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Research paper

Wood Polymer Composites Optimizer with Genetic Algorithm

Marina Yusoff [*1], Nur Farah Syazwani Sehat[2]

1Advanced Analytic Engineering Center (AAEC), Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.
2Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.
**Corresponding author, E-mail: marinay@tmsk.uitm.edu.my*

Abstract

Wood polymer composites, or natural fiber composites are basically made up from a combination of plastic and wood flour. Usually, its quality is measured and depended on the mechanical properties that were used as composite materials for product development. Hence, a lot of laboratory experiments were conducted in factories for testing the durability of this product. However, there is still a lack of the solution for an automated system to formulate the wood polymer composite composition efficiently. This paper addresses the use of a genetic algorithm in finding an optimal composition for each of the properties used in producing a better-quality product. A new solution representation to map the composite composition is pro-posed. Different parameters were employed in the computational experiments with the aim to find the best fitness value for the composition. The stochastic behavior that was embedded in genetic algorithm has demonstrated diverse solutions with regards to the search exploration and exploitation capability towards the feasible solutions and convergence. The findings demonstrate a great potential ability of genetic algorithm in finding good accuracy for other wood polymer composites such as tropical timber as wood polymer materials. It is expected to reduce cost and time as compared to traditional laboratory way.

***Keywords**: Genetic Algorithms; Metaheuristic; Stochastic; Wood Materials; Wood Polymer Composite*

1. Introduction

Wood Polymer Composites (WPCs) are normally known as a product that had been manufactured from a mixture of wood flour and plastics [1]. Since the product is basically made from a mixture of wood flour and plastics, it has a really light in weight compared to a raw wood. Hence, numerous industries in aviation, car, electrics and gadgets, building and development, and bundling territories have held onto these composite materials as their product items [2].

WPCs have their advantages and disadvantages. Since WPCs are made of from a part of wood flour, it can easily produce a large amount of dust when it had been cut. Based on the wood nature, it is widely known that wood are always absorbing water since there is a process which called as “osmosis” [3]. Even though plastic is a part of an element in WPCs, it doesn’t mean that WPCs will not be affected by the presence of water. There are few weathering issues and environmental impacts that had been found such as grow sprouts and mushrooms, exposed to moisture, and eaten by termites in WPCs [4] and WPCs have a high flammability [5]. There are numerous processes of laboratory experiment involved to process WPCs. Some of the methods used are extrusion, injection molding, or thermoforming which is a mill for shaping the wood [6]. However, in order to make a product of WPCs, there must be a formula of composition for each material used. To the best of our knowledge, there is still a limited system conducted for determining the composition of materials used in WPCs. Conducting laboratory experiment would incur high costs and time consuming to produce a quality product. In addition, the current method which is a manual formulated composition can also reduce the production of WPCs. Although, many optimization methods were used in solving an optimization problem. However it is still limited research were found related to timber strength For instance, timber strength optimization [7-9].

Hence, this paper addresses the use of artificial intelligent method, namely genetic algorithm as an initiative to improve solution time and reduce cost to find the best combination of a composite material.

2. Related Work

Laboratory experiment that needs to be conducted will always need to use certain machines or specialized tools. Hence, in manufacturing WPCs, the tools that are commonly used in the laboratory are injection molding machines and extrusion machines [10].

Extrusion is one of the common techniques used in manufacturing [10]. It is a process to create many kinds of objects and size such as plastic, composites, pipe and steel [11]. Process of extrusion is quite similar to other technique which is injection molding. An extrusion machine will receive the granules of materials through the heater. Then, the granules will melt and forced through a die which is a specialized tool that are used to cut or shape the product. After the granules being heated and came out from the die, it then will be cooled and form a solid shape.

Injection molding is one of the techniques in manufacturing WPCs have been by injection molding. The steps involved are quite similar to the process in other technique which is extruded. In injection molding, the mixed materials of WPCs will be injected into a mold to produce a new piece of WPCs [10]. After the mold being injected, it needs to be cooled for a while for the next piece to be manufactured. This process will be kept on repeating to produce the same piece in a large quantity.

There are several benefits of using injection molding in manufacturing industries. One of them is to get a consistent pro-deduction for every item[12]. This is because the next item that will be produced by using injection molding will be exactly the same as before. Thus, this will be very helpful for any industries that would want to produce identical items that made by thermoplastics in a large quantity.

