Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 9 (20): 3770-3774, 2009
ISSN 1812-5654

Dust-Emission from Abrasive Sanding Processes in the Malaysian Wooden Furniture Industry

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Abstract: A series of sanding experiments were carried out in a large dust tunnel, using an orbital sander with an aluminum oxide abrasive of 150 grit size, on twelve different hardwood species. Dust concentration measurements were taken using gravimetric isokinetic air-quality samplers. A field survey of 25 wooden furniture-manufacturing mills to ascertain the dust exposure levels at the sanding sections and also evaluate the labor productivity losses encountered among workers as a result of dust exposure. The results found that dust emission in the sanding process was primarily determined by the amount of wood removed. Further, the dust exposure levels at the sanding section in the furniture-manufacturing mills were above the standard 5 mg m^{-3} level and hence, control of dust emission and the use of dust protection gears by the workers must be enforced in the furniture-manufacturing mills to ensure the health and safety of the workers. Without such measures, labor productivity among the workers would be reduced.

Key words: Wood dust, furniture, wood removal, health, productivity

INTRODUCTION

The sanding process is an important value-addition task in the wooden furniture manufacturing industry. It is regarded an orthogonal cutting process with a negative rake angle, which implies that wood removal is achieved by crushing and scraping actions (Ratnasingam *et al*., 2004; Welling *et al*., 2009). Inevitably, the sanding process results in the production of wood dust that is injurious to the health of the workers (Whitehead, 1982; Black and Dilworth, 2007; Wutjaree *et al*., 2009). When the health of the workers suffers there is a corresponding loss in labor productivity, which will impair the business performance (Bemer *et al*., 2000; Schlünssen *et al*., 2008; Hursthouse *et al*., 2004). Dust from wood sanding processes is of particular interest in Malaysia because many different hardwood species, ranging from the light hardwood (<600 kg m^{-3} in density) to heavy hardwoods (>800 kg m^{-3} in density) are used in the manufacture of wooden furniture (Graham and Ratnasingam, 2007). Despite its industrial implications, studies on dust emission during the sanding processes of Malaysian hardwoods in the wood products and furniture industry are very limited (Graham and Ratnasingam, 2007).

A number of parameters have been found to affect the production of dust during the wood sanding process, such as the type of wood, density and hardness and also the sanding grit of the abrasives used in the process (Thorpe and Brown, 1995; Vinzents *et al*., 2001; Harper and Muller, 2002). By monitoring the quantity of dust produced as these parameters are varied it is possible to examine the dust-generating characteristics of Malaysian hardwoods during the sanding process. Therefore, this study aims to evaluate the dust-generation characteristics of selected Malaysian hardwoods and provide benchmark values on the amount of dust generated during the sanding operation in the Malaysian wooden furniture industry.

MATERIALS AND METHODS

Twelve species of hardwoods, which represented the commercially important hardwoods used in the Malaysian wooden furniture manufacturing industry, were selected based on its density and hardness for this study (Table 1). The materials were obtained from a local sawmill. The materials in the form of planks of 25×50×50 mm in dimension were conditioned to a final moisture content of 12±2%, before experimentation. A total of 5 planks of each species were used in this study. The density of the wood samples was determined gravimetrically by taking the weight and volume of a

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Table 1: Malaysian hardwood species used in the study

Hardwood specie	Average density (kg m^{-3})	Average hardness (N)
Resak (*Vatica* sp.)	870	7040
Merbau (*Intsia* sp.)	845	7010
Balau (*Shorea* sp.)	820	6980
Keranji (*Dialium* sp.)	805	6790
Kelat (*Syzygium* sp.)	670	5140
Kapur (*Dryobalanops* sp.)	660	5085
Merawan (*Hopea* sp.)	640	5060
Mengkulang (*Heritiera* sp.)	615	4955
Nyatoh (*Madhuca* sp.)	590	3825
Melunak (*Pentace* sp.)	575	3655
Rubberwood (*Hevea* sp.)	540	3440
Meranti (*Shorea* sp.)	530	3610

Density and hardness measurements taken from the sample boards. Hardness is defined as the force, in kg wt., applied to an 8 mm diameter sphere to produce a 2 mm depression in the wood sample

specimen (20×20×25 mm) from each wood species at the final moisture content, while the hardness was determined by enumerating the force applied by 8 mm steel ball to result in a 2 mm depression on the surface (Desch and Dinwoodie, 1996). The density and hardness values of the wood species of the samples obtained in this study were within the 5% difference of the average published values for the respective wood species.

