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Friction Stir Surfacing of Copper

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Abstract: ***The main objectives of the present investigations includes optimization of Friction Stir surfacing process parameters which include selection of appropriate rotational speed, traverse speed, axial force and evaluation of wear properties between parent material and deformed material. The experiment includes the study of surface wear features of severely deformed surface formed by friction stir mechanism. In the present experiment there is no addition of extra coating of material but instead the surface is deformed under huge compressive load using friction stir welding equipment. The process incorporates a hot forging action, which refines the microstructure of the surface material significantly, thus improving its basic surface properties. Friction stir surfacing can be considered as an alternative work for fusion based overlay coatings. The process applications are for corrosion and wear resistant coatings and for reclamation of worn out components.***

Keywords: Microstructure, Surfacing, SEM

1. Introduction

Friction stir surfacing is an advanced manufacturing process, which has been recently and successfully developed and commercialized. Friction Surfacing is a technique obtained from friction welding whereby a coating material, in rod form (termed the Mechtrode) is rotated under pressure, generating a plasticized layer in the rod at the interface with the work piece .By moving a substrate across the face of the rotating rod a plasticized layer between 0.2-2.5mm thick is deposited (depending on Mechtrode diameter and coating material). The resulting material is created to provide the characteristics demanded by any given application. Friction Surfacing has advantages over other competing processes. It introduces machine tool technology to surface engineering, making the process reliable and repeatable. It is also a solid phase process that metallurgical bonds the coating to the substrate without the problems of porosity, slag inclusions or dilution experienced with traditional welding processes. The process is used for corrosion and wear resistant coatings and for reclamation of worn engineering components. The Friction surfacing process is a derivative of friction welding process and retains all the advantages of the welding process like solid phase, forged microstructures and excellent metallurgical bond. Friction surfacing can deposit a wide variety of high specification materials, with an ideal metallurgical bond, onto a range of metal substrates. The process incorporates a hot forging action, which refines the microstructure of the deposition material.

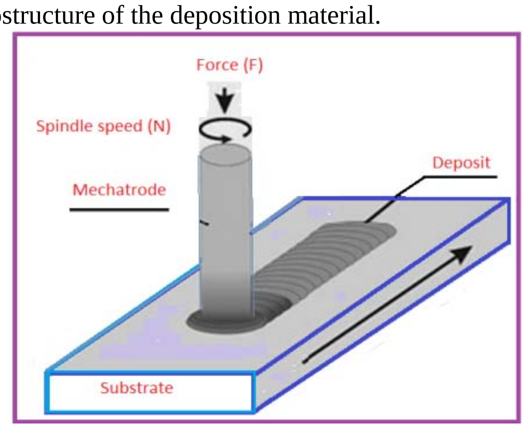


Figure 1: Friction Stir Surfacing with Mechatrode

1.1 Benefits of Friction Stir Surfacing

1. Strong bonding with no inclusions, porosity or oxidation
2. Surface properties improved like hardness and wear.
3. Improved microstructures.
4. No melting of materials
5. Negligible dilution
6. Small localized HAZ (heat affected zone)
7. No cracking in the HAZ
8. Automatic & highly repeatable process

1.2 Properties which make copper the standard material for engineering:

- **Thermal Conductivity**: The thermal conductivity of copper, twice that of aluminum and thirty times that of stainless steel. This means that copper is used for components where rapid heat transfer is essential.
- **Corrosion resistance**: Copper is non-reactive and does not rust or become brittle in sunlight.
- **High Ductility** - tubes are easily bent even when hard.
- **Toughness** - does not become brittle at sub zero temperatures.
- **Heat resistance** - withstands fire well, melting point is 1083^{o}C.
- **Antimicrobial**- copper is a naturally hygienic metal which slows down the growth of harmful germs.
- **Recyclability**- copper is 100% recyclable without loss of properties. The price of scrap copper is high.

CHEMICAL COMPOSTION OF COPPER

EQUIPMENT USED-
Optical Emission Spectrometer (BAIRD-DV6)

CONTENT	PERCENTAGE %
Cu	99.96
Zn	0.018
Ni	<0.005
Sn	<0.015
Pb	<0.002
P	0.015

Figure 2: Friction Stir Surfacing on Copper

2. Experimental Setup

Figure 3: Friction Stir Surfacing Equipment

Figure 4: HSS flat tool

In the present study Copper plate 6mm thickness; size 150x75 mm^2 was subjected to Friction Stir Surfacing using Friction Stir Welding Equipment. The High Speed Steel (HSS) flat tool 16 mm diameter and 100 mm length with 10% Cobalt was used for experimentation with following FSW machine parameters set (Table1). Figure 4 shows the surface before and after surfacing.

