumption behavior with regard to the machine parameters. Analyzing certain energy profiles of production machines is a common way in research nowadays to identify main drivers of consumption and derive optimizing measures. Reduction of the energy consumption can be comprehended by optimizing the knife sharpness angle and feed per knife in timber machining manufacturing process.

Several parameters like machining tool geometry, machine settings and wood structure would affect the surface quality and energy consumption. The larger the variation in wood features the more difficult it is to find a combination of tools and machine settings that will give the best surface quality and reduced energy consumption. The manufacturing process of wood products usually requires a series of wood transformation processes. Each of these processes facilitates the reduction of the wood size by machining. Planing operation is conceivably one of the main processes that widely use in wood machining industry. The machines and knives used during the planing process shall be properly deliberated and operated in order to achieve a wood machining process with high productivity and lower operation cost. To do this, it is crucial to have an elementary knowledge of factors related to the machining process, such as wood density, wood grain orientation, machining tool geometry, feed per knife, and milling direction. An optimum level of these parameters is also necessary for a reduction in production costs without reducing the quality of the product, such as power consumption parameter. However, non-uniform characteristics or heterogeneous character of wood play a significant role in its effective machining during the planing operation. In particular, the characteristic of wood species in contact with the cutter tools significantly affects power consumption during the planing operation. Therefore, an evaluation of the parameters relating to machining and wood properties is very essential in order to achieve an economical machining process.

Over the years, energy efficiency has become more a function of processing or machine innovation than of timber properties. In the light of growing national interest and desire to develop forest plantations amongst the tropical countries, it is deemed timely and pertinent to evaluate potential plantation species before planting decisions are made. The evaluation of power consumption of machining is one of the essentials and decisive parts of the required evaluation.

OBJECTIVES

Optimization of wood planing parameters nearly has been deserted by the wood technologists and researchers. At present, there is dearth documentation and still lacking of technical information on the planing operation for energy reduction while improving the surface quality of the wood in Sarawak, particularly on planted *Acacia mangium* species. Therefore, the objectives of this research are as follow:

i. to determine the optimum knife sharpness angle and feed per knife during the planing operation while getting the best surface quality among the planing condition;
ii. to reduce energy consumption in timber planing process.

LITERATURE REVIEW

A. Sawing Energy Efficiency of Planted *Acacia mangium* in Sarawak

A study on sawing energy efficiency for timber primary processing of planted *Acacia mangium* in Sarawak was studied by Teng (2015). By recognizing that knowledge on the effect of wood machining parameters on power consumption would improve energy efficiency, thus reduce operating costs and enhance profitability. This paper was reviewed and served as a bench mark study on energy efficiency of planted *Acacia mangium* in Sarawak. Power meter was used to measure the power consumption. The net maximum power consumption (kW) and net integrated power consumption (kWh) were obtained through an analytical method by using the data received from the power meter. Three different parameters namely, density, depth of cut and machining speed were discussed in this sawing experiment. Increase in feed speed, increase in net maximum power consumption but decrease in net integrated power consumption. Both power consumptions increased with specimen height. Older age group of specimen which was higher density samples consumed more energy during sawing than lower density samples. In this proposed research project, the same equipment, same data capturing and analysis methodology will be acquired to determine the optimize sharpness angle and feed per knife for energy reduction during the wood secondary processing in planing operation.

