International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 02, February-2019

INVESTIGATION OF PHYSICAL AND MECHANICAL PROPERTIES OF HYBRID NICKEL POWDER AND SILICON CARBIDE REINFORCED ALUMINIUM ALLOY COMPOSITES

Vandana Yadav [1], Dr. P. Sudhakar Rao[2]

[1]*Department of Mechanical Engineering,*
National Institute of Technical Teachers Training and Research, Chandigarh, India 160019.

[2]*Department of Mechanical Engineering,*
National Institute of Technical Teachers Training and Research, Chandigarh, India 160019.

ABSTRACT: The purpose of this paper to investigate the Physical and mechanical properties of Al 6061-T6- SiC–nickel powder hybrid composite. The composites sample are successfully prepared by stir casting method with different hybrid ratios of nickel powder (0,0.5, 1.0 and 1.5 wt. %) and SiC (fixed 2 wt. %). Mechanical test such as Density, void content hardness, tensile, flexural and impact test are performed on prepared sample. The results indicated that addition of filler content decrease density and increase in hardness, tensile strength and impact strength of composite sample while the flexural strength reduced marginally. The composite sample with combination of 1wt% of nickel powder and 2 wt. % of silicon carbide gives highest tensile strength. It was observed that Silicon carbide and nickel metal powder combination as reinforcements lead to a new composite material with unique properties

Key Words: Stir casting; Nickel powder; void content; flexural strength; hardness; tensile strength

I. INTRODUCTION

Material's importance can be realized from the fact that many researches are being done to apply new materials for different applications. Engineering materials that are consisted from two or more constituent materials remain separate and different on a macroscopic level and form a single component known as Composite materials [1-2].
In hybrid composite two or more different kinds of reinforcement are used in a single matrix. The hybrid composites have better properties than composite materials containing only a single kind of reinforcement [3].
Many investigations have been done on hybrid composite with addition two or more kind of ceramic reinforcement. Investigations have showed that, use of two or more types of ceramic particles reinforcement into AMCs could enhance their physical and mechanical properties. But aluminum based composites becomes brittle by the addition of Ceramic particles reinforcements. [4-6].
Very few investigation have been done on combine effect of ceramic and metal powder on mechanical properties on hybrid composite. Kumar et al. [7] investigated physical, mechanical properties and wear behaviour of Al-7075 composites filled with nickel powder. Results showed that void content, impact strength, compressive strength and Vickers hardness of composites were increased with the increase in percentage nickel reinforcement, while flexural strength of the composites decreased with addition reinforcement.
A lot of investigations have been done on reinforcement of silicon carbide in MMCs. SiC particle is easily available, low density reinforcement. In recent year, AMMCs with SiC reinforcements used in aerospace, civil, military and manufacturing industries because of its high strength, modulus, fatigue resistance and wear resistance [8-11].The properties of composites generally influence by fabrication method use. Stir casting route is simple and cost effective method for preparation of composites. [12-13]
The aim of the investigation is to fabricate Hybrid Nickel Powder and Silicon Carbide Reinforced Aluminium Alloy (Al6061-T6) Composites by stir casting method at different hybrid ratio, thereafter physical and mechanical characterization of fabricated composites are done.

II. MATERIALS AND METHOD

A. Raw material

1) Matrix Material (Aluminium 6061-T6): In order to prepare the samples, commercial aluminium rod of Al 6061-T6 of length size 4ft and diameter of 16mm was purchased from Bharat Aerospace Metals, Mumbai. The chemical composition of Al6061-T6 is given below in Table 1.

TABLE 1: CHEMICAL COMPOSITION OF AL6061-T6 [14]

Elements	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Weight %	95.8-98.60	0.04-0.35	0.15-0.40	Max 0.70	0.8-1.20	Max 0.15	0.40 - 0.80	Max 0.15	Max 0.25

2) Reinforcement Materials: The desirable properties of composites depend on filler material used in fabrication. Selection of filler material is the minimum criterion in any composite material because all the optimum results are associated with selection and distribution of filler material. In present work silicon carbide and nickel powder is selected as filler materials.