Table 1: Machine parameters applied thrust load and speed during friction stir surfacing

Trial	Surface	Speed in rpm	Thrust load in ton
1	Surface 1	700	1.96
2	Surface 2	700	2.45

Figure 5: Material before friction stir surfacing

Figure 6: Material after friction stir surfacing

3. Results and Discussion

3.1 Hardness Evaluation

Table 2: Micro Vickers Hardness Test on Copper before Friction Surfacing

Trial	Load applied 'P' in kg	Length of the diagonal 'd1'	Length of the diagonal 'd2'	Mean diagonal d= d1+d2/2	VPN=1.854 *P/d^2
1	5	0.292	0.298	0.295	105
2	5	0.284	0.292	0.288	111
3	5	0.296	0.300	0.298	107
4	5	0.302	0.298	0.300	103
5	5	0.300	0.299	0.2995	109

Table 3: Micro Vickers Hardness Test on Copper after Friction Surfacing on Surface 1

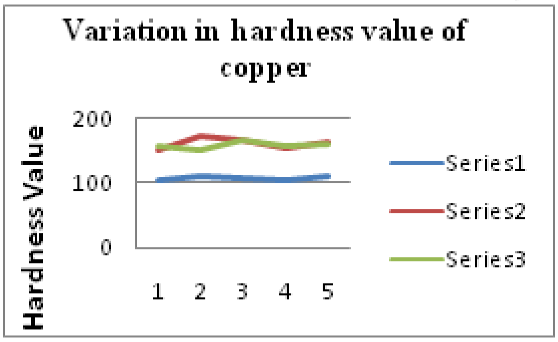
Trial	Load applied 'P' in kg	Length of the diagonal 'd1'	Length of the diagonal 'd2'	Mean diagonal d= d1+d2/2	VPN=1.854*P/d^2
1	5	0.251	0.245	0.2483	152
2	5	0.230	0.236	0.233	171
3	5	0.243	0.232	0.2375	166
4	5	0.239	0.252	0.2455	155
5	5	0.241	0.236	0.2385	163

Table 4: Micro Vickers Hardness Test on Copper after Friction Surfacing on Surface 2

Trial	Load applied 'P' in kg	Length of the diagonal 'd1'	Length of the diagonal 'd1'	Mean diagonal d= d1+d2/2	VPN=1.854*P/d^2
1	5	0.247	0.241	0.244	156
2	5	0.252	0.245	0.2485	151
3	5	0.238	0.232	0.235	166
4	5	0.249	0.237	0.243	157
5	5	0.245	0.239	0.242	159

Micro hardness test confirms that the Friction Stir Surfacing enhances the hardness of copper to a large extent.

3.2 Tabulated results are shown in graph



Series 1 -- Before Surfacing
Series 2 – After Surfacing (Trail 1)
Series 3 – After Surfacing (Trail 2)

3.3 Pin on Disc Wear Test

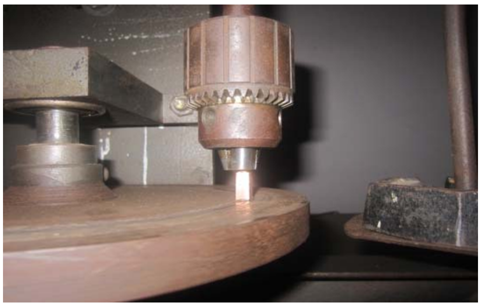


Figure 7: Pin on Disc Wear

Table 5: Pin On Disc Wear Test on Copper before Friction Stir Surfacing

Trial no	Initial weight (grams)	Final weight (grams)	Fr – Frictional force	Difference in weight after wear test in (grams)
1	12.7953	12.5496	1.66	0.2457
2	10.8907	10.6295	1.57	0.2612
3	12.4851	12.2359	1.61	0.2492
4	11.9627	11.7069	1.49	0.2558

Table 6: Pin On Disc Wear Test On Copper After Friction Stir Surfacing

Trial no	Initial weight (grams)	Final weight (grams)	Fr – Frictional force	Difference in weight after wear test in (grams)
1	9.2082	9.1352	1.42	0.0730
2	10.6593	10.5918	1.68	0.0675
3	8.1171	8.0408	1.53	0.0763
4	8.3607	8.2825	1.60	0.0782

Wear test carried out confirms the improvement in wear properties of copper after friction stir surfacing.

