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Application of Modern and Classical Optimization Techniques in Abrasion of Al-Cu-SiCp and Al-Cu-B4Cp Composites

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Abstract — *In this study, we introduce the abrasion resistance of Al-Cu-SiC_p and Al-Cu-B_4C_p. Based on Fuzzy Logic Modeling (FLM) and surface fitting techniques, we propose the abrasion model of Al-Cu-SiC_p and Al-Cu-B_4C_p which is decided by the rate of SiC_p and $B_4C_{p,}$ and the amount of applied pressure to the specimens. The model can lead to the best rate of SiC_p and B_4C_p and the amount of applied pressure to obtain the minimum abrasion.*

Keywords: Abrasive strength, Fuzzy logic modeling, Interdisciplinary modeling.
Mathematics Subject Classification: 62A86, 97M10.

1 Introduction

Aliminium (*Al*)- based composites have wide applications in many areas especially in defense and automotive industries since they have high specific strength and wear resistance with lightness. (*Al*)- based composites can be reinforced with ceramic particulate materials such as *SiC*, B_4C and etc. [1,2,3,4]. There are different ways to produce (*Al*)-based composites reinforced with ceramic particulate materials. In this study, the way offered by Bedir is followed [1]. By considering the data which is presented in the paper [1] , we aim to monitor the changes on abrasion on the material based on the rate of SiC in the composite and applied force by using the FLM.

Fuzzy logic is one of the very well known modern optimization techniques being widely used in many branches of science as well as the other modern techniques.

As is known, Fuzzy Logic was firstly introduced by L. A. Zadeh in 1965 [17]. The concept of fuzzy logic is based on the fuzzy sets. In 1985, Mamdani used the fuzzy logic to control the dynamical systems [6]. After that, Sugeno and the others tried to extend the application areas of fuzzy logic [11,12]. Recently, the fuzzy logic is used in many areas of engineering, physics, management science and etc [7,8,10].

In the literature, two types Fuzzy Inference Systems (FIS), Mamdani and Takagi-Sugeno are distinguished, clearly. It is argued that, each of these FIS outmaneuver each other from time to time. But there is not exact result about the superiority of one of them. We select the Mamdani type FIS since the use of the Mamdani type FIS is easy. Our main aim is to enrich the data collection by considering FIS.

After the fuzzy logic modeling process some surface fitting techniques can be used to obtain the rule of the objective function if more than one singular local minimizers of the objective function are thought to be existed. In fact, surface fitting is another way of the modeling of the any data collection. The advantage of surface fitting is to obtain the rule of the continuous function.

2 Preliminaries

2.1 Experimental Method

The complete experimental procedure can be founded at the paper [1]. For the sake of clarity, we summarize the experiments. Al-Cu-SiCp and Al-Cu-B4Cp specimens are prepared in different amounts of SiC and B4C as a 30×40mm plates. The specimens are cut from the plate and they are subjected to the abrasive wear test. The test is realized by using pin-on-disc type apparatus. The abrasive wear tests were performed at 2,4,6,8 and 10 N loads pressing and by using the 100 G abrasive paper.

2.2 Fuzzy Logic Modeling

Fuzzy logic modeling starts with the concept of a fuzzy set. Fuzzy set is a set without a crisp and clearly defined boundary. Suppose X is an ordinary set, whose elements are denoted by x. Membership in an ordinary subset A of X can be expressed by the characteristic function. If the point x is the element of A, then the corresponding value of x under characteristic function is 1. If not, then the corresponding value of x under characteristic function is 0. For any fuzzy set A, the corresponding value of characteristic function (membership) can be any point in the real interval [0,1].
Now, we continue with defining the basic elements of the FIS. Each FIS consists of fuzzification, inference engine and defuzzification stages (see Fig. 1.).

In fuzzification stage, the crisp values become fuzzy values and the membership functions is defined for the inputs and outputs. There are different types of membership functions: triangular, trapezoidal, Z-shaped, Gaussian, sigmoidal, S-shaped. We used triangular and trapezoidal membership functions in this study.
For inference engine, the linguistic rules “if… then…” are determined which are commands of the system behavior. These rules set down the relations between inputs and outputs.