III. FABRICATION METHOD USED FOR COMPOSITE MATERIALS

Fabrication method used for hybrid composite was stir casting method. In this method, reinforcing particles of nickel and silicon carbide were distributed into molten matrix of aluminium by mechanical stirring. The experimental arrangement consist of main furnace, muffle furnace, mechanical stirrer, graphite crucible, mould etc. Firstly, the required quantity of reinforcing particles (silicon carbide particles and nickel powder) and aluminium rods for each sample were pre heated into muffle furnace and main furnace at temperature 350^0 C for 3-4 h. The melting of the aluminium alloy Al6061-T6 is carried out in the graphite crucible inside the furnace 820°C. Then manual mixing of Al6061-T6 with reinforcing particle was done by a steel stick for approximately 15 minutes. Then molten mixture was casted in the mould. The dimension of the mould used is 145×90×10 mm. After casting process, specimens were prepared for density tensile, hardness, impact and flexural test specimen. The compositions of samples in wt% as shown in Table 2:-

TABLE 2: COMPOSITIONS OF SAMPLES IN WT%

S No.	**Sample**	**Al6061-T6**	**SiC**	**Ni**
1	N_0	98	2	0
2	N_1	97.5	2	0.5
3	N_2	97	2	1
4	N_3	96.5	2	1.5

IV. PHYSICAL AND MECHANICAL PROPERTIES

A. Density and void content

Theoretical density and void content of hybrid composites in terms of weight fraction was calculated by following formula given by Agarwal and Broutman [15] as shown in Eq. 1.

$$\rho_c = \frac{1}{\left(\frac{W_p}{\rho_p}\right)+(W_m/\rho_m)} \quad ....(1)$$

Where, ρ and w represents the density and weight fraction respectively. The suffix c, m and p stand for composite, metal matrix and reinforcement particles respectively

The void content of hybrid composites is obtained by Eq. 2 given by Agarwal and Broutman [15].

$$Void\ content = \frac{\rho ct-\rho ce}{\rho ct} \quad ....(2)$$

Where, suffix ct and ce represents theoretical and experimental values of density.

B. Tensile strength

The tensile strength test of the composite was performed according to ASTM E8 on universal testing machine at room temperature. Rectangle shape specimen with dimension equal to 90 mm x 15 mm x 4 m, and spam length of 50 mm is used to conduct the test.

C. Impact strength

The Charpy impact test was performed to find out the impact strength of composites. Impact test is conducted, as per ASTM 256 standard. The dimension of standard impact specimen used is 55 mm × 10 mm × 10 mm and a notch of 2 mm at the centre of the specimen.

D. Hardness

Vicker microhardness test was performed according to ASTM Standard E-9 to find micro hardness of the composite sample. To measure the micro hardness of composites, 10×10×10 mm^3 specimen was prepared from each sample. Mitutoyo micro hardness tester was used to measure the hardness of the fabricated hybrid composites.

E. Flexural Test

Flexural strength is carried out according to the ASTM standard E-290, using the universal testing machine (UTM). The standard specimen size is 10 mm × 10 mm of cross-sectional area and 50 mm in length and a span length of 40 mm. The flexural strength is given by:

$$FS = \frac{3PL}{bt^2}$$

Where, P = maximum applied load,
b = width of the specimen,
t = thickness of specimen,
L = span length of the sample.

V. RESULTS AND DISCUSSION

A. Density and void content of hybrid composite material

The theoretical density of silicon carbide and nickel powder filled Al6061-T6 alloy hybrid composites have been calculated by using rule-of-mixture via Equation (1), while the experimental density of alloy hybrid composites have been measured by simple water immersion technique at room temperature. After that void content is calculated as per Equation (2) the results are shown in Table 3. The results indicated that the increase in percentage of reinforcements increase density of hybrid composites and theoretical density is always relatively lower than the experimental density. This may be happened because theoretical densities are computed on idealistic condition that different from experimentally. The results also showed that the void content in the composite increase with increase in percentage of reinforcements.

TABLE 3: DENSITY AND VOID CONTENT OF HYBRID COMPOSITES

Composites sample	Theoretical Density (gm/cc)	Experimental Density (gm/cc)	Void fraction (%)
N_0	2.677	2.708	1.16665436
N_1	2.682	2.718	1.324503311
N_2	2.691	2.728	1.356304985
N_3	2.695	2.737	1.545318379

B. Hardness test analysis

The hardness test was carried out on vicker hardness tester. On each sample 3 impressions were made by diamond indenter and Average value was taken to calculate the hardness. The Table 4 summarized the results of hardness test obtained during experimentation.