The sanding experiment was carried out using a 3 M pneumatically-operated orbital sander, which had an orbit diameter of 80 mm and rotating at 10,000 revolutions per min. Aluminum oxide abrasive of the sanding grit size 150 was used in this study. The study backed abrasive was attached to the orbital sander using the velour hook-and-loop system.

The orbital sander was fixed in position by a specially made bracket, while the wood plank was attached on to a reciprocating platform that moved at a speed of 15 mm sec^{-1}. A force equivalent to 5 kg was applied on to the sander, to ensure consistent sanding operation (Fig. 1). This experimental configuration represented the typical sanding operation in the wood products manufacturing industry, as reported by Graham and Ratnasingam (2007).

The sanding experiments were carried out in a large dust tunnel at the experimental facility of Petaling Corporation in Sungei Buloh in Malaysia from March to May 2009, to ensure that the experiments were carried out in a moving air stream. The air velocity in the tunnel was maintained at 25 cm sec^{-1}, which was typical of industrial conditions. The experimental equipment was placed within a working section of approximately 3.0 by 3.0 m and all dust measuring instrumentations was placed several meters downstream. For all the hardwood species tested, sanding was carried out for a period of 30 min.

The quantity of dust removed from the hardwood planks during the 30 min of sanding was determined by weighing the planks before and after the operation. The dust concentration in the tunnel was measured using two gravimetric isokinetic samplers placed two meters apart long the length of the air tunnel. The concentration was taken as an average of the two samplers. The size distribution of the dust was measured using an aerodynamic particle sizer (APS 3300). The experimental techniques and the dust particle evaluation method used in this study, together with the statistical analysis undertaken were as reported in the previous studies by Lehmann and Fröhlich (1988), Thorpe and Brown (1995) and Graham and Ratnasingam (2007).

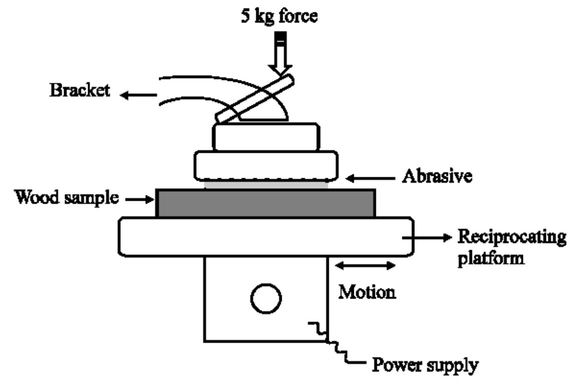

Fig. 1: Sanding experiment configuration

In order to evaluate the dust concentration and its effects on the labor productivity in the value-added wood products industry, dust-concentration measurements using the portable gravimetric isokinetic samplers placed 2.0 m from the various sanding machines, at 25 wooden furniture manufacturing enterprises in the Klang Valley in Malaysia. The average measurements at each sanding stations at the mills, were taken over a period of 30 min. Further, the workforce records at these mills were examined and the relevant labor productivity data calculated. All the mills consented to participate in this study prior to the implementation of the field survey, which was carried out from January to May 2009 around the Klang Valley, Malaysia.

