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Wear and Microstructural Behavior of SiC-B_4C Reinforced Aluminium Metal matrix Composite via Powder Metallurgy Technique

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Abstract—*Aluminium composites has wide application in automobile such as design of four wheeler rim, aerospace, sports, Machines etc. the problem associated with aluminium alloy is their low wear resistance during machining therefore an attempt is made to improve the wear properties of pure aluminium by reinforcing it with hybrid ceramic such as SiC-B_4C. In this research pure Al and Al with hybrid reinforcement of SiC-B_4C are fabricated using powder metallurgy technique. 10 billets i.e. PureAl,Al-3wt%SiC7wt%B_4C, Al-5wt%SiC5wt%B_4C and Al-7wt%SiC3wt%B_4C are compacted with compaction loads of 3, 4 and 5 Ton and then Sintered near the melting point. Physical properties such as density, porosity, XRD and wear properties are calculated. On progressive addition of SiC-B_4C, a significant enhancement in physical and wear properties is obtained. The effect of Compaction load on wear the property is also illustrated in this research.*

1. INTRODUCTION

A Composite material is the combination of two or more materials with different chemical property in order to form a stronger material. Aluminium metal matrix composite (AMMC) is formed by spreading reinforcement in the metal matrix. Reinforcement is usually done to improve the mechanical properties of the metal matrix like hardness, strength, temperature withstands capacity, wear resistance, environmental effect, density, porosity, etc. In recent year stringent requirements of material quality in automotive and aerospace industries have necessitated the development of light weight aluminium alloys [1]. Md. Habibur Rahman al [2] fabricated silicon carbide aluminium metal matrix composite taking the (0, 5, 10 and 20% of SiC) and obtained that 20% of reinforced AMC showed the maximum tensile strength and hardness. Clustering and non-homogenous dispersion were also observed in the microstructure and wear resistance were also increasing with increase in SiC content in Al matrix. Yusof Abdullah al[3] fabricated and analyzed the mechanical properties by making two sample of AL/B_4C with (5, 10 wt% of B_4C) reinforcement. In this experiment Al and B_4C powder were mixed by ball milling, dried and sintered at 850^0C for 2 hours. In this work milling time of 8 and 16 hours were the controlling parameter. The hardness test was conducted in these two different milling times and came to the result that showed, increased in hardness of Al/B_4C composite on increasing the amount of boron carbide in the composites. The hardness of Al/10%B_4C and Al/5%B_4C was 81.72 and 78.68% respectively. The density was also calculated in both 8 and 16 hours and the result indicated that the density increases with increase in milling time but decreases with increase in amount of B_4C reinforcement in Al-composites. Baradeswaran.A al [4] investigated the mechanical and tribological properties of Aluminium alloy (6061)-Boron carbide. In his study specimen was fabricated through powder metallurgy by taking 5, 10,15 and 20% volume of reinforcement(B_4C). Methods of fabricating the specimen were same as discussed earlier. The composite samples produced were characterized by hardness and compression tests. The result of this test showed that on increasing the volume percentage or amount of B_4C, the harness of composite increases accordingly because of the increase in ceramics phase of metal alloy. Compressive strength of the composite also increases with increase in B_4C content. Wear resistance of composite increases with increase in amount of B_4C, the coefficient of friction decreased on increasing content of boron carbide with minimum of .3 at 10% vol and remain steady between.3 to .4

No attempt has been done on calculating wear properties of Al-SiC-B_4C. In this research wear mass loss rate is being calculated for the different position of aluminium composite and results shows an increase in wear resistance to some extent of addition.

2. PROCESSING:

2.a) Material:

Pure Aluminium with purity ≥ 99.09% was used as base metal supplied by the metal powder co.ltd, thirumanglam, Madurai-India. SiC with size of 220 mesh supplied by Otto and B_4C with size of 150 mesh supplied by Otto, were used as reinforcements.

2.b) Powder metallurgy

In Powder metallurgy First pure Al and SiC-B_4C were weighed as per the required amount and then it was ball milled for 45 min at 350 rpm in RETSCH PM-400 (Restch GmbH, Haan, Germany) with the ball to powder ratio of 8:1. After milling the collected composite powder was compacted at load of 3,4 and 5 Ton. It was sintered at an elevated temperature near melting temperature (400°C) in furnace in presence of argon gas continuous supply.

