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Evaluation Effect of Process Parameter Plastic Waste and Sawdust Composition Material Fatigue Test

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Abstract:

Plastic waste management systems continue to emerge to reduce the increase in plastic waste from year to year, an alternative material that allows its use since the main material will be obtained from the use of plastic and wood waste, the need is needed of strong and light materials to allow the reprocessing of the plastic that has been used to obtain new material by combining other elements as a mixture, this research develops the principle of combining plastic mixtures of HDPE (High Density Polyethylene), Polypropylene Terephthalate (PET) and Sawdust because all three materials are abundant waste around us, using ASTM standards. D-7031 for the Fatique test found the strongest mixture of samples made at 67.1 N / mm with a composition of 1 gram of sawdust, 6.25 grams of PET, 10.75 grams of HDPE with a maximum temperature of 110 ° C, 3000 grams pressure, while the lowest value obtained by composition is 1 gram of sawdust, 5 grams of PET, 12 grams of HDPE of 31.3 N / mm at a temperature of 110 ° C with 3000 grams of pretreatment, so that from this value is found that the highest and lowest values of the material depend on the composition of the mixture in not giving the pressure or temperature.

Keywords: *Plastic Waste Composition (PWC), Fatique Test , SEM*

Introduction:

The habits of people in Indonesia who still appreciate plastic as a tool used to wrap or transport goods make plastic become products that accumulate at home, so that the government has a solution to use its own plastic bags during the last 3 periods indicating the quantity of rubbish bags in Discard each year reaches 187.2 million tons per year or equal to 520 000 thousand tons / day [1], this causes concern about the impact that will be caused, the use made so far in most of Indonesia still revolves around the use in terms of course, not all furniture and accessories will be used, which means that when making furniture not everything will be used the plastic used, since it will be formed according to the use and the rest will be discarded, since it needs a technological advance that is used as a solution for handling r one of them with the method of pressing up to h the plastic by using heat so that the product can join to form new products, such as plastic bricks or other types in addition to the pressing of the finished product, can save storage and reduce the danger potential because it can be used for other purposes, especially in coastal areas that require corrosion resistant materials Several alternative replacement materials have been tested, such as the use of metal, steel, aluminum and plastic. However, due to the high specific gravity factor,

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as well as its resistance to the environment, which is low or high, it causes less interest and its popularity decreases [2] [3]

Basic Teory

The wastes generated by each community consist of 3 types, namely solid, liquid and gaseous wastes of the three types of solid wastes, which are the most common wastes because the product is visible and requires a special storage area for the potential of solid waste increases and accumulates Currently, waste management in Indonesia is still dominated by urban areas. Until now, the processing of pastik waste is still in the form of cutting, melting and printing used plastic, without still processing the plastic waste to convert them into plastic granules.

In this research HDPE type and PET type plastic waste that has been Added to the formation by mixing the wood powder with the Fatique test and the SEM test. In various design environments, plastic wood will be used to replace wood, specifically for outdoor applications which plastic wood is considered most weather-friendly and greater than material, but It is somewhat difficult to understand the thermodynamic properties of sawdust, though plastic wood coposite (WPC) is not approved for use in structural applications in public buildings because The strength and rigidity are lower in terms of low temperatures or heat and the characteristics of high temperature plastic wood will decide the resistance and allowable rigidity. The plastic wood module is 5.79, 1.03 and 1.12 GPa with high temperature compression method and high temperature resistance values 16.8, 12.0 and 1.45 MPa at the time of output.. The effect is that plastic wood composite is more resistant to cutting than wood but can crack and break,. This is an engineering product, not a synthetic polymer, which will be more common in a table-shaped product of a structural nature. This can be joined by using glue / tongs and screws, in either a 48-hour creep check, plastic wood composite can be properly performed. Plastic wood is resistant to rot and insects without chemical treatment and does not release harmful substances, such as CCA or creosol, generally found in wood.. Most companies make plastic wood using the concept of industrial plastic waste, thereby reducing the amount of material to be produced from the wood. In summary, The use of plastic wood instead of wood has a positive environmental effect and plastic wood has insulative properties that are suitable of many applications, especially for decoration. [3].