B. Studies of Wood Machining Properties

Assessment of wood machining properties has been around for ages and essential among those referred to is the relevant standard (ASTM, 1999). As plantation forestry is gaining more attention as an alternative source of raw materials for the wood-based industries in many nations nowadays, wood planing property has become essential, especially when dealing with plantation logs which are relatively smaller in diameter but higher in material variability due to their juvenile nature. One of the significant characteristics of wood is the facility with which it can be machined and fabricated. Different species, however, vary greatly in their behavior under machining tools, so that some systematic method is needed for determining their suitability for uses where the character of the machined surface is of prime importance. Such uses include cabinetwork, millwork, and other products where favorable machining properties are essential to good finish. For such products as common boards, on the other hand, good machining properties are secondary, although still an asset. This test method covers procedures for planing, one of the common woodworking operations used in the manufacture of wood products. This test applies wood in the form of lumber, and because of the importance of planing, some of the variables that affect the results of this operation are explored with a view to determining optimum conditions. However, it is necessary to limit the work to one set of fairly typical commercial conditions in which all the different woods are treated alike. Several factors enter into any complete appraisal of the planing property of a given wood. Quality of finished surface is recommended as the basis for evaluation of planing property. Rate of dulling of machining tools and power consumed in machining are also important considerations but are beyond the scope of these test methods. Although the methods presented include the results of progressive developments in the evaluation of planing property, further improvements may be anticipated. For example, by present procedures, quality of the finished surface is evaluated by visual inspection, but as new mechanical or physical techniques become available that will afford improved precision of evaluation, they should be employed. New proposed method is by using surface roughness meter which is more scientifically analysed.

In Sarawak context, Wong *et al.* (2011) adopted the same set of testing methodology on study that revealed the wood planing property of planted *Shorea macrophylla*, or locally known as Engkabang jantong that collected at Sabal Forest Reserve, Km 100 Kuching-Sri Aman Road, Samarahan Division. The study outcome was represented by two age groups, i.e. 13 years old and 22 years old respectively. The objective of this study was mainly to determine the suitability and reliability of 'harmonized' test methodologies for evaluating the wood planing property of tropical plantation species. The best sharpness angle for planing is at 35 degree in terms of the lowest power consumption as well as the best surface quality. The planed surface quality generally improves with decreasing feed per knife. The best surface quality is obtained at 0.38 mm of feed per knife. *Shorea macrophylla* is assessed as easy to plan. However, planing defects such as fuzzy grain, chip mark and torn grain are quite commonly observed.

In another study by Teng & Ting (2018) on wood machining tests of another alternative source of material for wood based industries in Sarawak namely *Falcataria moluccana* or locally known as Batai, they revealed that its overall machining properties were graded as 'Easy' to work, with 'Fair' to 'Excellent' grades by visual grading. No informations were reported on power consumption, surface roughness data by scientific equipment and optimization of machining parameters.

In Peninsular Malaysia, Khairul *et al.* (2011) had adopted a suitable harmonized set of testing methodology on wood planing such as those proposed by Wong *et al.* (2010) is timely as it enables data derived to be comparable on a more scientific basis. This segment of the manual contained the procedures for conducting wood planing test. The procedures were based on methodologies that have been modified to various degrees to address requirements and circumstances typical of the testing of tropical plantation timbers. Management decision may then be adjusted accordingly if the results obtained are less favorable. The study summarized the results obtained on wood planing study conducted on two age groups, i.e. 16 and 20 years old of *Acacia mangium* collected from plantation sites located in Kemasul, Pahang, and Ulu Sedili, Johore, respectively. The lowest power consumption as well as the best surface quality was determined at using of 40 degree sharpness angle. No feed per knife information was reported. Generally, *Acacia mangium* is assessed as "Easy" to plan and graded as "Good to Excellent". However, planing defects such as fuzzy grain, chip mark and torn grain were quite commonly observed. In this study, surface quality was carried out by visual grading and it was subjective as different researchers might have different views. Therefore, in this propose study, the scientific assessment method by using surface roughness meter will be included.

