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# Effect of Tungsten Chromium Nickel (W-Cr-Ni) on the Abrasive Wear Behaviour of Al6061 Hybrid Composite

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## Abstract

*Strengthening of metals, towards approaching, inexorable climate, is a significant perspective in surface engineering. The Family of aluminium and its alloys, are more in demand. The uniqueness of the metal, lies, in its ability of being strengthier, simultaneously being lesser in weight, these parameters make it more suitable, in areas of Construction, Mining and Infrastructre associated equipments, wherein in, the objective of reducing, the static mass acting on the structure needed to be reduced. In automobiles, it is heat transfer, followed by less weight, which is the objective, get satisfied by these metals. In our present, endeavor, we have tried, to improve its defensive forefront, towards aggressive loss of surface in working, where in metal is set to abrade, in contact with a hard surface. The crucial components, in the extraction machinery equipment, undergo substantial surface loss in their working, the metals need to be strengthened with hard particles, which increases their defense against hard earth surface, wherein these machinery components rub towards each other. These fortified metals extend the service life of crucial elements. we are considering Al6061 as a Substrate, and to make its defense stronger, we are fortifying, the base alloy, with nickel, and chromium increments, added in tungsten environment. Our Hybrid alloy is realized, by heating the substrate, to its liquidous state, further, it is continuously stirred, to introduce reinforcements, in an incremental proportion starting from (Wt %) 2.5%, 5% and 7.5% respectively. The wear studies are conducted in three-body abrasion setup- ASTM G65 standard. The tests are conducted for two different loads and variable abrading distance varying from 700 to 2100m.The results are compared with as-cast Al6061 and reinforced composite. It has been observed that there is considerable reduction in volume loss visa-v- vis wear rate.*

**Keywords:** *Al6061, Metal Matrix Composites, Stir Casting, Three Body Abrasion, Wear Studies*

## 1.0 Introduction

In our urge towards finding a metal, which is not heavy, have good strength, and exhibit good defense, when exposed to, hard abrading surface, aluminium alloys, are the preferred solution. It has received a, wider acceptance, from varied areas of application, infrastructure to aircrafts.

Presence of aluminium in our daily life, is very predominant. In relation to ferrous metals, the loss of metal surface due to oxidation is lesser in non-ferrous. Ferrous, will undergo, surface loss, very fast. Aluminium, when subjected to cutting, forms a strong layer of its oxide, which in turn, will isolate, the cut surface, from reacting with surrounding environment,

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this activity, indirectly increases its, usable time period[1,2].

Loss of metal surface, can be identified, as loss due to, rubbing against harder metal, further the action may cause protrusions on the surface. There can be, an instance, where in, metal has sticky surface, attracting foreign particles, sticking and travelling along, causing pits on the alloy. The metal may also, loose its area, due to repeated loading, which can be intermittent. There are estimates, which read, an amount of 63% of loss of metal due to these activities[3]. In practice, Progressive loss of metal surface, is understood, based on two scenarios, firstly Metal rubbing another metal or a harder surface and, Second, metal getting abraded in its motion, rubbing another surface, via media, having loose particles, on intermediate area, which are strong enough to cause a fracture on one of the metal or surface, which are relatively, not harder. The motion can be sliding, follow through or circular. Most of the studies conducted, are Metal-to-Metal and Metal to Metal via Intermediate substance-abrading type. In all these, surface loss, due to abrasion are studied. Studies have found that, the loss of surface, is very minimal. Interestingly, the metals, subjected to study, having higher credential value, in terms of properties, are loosing out to the opposing medium. Study of progressive loss of metal is more relevant in equipment's working in, agricultural equipments and in mining and earth moving support systems[3]

Mining industry, has always tried, to reduce the maintenance cost, as the instruments which are in working, are subjected to surface loss, due to continuous interaction, with the hard earth surface, comprising stone and compacted soil. The base metals are needed to be fortified with hard particles to increase their resistance to aggressive environments. The loss of metal, is of significant magnitude in extraction equipments. In fact, the component loss, due to the abrading, environment, amounts to nearly half of, stipulated expenditure of maintenance. In further terms, loss of machinery functioning, due to surface loss in the hard, abrasion environment amounts upto, four percent, of a nation's gross domestic produce of an industry dependent country[4].

S. Mahdav[5] *et al.*, Have identified that, alloys of Aluminium, fortified with hard particles, are very much in demand, across varied domains, as they have demonstrated better strength, as compared to other alternates, which are heavier. They are more, predominant in automobile and infrastructure sectors.

Scale of their volume, physical geometry, and dimensions of the, strengthening agents, base distribution, of them in the substrate metal accounted in maximum portion, and the method of realizing them, as alloy, greatly define the physical strength, again identified parameters, are tuned to meet the sectoral demands.

