ISSN:1306-3111
e-Journal of New World Sciences Academy
2009, Volume: 4, Number: 3, Article Number: 1A0030

ENGINEERING SCIENCES
Received: November 2008
Accepted: June 2009
Series : 1A
ISSN : 1308-7231

Selda Akgün
Salim Şahin
Hülya Durmuş
Celal Bayar University
selda.akgun@bayar.edu.tr
Manisa-Türkiye

PRODUCTION OF CERAMIC REINFORCED ALUMINUM COMPOSITE MATERIALS BY USING POWDER METALLURGY METHOD AND DETERMINATION OF ITS PROPERTIES

ABSTRACT

The metal matrix composites were fabricated by a powder metallurgy. In produced composites, the reinforcement rates of FeB_x are 5, 10, 15, 20, 30, 40 (%wt.) and the reinforcement rates of SiC are 2.5, 5, 7.5, 10, 15, 20 (%wt.). The matrix Al powders were mechanically mixed with SiC and FeB_x particulates compacted in room temperature at 400 MPa for 10x10x55mm specimens and followed by sintering at 600˚C for 1 h. Density, hardness and three point bend tests were realized. The test results indicate that the mechanical properties of 99.9% Al is significantly improved with increase of SiC and FeB_x particles.
Keywords: Al-SiC Composite, Al-FeB_x Composite, Powder Metallurgy, Mechanical Properties

TOZ METALURJİSİ YÖNTEMİYLE SERAMİK TAKVİYELİ ALÜMİNYUM KOMPOZİT MALZEMELERİN ÜRETİMİ VE ÖZELLİKLERİNİN INCELENMESI

ÖZET

Metal Matrisli kompozitler toz metalurjisi yöntemiyle üretilmişlerdir. Üretilen kompozitlerde FeB_x in takviye oranları ağırlıkça 5, 10, 15, 20, 30, 40 ve SiC ün takviye oranları ağırlıkça 2.5, 5, 7.5, 10, 15, 20'tir. Al-FeBx ve Al-SiC kompozitleri 400 MPa basınçta sıkıştırılarak 10x10x55mm boyutlarında parçalar üretilmiştir. Daha sonra 600˚C'da 1 saat sinterlenmişlerdir. Yoğunluk, sertlik ve üç nokta eğme testleri gerçekleştirilmiştir. Test sonuçları SiC ve FeBx takviyelerinin oranlarının artmasıyla %99.9 Al'dan üretilen kompozitlerinin mekanik özelliklerinin arttığını göstermiştir.
Anahtar Kelimeler: Al-SiC kompozit, Al-FeBx Kompozit, Toz Metalurjisi, Mekanik Özellikler

1. INTRODUCTION (GİRİŞ)

Aluminum-based, particulate-reinforced metal matrix composites (MMCs) are of concerns for structural carrying outs where weight saving is of primary concern. There are several production techniques to getting in manufacturing the MMC materials (Koker and Altınkök, 2005; Altınkök and Koker, 2005).

Powder metallurgy is the study of the processing of metal powders including the fabrication characterization and conversion of metal powders into useful engineering components (Durmuş, 2007; Taşkın et al, 2008). Powder metallurgy methods are based on the classical blending of matrix powders and reinforcing elements (dispersionpowders, platelets and ceramic fibres) and further cold pressing and sintering followed by plastic working (forging, extrusion). Cold plastic working is normally applied when a green part is preliminary sintered and hot plastic working occurs when only cold pressing is applied. The method described above, on account of its simplicity, is applied widely for the production of composite materials with magnesium alloys matrix, aluminium alloys matrix, and copper matrices (Kaczmar et al, 2007).

Developments of light-weight and energy-saving materials in many applications, such as pulleys and linkage in automobiles, and track shoes for moving vehicles (besides aerospace applications), have become more numerous in the past few years. For example, ceramic-fiber - and particulate- reinforced MMCs have been employed in automotive or aircraft brakes and in diesel piston engines to improve wear resistance (Muratoğlu, 2006). Al matrix composites are known to have superior specific modulus, specific strength, and wear resistance and high temperature stability. The composites are being applied to the transport industry, as components in the automobile to increase fuel efficiency due to their light weight and mechanical soundness (Kim, 2006.A composite material, in general consists of a matrix material and reinforcement (Dasgupta, 2005).

