

Nadrah bt. Abd Hamid and Dr. Sharif Abdulbari Ali

Faculty of Chemical Engineering, Universiti Teknologi Mara

Moisture Uptake in Natural Rubber Via Genetic Algorithm

Abstract—This study was conducted to determine the behavior of moisture content in different shape of natural rubber and to implement the use of Genetic Algorithm on the behavior of moisture uptake in natural rubber. The time taken of water to absorb into different shapes of natural rubber and weight percentage of water absorbed inside the rubber at a given time were taken during the research. Two samples of natural rubber in rectangular and sphere shape were prepared. The dry weight of samples were taken before immersed them in water and the wet weight of sample were taken daily until the day of 21, which the equilibrium state has been reached. As a result, it has been find out that the different shape of natural rubber has affected the behavior of the natural rubber. The sphere sample has a small percentage of water absorption with value of 0.78% compared to square sample. This is due the large surface area with large volume of each unit of layer and more entry space for water to absorb completely inside the natural rubber. Thus it attained the equilibrium state faster than cube sample and it caused the low tendency of the behavior of natural rubber to change. The use of Genetic Algorithm (GA) method in this research has helped in obtaining and displaying a result in simplest way in order to further increase the understanding of people towards the results of this research.

Keywords— *Absorption, genetic algorithm and natural rubber.*

I. INTRODUCTION

A. Relationship between Natural Rubber and Moisture Absorption Principle

Natural rubber is a biopolymer material, which has good elastic properties, flexibility and damping behavior but poor chemical resistance and processing capability [10]. Natural rubber refers to a coagulated or precipitated cis- 1,4-polyisoprene products obtained from the latex of rubber producing plants [3]. Latex, a milky white liquid can be obtained by tapping process where it is being collected from the bark of certain tree that has been cut. Natural rubber is an elastic type of rubber whereby it returns to its original shape after some stretching force is released.

There are many manufacturing companies that use natural rubber as their raw material to produce several types of rubber product. The products that can be produced from natural rubber are medical gloves, balls, rubber tubes, insulator, gasket and footwear. Furthermore, natural rubber can produce a mixing of cement-latex in concrete building [11] and the mixing of bitumen-rubber can be produced from natural rubber to make road surfaces [10].

Natural rubber is a hydrophilic in nature, liable to absorb moisture and hence their mechanical properties get degraded over a period of time [10]. From the stated statement, it shows that there is a disadvantage that comes from natural rubber itself. Generally, the moisture uptake is usually measured by weight gain and the mechanism of water absorption takes place is according to Diffusion and Fick's Law [8]. Diffusion is a transportation of molecules or atoms from a part of system to another system.

In moisture uptake process, diffusion takes place when the molecule of water absorb into the surface of natural rubber then

diffuses into the inside of natural rubber. During diffusion, the water molecules are free and thus they move independently towards each [12]. It will enhance the moisture uptake through the surface of rubber and increase the rate of penetration into the natural rubber.

Diffusion process will enlarge the spaces among polymer molecules for further water absorption, which lowers the interfacial strength of the polymer chains and causes the polymer molecules to move more freely [12]. It indicates that the molecules inside the rubber can be separated from each other and cause the mechanical properties of rubber being degraded. Otherwise, the percent of originality or genuineness of natural rubber will be decrease.

B. Genetic Algorithm

Genetic Algorithm is a method that used in MATLAB software. Genetic algorithm has been used to solve severe problems with objective functions that do not possess "nice" properties such as constancy, differentiability, fulfillment of the Lipschitz Conditions [10]. Lipschitz conditions indicate the assurance of the presence and uniqueness method in solving the original problem.

The algorithm works by creating a random initial population at early stage. It builds a chronology of new populations at the second stage. Then at each populations created, the next population is being build up. The process continues until stopping criteria is met [9]. The working principle indicates that the algorithm consists of step-by-step process and it is one of the best methods to predict the outcome or solution towards any problem.