The composition of polymers of various types of wood dust and natural fibers is of concern for many parts, filler characteristics, types of binders, etc. The use of wood or lignocellulosic material in general as a reinforcing component in polymer compounds becomes more interesting for special research because the price of each wood and plastic raw material will continue to increase [4].

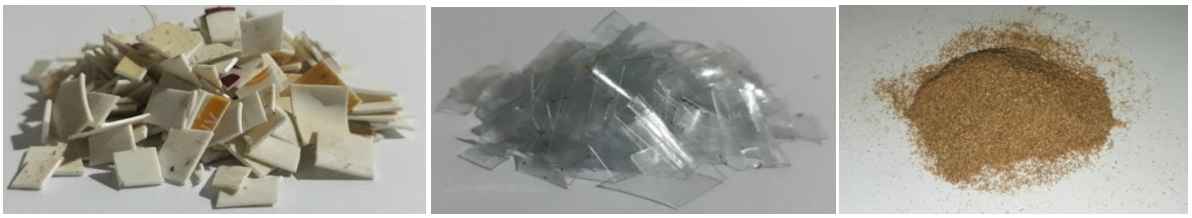

Figure-1 Material used as a mixture

The combination of 2 types of plastic with wood material has been widely developed in research in recent years. The production objectives that will be transmitted in this study can be used as a reference for the use of new materials that will be used as a reference in the manufacture of WPC (Wood Plastic Composite) products related to the temperature and composition of the material used to obtain products matching the maximum resistance.

The research that is being developed in the literature still revolves around a mixture of 2 existing materials, such as HDPE and wood dust or PET with wood dust and other natural fiber.

To determine the composition of the best additional components required for a reactive process, different sequences and modes of component addition are tested in resistance tests. All these experiments produced mixtures with very different mechanical properties [5].

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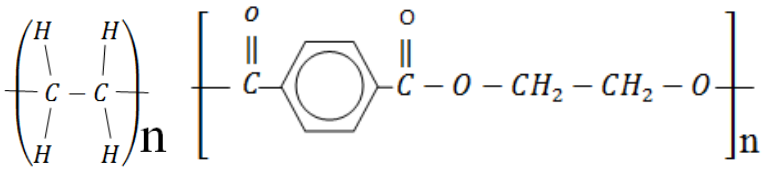
Their time-dependent behavior is one of the most important characteristics affecting wood and plastic composite products. The time-dependent deformation of a material under sustained load is generally referred to as creep [6].

The degradation of the plastic caused by repetitive processing cycles will change the microstructure and reduce the level of resistance, so focused research is needed to obtain the best results. The effect of the degradation rate of the recycling of plastics will affect the mechanical and physical properties of the WPC and should identify the beginning to obtain an acceptable level of physical safety that is generally accepted and used in the form of the final product [7].



Formula PET plastic and HDPE composite chemical elements

The use of plastic wood composite instead of wood has a positive environmental effect, and plastic wood has structural properties that are suitable for many applications, particularly for decorative materials and furniture.

Methode

Although the HDPE offers the benefit of binding properties between PET / sawdust, HDPE was selected to serve as a determinant factor for the mixing ratio. Samples were heated at temperatures between 100 ° C and 120 ° C. Finally, the samples were pressed at a pressure of 1 N/mm² to 5 N/mm² and allowed for up to 4 hours of self-cooling.

Recycled plastic forms that are frequently found and widely used in this study are recycled HDPE (recorded as RHD) with a melt flow index of 20.3 g/5 minutes (170 ° C) and recycling of polyethylene terephthalate (RPET) with flow rates of 25 g/5 minutes (170 ° C). Recycled high density polyethylene was obtained from milk bottles with a melt flow index of 18.54 g/10 min (170°C). The filler was the sawdust of softwood produced from a band saw mill. Sawdust was dried in an oven for 24 h at 100 °C (Kazemi Najafi, 2013).