3. PROPERTIES CHARACTERIZATION:

3.1 Green and Sintered Density:

The density of billet before sintering or after compacting is known as known as green density. It was calculated by using the simple density formula:

Density= mass/volume

By taking mass in electronic mass balance and measuring the dimension through digital vernier caliper, gives total green density. Density of the pellet after sintering is known as sintered density, it was calculated by measuring the mass and volume of billet just after the sintering process.

3.2 Microstructural Characterization:

Grain size was calculated using the electron microscope and with the help of MATLAB, final grain size of the component is obtained but for some composition we unable to calculate the grain size. The X-ray powder diffraction analysis is basically a technique primarily used for phase identification of crystalline material and can provide the information on unit cell dimensions. In this experiment Bruker XRD Model/supplier:D8 was used for the whole analysis.

3.3 Wear Properties:

In order to calculated wear loss rate, wear machine was used as shown in figure 1. The different sliding distances (200, 400, 600 m) were primarily factor. In the machine of having 8 cm dia of disc, load was set using the block and for sliding distance to set, different sliding speed and time period was used so for calculation of the wear weight loss rate first weight of billet before wear machine run was calculated and then difference between the weight after and before machine operation gives wear mass loss rate. Effect of compaction load on the wear properties is also observed in the same.

4. RESULT AND DISCUSSION:

4.1 Green Density:

Table 1. Shows green density results obtained via powder metallurgy and it can be observed that on progressive addition of SiC-B_4C, green density is increasing found to be maximum for Al-3%SiC-7%B_4C. The increase in density can be attributed to density difference between pure Al (2.70 gm/cm^3), SiC(3.16 gm/cm^3) and B_4C (2.52 gm/cm^3)[6].

S. N	Composition	Weight of powder (gm)	Weight of billets (gm)	Weig ht of billets (gm)	Green density (gm/cm^3)
1	Pure Al	2.00	1.99	1.99	2.70
2	Al-3%SiC-7%B_4C	2.01	1.95	1.95	2.72
3	Al-7%SiC-3% B_4C	2.03	2.01	2.01	2.70
4	Al-5%SiC-5%B_4C	2	1.99	1.99	2.71

4.2 Sintered Density:

Table 2. Shows sintered density result obtained via powder metallurgy technique. It can be observed that on progressive addition of SiC-B_4C density is increasing and found to be maximum for Al-3%SiC-7%B_4C. the increase in sintered density can be attributed to decrease in porosity level during the recrystallization of Al while sintering near melting temperature[7].

S.N	Composition	Weight of Sintered billet(gm)	Sintered Density gm/cm 3
1	Pure Al	1.99	2.50
2	90%Al-3%SiC-7%B4C	1.95	2.63
3	90%Al-7%SiC-3% B4C	2.0	2.52
4	90%Al-5%SiC-5%B4C	1.98	2.61

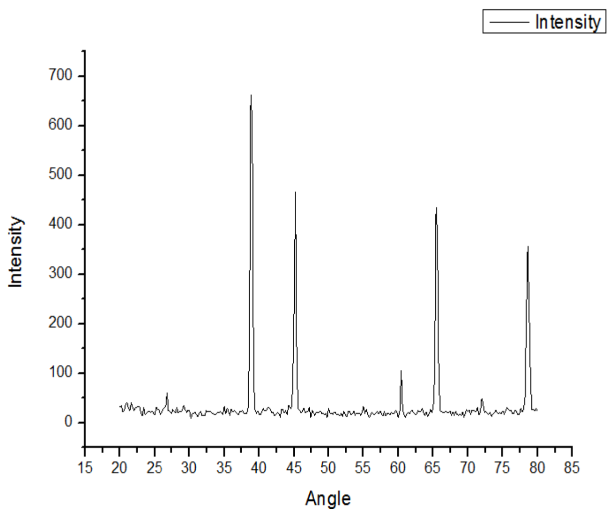
4.3 Microstructural Characterization:

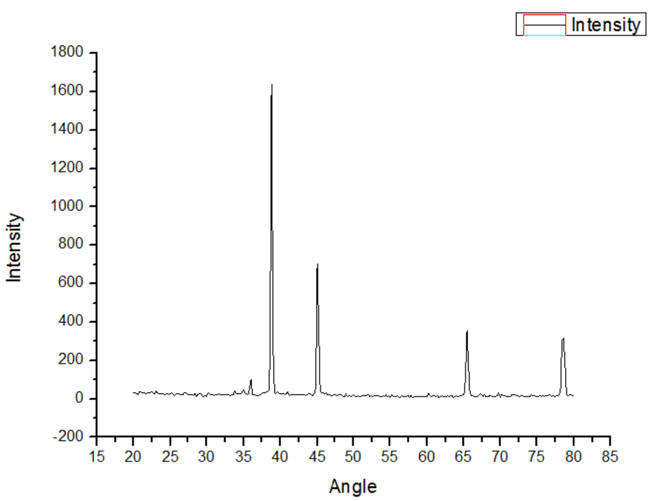
The table below shows the grain size study. All the composition were polished with (5, 1, .3 , .05) micron Alumina solution and diamond paste and then etched by keller reagent. The grains were only observed for Al7%SiC3%B_4C at 4 Ton and for other composition grain couldn't be observe.

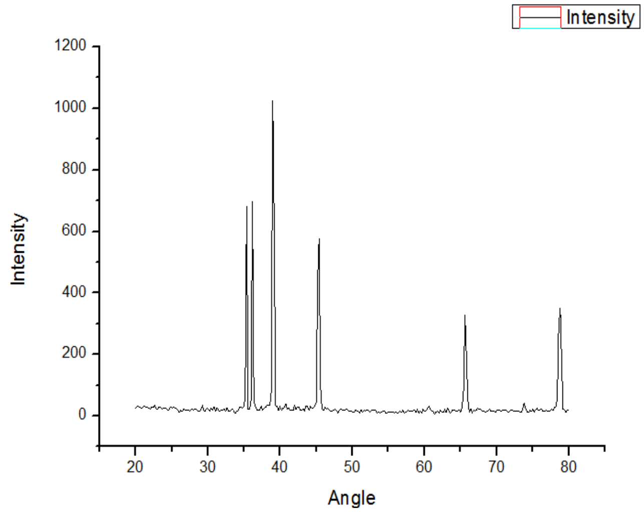
Through the optical microscope, the grain was observed. Through the MATLAB GRAINDIA, grain size was calculated by selecting the visible grains in large quantities.

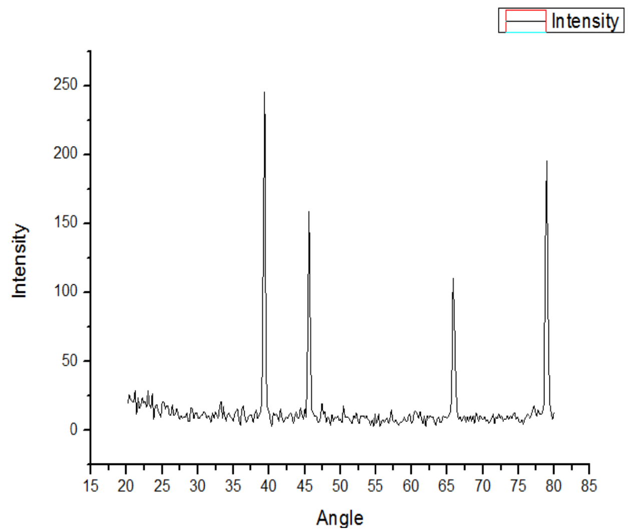
Composition	Grain Diameter (μm)	Roundness	Aspect Ratio
Al7%SiC3%B4C at 4 Ton	9.557 ± 1.691	0.9081 ± 0.039	6± 0.320