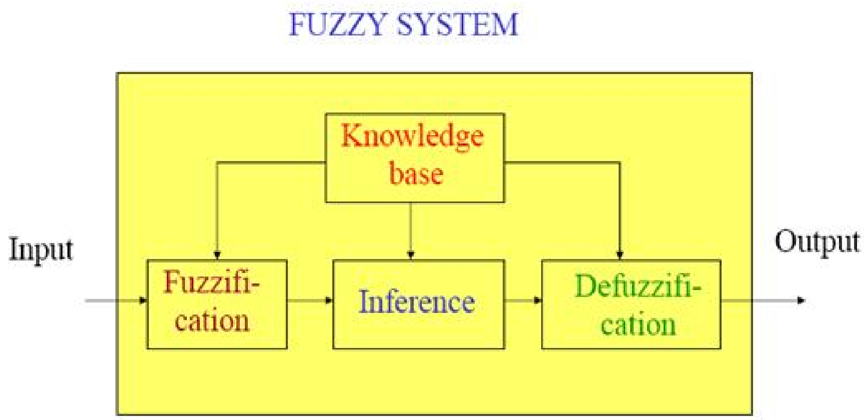


Figure 1. General structure of each Fuzzy Inference System

At the last stage (defuzzification), fuzzy values become crisp values. There are different types of defuzzification methods such as: centroid, bisector, middle of maximum (mom), smallest of maximum (som), and largest of maximum (lom). We prefer centroid technique for this study.
The more about FIS can be found in the literature [9,18].

2.3 Surface Fitting

Since we have 3-dimensional data, we use surface fitting to obtain the rule of the function that determines the relation between inputs and output. Surface fitting includes the exact fitting to the data, or constructs the smooth and approximate fits to the data. Fitted surfaces can be used for visualization of the discrete data to get information about the values of a function where no data are available and for taking the first impression referring to the relationships among the variables.

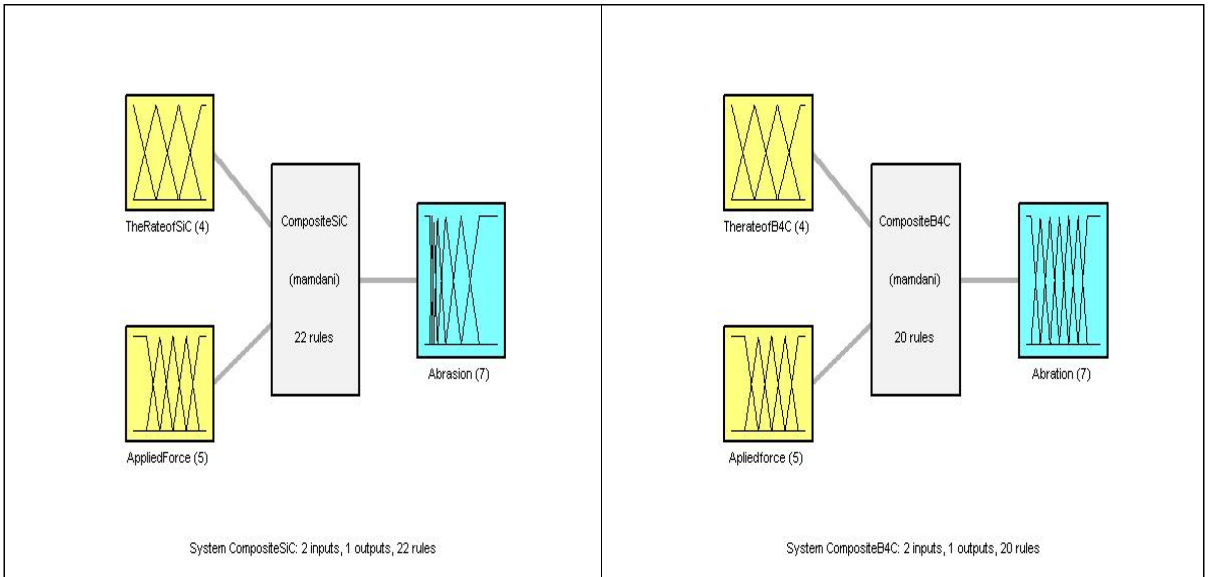
3 Main Results

3.1 Application of Fuzzy Logic Modeling

The parameters such as the rate of SiC_p and B_4C_p in composite and applied force amount effect the abrasion. We built a fuzzy logic model whose input variables are the rate of SiC_p and B_4C_p in composite and applied force amount and the output variable is abrasion. The general structure of the model is shown in Figure 2.