Preparation of sawdust

Teak sawdust as a filler material is obtained from furniture that is around the ponorogo after it is made with a particle size of up to 50 meshes. Then, the material dries naturally in direct full sun for 7 hours at temperatures around 28 °C - 34 °C in favorable weather conditions. The sawdust was dried for at least two days at 70 ° C, turned regularly and weighed constantly. [9].

The drying process produces a final humidity of 5.8%, the lowest rate (10% expected) with a 10-minute operating time. The lowest heat value for RDF in this moisture content is 5.660 kcal/kg. Food waste combined with sawdust has been found to produce a good quality RDF that meets quality standards in all mixing ratios [8].

The recycled plastic melts between 210°C - 170°C, The heat source is then turned off and the sawdust is deposited in recycled plastic with a mixture of 15 rpm and a temperature drop of 170°C to 130°C for all mixing formulas with expected temperature variations by pressing the surface process of the material created. This blending process takes 5.7 minutes on average. Thermoplastics have a melting point of approximately 90°C - 120°C and a mixture has very large and effective processing capacities processed at 160°C - 200°C in polyolefin processing machines [10]. The experiments were carried out under a nitrogen layer at rotor speeds of 60 rpm and temperatures ranging from 270°C to 290°C. The PET is preceded for 4 to 6 hours under vacuum at 120°C until the humidity level it is > 0.01% by weight [6]. A mixture of polymer and sawdust was added directly to the mixing chamber and composite samples were prepared at 180 ° C for 10 minutes at a roller speed of 60 rpm. Composite printed sheets with a thickness of 0.9 mm at 190 ° C and 4 MPa were produced Control Carver C for 5 minutes [11]

Preparation of sample.

The directly mixed plastic liquid and sawdust is poured into the mold according to the dimensions of the mold until it is evenly distributed throughout the mold and then pressed to the planned HDPE, PP formulations and sawdust

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pressure with hydraulic presses.Mechanical test samples were made on the basis of the reference used, namely the design of the experiment / DOE Fatigue tests on the material.
by increasing the percentage of wood flour, the mechanical properties decrease [12]. Mechanical properties of recycled plastic and sawdust are evaluated through hard properties. The properties of hard plastic and sawdust are calculated on the basis of the parameters and composition obtained from the nature of the experiment, testing using a standardized test machine autograph with a test machine with an angle angle inclination parameter. All research was conducted at room temperature (25 ° C) with relatively constant humidity with 3 test points per sample of 30 (main response) samples. The sample is prepared before the test at a constant temperature and relative humidity.

This study uses three types of material mixtures with pressure and temperature variations, namely high-density polyethylene (HDPE), polyethylene terephthalate (PET) and sawdust, which increases the number of uses of this type of plastic from year to year, This is the basis of the initial investigation and increases waste utilization Research-oriented plastic content and awareness of how good the product's breakage resistance is checked and manufactured.
The type of test results depends on the preparation and conditions of the sample preparation site, and several things to consider are the availability of the test equipment, as well as the connection of the cable connected to the computer with the sample test made for get the sample result.

Figure 2. Sample Preparation for Fatigue Test

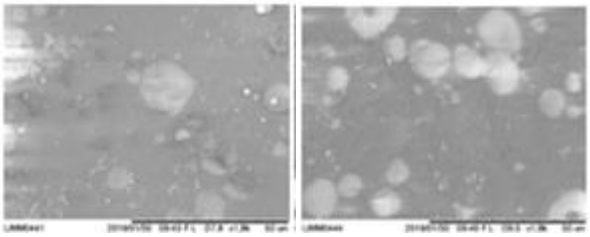

Figure 3. The fracture and surface test with the highest value in the Fatique Test

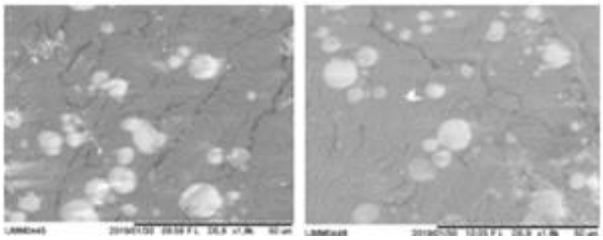

Figure 4. Fracture and surface test with the lowest value in the Fatique test

Figures 3 and 4 show the characteristics of the mixture and the force of the applied pressure. The highest density is seen even though there are still cracks on the other side of the sample, while for the lower one, many cracks occur in the sample and the trapped air. In general terms, SEM results show a significant difference, due to the pressure

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with the sawdust composition that is not too visible.