TABLE 4: VICKER HARDNESS OF COMPOSITES

S. No.	Composites Sample	Vicker Hardness Value (HV)
1	N_0	115
2	N_1	121
3	N_2	140
4	N_3	165

Graph plotted between hardness and filler content is shown in the Figure1. The graph indicated that the hardness of the composite increases with increase in percentage fraction of reinforcements in Al6061-T6 alloy composites. The hardness of hybrid composites is higher than neat alloy because silicon carbide and nickel particles are hard dispersion and dispersion of hard particle reinforcement in a soft ductile matrix improve the hardness of composites [16]. The maximum value of hardness is found at 1.5 %wt nickel and 2%wt silicon carbide (165HV).

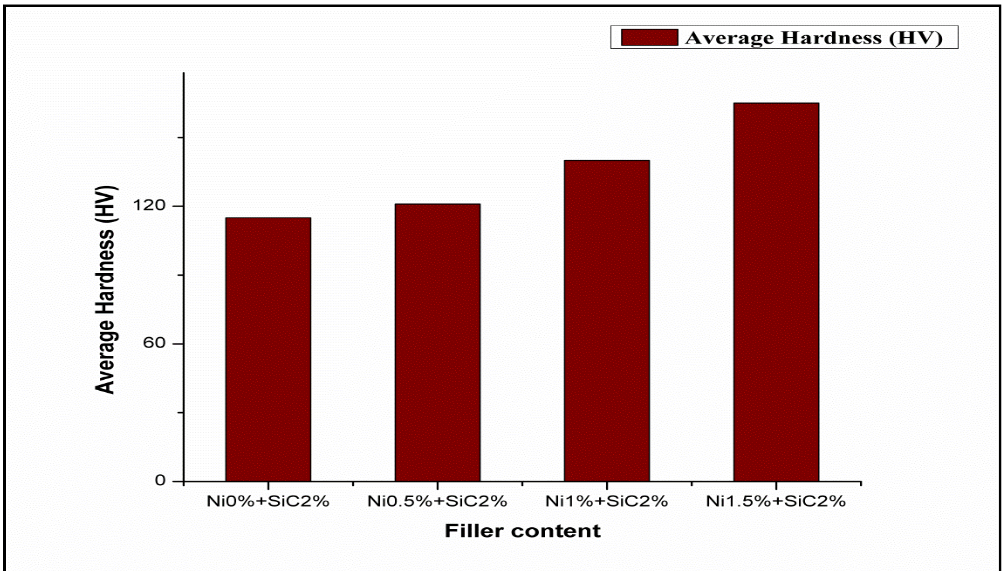

Figure 1: Vicker hardness of composites

C. Tensile test analysis

The tensile test is conducted under ambient condition to find out tensile strength (maximum load) of composite on UTM. The results of tension test of silicon carbide and nickel powder filled Al6061-T6 alloy composite are showed in Table 5. Figure 2 indicated the effect of filler content on tensile strength of composites. The results showed that tensile strength generally increase with increase the filler contents.

TABLE 5: TENSILE STRENGTH OF COMPOSITES

S. No.	Composites Sample	Tensile Strength (MPa)
1	N_0	131.31
2	N_1	133.90
3	N_2	152.80
4	N_3	133.47

For hybrid composite with fixed 2% wt of silicon carbide and nickel increased 0-1%wt the tensile strength increased 131.31-152.80 MPa respectively after that with addition of 1.5% nickel powder the tensile strength decreased to 133.47 MPa because bonding between the base material and reinforcement looses strength to withstand the tensile load. Similar trend of tensile strength was observed by Poovazhagan et al [8]. The reason was given that increased porosity content and agglomeration of the particles as the particle volume percentage increased. Agglomeration of particles cause micro clusters, and the loosely packed particles of the micro cluster decrease the tensile strength of material.