The rate of SiC_p and B_4C_p in composite is classified as R1, R2, R3, R4 between 0% and 32% , and the amount of applied force is classified as F1,F2,F3,F4,F5 between 0N (Newton) and 11N (Newton). (See Fig. 3 and 4, respectively).

The output "abrasion" is classified as A1,A2,A3,A4,A5,A6 and A7 for both models. The range for abrasion is 0 and 0.8 m/mm^3 and 0 and $1 m/mm^3$, respectively.



(a) (b)

Figure 2: General structure of the Fuzzy Logic Models

The rule structure is designed based on how the experts interpret the characteristics of the variables of the system. It is possible to write down a lot of "if-then" fuzzy rules and some of the rules used in the model are as the following:

- If (TheRateofSiC is R1) and (AppliedForce is F1) then (Abrasion is A5)
- If (TheRateofSiC is R1) and (AppliedForce is F2) then (Abrasion is A5)
- If (TheRateofSiC is R1) and (AppliedForce is F3) then (Abrasion is A6)
- If (TheRateofSiC is R1) and (AppliedForce is F4) then (Abrasion is A6)
- If (TheRateofSiC is R2) and (AppliedForce is F3) then (Abrasion is A3)

After simulating Mamdani method, the surfaces for abrasion in accordance with the constructed model is plotted in Figure 5 (a) and (b).

The correlation coefficient R^2 which is obtained by regression analysis shows that experimental results and fuzzy logic results of academic achievement is close to the rate of 97.26% (see Figure 6 (a) and (b)).