II. METHODOLOGY

A. Preparation of Apparatus and Materials

Apparatus used in this research were 500 mL of beaker, digital measuring weight and a large box of container. For the materials, 2 samples of different shapes natural rubber (cube and sphere) and distilled water were used to conduct the experiment in this research.

B. Dry Weight Sampling Procedure

Two different shapes of natural rubber, which are rectangular and sphere shape, were prepared. The experiment began after the initial weight of natural rubber measured with digital measuring weight. The measuring weight assigned to zero before placing the sample in order to get accurate value. The dry weights of both samples were recorded in a table after done placing the samples.

C. Absorption of Water Inside Natural Rubber at Given Time

The samples were completely immersed in beakers of distilled water after dry weight sampling taken. Beforehand, the temperature of distilled water was ensured to be at 25 °C by using thermometer. The samples were placed in a large box of container and left at some place at room temperature.

D. Collecting, Weighing and Recording the Wet Sample

At interval of 24 hours, both samples were removed from the beaker, cleaned and weighed. The values of weight of samples were tabulated in a table. The same samples then being placed back to the same beakers to undergo the next tests. The same procedure was repeated for about 5 times per week until the equilibrium state attained, which after water saturation in samples being noticed. The amount of water absorbed by the samples (in percentage) were calculated by using the equation:

$$W(\%) = \frac{W_t - W_i}{W_i} \times 100\% \quad \text{eq. (1)}$$

Where W is percent water absorption, W_i and W_t are the initial weight, and the weight of the sample after time t , respectively [1]. Then all the data obtained were tabulated in a table and a graph of moisture absorption in natural rubber against time was constructed.

E. Implementation of Results Via Genetic Algorithm

Results obtained from the experiment were inserted into Genetic Algorithm system in MATLAB software (MATLAB_R2017a). The steps taken as follows:

1. The 'New Script' button was selected and opened.
2. A function was assigned based on the equation of percent water absorption, eq. (1).
3. The 'Optimization' tool was selected in 'Apps' button and opened.
4. In Problem Setup and Results display and Options display, there were variables that need to be filled and assigned based on data available.
5. After done completing all the data, the optimization was run.
6. A graph appeared with the result of findings and the values of selected choices were adjusted until the optimization completed.

III. RESULTS AND DISCUSSION

A. Moisture Absorption into Different Types of Natural Rubber

The experiment was conducted by identifying the amount of percentage of water absorbed in natural rubber. The readings of wet weight of samples were taken for about 21 days and been recorded in Table 1.

Table 1: Wet weight of natural rubber.

Day	Wet weight sample (g)	
	Cube	Sphere
1	19.75	15.43
2	19.78	15.44
3	19.8	15.46
4	19.81	15.47
5	19.84	15.49
6	19.85	15.49
7	19.86	15.5
8	19.86	15.5
9	19.87	15.51
10	19.9	15.53
11	19.9	15.53
12	19.91	15.53
13	19.91	15.54
14	19.92	15.54
15	19.92	15.54
16	19.93	15.55
17	19.93	15.55
18	19.94	15.55
19	19.94	15.55
20	19.95	15.55
21	19.95	15.55

Based on Table 1, it can be seen that the weight values for sphere sample were constant from day 16 until day 21. Baschek, stated that immersion in water for more than 6 days at room temperature was enough to achieve a nearly saturated state [2]. In this research, it took about 16 days for water absorption to attain equilibrium state for sphere sample while square sample still does not reach the equilibrium state. Equilibrium state indicates that the composites in natural rubber have reached saturation point as water absorption concerned.

Water absorption percentage has been calculated by using eq (1) and tabulated in Table 2. In order to get clearer results or view, a graph of moisture absorption against time has been plotted. Table 2 below shows the values of water absorption percentage in natural rubber while Figure 3 shows the water absorption percentage against time taken.

Table 2: Water absorption percentage in natural rubber.