The SEM observation shows that the fiber and the fragment are damaged, while the surface looks different between the original and the recycling [13]. SEM photomicrography shows the fracture surface of sawdust composed of PP without and with malleable polypropylene (MAPP), the process of adding MAPP to PP sawdust compounds does not change the basic mechanism of fracture of the PP matrix [14]

Response Surface Methodology

Response surface methodology was used as one of the reliable statistical methodologies to understand the effect of process variables, their interaction and their contribution to performance measures.

In this analysis, the Face Center Cubic design of the response surface methodology was used because it increased the yield and efficiency of the process by contrasting the traditional method with less experimental runs. (Izamshah, Akmal, Ali, & Kasim, 2017)

The results of the experiment were adapted to the methodology of the response surface as shown in the equation (J.Anderson, Mark, 2007).

$$\hat{y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} {X_1}^2 + \beta_{22} {X_2}^2 + \beta_{111} {X_1}^3 + \beta_{222} {X_2}^3 + \beta_{12} X_1 X_2 \ldots + \beta_{112} {X_1}^2 X_2 + \beta_{122} X_1 {X_2}^2$$

Where the response or attribute is dependent on the answer. The β symbols are the coefficients to be fitted through regression. β_o is the constant model, X_1 and X_2 are independent variables; $\beta_1$and β_2 are linear coefficients; β_{12}, β_{112} and β_{122} are cross-product coefficients; β_{11} and β_{22} are quadratic coefficients; and The cubic coefficients are β_{111} and β_{222}.

Table 1. Design scheme in preparation of experimental specimens

Process	Factors	Unit	Levels	
			-1	1
Processing Parameters	A:Temperature	˚Celcius	100	120
	B:Pressure	gram	1000	5000
Composite Mixture Fraction	C:Sawdust	gram	0.5	1.5
	D:PET	gram	4.5	7.5
	E:HDPE	gram	8.5	12.5

Table 2. Result of the DOE table for the fatic analysis

Sample	Temperature (˚C)	Pressure (gram)	Sawdust (gram)	PET (gram)	HDPE (gram)	Fatique Test (N/mm²)
1	120	1000	0.5	5	12.5	34.8
2	100	5000	1.5	5	11.5	37.9
3	110	3000	1	7.5	9.5	34.1
4	120	5000	0.5	7.5	10	41.5

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5	110	3000	1	6.25	10.75	55.2
6	120	5000	1.5	5	11.5	57.1
7	110	1000	1	6.25	10.75	35.9
8	100	3000	1	6.25	10.75	41.1
9	110	3000	1	6.25	10.75	54.3
10	100	1000	0.5	5	12.5	60.5
11	120	5000	0.5	5	12.5	32.4
12	120	5000	1.5	7.5	9	43.8
13	100	5000	1.5	7.5	9	58.4
14	110	3000	1	6.25	10.75	66.1
15	100	1000	0.5	7.5	10	35.1
16	100	5000	0.5	7.5	10	38.9
17	100	1000	1.5	5	11.5	64.6
18	120	3000	1	6.25	10.75	63.2
19	110	3000	0.5	6.25	11.25	60.2
20	110	3000	1	6.25	10.75	35.2
21	120	1000	1.5	5	11.5	62
22	100	1000	1.5	7.5	9	62.5
23	110	3000	1	5	12	**31.3**
24	110	3000	1	6.25	10.75	**67.1**
25	110	3000	1	6.25	10.75	58.9
26	120	1000	0.5	7.5	10	32
27	110	5000	1	6.25	10.75	59
28	110	3000	1.5	6.25	10.25	41.6
29	100	5000	0.5	5	12.5	41.2
30	120	1000	1.5	7.5	9	49.1
31	100	1000	1.5	5.5	10	54.2
32	120	1000	0.5	4.5	12	57.6
33	120	5000	1.5	7	8.5	36.1
34	120	1000	0.8	5.2	11	41.5
35	100	5000	0.5	6	10.5	46.3