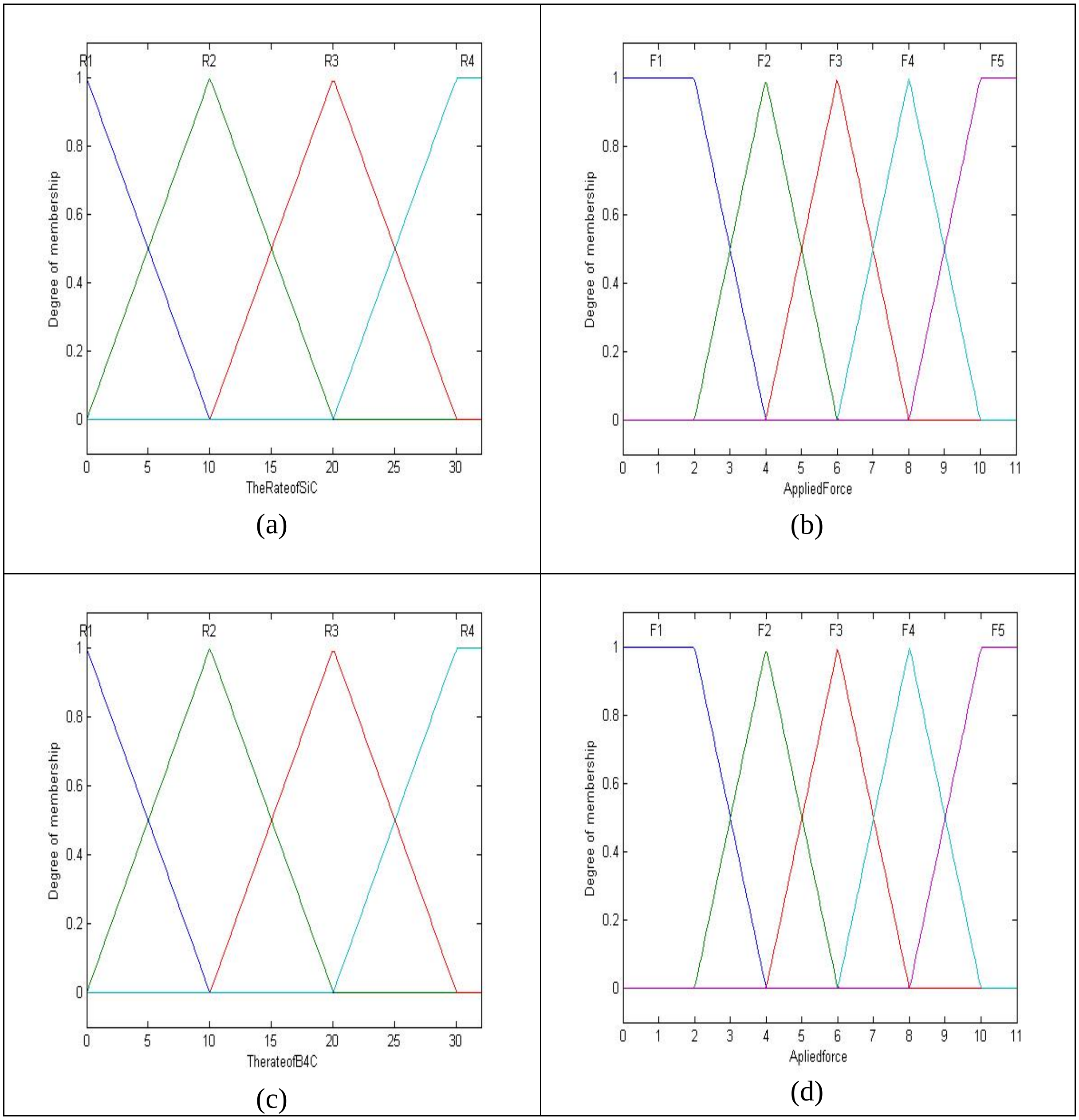


Figure 3: (a) and (b) the membership functions for inputs of fuzzy logic model of the Al-Cu-SiC, (c) and (d) The Membership functions for inputs of fuzzy logic model of the Al-Cu-B_4C.

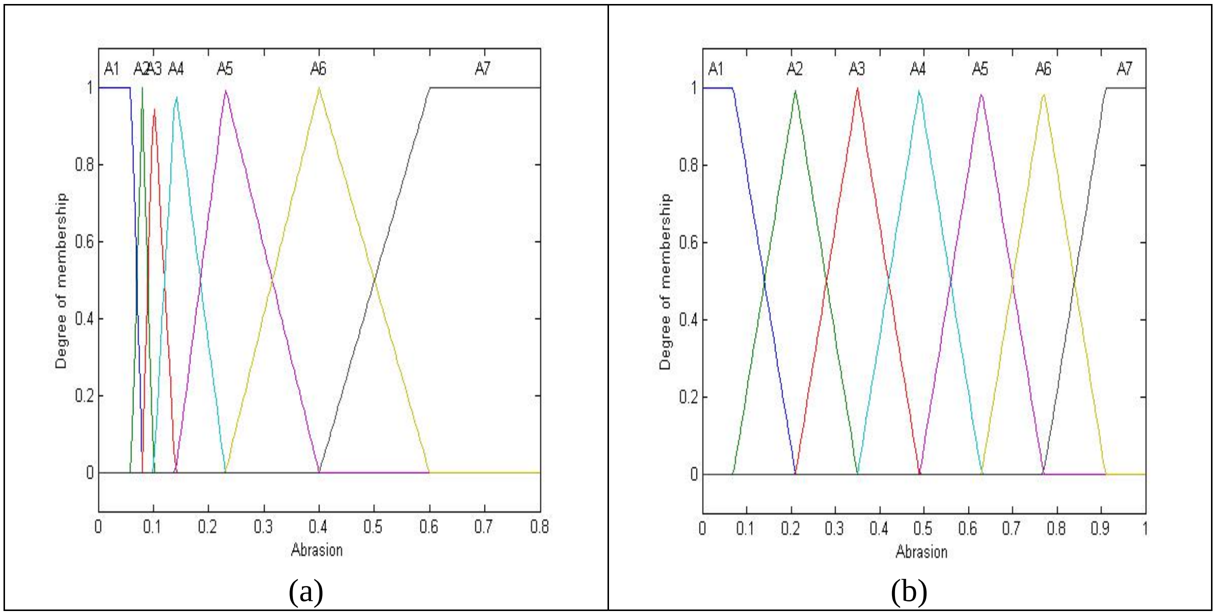


Figure 4: (a) and (b) the membership functions for outputs of the fuzzy logic model of Al-Cu-SiC and Al-Cu-B_4C, respectively.