3.4 Microstructure

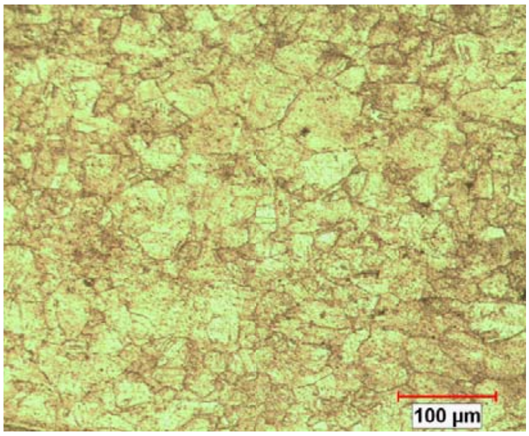


Figure 8: BEFORE SURFACING (200X)

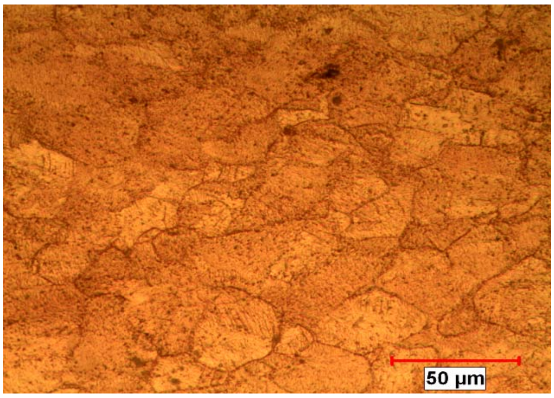


Figure 9: BEFORE SURFACING (500X)

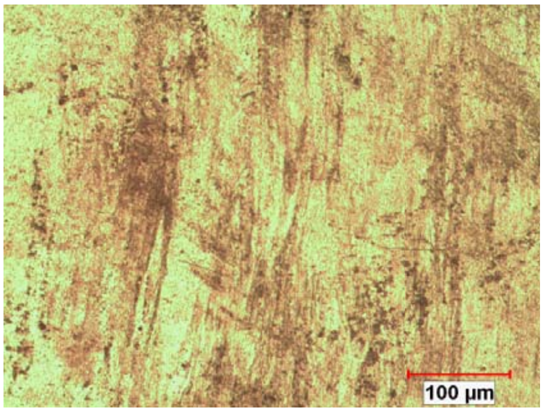


Figure 10: AFTER SURFACING (200X)

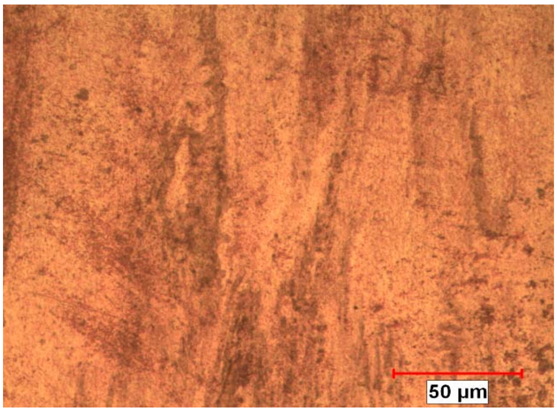


Figure 11: AFTER SURFACING (500X)

From the above images of copper microstructure reveals that:

- **Before Surfacing:** Microstructure consists of equiaxed grains of copper solid solution.
- **After Surfacing:** Microstructure consists of very elongated grains of copper solid solution; this is due to heavy compressive load & hot forging action on the material. During friction stir surfacing a large amount of heat is generated due to friction, this results in substantial heating at the contact region between the tool and material. Due to recrystallization during friction stir surfacing the friction stir surfaced material exhibits very elongated grains of copper. No distorted grains were observed in the friction stir surfaced region of the material.