Day	Weight percentage of water absorption (%)	
	Cube	Sphere
1	-	-
2	0.15	0.06
3	0.25	0.19
4	0.30	0.26
5	0.46	0.39
6	0.51	0.39
7	0.56	0.45
8	0.56	0.45
9	0.61	0.52
10	0.76	0.65
11	0.76	0.65
12	0.81	0.65
13	0.81	0.71
14	0.86	0.71
15	0.86	0.71
16	0.91	0.78
17	0.91	0.78
18	0.96	0.78
19	0.96	0.78
20	1.01	0.78
21	1.01	0.78

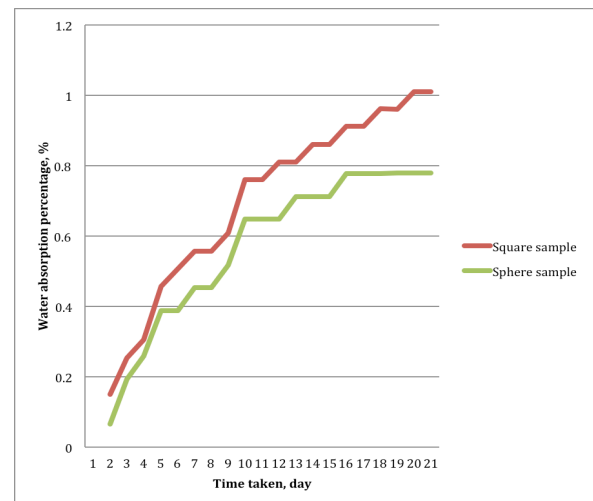


Figure 1: Graph of water absorption percentage against time taken.

From Figure 1, it was observed that initially the water absorption percentage for both samples had linear sharp increase from day 2 to day 3. It can be seen from Table 2 and Figure 1 that the water absorption percentage for cube sample is slightly higher compared to sphere sample but at the same time, it takes a longer time to reach the equilibrium compared to sphere sample. Since the water absorption reached equilibrium at day 16 for sphere sample,

the curve became constant and the value for water absorption percentage was 0.78%. For cube sample, the water absorption percentage value was 0.91% and still increasing until 1.01% at day 21. This is because of the different values obtained from the experiment for both samples were affected by their structure and shape.

For this research project, shape of samples played an important role in determining the water absorption percentage in natural rubber. The measurements for both samples were taken at initial experiment where their dimensions were almost same. It has been calculated that the sphere sample has a larger surface area compared to cube sample. The difference values of surface area obtained had an impact towards the absorption rate of water into natural rubber.

In detailed, as surface area increases, the volume also increases where the more volume for each unit of surface. From that, there is more space for the water molecules to be absorbed into layers of natural rubber. Based on Table 2 and Figure 1, sphere sample attained the saturated state faster than cube sample. This is because of the sphere sample has a larger surface area where it allows the more volume of water to be absorbed and more entry pathways for water to enter into natural rubber layers. This situation caused the water to completely absorb inside the natural rubber followed by reaching its saturation point much faster than cube sample.

Unfortunately, there were no similar researches found to be conducting the absorption of water on natural rubber with different shapes. But, since natural rubber is a type of polymer, there were a few researches that conduct the similar water absorption test but with different kinds of polymer used. For example, Cao stated that the water absorption in natural rubber is higher than the modified natural rubber [4]. This is because of the improvement of interfacial filler adhesion added to natural rubber caused the limitation of the penetration of water molecules into the composite.

Other than that, there was another type of polymer that can be called as polypropylene that has the similar criteria as natural rubber, which is hydrophilic in nature. According to Kord B., the similar water absorption test was conducted and it has been find out that the water absorption percentage decreased with the addition of coupling agent [6]. This means that the coupling agent was used in order to improve the polymer bonding and in turn to enhance water resistance. Even though these two researches were not very related to the purpose of this research, it can be seen that the mechanism and properties of natural rubber can be increased by improving the content of natural rubber so that the use of natural rubber will get a high demand in the future market.