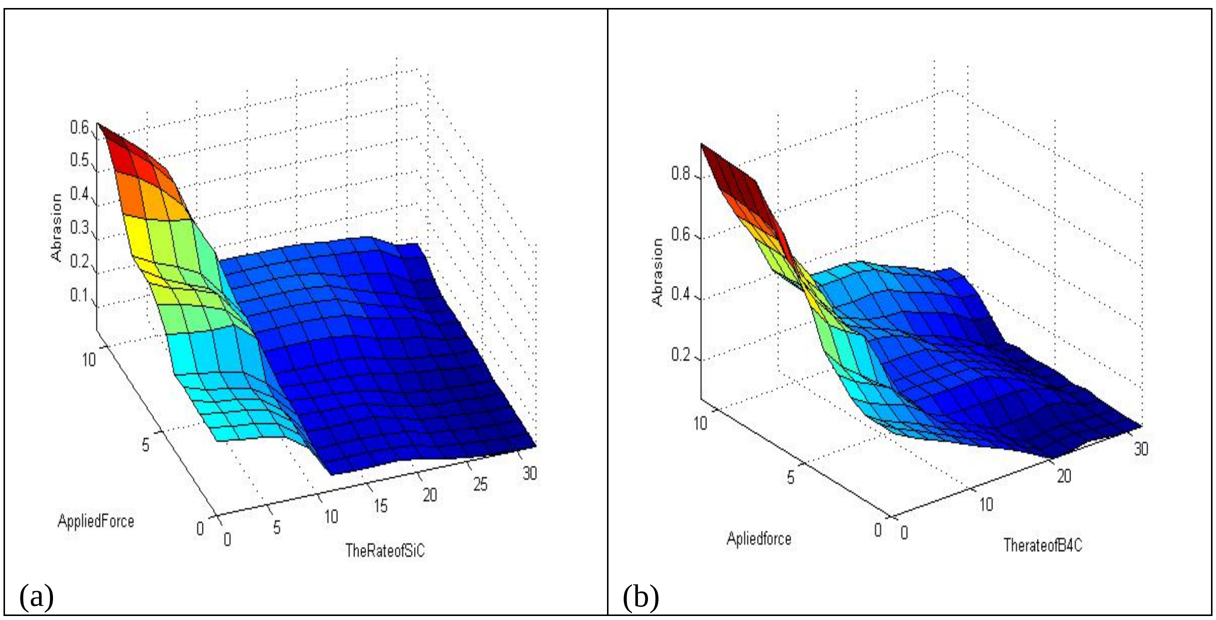


Figure 5: (a) and (b) the surfaces of the model obtained from the fuzzy logic modeling.

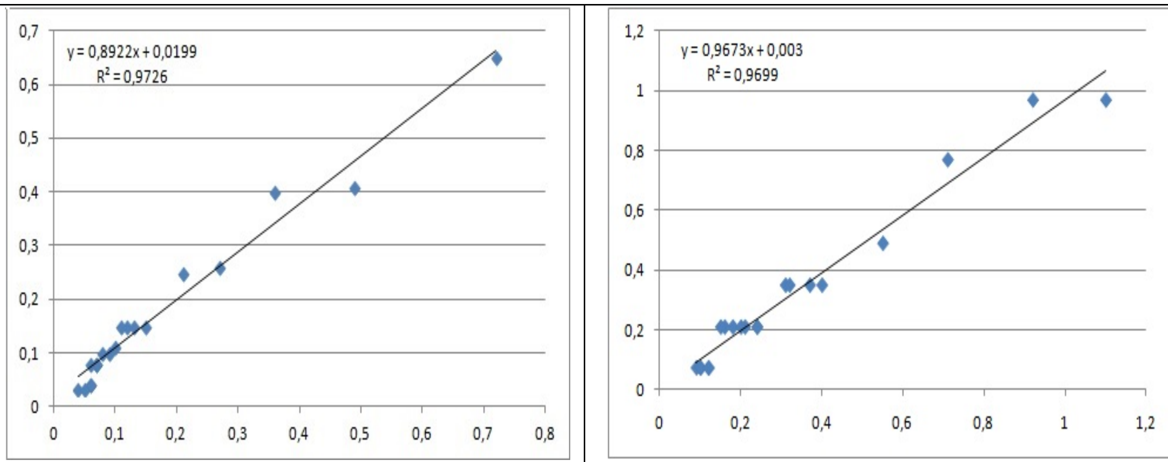


Figure 6: (a) and (b) are the comparison of measured values and estimated values.

3.2 Setting of the Objective Function

By using enriched data obtained from fuzzy logic process we need to set up the objective function. To set up the objective function, enriched data is used in the surface fitting techniques to obtain the following objective functions: The first function is the function of *SiC* included composite

$$f(x, y) = 0.1572 - 0.005425x + 0.01515y - 2.25 \times 10^{-5}x^2 - 0.002703xy + 0.001826y^2 + 0.0001163x^2y - 0.0002125xy^2 + 0.0001823y^3,$$

the second one is the function of B_4C included composite

$$g(x, y) = 0.2047 - 0.01008x + 0.08458y + 0.0002025x^2 - 0.00602xy - 0.001585y^2 + 0.0001188x^2y - 8.929 \times 10^{-6}xy^2 + 0.0001823y^3.$$

The graphs of these functions are shown in Figure 7 (a) an (b).