## 2.0 Experimental Procedure

The specimen is prepared by melting Al6061(Table 1) in Stir casting setup, followed by the introduction of Amalgamated Tungsten integrated with Nickel and chromium. After useful degassing, the melt is poured into the moulds. The next step is the solidification of the melt containing suspended particles of tungsten, in Aluminium, in order to improvise the, defensive support, towards, aggressive counterparts, in particular defending, wearing out of metal layer, in action. It is a strong Non-ferrous metal further, it has highest melting range.

In its purest form, Tungsten is a hard-to-machine metal. In addition, it is integrated with metals, like, nickel, which will bring in high strength and corrosion resistance. Addition of copper will bring in increased conductivity to heat. Amalgamation of all the listed metals will increase the alloy strength, bring in extended resistance to elevated temperature obtain the desired distribution of the dispersed phase in the cast matrix Further the cast matrix is subjected to machining with the methods involving milling and to have precise size of the specimen we have undertaken wire-cut EDM (Figure 1)

### 2.1 Dry Sand Arasion Testing-ASTM G65

The test rig has a rotating wheel having a lining of Rubber, with a slot for testing specimen with control size and having specified composition. The Dry silica which is a working medium as abrasive, is fed over the testing sample, which will touch the moving wheel, having specified hardness. The Sample will have backing load from behind, in-turn it will be made to touch the moving wheel, through via media, sand made to drop, through gravity fall, from a hopper, which will lead to aggressive environment for testing abrasive resistance (Figure 2). The sand used in the test is of 200-300-micron size, the sand flow rate is in the range of 300g/min to 400g/min [6].

The specimen is subjected to undergo wear by travelling the abrading distance in the order of 718, 1436, and 2154m respectively[7]. The load applied is varied in order of 23.54N and 47N.

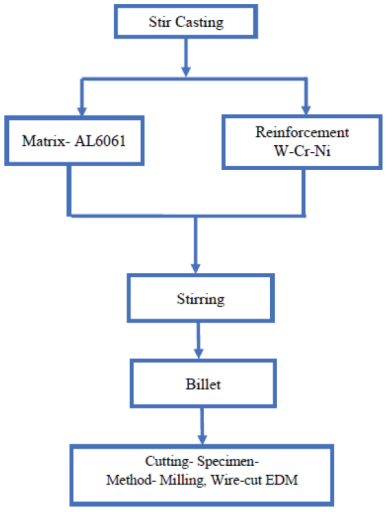



**Figure 1.** Specimen preparation route.

**Table 1.** Chemical composition of Al6061

| | Max | Min |
|---|---|---|
| Magnesium (%) | 0.8 | 1.2 |
| Silicon (%) | 0.4 | 0.8 |
| Iron (%) | 0.7 | |
| Copper (%) | 0.15 | 0.4 |
| Manganese (%) | 0.15 | |
| Chromium (%) | 0.04 | 0.35 |
| Zinc (%) | 0.25 | |
| Titanium (%) | 0.15 | |
| Aluminium (%) | Remaining | |

The abrading distance followed and the load applied by the lever arm are varied as mentioned above, further volume loss for each test is arrived by measuring comparative loss of weight due to wear. It is necessary to convert the mass loss to volume loss in, cubic millimetres, due to the vide differences in the density of materials.

## 3.0 Results and Discussions

From our experiments conducted, we have got the results tabulated in Table 2 corresponding to the load applied of 25.4N (Figure 3).

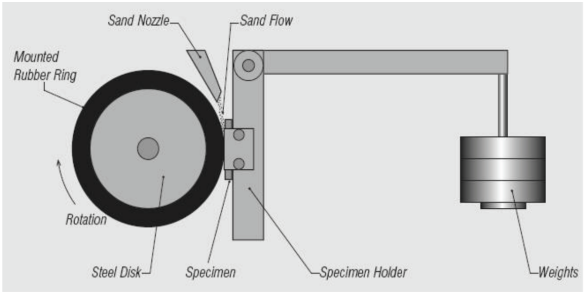



**Figure 2.** ASTM-G65-particle abrasion-setup.

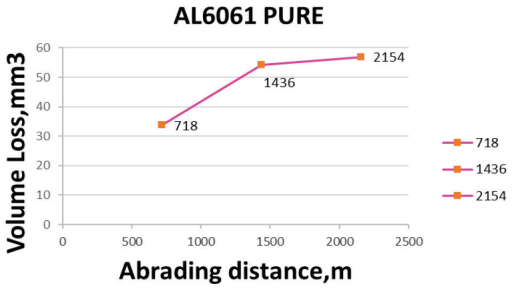



**Figure 3.** Volume loss for Al6061-Pure.

**Table 2.** Loss of material volume and rate of material loss for Al6061-Pure -Load-25.4N

| Sl no | Specimen No | Alloy | Distance Travelled in m | Loss of Material Volume ($mm^3$) | Rate of Material loss ($m^3$/N-m) |
|---|---|---|---|---|---|
| 1. | S1 | Al6061-0% Load -23.54N | 718 | 33.76376757 | 1.99765E-12 |
| 2. | S2 | | 1436 | 54.03124213 | 1.60629E-12 |
| 3. | S3 | | 2154 | 58.94431847 | 1.16823E-12 |