3.5 SEM

A

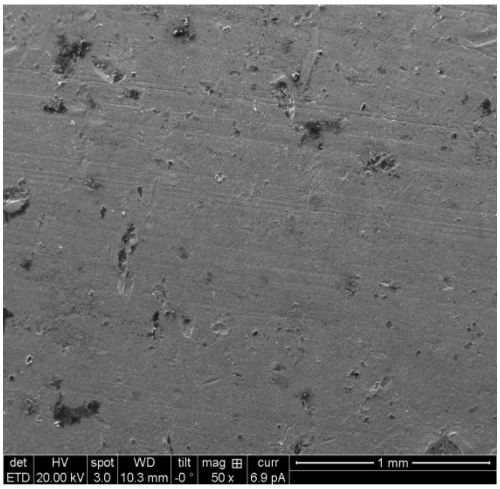


Figure 12: Before Friction Stir Surfacing (50x)

B

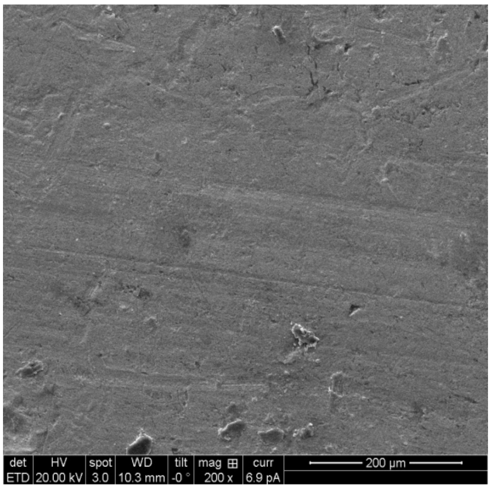


Figure 13: Before Friction Stir Surfacing (200x)

C

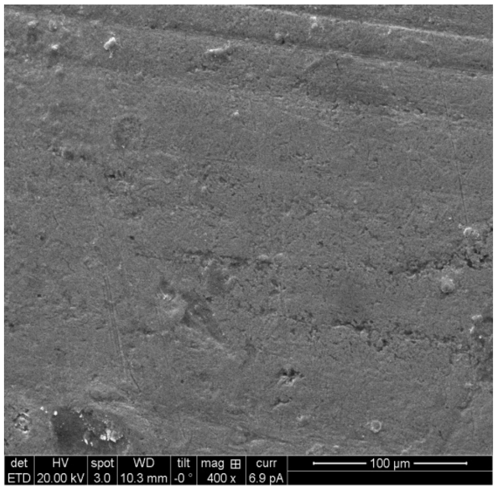


Figure 14: Before Friction Stir Surfacing (400x)

From the above figures A,B,C,SEM images under different magnifications, shows that the parent metal before friction stir surfacing have cracks, dents, voids and the surface is rough ,irregular and scratches can be seen.

C

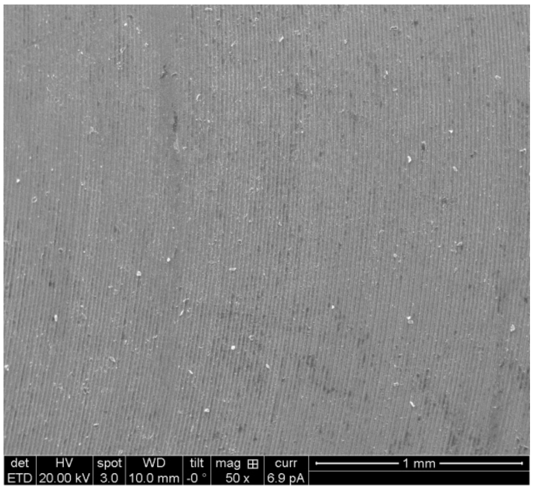


Figure 15: After Friction Stir Surfacing (700 Rpm) (50x)

D

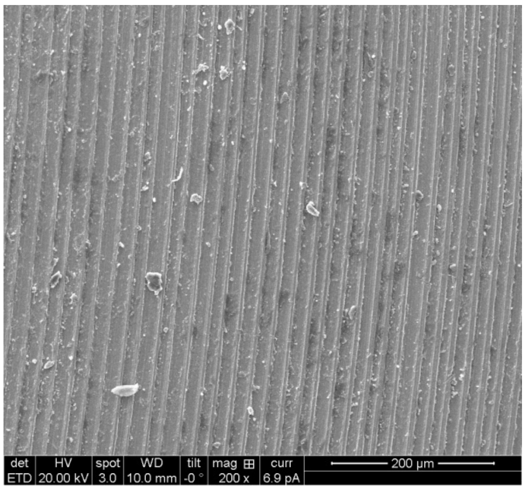


Figure 16: After Friction Stir Surfacing (700 Rpm) (200x)