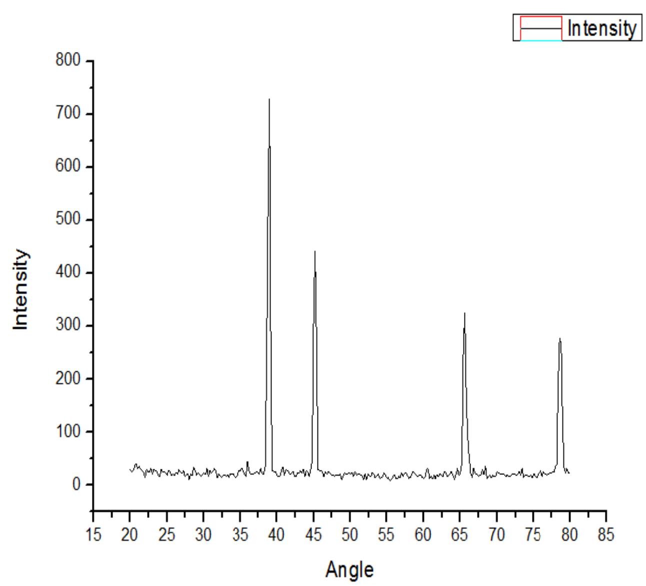
Figure shows longitudinal XRD results for different Composition