Since the 1980s there had been extensive investigation of aluminum MMCs reinforced with hard ceramic phases, such as Al_2O_3 or SiC, in an effort to understand and improve the tribological properties of aluminum (Walker, 2005). Several reinforcements have been used, with SiC and Al_2O_3 being the most widely used (Velasco et al, 2002).

2. RESEARCH SIGNIFİICANCE (ÇALIŞMANIN ÖNEMİ)

This study investigated mechanical properties of aluminum composites that Al99-SiCp and Al99-FeB_x composites produced through a powder metallurgy process. The objective of this study, is to offer an alternative reinforcement material and to obtain Al matrix composite material with high hardness and wear resistance by reinforcement of high wear resistance ferroboron.

3. MATERIAL AND EXPERIMENTAL STUDY (MALZEME VE DENEYSEL ÇALIŞMA)

The materials used for test samples were Al99-SiC composite and Al99-FeB_x composite. The sieve analysis and chemical composition of matrix material and reinforcement materials are given in Table 1, Table 2 and Table 3, respectively. Aluminium alloy powders were supplied by ECKA Aluminium Granules. SiC particles were supplied by SIKA and FeB_x was supplied by Metallurg. Test specimens were fabricated using powder metallurgy techniques. The matrix Al99 powders were mechanically mixed with SiC and FeB_x particulates. The mixed particulates were compacted in room temperature at 380 MPa for 10x10x55mm specimens and followed by sintering at 600˚C for 1 h. Carbolite W1000 was used for sintering process.

Table 1. Specified compositions (wt. %) for Aluminum powder from ECKA Aluminium Granules and sieve analysis

Properties	Value
Chemical Analysis	
Al	Min 99.9 %
Fine Sieve Analysis	
>63 µm	0 %
<45 µm	84 %

Table 2. Specified compositions (wt.%) of SiC particulates and sieve analysis

Properties	Value
Chemical Analysis	
SiC	99.7 %
C	0.05 %
SiO_2	0.1 %
Si	0.05 %
Fine Sieve Analysis	
>106 µm	1.5 %
>90 µm	16.9 %
>75 µm	64.4 %
>63 µm	94.8 %
<63 µm	5.2 %

Table 3. Specified compositions (wt. %) of FeB_x particulates and sieve analysis

Properties	Value
Chemical Analysis	
SiO_2	0,44 %
B	18,41 %
Al	0,11 %
C	0,20 %
Fe	80,84 %
Fine Sieve Analysis	
>90 µm	56,10 %
>45 µm	81,30 %

Vickers microhardness values of Al, FeBx and SiC, represented in Table 4. The microhardness was determined using a Future - Tech FM - 700.

Table 4. Microhardness values of Al, FeBx and SiC

Material	Hardness Value (HV)(g/mm^2)
Al	23,3
FeB_x	1092,9
SiC	1598,2

The weight percentage of SiC and FeB_x was used as in Table 5. Materials were mixed 50 min. for homogeny dispersion mechanically. %3 stearic asit and ethyl alcohol mixture were used as lubricate in mold during pressing. Specimens polished for microstructure investigation. Material densities were measured by Archimedean principle. Macrohardness of polished specimens was measured by Vickers method from five points. Average of five hardness values was finding and hardness graphics were formed.

Table 5. Mixture ratios of produced specimens (wt. %)

Specimen number	SiC	Ferrobor	Al
1	-	-	100
2	-	5	95
3	-	10	90
4	-	15	85
5	-	20	80
6	-	30	70
7	-	40	60
8	2.5	-	97.5
9	5	-	95
10	7.5	-	82.5
11	10	-	90
12	15	-	85
13	20	-	80

For three point bend test, mechanism in Figure 1 was prepared. Test specimens dimensions are 10mmx10mmx55mm for this test.