RESULTS AND DISCUSSION

Effect of wood density and hardness on dust concentration: The results from the study revealed that there is a good correlation between the mass of wood removed during the abrasive sanding process and the concentration of airborne dust produced, irrespective of the sanding grit and the type of hardwood specie. Generally, the amount of wood removed and airborne dust produced both varied inversely with density and hardness as shown in Fig. 2. Since, the correlation

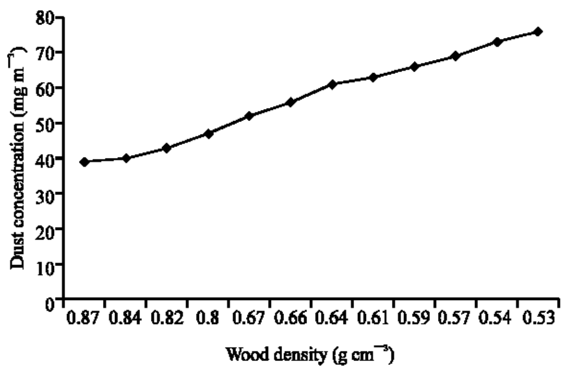

Fig. 2: Effect of wood density on dust concentration

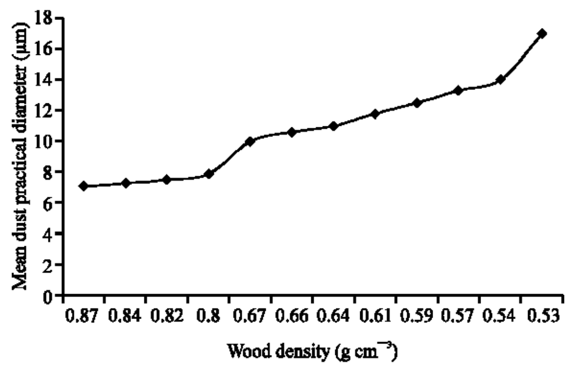

Fig. 3: Effect of wood density on mean airborne-dust particle diameter

between wood density and hardness was very good, with a coefficient correlation of 0.981, it may be implied that the correlation of other parameters with any of these intrinsic characteristics of the hardwoods will results in similar results, as suggested by Thorpe and Brown (1995) and Desch and Dinwoodie (1996). Consequently, any change in wood density or hardness will results in a comparable rate of wood removal and rate of airborne dust production. Martin and Zalk (1997) reported that the crushing effect of the hardwood cells is more pronounced in low density materials compared to high density hardwood species. In fact, abrasive sanding is more efficient on materials of lower density and hardness, as the abrasive grains are able to penetrate deeper into the material during the sanding process, thus resulting is a higher mass of material removed, when all other conditions are kept constant (Ratnasingam *et al.*, 2004).

Effect of wood species on dust particle diameter: The study revealed that the geometric mean particle size of the dust produced during the sanding process was significantly influenced by the wood density and hardness. Softer and low density wood species produced coarser dusts, while harder and high density wood species resulted in finer dust particles (Fig. 3). This observation is attributed to the fact that during the sanding process, the abrasive grits penetrated deeper into the softer wood species to remove a larger amount of wood material, resulting in coarser dusts. On the other hand, harder wood species restrained the penetration of the abrasive grits, thus resulting is smaller amount of wood removed, which in turn manifested as finer dust particles (Ratnasingam *et al.*, 2004). Nevertheless, denser hardwoods give rise to airborne dust at a lower rate compared to the less dense hardwoods, but the total amount of airborne dust produced is a function of the total amount of wood removed during the sanding process, attributed to the mechanics of the abrasive sanding process (Ratnasingam *et al.*, 2004). This result suggest that contrary to common belief, the amount of airborne dust produced during the abrasive sanding process is not influenced by the density of the wood and hence, dust emission during the process can be reduced by minimizing the amount of abrasive sanding carried out.

Sanding dust-emission profile in the malaysian wooden furniture industry: From the field survey conducted, the dust concentrations at the various sanding stations in the furniture manufacturing mills were markedly different, as shown in Fig. 4. It is obvious that this difference is closely related to the amount of wood removed at the sanding station. Increasing amounts of wood removed would lead to greater amount of dust concentration and it appears that the wide-belt sanding machine has the highest level of dust concentration. Further, all the sanding sections recorded dust exposure levels in excess of the standard value of 5 mg m^{-3} (Whitehead, 1982), implying that the use of dust protection gears or dust mask by workers is a necessity in order to ensure their health and safety.