Result and Discussion

Tables 3 and Table 4 show the results obtained from the variance analysis (ANOVA) depending on the experimental date. The relationship of the model formed by using ANOVA was derived from the reduced quadratic model of Ra as summarized in Table 3. According to the statistical analysis, the model developed is consistent with the experimental data, adequate model, no significant fit shortages, and has a satisfactory Ra and MRR determination coefficient (R^2). Likewise, some of the terms were set aside in the model despite being insignificant as maintaining model hierarchy often ensures a fair agreement between the "Pred R-Squared" and "Adj R-Squared" to achieve insignificant inadequacy. R^2 results were 0.8588 and Adeq precision (AP) = 5.700. It is desirable to have AP greater than 4 as it measures the signal-to-noise ratio. The final regression models are thus shown below in terms of actual MRR and EWR prediction factors.:

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Table 3. ANOVA for fatigue test response — reduced cubic model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	3658.98	22	166.32	2.76	0.0494	significant
A-Temperature	772.54	1	772.54	12.84	0.0050	
B-Pressure	977.90	1	977.90	16.25	0.0024	
C-Sawdust	20.65	1	20.65	0.34	0.5710	
D-PET	72.64	1	72.64	1.21	0.2977	
E-HDPE	468.59	1	468.59	7.79	0.0191	
AB	138.40	1	138.40	2.30	0.1604	
AC	685.72	1	685.72	11.39	0.0071	
AD	540.14	1	540.14	8.98	0.0134	
AE	525.01	1	525.01	8.72	0.0144	
BC	1107.08	1	1107.08	18.40	0.0016	
BD	784.83	1	784.83	13.04	0.0048	
BE	877.74	1	877.74	14.59	0.0034	
CD	680.38	1	680.38	11.31	0.0072	
CE	140.31	1	140.31	2.33	0.1578	
DE	587.87	1	587.87	9.77	0.0108	
A^2	53.78	1	53.78	0.89	0.3668	
D^2	482.33	1	482.33	8.01	0.0178	
ACD	279.20	1	279.20	4.64	0.0567	
ACE	375.62	1	375.62	6.24	0.0315	
BCD	341.53	1	341.53	5.68	0.0385	
BCE	364.24	1	364.24	6.05	0.0337	
A^2C	505.28	1	505.28	8.40	0.0159	
Residual	601.80	10	60.18			
Lack of Fit	499.71	7	71.39	2.10	0.2916	not significant
Pure Error	102.09	3	34.03			
Cor Total	4260.78	32				

Table 4: R-squared analysis of the fatigue index surface response model

Std. Dev.	7.76	R-Squared	0.8588
Mean	48.16	Adj R-Squared	0.5480
C.V. %	16.11	Adeq Precision	5.700

Fatique Test = -19284.28412+226.35269*Temperature+996.51371*Pressure+16265.70791 * Sawdust -52.22484 * PET +923.15311 * HDPE+0.14480 *Temperature * Pressure-170.77068 * Temperature * Sawdust -8.77864 * Temperature * PET-9.49094 * Temperature * HDPE-509.82177 * Pressure * Sawdust-56.01649* Pressure * PET -58.14295 * Pressure * HDPE -597.77728 * Sawdust * PET-740.87342 * Sawdust * HDPE +55.79012 * PET * HDPE -0.29680 * Temperature^2+46.49230 * PET^2+4.99931 * Temperature * Sawdust * PET +5.76147 * Temperature *

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Sawdust * HDPE +27.70254 * Pressure * Sawdust * PET +28.36764 * Pressure * Sawdust * HDPE +0.33699 * Temperature^2 * Sawdust.