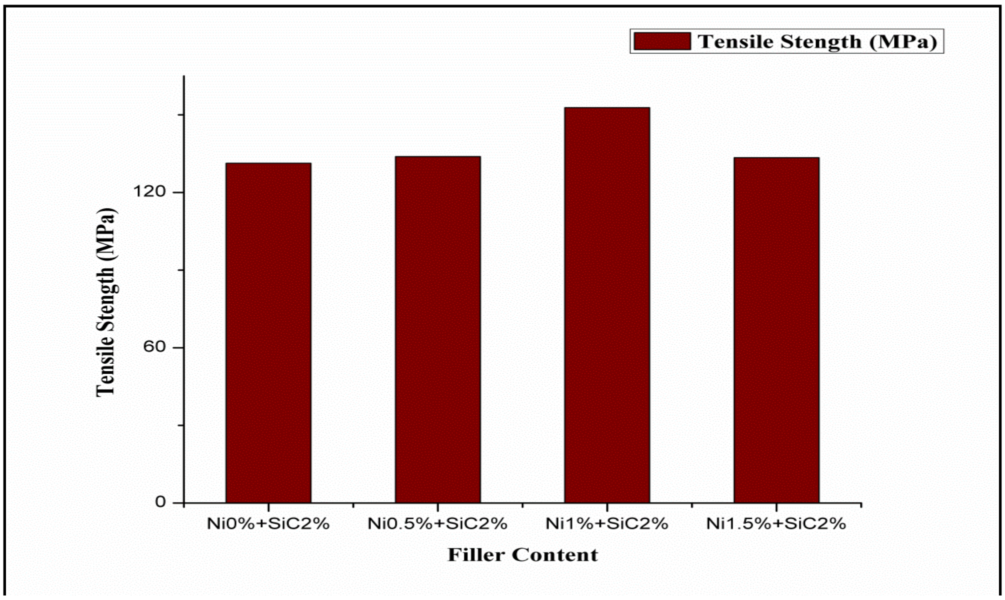

Figure2: Tensile strength of composites

D. Flexural strength analysis

The graph between flexural strength and percentage variation of reinforcements is shown in Figure 3 and Table 6. The increase in voids content in hybrid composite may cause poor flexural strength due to poor interfacial strength between ingredients [17-20].

TABLE 6: FLEXURAL STRENGTH OF COMPOSITES

S. No.	Composites Sample	Flexural Strength (MPa)
1	N_0	269.115
2	N_1	287.475
3	N_2	279.825
4	N_3	252

When the weight fraction of SiC is fixed to 2% and nickel powder is increase to 0-0.5% the flexural strength increased to 287.475 MPa. After that the flexural strength decreased. The lowest value of flexural strength is found at 1.5%wt nickel powder.