E

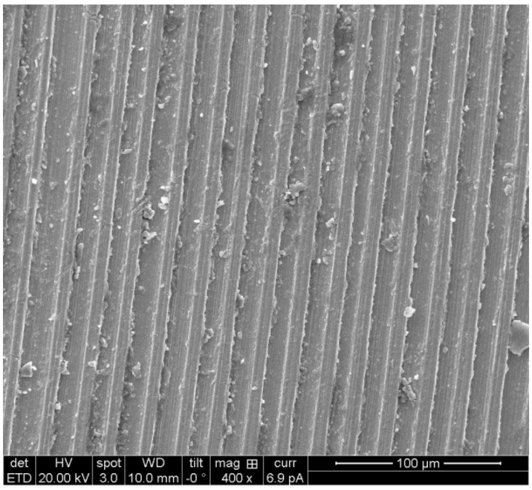


Figure 17: After Friction Stir Surfacing (700 Rpm) (400x)

From the above figures C,D,E, SEM images under different magnifications, the friction stir surfaced metal under load 2.45 ton at 700rpm,shows that friction stir surfaced region is free from cracks, dents and voids. There is no porosity or slag or inclusions in the friction stir surfaced region.

4. Conclusion

1. Friction stir surfacing was carried out using HSS flat tool instead of Mechatrode to generate Friction Surafcing.
2. No extra layer was deposited in this process.
3. Considerable hardness improvement was noticed in the Friction Stir Surfaced region.
4. Wear resistant of copper was evaluated confirming there was reduction in weight loss due to abrasion.
5. Before friction stir surfacing: Microstructure consists of equiaxed grains of copper solid solution
6. After friction stir surfacing: Microstructure consists of very elongated grains of copper solid solution.
7. SEM images for different magnifications shows the friction stir surfaced metal is free from cracks, dents, voids and scratches compare to its parent metal.

5. Future Scope of this Project

1. Friction stir surfacing process can be tested on other materials.
2. Friction stir surfacing is a novel method to increase hardness and wear properties of a material without using any extra coating material.
3. Friction stir surfacing process parameters can be optimized under different loads and speed.
4. There is no need of any other separate equipment for this process friction stir surfacing process can be carried out using friction stir welding equipment

References

[1] Scott F.Miller "New friction stir techniques for dissimilar materials processing" Mechanical Engineering, University of Hawaii at Manoa, Honolulu, HI 96822, United States ,Manufacturing Letters 1 (2013) 21–24 elsevier.

[2] S.Janakiraman and K.Udaya Bhat "Formation of composite surface during Friction surfacing of steel with aluminium" Hindawi publishing corporation advances in tribology volume 2012.article ID614278.

[3] H.S.Grewal, H.S.Arora, H.Singh, A.Agrawal " Surface modification of hydroturbine steel using friction stir processing" AppliedSurfaceScience268 (2013) 547–555 elsevier.

[4] I.Voutchkov, B.Jaworski, V.I.Vitanov, G.M.Bedford," An integrated approach to friction surfacing process optimisation".Surface and coating technology 141(2000) 26-33.

[5] V.I.Vitanov and I.I.Voutchkov,"Process parameter selection for friction surfacing applications using intelligent decision support". Journals of Material Processing Technology 159 (2005) 27-32.

[6] J.Gandra, R.M.Miranda, P.Vilaca,"Performance analysis of friction surfacing". Journals of Material Processing Technology 212 (2012) 1676-1686.

[7] H.Khalid Rafi, G.D.Janaki Ram, G.Phanikumar and K.Prasad Rao,"Microstructural evolution during friction surfacing of tool steel H13". Materials and Design 32 (2011) 82-87.

[8] Stefanie Hanke, Alfons Fischer, Matthias Beyer, Jorge dos Santos,"Cavitation erosion of NiAl-bronze layers generated by friction surfacing". Wear 273 (2011) 32-37.

[9] K.Prasad Rao, A.Veera Sreenu, H.Khalid Rafi, M.N.Libin, Krishnan Balasubramaniam,"Tool steel and copper coatings by friction surfacing-A thermography study". Journals of Material Processing Technology 212 (2012) 402-407.

[10] H.Khalid Rafi, G.D.Janaki Ram, G.Phanikumar, K.Prasad,"Friction Surfacing of Austenitic Stainless Steel on Low Carbon Steel: Studies on the Effects of Traverse Speed". Proceedings of the World Congress on Engineering 2010 Vol 2 WCE 2010 June30-July2, 2010, London, U.K.