Tables 3 show the ANOVA result. The terms A, B, C, D, E, AB, AC, AD, BC, BD, BE, CD, CE, DE were statistically significant with confident level, p-values less than 0.05 in this Fatique Index response test. The other terms of the model are not important.

Effect of Parameter Research

Figure 5 shows the one factor plots for process factors coded values and their influence on the fatic test. The graph is a useful statistical analysis tool that simplifies the observation of the influence of the factors on the response by means of analysis.

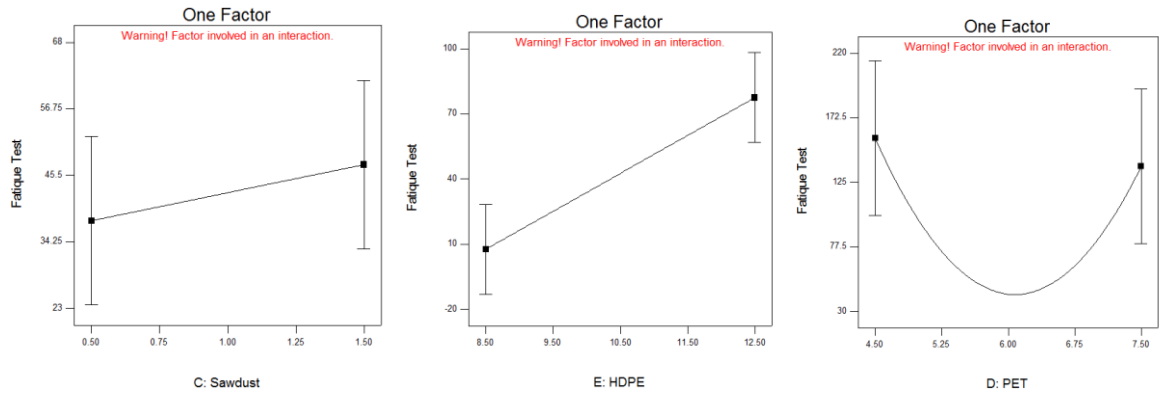

Figure 5. One Factor Plot for Fatique Test

A high slope for factor C and factor E is very prone followed by factor B and factor A, while factor D undergoes significant changes to decrease and eventually increase again at the beginning of the study..

Moreover, there is a similar configuration in the trend for C and E. The Ra value is increased by increasing each parameter value. Also, there is a similar picture of the trend for B and A. Ra is decreasing by increasing the value of each parameter. It can be inferred that factor C and factor E are directly proportional to Ra, which varies from factor B and factor A, since it is inversely proportional to Ra, while factor D changes.

Ra has the effect of statistical significance and decreases with increases in D and E for PET from 6.25 grams to 5 grams and increases in HDPE from 10.75 to 12 grams, thereby increasing the fracture value from 31.1 N / mm to 67.1 N / mm..

Through comparing the results of the experiment with the literature (Sombatsompop, Yotinwattanakumtorn, & Thongpin, 2005) Durability and fatic of PP / wood composites with different amounts of sawdust. It can be found that the presence of wood sawdust fiber greatly reduced the resilience of the PP / wood composites with an increase in the composite fatic, although the effect was less pronounced because of the wood content.

According to the literature, these results are consistent with the research that the decrease in fatigue is due to the presence of a sawdust mixture resulting in material degradation.

MODEL / INTERACTIVE EFFECTS RESPONSE

In addition to the individual terms that were found to be significant, the results of ANOVA also initiated the significant factors as shown in Figure 6 with a confident level of less than 0.05.