Again in Peninsular Malaysia, a study on characterization of machining defects in wood planing operation had been conducted by Farrokhpayam (2010). The objective of the study was to evaluate the effect of some machining factors on the machinability of selected Malaysian hardwoods and to quantify the major types of machining defects in the planing operation. The study aimed to reveal the relationship between the types of surface defects generated after planing with the variable factors. In that study, three wood species, Rubberwood (*Hevea brasiliensis*), Melunak (*Pentace* spp) and Dark Red Meranti (*Shorea* spp) were chosen based on their machining characteristics, commercial position in the local and global market, and their usage as a solid material in the furniture industry. The depth of cut (0.8, 1.6 and 2.4 mm) and feed rate (8, 12 and 16 m/min) were the experimental variables, while all other factors were kept constant. The surface quality of the individual sample was examined both visually, and sense of tactile to classify the samples into five grades based on the amount and severity of defects present, as given in the standard. An in-depth analysis of the samples surfaces, machined under the three parameters of processing, found that among these three factors, depth of cut had the most significant effect on torn and fuzzy grain. But no information on power consumption for energy reduction was reported. This research showed that the planing operation as a part of wood products manufacturing can influence the quantity or volume of product parts manufactured from a given amount of lumber and labor by affecting the processing yield. The proper machining factors in relation to the wood species used decreases the surface defects. These defects results in increasing labor cost, machining cost and loss of wood material. Therefore, the optimal condition for planing operation of the three Malaysian woods to produce the best yield was realized at the minimum of depth of cut, and maximum machining marks number per millimetre (mm).

Whereas in Indonesia, Rianawati *et al.* (2015) conducted research study on the difference of machining properties between timo wood (*Timonius sericeus* (Desf) K. Schum.) and kabesak wood (*Acacia leucophloea* (Roxb.) Willd.) from the village of Reknamo, Kupang district, East Nusa Tenggara. Recognized that machining properties is one of the parameters to determine the quality of the wood, tests on machining properties of wood are important to know the easiness level of workmanship as raw materials of furniture industry, construction wood and other wood products. Testing procedures were based on ASTM (1999) including: planing, shaping, sanding, drilling and turning. The observation of qualities of the machining were done visually by calculating the percentage of defects that arise on the surface of the samples after the machining process, then the qualities were classified into five quality classes. The results showed that the machining properties of timo wood and kabesak wood were very good and belonging to the quality of class I. The significant difference between the machining properties of both the timbers is in the sanding properties, where the average free defect of sanding timo wood is 85% while kabesak wood is 84.5%. Both timo and kabesak wood are suitable as raw material, for the variety of furniture and molding products.

In Australia, Benoit *et al.* (2016) studied on wood planing properties of Australian plantation-grown Eucalypts. This paper revealed that seven Australian plantation-grown eucalypts were studied on its planing property. The species were evaluated to provide recommendations on how these species should be machined and considered for the manufacturing of high quality furniture and furnishings. The surface quality produced for each species was evaluated using eight planing conditions. All species performed well producing equivalent or better results than mature traditional furniture species, and could be used for high value furniture manufacturing. Tungsten carbide cutters produced better results than high-speed steel for most eucalypts and the grinding of a small chip-breaker usually produced improving results as the size of the chip-breaker was reduced. Grain orientation did not affect the planed surfaces for some species but planing with the grain usually produced better surface. Recovery and presence of torn grain could not be related to the wood density. This project provides the necessary technical information on machining of a number of potential hardwood species which have met tree growth and primary processing requirements regarding their potential for high quality furniture and furnishing products. The data obtained within this study will allow optimizing the machining process of plantation-grown wood in Australia and increase value from the current plantation resource.

Recently, Paiman *et al.* (2018) had evaluated wood machining properties of natural regeneration and planted *Acacia mangium* x *A. auriculiformis* hybrid. Particularly in wood planing test, the test was conducted to assess the planing property of *Acacia* hybrid wood obtained from two different study sites, namely, mature natural regeneration and plantation-grown areas. For each study site, stressed and non-stressed trees were selected and felled at 15 cm above ground. Samples with dimensions of 20 mm × 100 mm × 900 mm were then prepared from three different height levels (top, middle and bottom) of the felled logs prior to machining test. The results showed that non-stressed wood generally had better planing characteristic than stressed wood. In terms of height level, there was no significant difference between height levels and planing property of the wood samples.