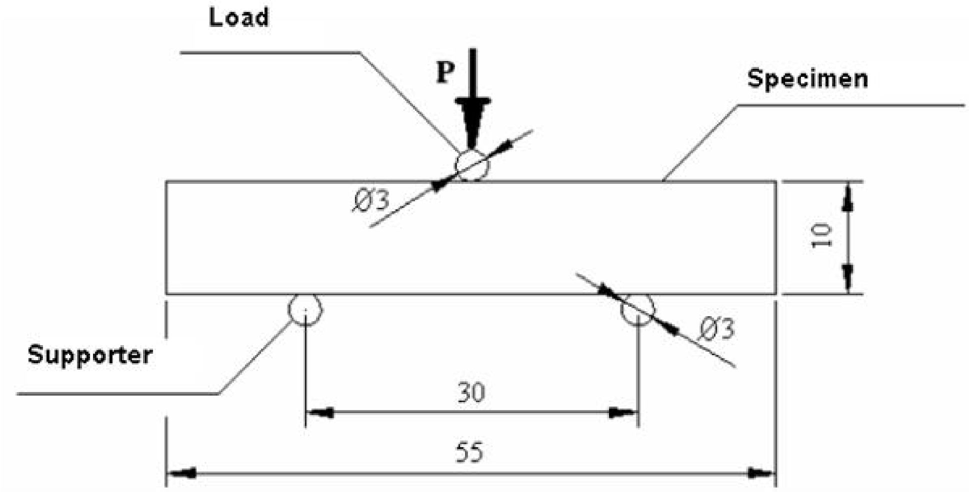

Figure 1. Mechanism of three points bend test

3.1. Microstructure (Mikroyapı)

Microstructure photographs of Al99-FeB_x and Al99-SiC composites were demonstrated in Figure 2-9. In these figures, distribution of reinforcements was investigation. The reinforcements were homogeny in matrix.

Figure 2. 100% Al powder metal specimen.

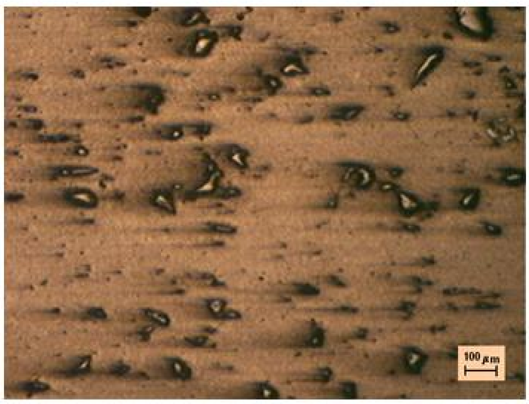

Figure 3. 15 % FeB_x particles in the Al Matrix.