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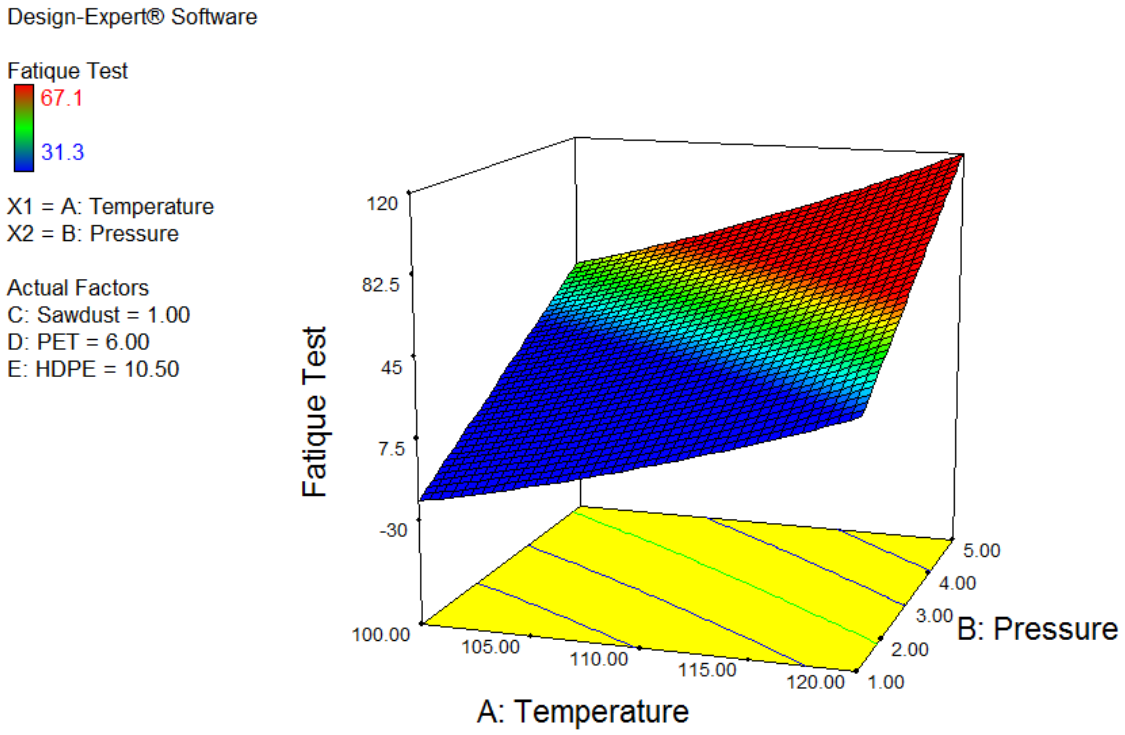

Figure 6. Control of processing parameters Fatigue Test

The impact of factor C on the fatic index is also strongly influenced by factor E and factor D, both in factor A and factor B lower and higher, factor D has a trend pattern that fluctuates on the fatigue index.

OPTIMIZATION

The desirability function approach for optimization technique has been selected in this research work, which allows multi-objective optimization. The desirability provides the estimate based on the statistical model's calculated responses. Higher desirability value represents a better response topic optimization.

In this analysis, the goals of optimization can be divided into two forms of optimization: single and multiple optimization. Single objective optimization of the formula for combining HDPE, PET and Sawdust materials is given by Factor E 11.5 grams, Factor D 5 grams and Factor C 1.5 grams providing a 67.1 N / mm² fatigue index. Figure 7 indicates the optimal solution and validation experiment to hit the full fatigue index. For multi-optimization, the suggested factor C 1 gram, factor D 7 grams and factor E 11 gram indicates the achievement of the 195.48 N/mm² fatigue index with mid-range criteria.