C. Optimization of Wood Machining Parameters

Wood machining is the field of study dealing with the manufacture of wood and wood-based products using machining tools. The wood machining process can be described by a long list of parameters and conditions. An awareness of the importance of these parameters and conditions allows the operator to conduct the machining smoothly, efficiently, and precisely. The efficiency of the wood machining process can be quantified in terms of low material and/or labor costs and by high (or expected) yield. Porankiewicz (2014) studied parameters to consider for thorough experimentation in wood machining investigations. It revealed that depending on the scope of the planned research, various dependent variables can be considered. When planning wood machining experiments, it can be important to precisely specify the constant parameters, including their acceptable range of variation, in order to allow future comparison with results of other published experiments. Also, it is good practice to describe the tool life using several parameters, especially expressing maximum machining edge wear, as well as a criterion of evaluation of the machining process quality (physical or technological). For the determination of the machining edge state, the use of total area of machining edge wear (often without specifying the measurement plane) can be a problematic choice, because it can hide information about unacceptable blade state changes, as a basis to stop the machine and replace a tool.

In Sofuoglu (2015) study, the optimization of computer numerical control (CNC) machining parameters were conducted using the Taguchi design method on the surface quality of massive wooden edge glued panels (EGP) made of European larch (*Larix decidua* Mill). Three machining parameters and their effects on surface roughness were evaluated. These parameters included tool clearance strategy, spindle speed, and feed rate. An analysis of variance (ANOVA) was performed to identify the significant factors affecting the surface roughness (Ra and Rz). Optimum machining parameter combinations were acquired by conducting an analysis of the signal-to-noise (S/N) ratio. Optimal machining performance for the Ra and Rz was obtained for the cutter at a tool clearance strategy of an offset 16000 rpm spindle speed and 1000 mm/min feed rate. The surface roughness, both the Ra and Rz, increased with increasing feed rate. Optimal machining performance for Ra and Rz was obtained for a tool clearance strategy of an offset 16000 rpm spindle speed, and 1000 mm/min feed rate machining settings. Based on the confirmation tests, Ra decreased 2.2 times and Rz 1.8 times compared to the starting machining parameters. The Taguchi design analyze method is suitable for solving the wood machining problems by CNC router machining which they were described in the present works. Better results have been obtained in terms of techniques such as Taguchi design method using MINITAB software.

In Luis (2013) study on machining properties of wood: tool wear, machining force and tensioning of blades, the studied wood species were five Mozambican tropical species, namely: *Swartzia madagascariensis* (ironwood); *Pseudolachnostylis maprounaefolia* (ntholo); *Sterculia appendiculata* (metil); *Acacia nigrescens* (namuno); *Pericopsis angolensis* (muanga) and two main Swedish wood species: *Pinus sylvestris* L. (Scots pine); and *Picea abies* (L.) Karst. (Norway spruce). A series of experimental tests were conducted to determine the suitability of different machining tool materials when machining these wood species. Machining tropical hardwood and Swedish frozen wood under winter conditions is still a challenge when it comes to the choice of which machining tool material to use. Tool wear was used as a criterion to evaluate the performance of the machining tool materials. Additionally, the relationship between tool wear and some chemical and physical properties for Mozambican tropical wood species was analyzed. Different wear mechanisms were identified using a scanning electron microscope. It was concluded that tool hardness alone was not the only factor affecting tool wear; a certain amount of tool toughness was also needed to obtain low tool wear. The predominant wearing mechanisms for the tropical wood species tested were abrasion and edge-chipping. Furthermore, tropical hardwood species were subjected to machining force tests. A standard single saw tooth, mounted on a piezoelectric load cell, was used to evaluate machining forces. The theoretical approach used for the prediction of the main machining forces was based on surface response methodology. Among the studied variables, chip thickness and machining direction had the greatest effect on the main machining force level, while wood density, moisture and rake angle had the least effect.