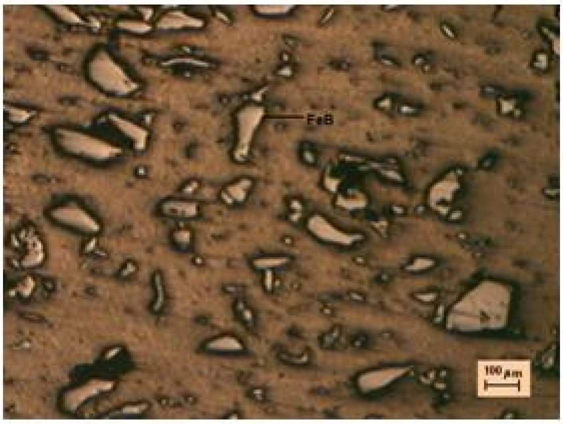

Figure 4. Al99-30% FeB_x composite

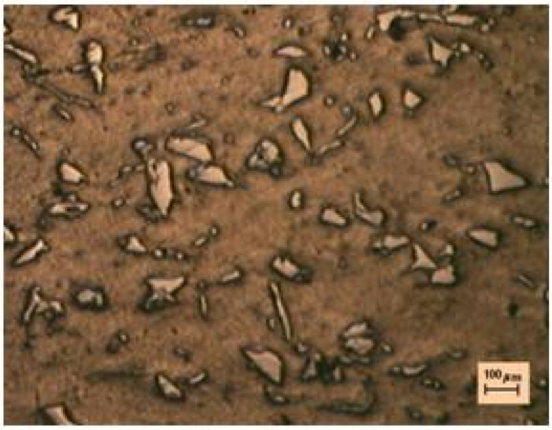

Figure 5. Al99-40% FeB_x composite

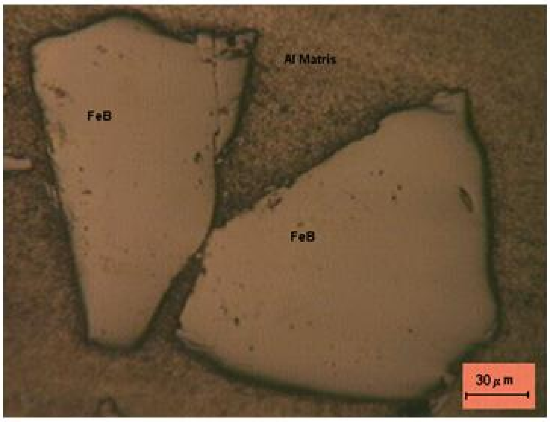

Figure 6. Al99-20% FeB_x composite

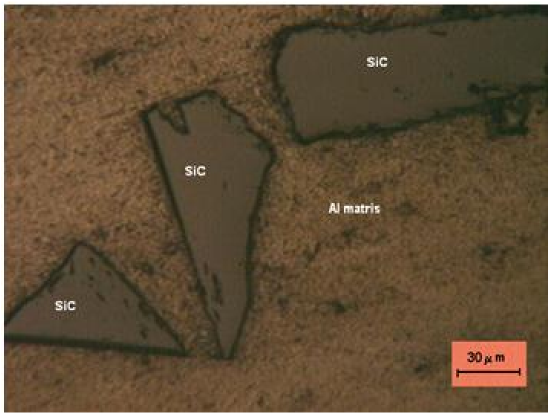

Figure 7. Al99-7.5 % SiC composite

Figure 8. Al99-10% SiC composite

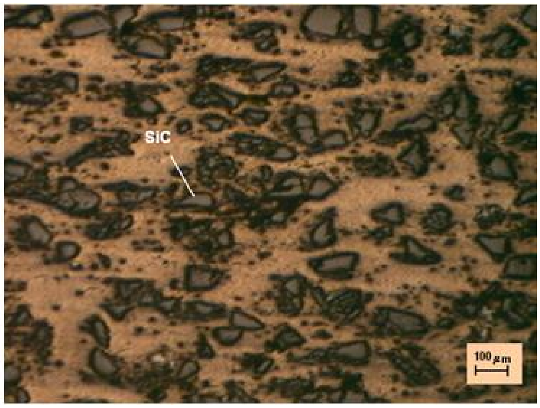

Figure 9. Al99-15% SiC composite

3.2. Density (Yoğunluk)

The densities of materials are in Table 6. Theoretical density values of composite material calculated according to rule of mixture after increasing reinforcement ratio is high as excepted. This increase can be explained by density difference between reinforcement element and matrix element.

Table 6. Density values of Al99-SiC and Al99-FeB_x

Mix rate	Density (g/cm^3)	Real density (g/cm^3)	Theoretical density (%)
Unreinforcement	2.616	2.7	0.969
5% FeB_x	2.685	2.88	0.932
10% FeB_x	2.785	3.06	0.910
15% FeB_x	2.875	3.24	0.887
20% FeB_x	2.96	3.42	0.866
30% FeB_x	3.11	3.78	0.823
40% FeB_x	3.34	4.14	0.806
2.5 %SiC	2.626	2.713	0.968
5 %SiC	2.628	2.725	0.964
7.5 %SiC	2.633	2.738	0.962
10% SiC	2.639	2.75	0.960
15% SİC	2.657	2.775	0.957
20% SiC	2.658	2.8	0.950

With increasing reinforcement rate, the composites exhibited low teorical density. The best theorical density is in unreinforcement specimen.

Between composites reinforced with SiC and FeB_x, density values of Al99- FeB_x composites are lower than density value of Al99- SiC composites.

3.3. Hardness Test (Sertlik Testi)

In composites, hardness increase by increasing reinforcement amount. Macrohardness of the specimens depending on reinforcement ratio is demonstrated in Figure 10-11.

Hardness values of Al99-SiC and Al99-FeB_x were close each other. Maximum increase in hardness value is found in 40 wt. % FeB_x reinforced composite by a 113% increase when 65.2 HV value of pure Al metal matrix material is taken into consideration. This is suitable result for material production purposes.

Hardness and three point bend test of materials which were produced by powder metallurgy method and by adding 5, 10, 15, 20, 30, 40 wt % of FeB_x and 2.5, 5, 7.5, 10, 15,20 wt. % of SiC to pure Al are shown in Figure 11-13.