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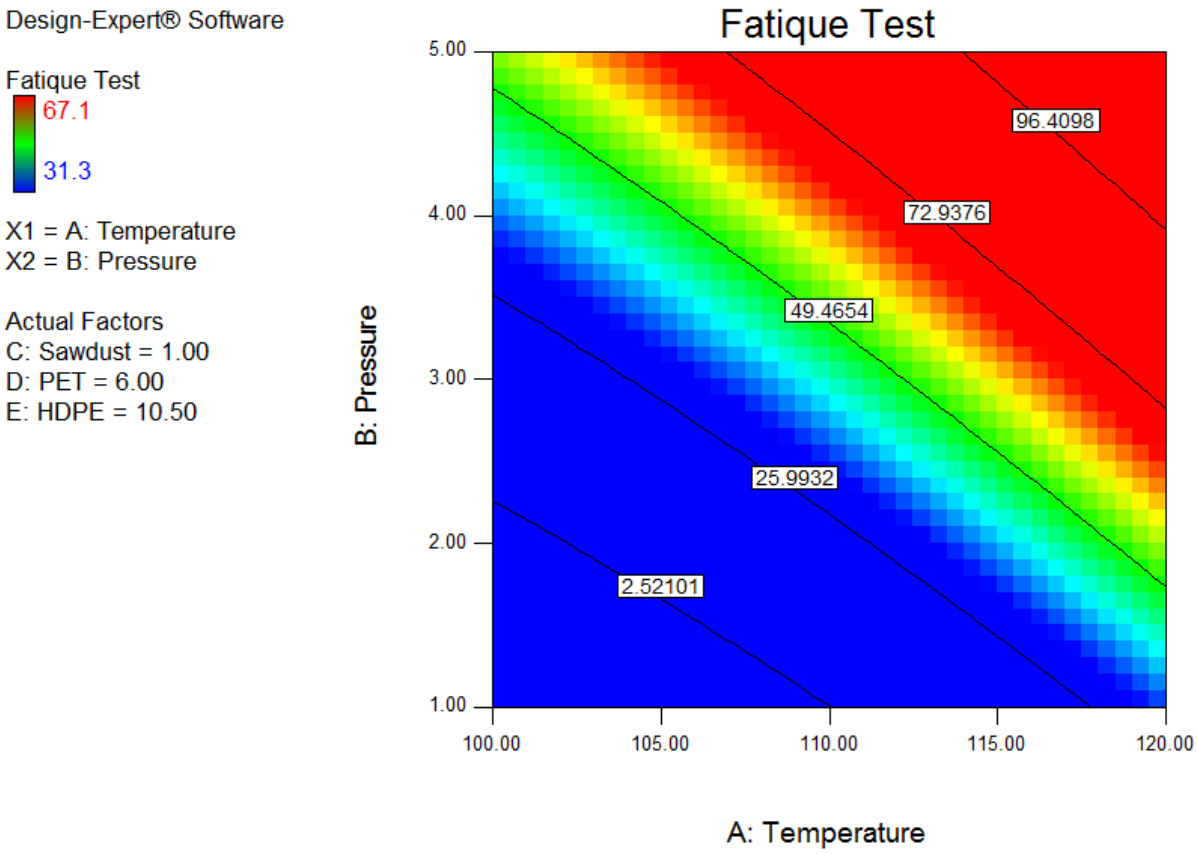

Figure 7 Optimatian and predict Fatique Of DOE

The relative error between the results predicted by the response function and the actual experiment was found to be 5.9%, which could lead to the conclusion that the model proposed for the Fatigue index was quite accurate.

CONCLUSION

The application of the response surface method to model the waste plastic composite is successfully developed for fatigue testing in this research work.

From the results obtained, the highest and lowest data for the same temperature and pressure of 110 ° C with different pressures of 3000 grams resides in the composition of the highest sample mixture of 1 gram sawdust, PET 6, 25 grams and HDPE of 10.75, while the lowest sawdust composition of 1 gram, 5 grams PET and 12 grams of HDPE, so that from this data, the mixture of HDPE and PET is closely related.

Consistent property improvement for these recycled systems can be obtained even in the presence of a low amount of E-GMA compatibilizer if compared to that recorded for HDPE-g-MA or SEBS-g-MA compatible PET / HDPE blends (up to 20 pph content)(Pracella, Rolla, Chionna, & Galeski, 2002).

Significant factors that determine this composition are the mixture of HDPE, PET and sawdust ingredients and the dominant factor in the specific response is sawdust with an increase in the amount of sawdust composition. Optimization using DOE is accomplished by obtaining a consistent composition from the total mixture of different specimens, validating this data as a guide for the production and use of this substance for product fatigue.

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