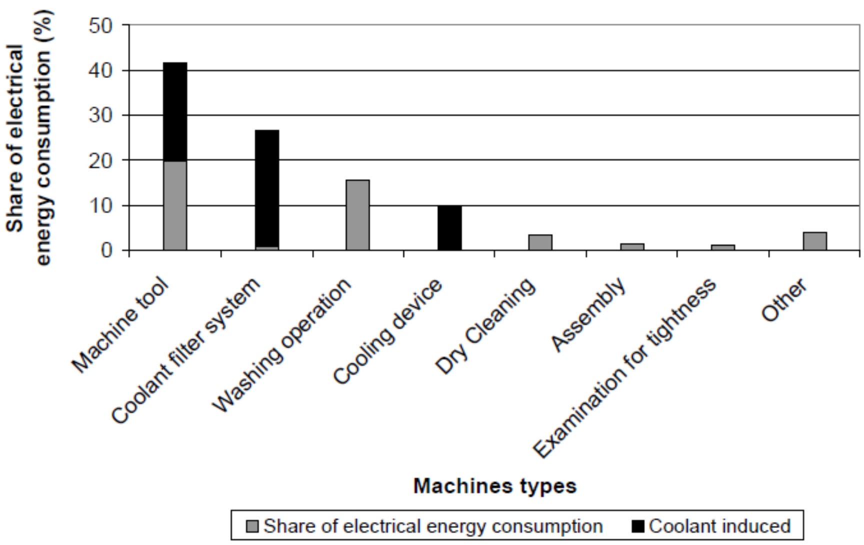
It is important to evaluate the effect of machining and wood machining properties on surface quality to determine and upgrade the data on wood machining properties and to define convenient usage areas for some native wood species of Turkey. Therefore, Dundar & Kurtoglu (2015) had studied the effects of machining conditions on surface roughness in planing and sanding of European black pine (*Pinus nigra* Arnold) and cedar of Lebanon (*Cedrus libani* A. Rich). They are two softwood species and sessile oak (*Quercus petraea* Lieble) and black poplar (*Populus nigra* L.) are two hardwood species commonly used and grown in Turkey. These trees species were selected as experimental material for the study. Roughness measurements are significant in the determination of wood surface quality for use as a final product. Surface roughness can be evaluated quantitatively and qualitatively. Each approach has advantages and disadvantages, such as a slower speed, sensitivity, and the accuracy of results. There are various methods of surface roughness measuring in the area of woodworking. The stylus trace method has emerged as the most suitable and applicable method in the measurement of surface roughness. The average roughness values for wood in directions perpendicular to the grain and along the grain from highest to lowest were sessile oak, black poplar, black pine, and cedar of Lebanon.

D. Power Consumption and Energy Reduction

Meanwhile, Aguilera & Martin (2001) conducted machining qualification of Beech and Spruce solid wood with different types of density to study correlation among machining forces, power requirements and surface roughness. The machining process was carried out on a shaper with specific devices. The concerned variables were: the machining depth, the feed per knife and the machining speed. The mean chip thickness and machining width were constants. The machining process it was done in two different ways: up and down milling, thus it was possible to compare both working directions with the same machining parameters and watch his influence in the machining forces, the power requirements and the surface roughness. The most important variables that had a big influence on the machining forces were the depth of cut, the wood density and the milling direction. With regard to the power requirements, it was detected that the most important variables were the machining forces, the feed per knife, the milling direction, the depth of cut and the wood density. It was concluded that the measured and calculated horsepower had a very good correlation, and also the machining forces are determined by the calculated horsepower, thus if we do the measurement of the power cut for an specific conditions of wood and machine, one can estimate the machining forces. The surface roughness has very homogeneous in all of the tests. The machining process it was performance if to work in up milling, where the machining forces, the power requirements and the roughness standard deviation reach the smaller values. This environmental analysis of machining highlights a few important points. From the energy analysis of the material removal process, it is clear that the actual machining energy can be quite small when compared to the total energy required during material removal. It is also important to note that the energy used to power machine tools typically comes from the electricity grid. Thus, electricity requirements for the material removal process must be correctly burdened to reflect their true environmental impact. Another important point is that the energy involved in the material production process can, in some cases, dominate the energy involved in the material removal process. This result is particularly true if the material being machined is virgin aluminum, or an equally energy-intensive material. However, in the case of recycled steel, or an equally non-energy-intensive material, the material production energy and material removal energy may be on the same order of magnitude. With regards to machining fluid preparation and cleaning, the focus shifts from one of energy to one of liquid and gaseous emissions.