**Table 3.** For Al6061 with 2.5% - W-Cr-Ni at 23.54N load

| Sl no | Specimen No | Alloy | Distance Travelled | Loss of Material | Rate of Material loss |
|---|---|---|---|---|---|
| 1. | S4 | Al6061- W-Cr-Ni-2.5% Load-23.54N | 718 | 17.39732918 | 1.02932E-12 |
| 2. | S5 | | 1436 | 39.83371126 | 1.17839E-12 |
| 3. | S6 | | 2154 | 56.66414701 | 1.11752E-12 |

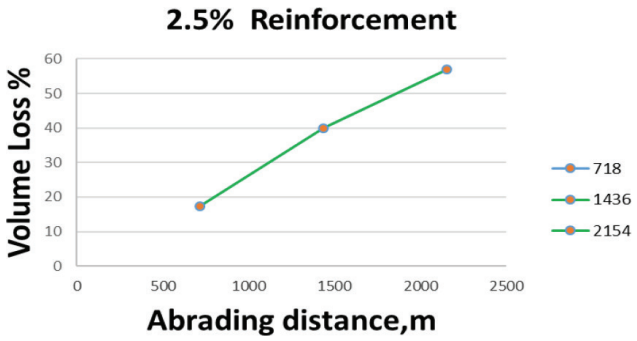



**Figure 4.** Volume loss for Al6061-2.5%, W-Cr-Ni (Wt%).

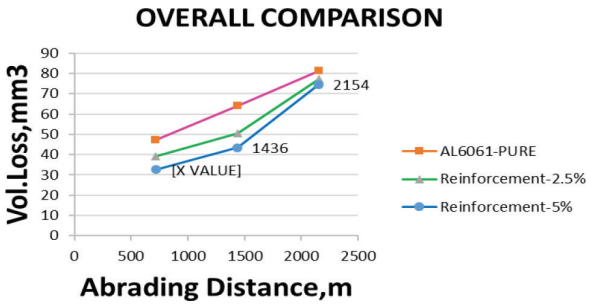



**Figure 7.** Comparative wear rate, Pure, 2.5%,5%- W-Cr-Ni at 47N Load.

**Table 4.** Loss of material volume and rate of material loss, Al6061 Hybrid alloy Al6061-5%, W- Cr-Ni (Wt%)

| Sl. no | Specimen No | Alloy | Distance Travelled in m | Loss of Material Volume ($mm^3$) | Rate of Material loss ($m^3$/N-m) |
|---|---|---|---|---|---|
| 1. | S7 | Al6061- W-Cr-Ni-5.0% Load-23.54N | 718 | 16.21115687 | 9.59142E-13 |
| 2. | S8 | | 1436 | 32.13528017 | 9.50651E-13 |
| 3. | S9 | | 2154 | 38.07562711 | 7.50922E-13 |

