RESEARCH ARTICLE

Using of design and analysis of experiments to estimated properties of polymeric composite

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Manuscript Info	*Abstract*
	Compressive strength of polyethylene reinforced by ceramic fibers was studied in the paper. Ceramic fibers were added in deferent volume fraction (0-80) %wt. Mechanical test has shown an enhancement in these compressive strength after reinforcement by fibers the value of mechanical properties will increase with increasing percentage of reinforcement until 60 %wt. from fibers and after this ratio deteriorates compressive strength. Design and analysis of experiments was used to evaluated the compressive strength results obtained by mechanical test .Determination the percentage contribution effects of main factors were time, load ,and error, to the variability of the compressive at significant level (α=0.05).

Introduction

Design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not. However, in statistics, these terms are usually used for controlled experiments. Formal planned experimentation is often used in evaluating physical objects, chemical formulations, structures, components, and materials [1]. Other types of study, and their design, are discussed in the articles on computer experiments, opinion polls and statistical surveys (which are types of observational study), natural experiments and quasi-experiments (for example, quasi-experimental design). See Experiment for the distinction between these types of experiments or studies [2]. In the design of experiments, the experimenter is often interested in the effect of some process or intervention (the "treatment") on some objects (the "experimental units"), which may be people, parts of people, groups of people, plants, animals, etc. Design of experiments is thus a discipline that has very broad application across the entire natural and social sciences and engineering [3].
Factorial design is an important method to determine the effects of multiple variables on a response. Traditionally, experiments are designed to determine the effect of ONE variable upon ONE response. R.A.

Fisher showed that there are advantages by combining the study of multiple variables in the same factorial experiment. Factorial design can reduce the number of experiments one has to perform by studying multiple factors simultaneously. Additionally, it can be used to find both main effects (from each independent factor) and interaction effects (when both factors must be used to explain the outcome) [4]. However, factorial design can only give relative values, and to achieve actual numerical values the math becomes difficult, as regressions (which require minimizing a sum of values) need to be performed. Regardless, factorial design is a useful method to design experiments in both laboratory and industrial settings [5]. Factorial design tests all possible conditions. Because factorial design can lead to a large number of trials, which can become expensive and time-consuming, factorial design is best used for a small number of variables with few states (1 to 3). Factorial design works well when interactions between variables are strong and important and where every variable contributes significantly [6].
Let the number of levels of factor A be a and the number of levels of factor B be b. then, there is a total of (a × b) combinations in a full factorial design. If there are n replications, then there is a total of (n × a × b) observations. Simpler formulas for computing the sums of squares are given below [7] :

$$SST = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{n} y_{ijk}^2 - \frac{y^2}{abn} \qquad (1)$$

$$SSA = \frac{\sum_{i=1}^{a} y_i^2}{bn} - \frac{y^2}{abn} \qquad (2)$$

$$SSB = \frac{\sum_{j}^{b} y_j^2}{an} - \frac{y^2}{abn} \qquad (3)$$

$$SSE = SST - (SSA + SSB) \qquad (4)$$

Where (SST) is the sums of squares total, and (SSA ,SSB ,SSE) are the sums of squares times , exposed distance and error respectively . The degrees of freedom, mean squares and test statistics are summarized in Table 1. Also values of tabulated F at the significant level $(\alpha = 0.05)$ are determining from Table 2.

Table 1: Summary of test statistics

Source of variation	Sum of squares	Degrees of (DF) freedom	Mean square	Computed F and F From results at $(\alpha = 0.05)$
Time (A)	SSA	$a-1$	$MSA = SSA/a-1$	MSA/MSE $F_\alpha[(a-1),(a-1)(b-1)]$
Exposed distance (B)	SSB	$b-1$	$MSB = SSA/b-1$	MSB/MSE $F_\alpha[(b-1),(a-1)(b-1)]$
error	SSE	$(a-1)(b-1)$	$MSE = SSE/(a-1)(b-1)$	------------

The following formulas are used for computing the approximate percentage contribution of each effect (main factor or interaction) to the variability of the response variable:

$$\% \, Contribution \, of \, A, B = \frac{MSA, B - MSE}{SST} \times DF \times 100 \qquad (5)$$

$$\% \, Contribution \, of \, error = 100 - (sum \, \%A \, and \, \%B \, factor) \qquad (6)$$

Material and Methods

Low density Polyethylene resin and Ceramic fibers °) (0 ° - 45.Samples were manufactured according to (ASTM-D618) standard. Compressive strength test can be measured by three point test by using universal hydraulic press (Leybold Harris No.36110).

Result and Discussion

Figure.1 shows the compressive strength results before and after reinforcing with fibers .As we seen from this figure the compressive strength of resin will be low before reinforcement because the brittleness of resin. But after added the fibers to this resin the compressive strength will be raised to the producing material because the high modulus of elasticity of these fibers will helps to carry a large amount of loads and raise this strength. And when the reinforcing percentage 70% to 80% compressive strength will strongly decreased due to low wettability between fibers and resin [8].

Figure.2 represent Pareto chart of main effects . A large percentage of contribution by time equal to (72 %) and a small percentage of contribution by error equal to (10 %) and are load equal (18%). indicating that, small possible changes in the levels of compressive not controlled during the experiment and small inherent variation in process due to error (noise variables) [7].
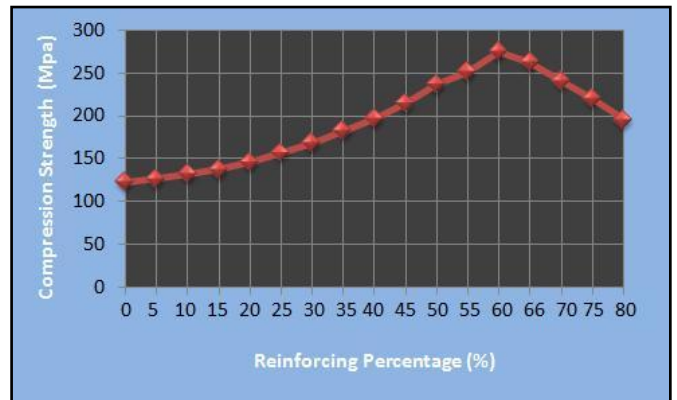

Figure1 : Compressive strength values of composite material vs. fibers reinforcing percentage

Figure 2: Pareto chart of main effects

Conclusion

The addition of 60% ceramic fibers improves the compressive strength of low density polyethylene resin, but when reinforcement percentage becomes 70% to 80% compressive strength will decreased due to low wettability between fibers and resin and the fibers will extract from resin easily .The optimum ratio was 60% fibers with 40% resin. The effect of an interaction between main effects is not found.Reduction of an inherent variation in the process due to noise variables.

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