In energy efficiency of machine tools study by Herrmann *et. al.* (2009), there is a necessity and potentials of an extended perspective on machine tool energy consumption. Due to increasing energy costs and the environmental impact of energy generation, energy consumption has become a major topic in manufacturing in the past few years. Therefore, the energy consumption of production machines as interaction of different components is not static but rather highly dynamic depending on the operation mode (Figure 1). Hence, as a prerequisite for optimizing energy efficiency on the machine level it is crucial to understand the energy consumption behavior. Analyzing certain energy profiles of production machines is a common way in research nowadays to identify main drivers of consumption and derive optimizing measures. However, whereas only focusing on electricity as input variable these analyses do not provide the full picture of energy flows within the machines and neglect existing coherences and significant energy losses. Therefore a holistic perspective on the system machine tool considering all relevant input and output flows (e.g. heat, compressed air, coolant) and supporting equipment (e.g. filter systems) with all interdependencies is necessary to avoid problem shifting and enable the identification of further optimization potentials.

Figure 1: Induced energy consumption of machining in process chains



Based on research findings discovered by Andy & Jonathan (2013), the actual energy consumption varies widely for each parameter and in some cases such as when by increasing feed rates, it can actually be decreased dramatically. Machining speeds, feed rates, and end-mill immersions are varied and the resulting varied peak power consumption. Increasing any one of these parameters would increases MRR and the peak power loads of the spindle and machine tool.

In the same year, Negrete (2013) studied on optimization of machining parameters using robust design for minimizing energy consumption, it revealed the effects of depth of cut, feed rate and machining speed on the response variable could be analyzed by using robust design. Robust design is an engineering methodology whose objective is to create high-quality, cost-effective products that perform well during its useful life independently of how and under which circumstances are used. These external circumstances that are outside the control of the design engineering are called noises. Robust design increases the quality of products minimizing the effect of noise on the performance of the product. The strategies to reduce energy consumption are obtaining emphasis due to the constant increase in electricity prices, and concern of manufacturing companies and clients about the environmental impact that results from activities related to the production of goods.

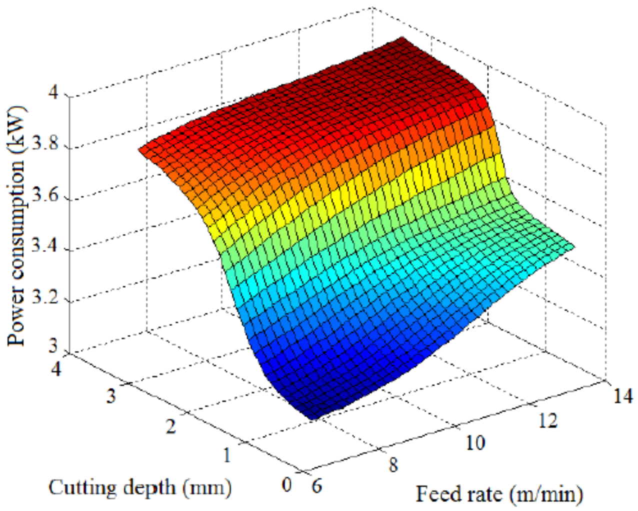
The relationship between energy consumption and other wood machining parameters was characterized by Vivek *et al.* (2014). Energy consumption in machining operation and the input electrical energy of the machine was studied. A reliable prediction of energy consumption would enable industry to develop energy saving strategies during various machining operations. To verify its feasibility and validity, the assessment method is applied to small machining workshop. The study focus on the effect of automation on energy consumption during machining; effect on energy consumption due to defects during machining; and to find the optimal range of friction during machining processes. Wood machining parameters could be optimized through intensive study in order to minimize the power consumption and at the same time to produce the best surface quality on the wood. So the energy wasted in form of heat may be minimized and its impact on environment can be reduced. Along with this certain modifications for the existing system for increasing the energy efficiency are also projected.