The main components of injection molding machine which are the clamping unit and plasticizing/injection unit. The first process will be an injection unit which it takes place on melting the plastic before injecting to the mold. Characterization of injection molding machine is basically depending on the clamp force which will be applied to a mold. The clamp force will be determined by the features of the parts in the mold which will be injected. Hence, the size of the features of the mold will determine the size of the clamping force. There are also various models of injection molding machines which are known as Babyplast, Powerline, and Maxima [13] For the clamping part, it is basically it is used for holding the mold. Its usefulness is to close, clamp and to open the mold. Hence, just like the injection unit, clamping unit also has its main components which are stationary platen, movable platen tie rods, and clamping cylinder.

3. Implementation of Genetic Algorithm

Data acquisition is referred to recorded data from [14]. Table 1 shows the sample of datasets used for chromosome representation and fitness function. This data is used to identify the equations. As can be seen in Table 1, the attribute of plastic type, indicate 1 – Recycled plastic and 0 – Virgin plastic.

Table 1: Sample of datasets and tensile strength

Composite sample code	Plastic type	Plastic content	Wood flour content	Coupling agent content type	Tensile strength
a	1	100	0	0	32.89
b	0	60	40	0	27.27
c	1	50	50	0	25.86
d	1	45	50	5	34.45

Implementing GA in finding the best combination for WPCs will need to specify the parameter the suitable parameters. To accomplish proficient advancement, various types of operator were used in order to get the optimal solution. In this way, these parameters comprise of determination, hybrid and trans-formation in the population of each individual. GA was introduced by John Holland in the 1970s [15] It is biologically inspired from the genetic evolution that performs selection, crossover and mutation of chromosomes. GA is one of the evolutionary algorithm which is meta-heuristic and stochastic method in solving an optimization problem (Kendall, 2005). It is usually used to solve a difficult optimization problem and it reflects the process of natural selection which the best individuals are being selected and being carried out to the next generation. Figure 1 demonstrates the flowchart of GA from the first step until the end.

There are five phases require in GA which are the initialization, fitness function, selection, crossover and mutation [15]. Initialization is process where the candidate solutions will be generated randomly. After all the candidate being initialized with the parameters, the fitness value for each of the candidate solutions will be calculated. The fitness function is an objective function that is used to determine how close each of the candidate solution towards the objective. The fitness value of candidate solution can be determined whether an optimal solution can be achieved or not.

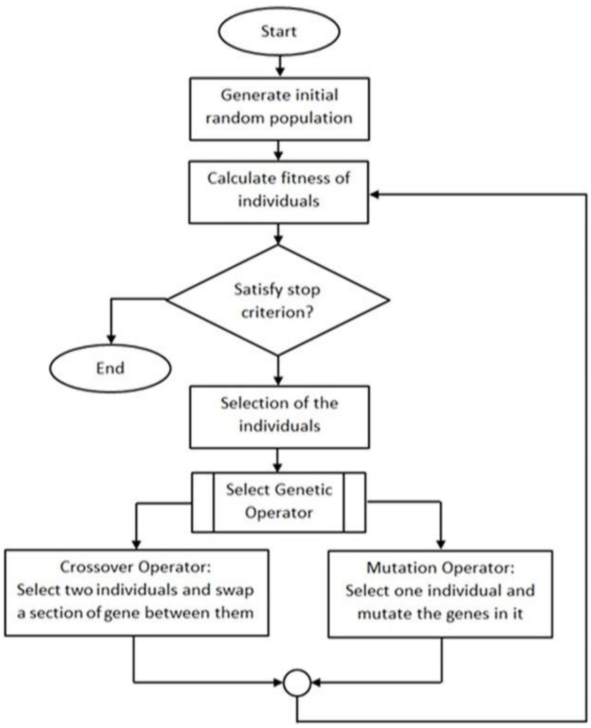

Fig. 1: GA steps

Solution representation is a representation of the candidate solution. The representation can be in many kinds of form, such as, vector, an arbitrary-length, unordered set, decision tree or binary bits. Below is a solution representation of the chromosome.