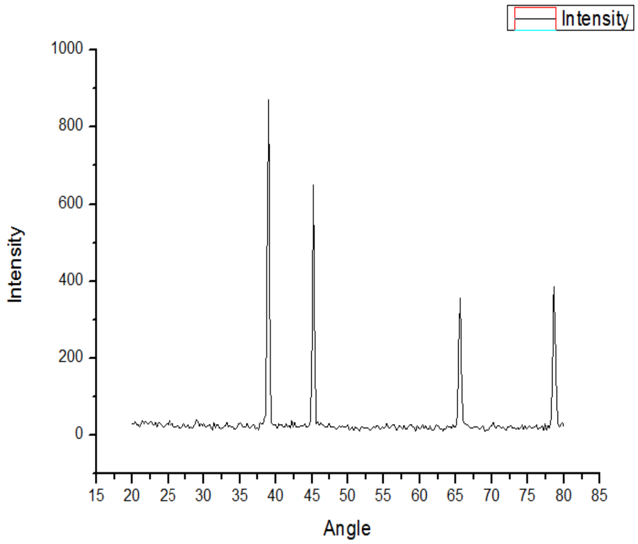


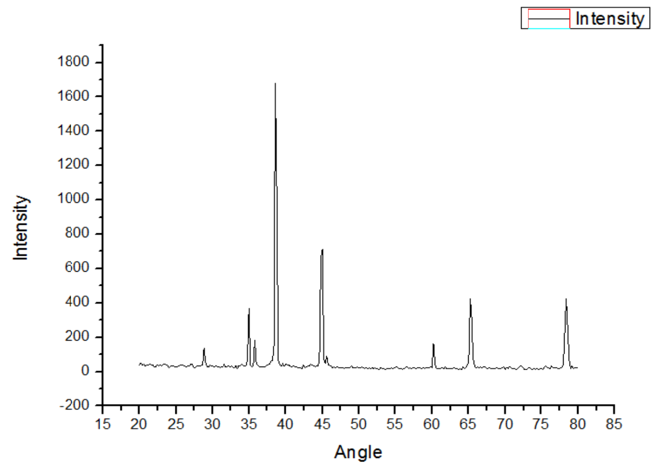


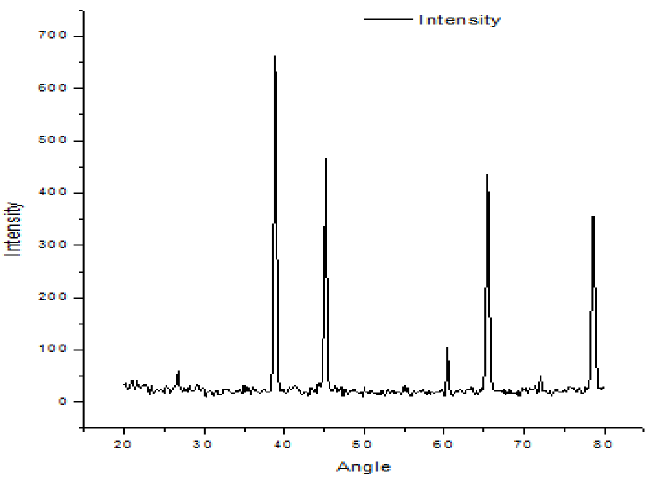












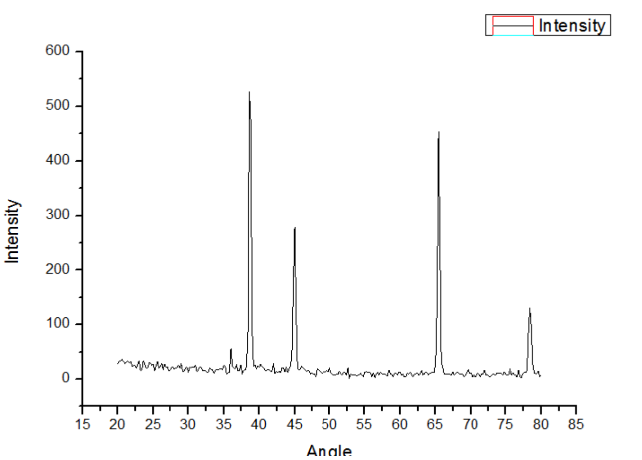


Figure 2, 3, 4, 5, 6,7,8, 9 &10 represents XRD results for 3Ton3%SiC7%B_4C,3Ton5%SiC5%B_4C,3Ton7%SiC3%B_4C,4 Ton 3%SiC7%B_4C, 4 Ton 5%SiC5%B_4C, 4 Ton 7%SiC3%B_4C,5Ton3%SiC7%B_4C,5Ton 5% SiC5%B_4C, 5 Ton 7% SiC3%B_4C respectively.

As peak of intensity can be observed for each composition obtained at different compaction load and peak in each graph represent base metal Aluminium and in some composition peaks cannot be obtained for SiC-B_4C, this may be because of lower amount of reinforcement mixing [8].

4.4 Wear Properties:

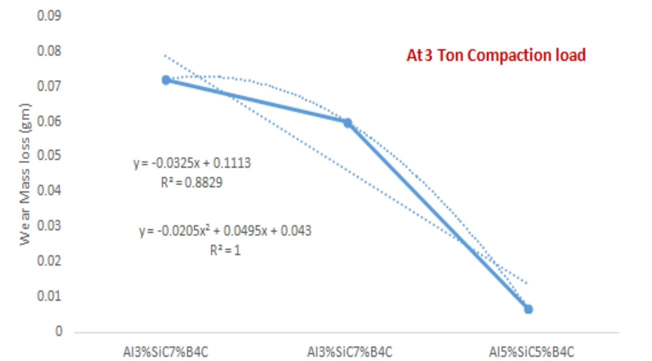
Table 3,4,5 shows wear weight loss data

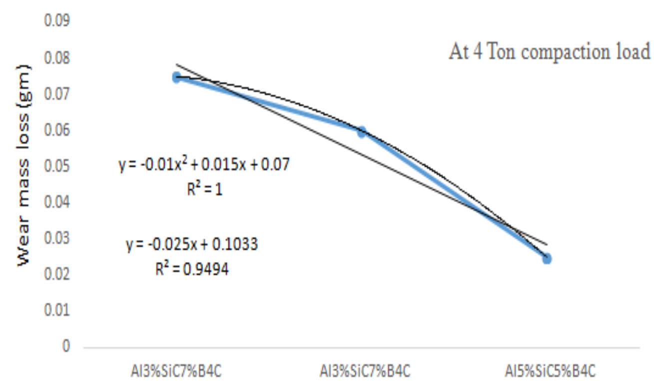
S.N	Composition	Load (Ton)	Weight before Wear(gm)	Weight after wear(gm)
1	Al-5%SiC5%B4C	3	1.977	1.970
2	Al-7%SiC3%B4C	3	1.99	1.93
3	Al-3%SiC 7%B4C	3	1.94	1.868

S.N	Composition	Load (Ton)	Weight before Wear(gm)	Weight after wear(gm)
1	Al-5%SiC5%B4C	4	1.975	1.950
2	Al-7%SiC3%B4C	4	1.985	1.910
3	Al-3%SiC 7%B4C	4	1.95	1.89

S.No	Composition	Load (Ton)	Weight before wear	Weight after wear
1	Al-.5%SiC.5%B4C	5	1.98	1.95
2	Al-.7%SiC.3%B4C	5	2.00	1.89
3	Al-.3%SiC .7%B4C	5	1.95	1.922

Mass before the machine run and after machining was calculated and tabulated above. Now the variation of wear mass loss rate for different composition for fixed compaction load is shown in figure 10,11,12.