Several researches have been conducted to study consumption of energy in machining process. Most of these researches are focusing to measure the consumption and propose consumption reduction methods. In Shiva & Daniel (2014) study, the relation between the machining parameters and the consumption is investigated in order to establish a generalized energy consumption model that can be used for process and production planning in real production lines. Using the generalized model, the process planning will be carried out by taking into account the energy as a function of the selected process parameters. Similarly, the generalized model can be used in production planning to select the right operational parameters like batch sizes, routing, buffer size, etc. in a production line. The description and derivation of the model as well as a case study are given in this paper to illustrate the applicability and validity of the model. Developing an energy consumption model for characterizing Machine Tools Energy Consumption (MTEC) helps to analyze the estimated energy consumptions with respect to the influencing factors such as machining conditions and machine type. It was aimed to formulate the energy consumption of machine tools as the function of machining parameters (machining depth, rotation speed and feed per knife). This model can be undertaken as a decision based framework for process and production planning in real manufacturing systems.

More advanced approach in the wood machining requires constant monitoring of the machining process in real time. Such techniques can be provided by measuring different process outputs. The amount of heat generated during machining, machining forces, power consumed are common examples of machining process output. The specific construction and the shape characteristics of the machining knives indicate possible relationship between the power consumption, acoustic mission and the machining process progress. The results obtained by Marija *et al.* (2015) in the comparative analysis of two methods for the power consumption measurement, indicated that for the power consumption and the acoustic emission spectrum analysis strongly suggest dependence of the former to the tool override. The intention of the study is to compare the results obtained from already existing, but slightly altered, technique of the power measurement and one still developing, the sound analysis. The actual environmental conditions performed in the research, incorporating auxiliary systems, such as exhauster installation, had to bring the results of the conducted research to the point of practical implementation. The utilization of the acoustic emission analysis as an instrument for fast determination of the consumed power during machining operation of the laminated particle board might become powerful indicator of the state of materials involved in the machining process, both the tool and the wood based board. The results presented would clearly indicate the possibility of such implementation of the frequency and spectrum sound analysis.

Optimum power consumption in wood machining could be predicted through artificial neural network modeling as reported by Tiryaki *et al.* (2016). This paper investigated and modeled the effects of wood species, feed rate, number of cutters and machining depth on power consumption during the wood planing process. The study aimed a low-density wood species as well as a higher-density species. The species selected were spruce (*Picea orientalis* (L.) Link.) and beech (*Fagus orientalis* Lipsky.) for low and high density, respectively. For power consumption tests, the wood machining process was conducted using a planer machine. The samples were planed at feed rates of 7 and 14 m/min, machining depths of 0.5, 1.5, 2.5 and 3.5 mm and using 1, 2 and 4 cutters. The current intensity drawn by the machine motor during the planing process was measured using an ammeter. As the current which reached the engine was the same in 3 phases, an analogue ammeter was connected to one phase and an experimental setup was prepared. When the planer machine was operated for the first time, an ammeter capable of measuring high voltages was used due to the high current amount drawn from the engine. Moreover, it is important to mention that the power consumption was not linear during the planing process. At the beginning of planing, the power consumption was generally higher. However, it was seen that the power consumption reached a steady value after some time. To ensure the reliability of the measurement values, when the engine acceleration and the values shown by the ammeter and voltmeter were stable, the current and voltage values were recorded. The analysis of variance (ANOVA) was performed to evaluate the influence of the considered parameters on the power consumption during the planing of the wood. Power consumption increased with increasing feed rate, machining depth and number of cutters. In artificial neural network model, the mean absolute percentage error values between the actual and predicted values were 0.32% for the training data set and 1.15% for the testing data set. In addition, the values of R^2 were found to be 0.99 and 0.97 in the training and testing data sets, respectively. It is evident from the results that the designed model may be used to optimize the effects of process parameters on power consumption during the planing process of different wood species. Thus, the findings of the current study can be effectively applied in the wood planing industry in order to reduce the time for further experimental investigations, to lower energy consumption and avoid high machining costs (Figure 2).