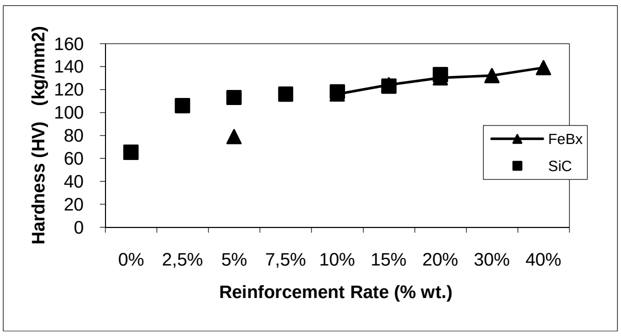

Figure 10. The effect to hardness of reinforcement rate (wt. %)

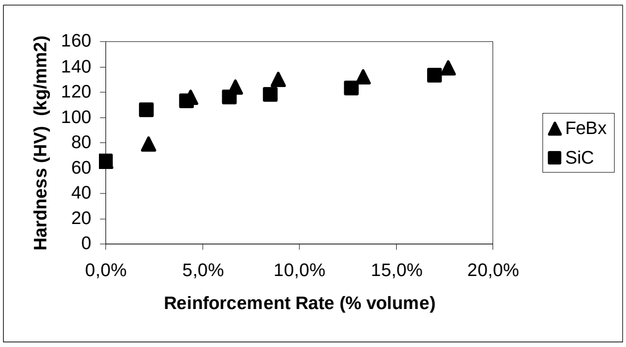

Figure 11. The effect to hardness of reinforcement rate (volume %)

3.4. Three Point Bend Test (Üç Nokta Eğme Testi)

Three point bend force of composite specimens is low because of increased reinforcement materials. Al99-SiC and Al99-FeB_x composites are brittle structure. Three points bend test results are shown in Figure 12-13. Extremely rigid intermetalic compound formation particularly between reinforcement element and matrix material interface cause a decrease in mechanical properties of composite specimens.

According to graphics, with the increase in reinforcement ratio, three point bend strength of composite specimens decreased.

The strength in lower reinforcement rate of FeB_x is higher than SiC. But at increased reinforcement rates, strength of the FeB_x is lower than SiC. The cause of this result, the wetting capability of SiC is better than FeB_x.

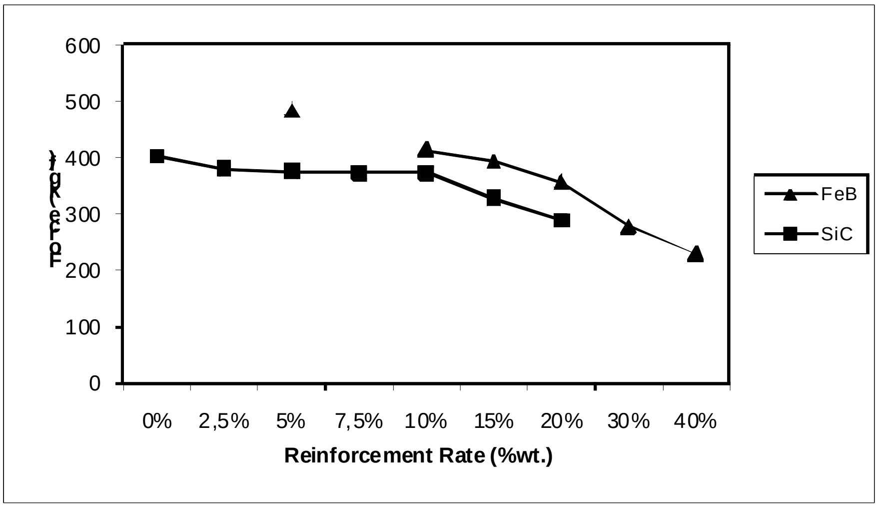

Figure 12. The effect to three point bend strength of reinforcement rate (wt%)

