EXPERIMENTAL INVESTIGATION AND TAGUCHI OPTIMISATION OF DRILLING PROPERTIES ON TEAK WOOD REINFORCED EPOXY RESIN

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Abstract. The drilling properties of teak reinforced epoxy resin composite are explored in this work. The thrust force and temperature during the drilling process was found and optimised. Nine holes were drilled in accordance with L₉ orthogonal array on Medium Density Fibre board and Teak wood reinforced epoxy composite board and the thrust force and temperature induced during drilling is measured. Drilling experiments were conducted using CNC Vertical drilling machine and the thrust force was measured using dynamometer and temperature using infra-red thermometer. The experiments were conducted with varying levels of spindle speed and feed rate and optimised using Taguchi optimisation. It was observed that higher thrust and temperature were observed while drilling teak wood composite due to the high mechanical strength of teak wood. The hard and brittle properties of the resin seemed to be more pronounced in the composite. The experimental results were optimised to find the best combination of input parameters for reduced thrust and temperature. When speed increases, thrust force decreases and temperature increases. When feed increases, thrust force increases and temperature decreases. Experimental findings encourage to use teak wood reinforced epoxy resin as a substitute for the traditionally used Medium Density Fibre Board. The percentage of mixing of teak dust can be increased with various resin combinations to arrive at the best suitable combination for obtaining optimal mechanical properties.

Keywords: Wood Composite, Taguchi Optimisation, Drilling properties, Thrust force, Temperature.

1. Introduction

Wood composites find its applications in interior decoration industry which involves furniture, kitchen cabinets, office tables etc. During the assembly process of joining the panels together for these applications, drilling is an unavoidable machining operation. Often drilled holes exhibit poor surface finish, delamination of outer layer and improper hole diameter which results in proper fitting of bolts and screws during assembly. Due to stress developed in the misaligned joints the drilled holes enlarges leading to unbalanced assembly of wooden parts. The problems encountered in the quality of drilled holes can be reduced to a large extent by controlling drilling parameters. Feed rate and thrust force were found to be the critical parameters contributing to the delamination of the composite. The influence of cutting parameters on the torque and cutting forces during drilling of GFRP laminate were
analysed and it was found that the drill size as well as the speed of the drill bit had major influence on the thrust force. A number of experiments were conducted on the composite by varying the parameters and the results were then optimised by Taguchi’s design of experiment method. Composites consisting wood fibers generally include added teak wood, maple wood, oak wood, cane straw and bagasse. Teak wood was added to manufacture the wood plastic which not only rendered a natural wood like appearance but also imparted the sturdiness of the teak. Medium density fiber board is the commonly engineered wood board in the present times. Therefore this experiment aims at the study of characteristics of teak wood specimen and comparison to that of a medium density fiber board, procured from the market.

2. Materials and Methods

2.1 Fabrication of teak wood composite

Teak dust and chips were procured from the local saw mill. It is mixed in the ratio of 1:5 with LY556 epoxy resin at room temperature manufactured and supplied by Araldite. Mechanical stirrer is used to mixed wood and epoxy composites till the resin forms a uniform viscous liquid. The hardener HY951 is then added to the resin at the ratio of 1:10. Aluminium moulding die 300x300mm is used where the resin mixed with teak dust is poured. This mould was kept in hot press moulding machine at a pressure is 1MPA and temperature was maintained at 60°C. Figure 1 shows the fabricated Teak wood composite plate and Figure 2 shows the MDF board purchased.

| Figure 1. Fabricated Teak wood composite plate | Figure 2. Purchased Medium density fibre board |

2.2 Input parameters

The drilling parameters spindle speed and the feed rate of the drill is included in this study. Previous studies explain the dominant impact of these 2 parameters during the drilling process. The factors and levels taken for the study are shown in Table 1.

Table 1. Experimental factors and levels
The drilling experiment was conducted using a CNC drilling machine having spindle speed range of 60 to 6000 rpm and a table of size 710*400mm was manufactured and supplied by Bharat FrietzWemer. The feed rate was set at three levels in arithmetic progression starting from 0.05rpm and having a common difference of 0.02rpm and the recommended speed corresponding for each level was taken for experimentation. The CNC drilling machine used for the experiment is shown below in figure 3.