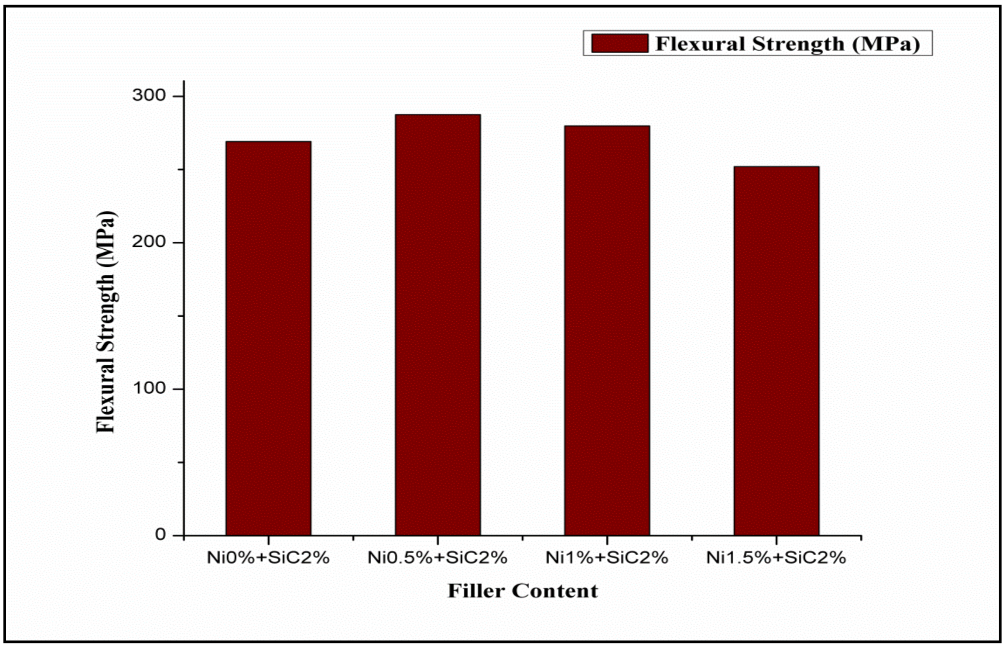

Figure 3: Flexural strength of composites

E. Impact strength analysis

In this test energy absorbed by the specimen before rupture is measured in joule. It reflects the capability of material to resist sudden and dynamic application of the load. The results of charpy impact test are shown in Figure 4 of fabricated hybrid composite. The impact energy increased with increase in wt.-% of reinforcements in composites as shown in Table 7.

TABLE 7: IMPACT STRENGTH OF COMPOSITES

S. No.	Composites sample	Impact strength (JOULE)
1	N_0	8
2	N_1	12
3	N_2	32
4	N_3	56

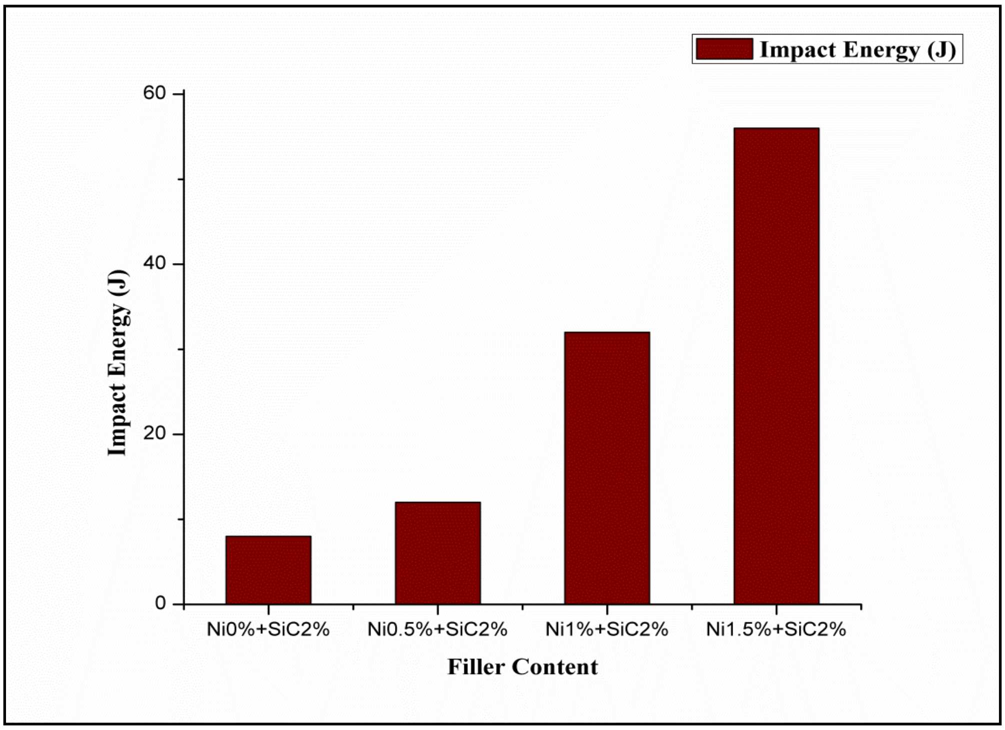

Figure 4: Impact strength of composites

VI. CONCLUSIONS

1) Al6061-T6 hybrid composite filled with nickel powder and silicon carbide was successfully fabricated by stir casting method.
2) The addition of filler content decreased the density of hybrid composites. The value of theoretical density and experimental density are near to each other. So the void content is very low which indicated fair casting of composites.
3) It was observed that Micro hardness of the composite material increases with adding wt% filler content in composites. With increase in filler content (fixed 2% wt of silicon Carbide and increase percentage of nickel powder (0-1.5%) wt) hardness increases from 115Hv to 165Hv.
4) Increase in weight percentage of nickel powder (0, 0.5, 1%) tensile strength increases 131.31 to 152.80 MPa after that at 1.5%wt of nickel powder, tensile strength decreases.
5) Impact strength increases slowly with addition of fillers upto 0.5 weight percent nickel powder and 2% weight of silicon carbide. After that impact strength sharply increases with increase in weight percentage of filler content
6) For increase weight percentage of nickel powder the flexural strength increase up to 0.5% after that continue decrease in flexural strength.