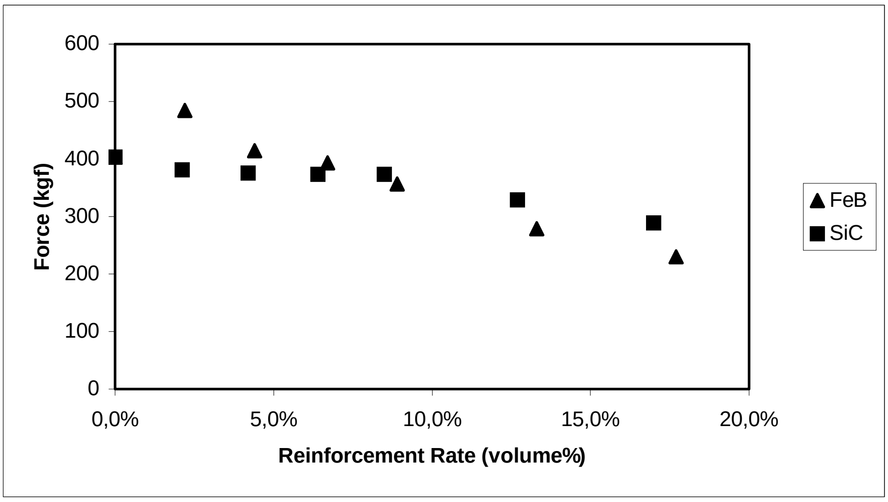

Figure 13. The effect to three point bend strength of reinforcement rate (volume %)

Table 7. At the composites, dimension changes with sintering process

Mix rate	Before sintering Dimension (mmxmm)	After sintering Dimension (mmxmm)
0% FeB_x	10.23 x 55.41	10.22 x 55.40
5% FeB_x	10.28 x 55.63	10.28 x 55.64
10% FeB_x	10.28 x 55.63	10.29 x 55.63
15% FeB_x	10.28 x 55.56	10.28 x 55.56
20% FeB_x	10.28 x 55.51	10.28 x 55.52
30% FeB_x	10.26 x 55.51	10.26 x 55.52
40% FeB_x	10.22 x 55.40	10.23 x 55.44
2.5% SiC	10.24 x 55.48	10.25 x 55.53
5% SiC	10.14 x 55.17	10.15 x 55.23
7.5% SiC	10.28 x 55.63	10.29 x 55.64
10% SiC	10.19 x 55.36	10.20 x 55.36
15% SiC	10.22 x 55.35	10.23 x 55.35
20%SiC	10.23 x 55.36	10.24 55.41

4. RESULTS (SONUÇLAR)

- Density values of Al99- FeB_x composites are lower than density value of Al99- SiC composites.
- With the increase in reinforcement ratio, hardness of composite materials increased.
- Three point bend strength of composite specimens decreased with the increase in reinforcement ratio.
- The dimension change weren't observed at the dimensions of materials.

ACKNOWLEDGMENTS (TEŞEKKÜR)

The authors are grateful to Celal Bayar University Research committee since this study is suggested and supported through grant (CBÜ FBE 2002-092).

REFERENCES (KAYNAKLAR)

1. Altinkok, N. and Koker, R., (2005). Neural Network Approach to Prediction of Bending Strength and Hardening Behaviour of Particulate Reinforced (Al–Si–Mg)-Aluminium Matrix Composites, Materials and Design, 25, 595–602.
2. Dasgupta, R. and Meenai, H., (2005). SiC particulate dispersed composites of an Al–Zn–Mg–Cu alloy: Property comparison with parent alloy, Materials Characterization, 54, 438– 445.
3. Durmuş, H.K. ANDMeriç, C., (2007), Age-Hardening Behavior of Powder Metallurgy AA2014 Alloy, Materials & Design, Volume 28, Issue 3, 739-1082.
4. Kaczmar, J.W., Pietrzak, K., WøosinÂski, W., (2000). The production and application of metal matrix composite materials, Journal of Materials Processing Technology, 106 58±67.
5. Koker, R., Altinkok, N., (2005). Modelling of The Prediction of Tensile and Density Properties in Particle Reinforced Metal Matrix Composites by Using Neural Networks. Materials and Design, p. 1-7.
6. Muratoğlu, M. and Aksoy, M., (2006). Abrasive wear of 2124Al–SiC composites in the temperature range 20–200 ˚C. Journal of Materials Processing Technology, 174, 272–276.
7. Velasco F., Costa C.E., and Torralba J.M., (2002). Mechanical properties and wear behaviour of PM aluminium composite reinforced with (Fe_3Al) Particles, Powder Metallurgy, 45, 3.
8. Walker, J.C., Rainforth, W.M., and Jones, H., (2005). Lubricated sliding wear behaviour of aluminium alloy composites, Wear, 259 577–589.
9. Taskin, M., Çalıgülü, U., and Gür, A.K., (2008). Modeling adhesive wear resistance of Al-Si-Mg-/SiCp PM compacts fabricated by hot pressing process, by means of ANN, The International Journal of Advanced Manufacturing Technology, (37), 715-721.