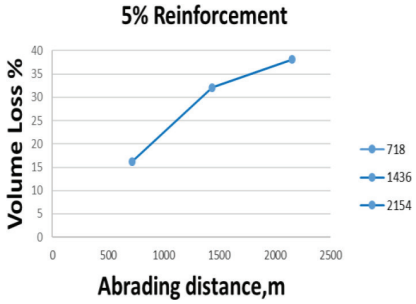



**Figure 5.** Loss of material volume, Al6061-5%, W-Cr-Ni (Wt%), at 23.54N.

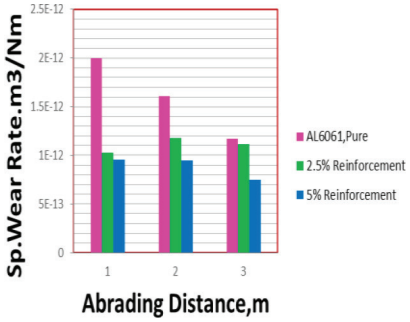



**Figure 8.** Comparative and rate of material loss for Pure, 2.5%,5%- W-Cr-Ni at 23.54N Load.

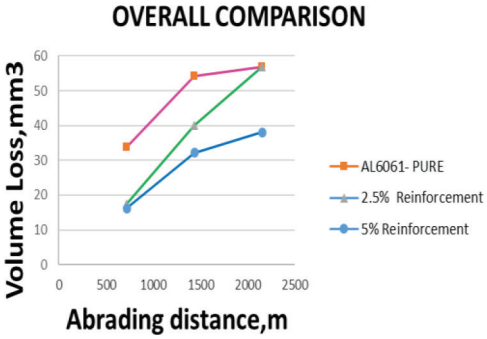



**Figure 6.** Comparative wear rate.

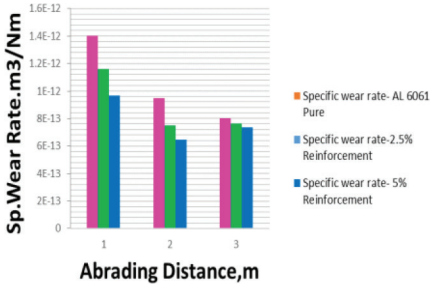



**Figure 9.** Comparative and rate of material loss for Pure, 2.5%,5%- W-Cr-Ni at 47N Load.

As we see further, that the introduction of reinforcement 2.5wt%-WC-Cr-Ni, the wear rate is significantly reducing (Figure 4), for a travel of 718m it is 17.39$mm^3$ and for travel of 1436m it is 39.83$mm^3$, for a travel of 2154 m it is 56.66$mm^3$.

In all our studies, the highest abrading distance we studied was 2154 m (Load- 23.54N), in this condition, the volume loss is being highest for pure Al6061, it is 58.94$mm^3$, consecutively it is lesser for 2.5wt%, i.e 56.6

$mm^3$, further it is lesser for 5wt%, i.e 38.07 $mm^3$ (Figures 5,6). If we observe here for 5Wt%, it is reading that amount wear is almost equal to that of in pure Al6061 for 718m where as the latter has covered 2154m of travel. From the above we can draw an inference that the reinforcement has increased wear resistance[8] of the material up to three times as compared to the base matrix.

In continuation the above study is exercised again for increased load of 47N (Figure 7), keeping all the trails same as for 23.54 N. Here the results show improved wear resistance as compared to reinforced alloy. The important parameter observed is the load applied, as we increase the load, the wear rate also increases and for the reinforcements compared to base matrix, there is an improvement in wear resistance. For 5wt%, for travel of 2154m we observe a significant improvement with respect to pure Al6061.

## 4.0 Conclusion

As we find from the results with respect to specific wear, it is observed that, wear rate is reducing considerably as we increase the reinforcement, from the Figure 8 we find that for pure Al6061, it is 1.99765x $10^{-12}$ $m^3$/Nm being highest for abrading distance travel of 718m, and comparatively it is reducing as we increase the reinforcement, and the wear rate is lowest for 5%(wt%) at 7.50922 x $10^{-13}$ for abrading distance of 2154m. In continuation for a load of 47N, the results are in similar order for pure Al6061 it is 1.40006 x $10^{-12}$ and for abrading distance travel of 718m (Figure 9), for 2.5%(wt%) it is 6.44215 x $10^{-13}$ being the lowest wear rate[9]. Infrastructure and excavation activities are the major areas, where, we see, severe surface loss of crucial machinery components, in all the above instances, machineries undergo aggressive rubbing with soil and stones, in the extraction of minerals, from the nature earth. The studies conducted in the current experimentation, exhaustively will simulate the circumstance, of wear loss, in components

## 5.0 References


1. Singh J. Fabrication characteristics and tribological behaviour of Al/SiC/Gr hybrid aluminium matrix composites: A review. Friction. https://doi.org/10.1007/s40544-016-0116-8
2. Sheasby PG, Pinner R. The surface treatment and finishing of aluminium and its alloys. 6th ed. ASM International; 2001.
3. Patnaik A, Satapathy A, Biswas S. Investigations on three-body abrasive wear and mechanical properties of particulate-filled glass epoxy composites. Malaysian Polymer Journal. 2010; 5(2):37-48.
4. Svanberg A, Larsson S, Mäki R, Jönsen P. Full-scale simulation and validation of wear for a mining rope shovel bucket. Minerals. 2021. https://doi.org/10.3390/min11060623
5. Mahdavi S, Akhlaghi F. Effect of the SiC particle size on the dry sliding wear behaviour of SiC and SiC-Gr-reinforced Al6061 composites. Journal of Materials Science. 2011; 46:7883-7894. https://doi.org/10.1007/s10853-011-5776-1
6. Misra A, Finnie I. An experimental study of three-body abrasive wear. Wear. 1983; 85:57-68. https://doi.org/10.1016/0043-1648(83)90335-6
7. Instruction Manual, Sand Abrasion Tester. Magnum.
8. Andrews MG. Tungsten: The Story of an Indispensable Metal. Washington, D.C.: The Tungsten Institute.
9. Kumar GBV, Rao CSP, Selvaraj N, Bhagyashekar MS. Studies on Al6061-SiC and Al7075-$Al_2O_3$ metal matrix composites. Journal of Minerals and Materials Characterization and Engineering. 2010; 9(1):43-55.