It is expected that this work leads to contribute in the development of light weight component with improved mechanical properties.

REFERENCES

[1] Wang DZ, Peng HX, Liu J, "Wear behaviour and micro structural changes of SiCp-Al composite under unlubricated sliding friction." Wear, vol. 184(2),1995, pp187–192.
[2] W. D. Callister, Jr., "Materials Science and Engineering", (2008), John Wiley & Sons, page 400-736.
[3] Karl Ulrich Kainer, "Basics of Metal Matrix Composites", (2006), WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.
[4] Clyne TW. and Withers PJ. , "An introduction to metal matrix composites", Cambridge: Cambridge University Press; 1993.
[5] R. Keshavamurthy, Sadananda Mageri, Ganesh Raj, B. Naveenkumar, Prashant M Kadakol and K. Vasu,' "Microstructure and Mechanical Properties of Al7075-TiB_2 in-situ composite", Research Journal of Material Sciences Vol. 1(10), November (2013),pp 6-10.
[6] Mohanavela, K. Rajanb, P.V. Senthilc, S. Aruld, "Mechanical behaviour of hybrid composite (AA6351+Al_2O_3+Gr) fabricated by stir casting method", Materials Today, Vol. 4, Issue 2, Part A, (2017), pp. 3093-3101.
[7] Ashiwani Kumar, Amar Patnaik, I. K. Bhat, "Investigation of nickel metal powder on tribological and mechanical properties of Al-7075 alloy composites for gear materials", Powder Metallurgy, vol.60(5), (2017), pp.1-13.
[8] Poovazhagan. L, Kalaichelvan. K, Rajadurai. A and Senthilvelan. V, "Characterization of Hybrid Silicon Carbide and Boron Carbide Nanoparticles-Reinforced Aluminum Alloy Composites", Procedia Engineering vol.64 (2013),pp. 681 – 689.

[9] P.B. Pawar and Abhay A. Utpat, "Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite for Spur Gear", Procedia Materials Science, vol. 6 (2014),pp. 1150 – 1156.
[10]Kenneth Kanayo Alanemea and Olusola Joseph Ajayi, "Microstructure and mechanical behavior of stir-cast Zn–27Al based composites reinforced with rice husk ash, silicon carbide, and graphite", Journal of King Saud University – Engineering Sciences,vol.29, (2017),pp.172–177.
[11]Essam A.M. Shalaby, Alexander Yu. Churyumov N, Alexey N. Solonin, A. Lotfy, "Preparation and characterization of hybrid A359/ (SiC and Si_3N_4) composites synthesized by stir /squeeze casting techniques", Materials Science & Engineering, vol.A674,(2016),pp.18–24.
[12]M.R. Ghomashchi, A. Vikhrov, "Squeeze casting: an overview" Journal of Materials Processing Technology,vol.101,(2000), pp. 1-9.
[13]A. LUO, "Metall. Mater. Trans.", vol. A 26A, (1995), pp. 2445.
[14]www.glemco.com/pdf/NEW_MARTERIAL_LIST/Alumina%206061-T6.pdf/(date of access15-10-2017).
[15]Agarwal BD, Broutman LJ. Analysis and performance of fiber composites. 2nd ed. New York: John Wiley and Sons; 1990.
[16]Reddy MS, Chetty SV, Reddappa HN. Influence of reinforcements and heat treatment on mechanical and wear properties of Al 7075 based hybrid composites. Proc Mater Sci. 2014;5:508–516.
[17]Abdullah Y, Daud AR, Shamsudin R, et al. Flexural strength and fracture studies of al-si/sicp composites. Int J Mech Mater Eng. 2009;4:109–114.
[18]Han, Q., Dunand, D C., 2000. Microstructure and mechanical properties of magnesium containing high volume fractions of yttrium dispersoids, Material Science and Engineering A 277, p. 297.
[19]Kouzeli, M., Mortensen, A., 2002. Size dependent strengthening in particle reinforced aluminium, Acta Materials 50, p. 39.
[20]Arsenault, R J., Shi, N., 1986. Dislocation generation due to differences between the coefficients of thermal expansion, Material Science and Engineering 81, p. 175.