As can easily seen from the above graphs the surfaces are quite consistent with the surfaces obtained by fuzzy logic and this shows that our modelling is very satisfactory for our purposes.

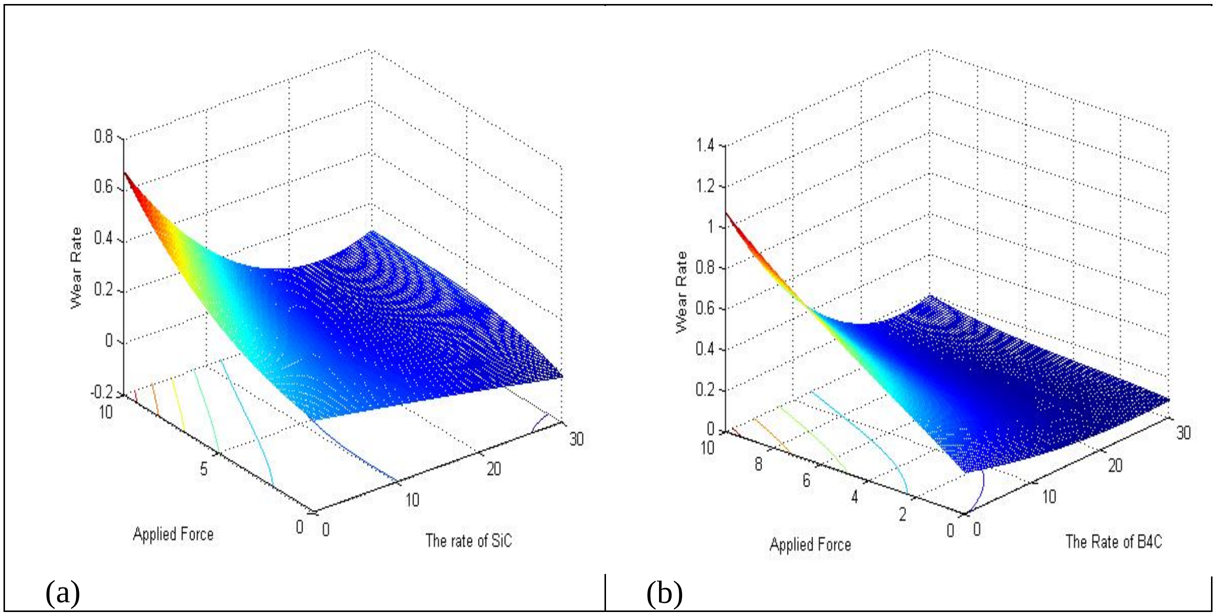


Figure 7. (a) and (a) are the graphs of the functions $f(x,y)$ and $g(x,y)$, respectively.

3 Conclusions

Fuzzy logic modeling gives opportunity for complete monitoring of relationships between inputs and output variables. The modeling process gives acceptable and reliable results. (see for example Fig. 7). At this modeling procedure we can estimate the wear rate for untested conditions. By considering the data obtained from fuzzy logic modeling, besides the original data, more likely results are obtained for the relationships between inputs and output variables.

In this study, we consider effects of the rate at SiC (or B4C) and applied force on abrasion (wear rate). The wear rate decreases when the amount of SiC (or B4C) increased. The wear rate of SiC is smaller than the composite including B4C. The wear rate of the composites which are including 10% or more ceramic particulate materials is not change too much when applied force is increasing. The wear rate of the composites which includes 10% or more ceramic particulate materials is not change too much according to increasing the amount of ceramic particulate materials.

We remark that abrasive paper worn over 220 G was used throughout our study. But we carried out experiments by using abrasive papers worn over 100G, 150G and 220G, 10h aged and worn over 100G, 150G and 220G. In this case, our model functions (objective function) representing the character of abrasion are behaving a little bit complicated and may have local minimizers more than one. So this is just what filled function method requires to be applied. Although experiments have been carried out for this purpose and we have the obtained results it is going to be a subject of another study. Because it may require some additional works such as offering new FF and some new smoothing techniques [3,4,14,15,16].

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