Figure 2: The effect of cutting depth and feed rate on power consumption



RESEARCH FRAMEWORK

Improving energy efficiency of machining process requires knowledge about the energy consumption as a function of the machine tool and machining process itself (Pavanaskar, 2014). Energy consumption of the machine tool is found to be dependent on the average power demand and the processing time dictated by the machining parameters. Designing high-quality products and processes at low cost is an economic and technological challenge to the engineer. Robust Design is a systematic method and efficient way to meet this challenge, introduced by Genichi Taguchi. Its fundamental principle is to improve the quality of a product by minimizing the effect of the causes of variation without eliminating them. Signal-to-noise ratio is employed to measure quality and minimize variation around a target value.

The up milling assures a work in safety and the machining forces are lower than the down milling. The negatives points are that always there are problems of breaking knives if the wood has an inadequate fiber direction, the resulting machining surface will be of poor quality. The down milling permits the woodworking at higher feed per knife, there are no problems of breaking and either of reducing the knife sharpness. The power requirements are important and the machining waves are deeper if we compare with the up milling.

There is very important to calculate the chip size, because the work quality and the reduction of knife sharpness are very dependent by this value, and also a chip of big dimensions could done an important production, but with poor quality. By other hand if we have a small chip size the surface quality will be higher, but the loss of knife sharpness will be easy. For pulling out a chip, the knives' sharpness angle does a force bigger than the cohesion of the material. This effort it's the resulting of several forces for flexing the fibers, the shearing force and the friction on the faces of the tool. This effort is called feed per knife as its function of the kind of machining wood, the work conditions and the tool that related wood machining parameters are the wood density, the nature of the species and humidity. The factors related to the work conditions are the feed direction, the depth of cut, the sharpness angle, the chip size and the feed per knife and rotation speed. The consumed machining energy is directly linked with the forces acting on the tool. The power corresponds at the wood volume transformed into chip per second, multiply for the specific machining energy W_{sp}. This factor W_{sp} is function of the parameters associates at the material and work conditions. The power consumption is directly proportional to the number of knifes, all other factors remaining constant. The greater the volume of wood removed, the greater the power required. The greater the density of wood, then more work makes more noise.

The study is intended to test on major planted *Acacia mangium* species in Sarawak. In the evaluation of power consumption and surface roughness results, correlation analysis, analysis of variance (ANOVA), and also a t-test will be employed to investigate whether there is a significant difference between the power consumption and surface roughness values with respect to the tested sharpness angles and feed per knife. As a relationship at the $P \leq 0.05$ level to make available between the factors, Duncan's multiple mean comparison test will be applied and homogenous groups to be detected. The analysis will be performed using SPSS 11.5 (Statistical Package for the Social Sciences).

CONCLUSIONS

The energy consumption in the wood planing operation in wood production processes which mainly is emerge from production equipment. Machining tool is one of the typical production equipment widely used in the industry. In machining process, saving money and improving sustainability performance can be achieved by reducing energy consumption because energy is an essential resource for production. It is evident from the literature reviews that the intended study may be used to optimize the effects of process parameters on power consumption during the planing process of different wood species. Thus, the findings of this study on optimizing machining tools parameters such as sharpness angle and feed per knife in wood planing operation can be effectively applied in the wood planing industry in order to reduce the time for further experimental investigations, to lower energy consumption and avoid high machining costs.

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