![CNC drilling machine used for the study](image)

### Factors Levels

| Factors     | Levels  |
|-------------|---------|
| Speed (rpm) | 3       |
| Feed (mm/rev)| 3       |
|             | 1       |
|             | 2       |
|             | 3       |

|       | 600  | 852  | 1260 |
|-------|------|------|------|
| 0.05  | 0.07 | 0.09 |

2.3 Measured Output responses

The output responses measured are Thrust force and Temperature during the drilling process. Thrust represents the force at which the drill bit forces through the work piece. Hard and tough materials exhibit higher resistance to the cutting action and hence the thrust increases. However, thrust force depends on the nature of drill bit, the angle of cutting lip etc. The major 2 factors of the drilling process, the speed and feed rate of the drill on the Thrust force evolved is assessed in this study. The temperature generated during the drilling process is measured using an infrared thermometer, which measures the temperature through infra-red radiations. The Thrust force and Temperature needs to be low to produce a neat drilling process.

2.4 Design of Experiments

Conventional method of conducting experiments by varying one parameter at a time leads to many experiments which are costly and time consuming. Hence Taguchi Design of experiments was considered to reduce the number of experiments, but at the same time not lose the accuracy in getting reliable conclusions. In the present study considering 2 factors and 3 levels, Taguchi’s L₉ orthogonal array was chosen and hence 9 drilling experiments were conducted varying the speed and feed rate of the drill.

2.5 Experimental results
The results obtained from the drilling experiments by drilling the fabricated teak wood composite and the purchased MDF board are shown in Table 2. The MDF board after drilling is shown in Figure 4 and the Teak wood board after drilling is shown in Figure 5.

![Figure 4. Drilled MDF wood board](image)

![Figure 5. Drilled Teak wood board](image)

### Table 2. Experimental results on drilling MDF and Teak wood composite

| Experiment No | Input Parameters | Output Responses |
|---------------|------------------|------------------|
|               | Speed (rpm)      | Teak wood Composite | MDF wood board |
|               | Feed (mm/rev)    | Thrust Force (N) | Temperature (C) | Thrust Force (N) | Temperature (C) |
| 1             | 600              | 69.55            | 32.35          | 31.86          | 33.16          |
| 2             | 600              | 78.4             | 31.14          | 47.42          | 32.37          |
| 3             | 600              | 100.4            | 30.79          | 56.76          | 31.54          |
| 4             | 852              | 58.87            | 33.21          | 29.02          | 33.71          |
| 5             | 852              | 61.48            | 32.47          | 37.26          | 33.09          |
| 6             | 852              | 72.4             | 31.72          | 38.86          | 32.27          |
3. Taguchi Optimisation of Output responses

3.1 Response table
The responses for the individual input parameters were analysed for its effect on the thrust force and temperature. Table 3 shows the response table for each level of speed and feed rate on the output responses.

| Levels | Thrust Force | Temperature |
|-------|--------------|-------------|
|       | Teak wood board | MDF wood board | Teak wood board | MDF wood board |
|       | Speed | Feed | Speed | Feed | Speed | Feed | Speed | Feed |
| 1     | 82.7  | 55.54 | 45.34 | 28.08 | 31.42 | 33.3 | 32.35 | 33.63 |
| 2     | 64.25 | 64.48 | 35.04 | 36.98 | 32.46 | 32.23 | 33.02 | 33.01 |
| 3     | 50.98 | 77.98 | 27.39 | 42.72 | 33.2  | 31.72 | 33.41 | 32.14 |

3.2 Discussion
From the response table shown in table 3, the following conclusions can be drawn. When the speed increases, the Thrust force decreases by level and when the feed increases the thrust force also increases. This is because higher speed makes the cutting lips to pass through frequently over the periphery of the hole, making the cutting process smooth and easier\(^{12}\). Increase in thrust force due to increase in feed rate is due to the fast progress of drill bit into the work piece within a short span of time\(^{13}\). The thrust force value of teak wood board is high compared to MDF board. We can infer that teak wood board is stronger than MDF wood board offering high resistance during drilling. In case of temperature, when the speed increases, the temperature also increases whereas when the feed increases the temperature decreases. The increase in temperature due to increase in speed can be attributed to the fact that the friction between the cutting surfaces is more as the frequency of the lips touching the wood surface is more. More feed facilitates deeper penetration of the drill bit into the workpiece, providing more space for heat dissipation. The temperature generated during drilling of teak wood board is almost the same when compared to MDF.

4. Conclusion
The teak wood composite comprising of teak wood powder and epoxy resin could be successfully fabricated. The comparative study of the drilling properties of MDF wood board and Teak wood board gives the inference that Teak wood board produces more Thrust Force during drilling when compared to MDF, making it less suitable for hole drilling applications. However, in the view of the strength of the wood composite, Teak wood board seems to offer better resistance to cutting process. The strength of the teak wood powder and the epoxy resin seems to pronounce the nature of the composite.

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