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Tool Wear Characteristics of Oil Palm Empty Fruit Bunch Particleboard

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Abstract: A series of machining experiments on the Oil-Palm Empty Fruit Bunch (OPEFB) particleboard were carried out using a CNC router, to evaluate the tool wearing properties of the composite in comparison to the conventional wood-material particleboard. A single-fluted tungsten-carbide router bit (12 mm ϕ, 18 000 rpm), with a rake angle of 15° was used in this experiment, in which the depth of cut was 1.5 mm and feed speed was 4.5 m min^{-1}. The router bit machined the edge of the board, moving along the full length before returning to repeat the cycle. The tool was examined for the extent of wear after complete failure had occurred. The result found that the wear pattern was similar in the oil-palm based particleboard and the wood-based particleboard, but the former was twice more abrasive compared to the latter. Microscopic examination of the cutter edge revealed greater incidence of micro-fracture when cutting the oil-palm based particleboard, indicating the presence of hard impurities in the composite. From an economic perspective, the tooling cost for machining oil-palm based particleboard is estimated to be twice of the cost for machining wood-based particleboard. This study shows that the machining properties of oil-palm based particleboard will be a primary concern, if the board is to find widespread application as a potential substitute for wood-based particleboard.

Key words: Oil palm, particleboard, tool wear, micro-fracture, process economics

INTRODUCTION

Oil palm (*Elaeis guineensis*) is one of the most important plantation tree crops in Malaysia and it covers a land area of almost 3.5 million hectares (Khalil *et al*., 2006). Cultivated primarily for the production of palm oil, the tree crop is an important source of alternative fibers for the manufacture of value-added products. Approximately, 30 million tons of usable fibers from the trunk, frond and empty fruit-bunch of the oil palm is produced annually in the country. The empty fruit-bunches produces approximately 4 million tons of fibers per annum (Khalil *et al*., 2006). This fiber source is highly cellulosic and exhibits good mechanical properties (Sreekala *et al*., 1997).

The feasibility of manufacturing OPEFB particleboard in Malaysia is proven (Chew and Ong, 1985) and industrial production is estimated to be 25,000 m^3 per annum (Khairiah and Khairul, 2006). Despite the industrial success, the OPEFB particleboard has limited market acceptance, due to the accelerated wear of cutting tools during machining processes and the resultant high tooling cost (Ratnasingam and Scholz, 2006). Although the OPEFB particleboard has a lower production cost and comparable mechanical properties compared to the conventional wood-based particleboard, its excessive tooling cost may offset these advantages. Therefore, a study was undertaken to evaluate the tool wearing and tooling cost incurred when machining OPEFB particleboard, in order to provide information on the process economics.

MATERIALS AND METHODS

OPEFB particleboards were obtained from a local manufacturer in Malaysia. The boards of the dimension 18×2000×2000 mm were conditioned in a controlled environment at a temperature of 20°C and 70% relative humidity for a week prior to experimentation.

The machining experiments were carried out using an ANDERSON-810 Computer-Numerical Control (CNC) router. Commercially available single-fluted router bits, 12 mm in diameter, with a 15° rake angle, were used as the cutting tool. The bit was operated at 18,000 revolutions per minute (rpm), while the feed speed and depth of cut were fixed at 4.5 m min^{-1} and 1.5 mm, respectively. The cutting tool traveled along the length of the experimental board and retracted automatically to the starting point before resuming the next cutting operation. Due to the high silica content in the oil palm EFB fiber (Sreekala *et al*., 1997), tungsten carbide cutting tools were selected on its high wear resistance (Bayoumi and Bailey,

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Table 1: Composition of tungsten carbide tools

Tool	WC content (% of weight)	Co content (% of weight)	Cr content (% of weight)	Average carbide particle size (μm)
Grade A	88.5	10	1.5	1.6
Grade B	87.5	10	2.5	1.4
Grade C	86.5	10	3.5	1.0

1985). In this study, however, three different compositions of tungsten carbide was used, in order to establish the optimal grade of tungsten carbide for cutting OPEFB particleboard (Table 1). The extent of cutting tool wear during the machining operation was measured using the cutting edge-recession technique as described by Ratnasingam and Perkins (1998). Since, cutting edge-recession has a direct link to tool life, it allow the cost of tooling to be determined when machining the experimental boards. Microscopic examinations of the cutting edges were done at the end of the experimentation to characterize the mode of failure in the cutting tools. The power consumption during the machining operation was also measured on the basis of the changes in the torque of the drive-motor of the CNC router, as described by Ratnasingam and Perkins (1998). A parallel study was conducted on wood-based particleboards under similar experimental conditions for comparison purposes.

RESULTS

Extent of tool wear and power consumption: The extent of wear experienced by the tungsten-carbide tools of the three different compositions is shown in Table 2. The best performance, in terms of tool edge recession and distance of cut before failure, was obtained from the grade C tool, with the highest chromium content in the matrix and smallest carbide particles. Complete cutting tool failure for the three grades of cutting tools occurred after cutting distances of 2150, 2380 and 2890 m, respectively. This is in line with the study by Bayoumi and Bailey (1985), who found that higher chromium content in the tool matrix and smaller carbide particles improved the wear resistance of tungsten carbide tools. In this context, machining OPEFB particleboard requires the use of highly wear resistant cutting tools, in order to optimize the process.