	X_1	X_2	X_3	X_4
Range values	[0, 1]	[1 – 50]	[1 – 50]	[0– 5]

Fig.2: Solution representation

Where;
X_1: Types of plastic
X_2: Percentage of wood
X_3: Percentage of plastic
X_4: Percentage of coupling agents
The fitness function was obtained from the analysis of datasets from [14]. Equation 1 shows the fitness function formula that was produced from the datasets.

$$f(x) = (-0.004 * x1) + (0.32894 * x2) + (0.18834 * x3) + (2.04694 * x4) \quad (1)$$

4. Results and Discussion

The accuracy of GA is calculated by using the average fitness value for all generations in percentage (%), divided by the target of real data, for instance, 34.45 for composite code, d and then multiplied by 100. Table 2 demonstrates the computational results for 20 generations and compared with 100, 200, and 300 numbers of populations. It is interesting to note that the best result among those numbers of populations is 100 populations with the highest accuracy of 80%. It is evident that the with more generations, the result were not improved. Theoretically, the searching exploration of GA can be said, lead to the issue of diversity. Thus, exploitation strategy can be embedded in future research.

Table 2: Computational results for 20 generations using different population size

Population size	Final Individual	
100	**Generation**	**6^{th}**
	Chromosome Detail	**[1, 49, 48, 3]**
	Fitness Value	**34.59**
	Accuracy (%)	**80.0**
200	Generation	2^{nd}
	Chromosome Detail	[1, 47, 50, 3]
	Fitness Value	34.88
	Accuracy (%)	70.0
300	Generation	5^{th}
	Chromosome Detail	[1, 49, 46, 5]
	Fitness Value	35.01
	Accuracy (%)	55.0

Table 3 shows the experiment of a maximum of 40 generations. It is shown the population size of 300 provides the highest accuracy of about 85% and the lowest is the population size of 200. From the results, it signifies the use of GA requires more generations and the stochastic behavior plays an important role in offering good or bad solutions. In terms of convergence, GA has shown in all experiments, the feasible solutions are achieved. However, to obtain an optimal solution is seems required more testing and enhancement of GA or there is a possibility to be hybridized and other computational optimization methods.

Table 3: Computational Results for 40 generations using different population size

Population size	Final Individual	
100	Generation	3^{rd}
	Chromosome Detail	[1, 47, 48, 5]
	Fitness Value	35.16
	Accuracy (%)	75.0
200	Generation	3^{rd}
	Chromosome Detail	[1, 50, 47, 3]
	Fitness Value	34.74
	Accuracy (%)	60.0
300	**Generation**	**3^{rd}**
	Chromosome Detail	**[1, 48, 47, 5]**
	Fitness Value	**34.88**
	Accuracy (%)	**85.0**

Table 4 demonstrates the computational results for 60 generations and compared with 100, 200, and 300 numbers of populations. It is interesting to note that the best result among those numbers of populations is 200 populations with the highest accuracy of 88.33%. This result is the highest compared to 20 and 40 generations as shown in Table 2 and 3.

Table 4: Computational Results for 60 generations using different population size

Population size	Final Individual	
100	Generation	13th
	Chromosome Detail	[1, 50, 45, 5]
	Fitness Value	34.73
	Accuracy (%)	80.0
200	**Generation**	**5th**
	Chromosome Detail	**[1, 49, 46, 5]**
	Fitness Value	**35.15**
	Accuracy (%)	**88.33**
300	Generation	7th
	Chromosome Detail	[1, 49, 47, 4]
	Fitness Value	34.59
	Accuracy (%)	50.0

It can be concluded, the a one-point crossover and a mutation rate of 0.05, the accuracy of GA is increasing if the number of generations is higher. From the experiment that the most optimal composition for making WPCs is [1, 49, 46, 5]. GA is normally required a large number of population and it is problem dependent. The solution from this work is evident on the requirement for large populations size and diversity. However, the result is only about 88%. This result is shown a great potential for GA to be improved for a better exploitation and exploration of searching. The balance of these search strategies is important to control and lead to fast convergence and better results.

4. Conclusion

The employment of GA has interestingly demonstrated a good potential to enabling the efficient way of finding the best combination for the tensile strength of WPCs. The results indicate that the use artificial intelligent method can be adopted in assisting of providing materials composition as low cost and time compared to traditional laboratory that required an expensive and a lot of materials for testing. It is hoped that this method can be enhanced and tested with a real tropical timber as a material in WPCs to support green initiatives and usage of timber.

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