B. Optimization Via Genetic Algorithm

The role of Genetic Algorithm used in this research was only as an addition method in acquiring and displaying the results of the experiment. After done with inserting and adjusting all the data, a graph appeared based on the assigned function before. The formula assigned in the function was equal to; $y = (x - 19.75)/19.75 \times 100$ which according to the equation of water absorption percentage, eq (1). The value of 19.75 was the initial weight of natural rubber and there was no value for x set in the function because it has been set up by Genetic Algorithm software itself.

In addition, by setting up the lower and upper bound value in the software, Genetic Algorithm helped us to find the solution to the problem or formula provided. The algorithm stopped to run until the phrase 'Optimization completed' appeared. Thus it shows that the result has been obtained. The Figure 4 below shows the result obtained from Genetic Algorithm method.

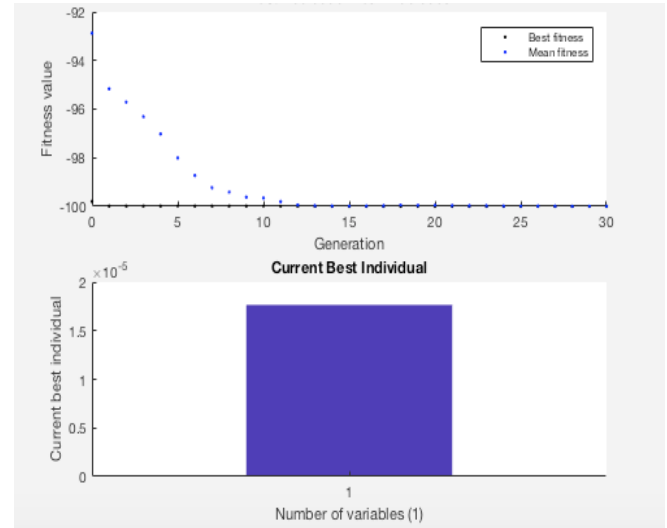


Figure 2: The results from Genetic Algorithm method.

Based on Figure 2, the fitness value on x-axis indicates the values of x assigned by the algorithm while the generation on y-axis indicates what was the prediction of the result outcome. Since the graph in Figure 1 increase uniformly, it can be seen that the graph was uniformly decreased in Figure 2 also where it shows that the result was good enough by using the assigned formula. Furthermore, it shows that the prediction values of x were compatible with the exact values provided in Table 1.

Compared to the result shown in Figure 3, the outcome of the results were more accurate rather than Genetic Algorithm (GA) method. This is because; GA was the best method in predicting the results or solution to a problem only and it will not give the accurate result. Even though the use of GA was not very important in this research, it helped us to find a new way of finding and predicting a solution to a problem before the experiment can be done.

IV. CONCLUSION

As a conclusion, it can be concluded that the different types of sample with different values of surface area has affected the moisture absorption behavior into natural rubber. Furthermore, it can be seen that the sphere sample is a good sample because the percentage of water absorption is smaller with value of 0.78% and it attained the equilibrium state faster compared to cube sample, which is starting at the day of 16. The more entry space given by the natural rubber, the faster the water to completely diffused and fill all the each unit of layer of natural rubber mechanism.

In addition, the lesser the water absorption percentage, the lower the tendency of the mechanism and behavior of natural rubber to change. Thus it can make the natural rubber to be a useful material to be used in any types of rubber industries in the future. Otherwise, the implementation of Genetic Algorithm method in this research was an addition method that can be used in obtaining and presenting the results. It gave us an opportunity to try a new and high-level technical computing language for algorithm development, data visualization, data analysis, and numerical computation. By using Genetic Algorithm, any technical computing problems can be solved faster than manual data computation. In addition, GA used in this research is to validate and verify the results of the finding.

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