When the power consumption curves during the machining operations were compared, a similar result was obtained. Since power consumption during the machining operation is closely related to the cutting tool wear, the power consumed was the least with the high chromium content tungsten carbide tools (Fig. 1). The improved wear resistance of the grade C cutting tool ensured lower power consumption during the machining operation, which in turn improved the process economics.

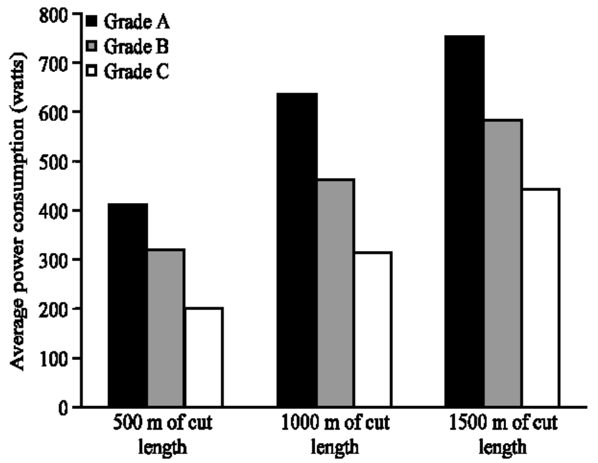

Fig. 1: Comparative power consumption of different tool materials

Table 2: Extent of wear of the various grades of cutting tool

Tool	Edge recession (μm) at 500 m	Edge recession (μm) at 1500 m	Edge recession (μm) at 2000 m	Cut distance (m) at tool failure
Grade A	120	175	219	2150
Grade B	93	139	181	2380
Grade C	55	97	138	2890

Upon microscopic examination of the tool cutting edge, it was found that wear occurred primarily as a result of indentation, micro-fracture and mechanical abrasion. This wear mechanism has been suggested by Bayoumi and Bailey (1985), who reported that the presence of silica and other impurities in material resulted in the removal of the binder followed by the loss of carbide grains from the cutting tool. In fact, the tools cutting OPEFB particleboard suffered greater mechanical wear compared to those cutting wood-based particleboard, due to the high silica content in the EFB fiber.

Comparative wear characteristics: When compared to wood-based particleboard, it is apparent that the OPEFB is almost two times more abrasive on the cutting tool (Fig. 2). Further, the initial wear rate is significantly higher in the OPEFB particleboard compared to that of the wood-based particleboard, possibly due to the inherent density gradient in the boards (Klamecki, 1979, 1980). Coupled with its high silica content, the OPEFB particleboard is highly abrasive on the cutting tools.

Industrial implications: On the basis of the tool wear experiments that were conducted, Table 3 provides a comparative tooling cost for machining OPEFB particleboard and the conventional wood-based particleboard. It is apparent that the OPEFB particleboard is much more abrasive and therefore, results in a higher tooling cost during its machining processes. On this

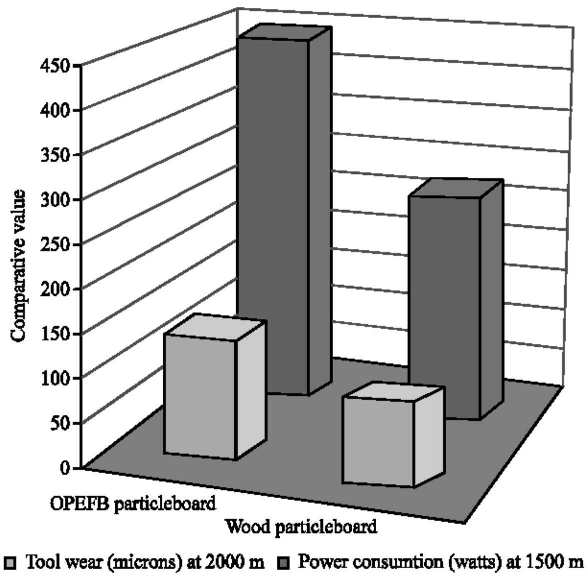

Fig. 2: Comparative tool wear characteristics

Table 3: Comparative tooling cost

Parameters	OPEFB particleboard	Wood-based particleboard
Cost of tool (US$)	100.00	100.00
Cost per grind (US$)	1.50	1.50
No. of grind	3.00	3.00
Edge life per grind	2890.00	5550.00
Overall cost	104.50	104.50
Life time per tool (m)	11560.00	22200.00
Cost per meter cut during life time of tool (US$)	0.010	0.004

account, the acceptance of OPEFB particleboard in the marketplace as a substitute for the wood-based particleboard may be hampered due to the higher tooling cost and hence, the unfavorable process economics. Further, the study also indicates that highly wear resistant tools need to be developed, in order to improve the process economics of machining OPEFB particleboard.

CONCLUSION

Although the production of OPEFB particleboard is competitive, it acceptance in the marketplace as a substitute for wood-based particleboard is constrained by its high tooling cost incurred during its machining. The high silica content in the EFB fibers accelerates the wear of cutting tools, which in turn has a negative effect of the process economics.

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