Dust emission and labor productivity in the wooden furniture industry: The labor records examined show that labor productivity among the workers in the sanding section at the 25 furniture manufacturing mills was consistently lower than the workers from the other section. On the average, non-productive time of an average of 27% were recorded among the workers due to respiratory related illness. As a result, worker's turnover was also the highest among workers in the sanding section. On the other hand, productive-time loss was much lower among workers from the other sections in the furniture manufacturing mills, averaging 8% in the 25 mills surveyed (Fig. 5). The findings of this study corresponds with the previous report by Whitehead (1982) and

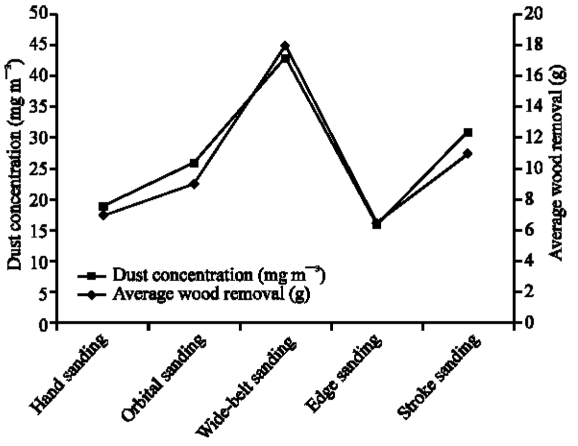

Fig. 4: Dust concentration at different sanding stations

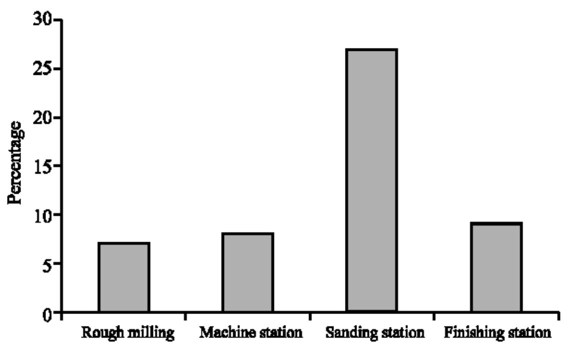

Fig. 5: Average productive-time losses in furniture manufacturing

Graham and Ratnasingam (2007), who found that labor productivity was significantly effected by dust emission in the value-added wood products industry.

Industrial implications: The results from this study reveal the abrasive sanding characteristics of selected Malaysian hardwoods and it is apparent that the amount of airborne dust produced is a function of the amount of wood removed during the abrasive sanding process, rather than the density of the wood, as previously thought. Hence, the hardwoods used in this study resulted in similar amount of airborne dust, but only differed in the rate at which the dust was produced. The results of this study also confirm the observation that the sanding operation in the furniture manufacturing industry generates a high concentration of airborne dust. Although, the dust concentration is related to the amount of wood removed during the sanding operation and indirectly, to the wood species used, the airborne dust concentration levels recorded at the mills which exceeds the standard 5 mg m^{-3}, suggest that dust-emission control and dust protection gears for the workers are essential requirements that must be enforced in the furniture manufacturing mills in order to ensure the health and safety of the workers. Further, the study also suggests that the sanding operation should be optimized to ensure minimal wood removal, which in turn, will reduce the dust emission. Such an effort will help create a more hygienic and comfortable working environment in the furniture manufacturing mills. It is also recommended that a further study of industrial air-borne dust concentration levels be carried out in the wooden furniture-manufacturing factories using different wood species, to ascertain wood species influences on the overall dust concentration in the mills.

CONCLUSION

Dust emission during the sanding process of hardwoods is influenced primarily by the amount of wood removed during the sanding operation and hence, dust emission control can be achieved by minimizing the amount of wood removed during the sanding operation. The study also reveals that airborne dust concentration in the sanding operation exceeds the allowed standard and hence, control of dust emission and the use of dust protection gears by the workers, must be enforced in the furniture manufacturing industry to ensure workers health and safety.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Petaling Corporation Sdn. Bhd. in Sungei Buloh, Selangor, Malaysia, for the support with the experimental facilities and equipments during the study.

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