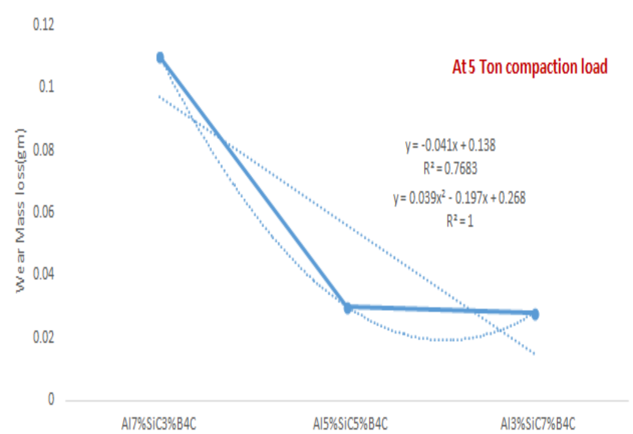


Figure 11 represent variation of wear mass loss rate at 3 Ton compaction load and it can be observed that on increasing the percentage of Boron carbide wear properties improves but maximum improvement in wear resistance is found to be in Al5%SiC5%B_4C. Figure 12 represent the wear behavior at 4 Ton compaction load and it can be observed that on addition of SiC-B_4C, wear resistance is increasing (wear loss is decreasing) and found to be minimal for Al5%SiC5%B_4C. Figure 13 shows wear loss at 5 Ton Compaction load and it can be observed that wear loss is decreasing and found to be minimal for Al5%SiC5%B_4C also wear loss of Al3%SiC7%B_4C is approximately same as that of Al5%SiC5%B_4C. Improvement in wear property while addition of these ceramic can be attributed to a) decrease in void found in metal matrix on addition of SiC-B_4C [9] b) good interfacial bonding and compaction [9]. It can also be observed that equal amount addition of SiC-B_4C gives maximum improvement in wear properties.

To determine the more accurate relation trend line had been shown between the wear loss and % of reinforcement which shows that curve between them is polynomial (R^2=1).

Variation of Wear with Compaction Load:

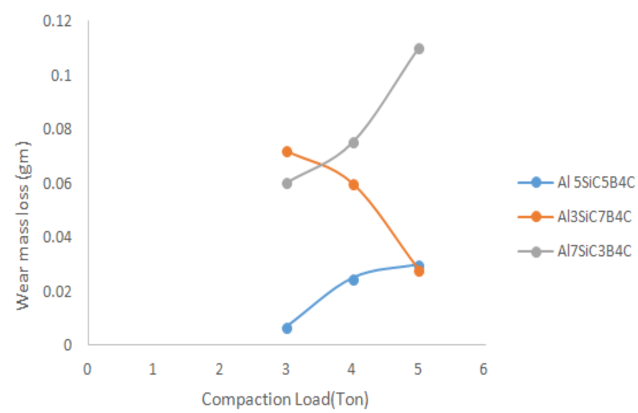


Figure 13 shows variation of wear loss of Al-3%SiC7%B_4C, Al-5%SiC5%B_4C and Al-7%SiC3%B_4C composite. From the graph it can be referred that for Al-5%SiC5%B_4C and Al-7%SiC3%B_4C wear loss is increasing on increasing the compaction load (3,4 & 5Ton) but for Al-3%SiC7%B_4C wear loss is decreasing on increasing the compaction load this may be due to inappropriate compaction of this composite.

5. CONCLUSION

From the above experiment following conclusion can be drawn:

1) On addition of SiC-B_4C (hybrid reinforcement) green density is increasing.
2) Sintered density of billet is increasing on addition of SiC-B_4C
3) XRD results shows the peaks of intensity representing the presence of Al with higher peak and because of low amount addition of reinforcement clear peak couldn't be found for composite.
4) Wear behaviour have been analysed for Al-3%SiC7%B_4C, Al-5%SiC5%B_4C and Al-7%SiC3%B_4C and from the plot between wear mass loss, improved wear properties are obtained on addition of the reinforcement.

5) Effect of compaction load on wear mass loss is being observed and found to be increasing with increase in compaction load, but for Al-3%SiC7%B_4C composite an unusual behaviour can be observed just because of inappropriate compaction.

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