International Journal of Latest Trends in Engineering and Technology
Vol.(16)Issue(4), pp.018-025
DOI: http://dx.doi.org/10.21172/1.164.03
e-ISSN:2278-621X

MRR AND CRACK PROPAGATION BEHAVIOUR OF BURR COVER PLATE BIOIMPLANTS MADE BY 316L SS & A203 LAS MACHINED IN WEDM

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Abstract- Burr cover plate (BCP) is a body implant used in keyhole fracture surgery. The common material used to fabricate these bio-implants is 316L SS. As a new means, it is machined with A203 low alloy steel and is analyzed using SEM to compare the behavior of these implants (both 316L SS & A203 steel variants) for their respective performance under functioning conditions.

Key Words: **Wedm, Biomaterials, Implant, Crack propagation, MRR**

I. Introduction

A burr cover plate is an implant used to cover the fracture in the human skull. It is used to cover a particular type of fracture called as 'Keyhole fracture'. A keyhole fracture is a fracture that is caused by collision of skull with an acute, sharp particle such as a shrapnel (general term for fragmentation that is thrown out as a bomb, shell or other object explodes) or when the skull is impacted with a bullet. The burr cover plate is also used to cover the skull after tumor removal operation. 316L stainless steel is the material commonly used to make body implants. Recent studies and advances in inspection technology have shown that this material is not completely flawless and has some disadvantages. One of the disadvantages that needs attention is its vulnerability to form cracks under acute loads which is the exact scenario of a keyhole fracture. On the other hand, A203 low alloy steel is a nickel alloy with scope to be used as human implant material. A few tries have been successfully made in using it in orthopedic implants. In this project an attempt has been made to check if A203 Low Alloy Steel is more apt than 316L SS for making Burr cover plates. Burr cover plates are machined using both 316L SS and A203 LAS and are tested for micro defects under loading conditions similar to which causes a keyhole fracture.

II. Material Selection

Biomaterials must be good with the body and there are regularly gives identified with biocompatibility that must be settled before an item can be utilized in the market and utilized in the clinical setting. So the biomaterials are often subjected to tests that are undergone by drug therapies.

The following are the characteristics that define the biocompatibility of a material.

Corrosion and corrosion resistance: It is the loss of metallic particles from metal surface to the encompassing condition. Following kinds of consumption are seen,

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Crevice corrosion: It happens in thin district like embed screw-bone interface. At the point when metallic particles break up, they can make a decidedly charged neighborhood condition in the fissure, which may give chances to hole consumption.
Pitting corrosion: It happens in an embed with a little surface pit. In this the metal particles disintegrate and consolidate with chloride particles. Setting erosion prompts roughening of the surface by arrangement of pits.
Galvanic corrosion: This happens on account of contrast in the electrical angles. Nickel and chrome particles from fake prosthesis may go to peri-embed tissues because of spillage of spit among embed and superstructure .This may bring about bone reabsorption and furthermore influence the steadiness of the embed and in the end cause disappointment.
Electrochemical corrosion: In this anodic oxidation and cathodic decrease happens bringing about metal weakening just as charge move by means of electrons. This kind of erosion can be averted by nearness of aloof oxide layer on metal surface.
Clinical significance of corrosion: Embed bio-material ought to be erosion safe. Erosion can bring about roughening of the surface, debilitating of the reclamation, arrival of components from the metal or combination, lethal responses. Contiguous tissues might be stained and unfavorably susceptible responses in patients may result because of arrival of components.

Table -1 Composition of 316LSS and A203 LAS

Element	**Contents 316LSS (%)**	**Contents A203 LAS (%)**
Carbon	0.08	0.20
Manganese	2.00	0.80
Phosphorous	0.045	0.035
Sulfur	0.03	0.040
Silicon	0.75	0.15
Chromium	16.00	-
Nickel	12	3.50
Molybdenum	3.00	-
Nitrogen	0.10	-
Iron	95.00	96.00

A comparison of their major mechanical properties is listed in the table below,

Table -2 Mechanical properties of 316SS and A203 LAS

Material	**Biocompatibiliy**	**Ultimate Tensile Strength (Mpa)**	**Yield Strength (MPa)**	**Fatigue Strength (MPa)**
316L SS	YES	515	205	170
A203 LAS	YES	520	285	210

Reasons for selecting A203 Low Alloy Steel

Better yield strength (39%), Slightly greater Ultimate strength (0.96%), Fatigue strength is more than that of 316L SS (23.5%), Considerable economic efficiency (21.56%). Hence, for the above reasons A203 low alloy steel is chosen to machine Burr cover plate and is compared with 316L stainless steel.

III. Machining Burr Cover Plate

A burr cover plate is an implant used to cover a part of skull after being operated, this can either be a tumor removal operation or after a trauma caused by an accident. In this project Burr Cover Plate is machined for covering a keyhole fracture. A keyhole fracture is a fracture caused by collision of skull with an acute, sharp particle such as a shrapnel or a bullet. The burr cover plate should have an outer diameter that is 2.5 times the size of the tumor operated out or the part of the skull that is removed. The curvature depends on the specific region of the skull which is implanted. Wire-cutting EDM is usually used when low extra weights are needed, considering the way that it doesn't require high cutting forces for ejection of material. In case the imperativeness/control per beat is commonly low (as in finishing assignments), little change in the mechanical properties of a material is required due to these low waiting tensions, yet material that hasn't been pressure relieved can reshape in the machining methodology. The work piece may encounter a significant warm cycle, its reality depending upon the inventive parameters used. Such warm cycles may cause game plan of a recast layer on the part and remaining malleable loads on the work piece. In the occasion that machining occurs after warmth treatment, dimensional exactness won't be impacted by heat treat bending.

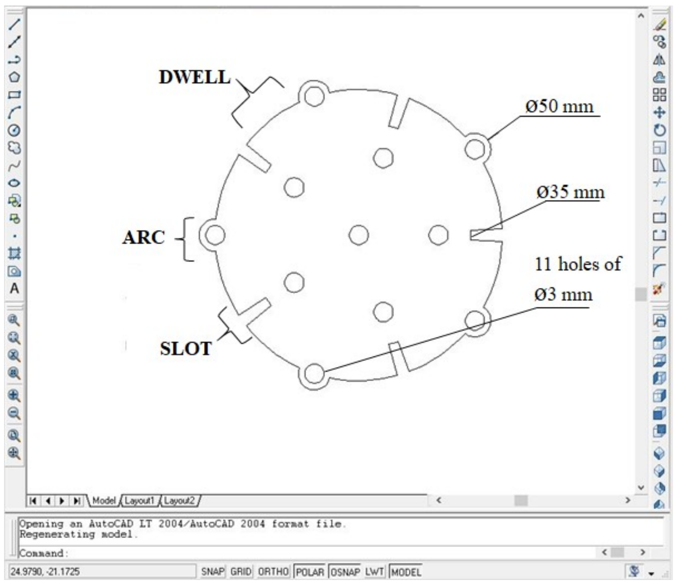

Figure 1. Burr cover plate model

Figure 2. Finished burr cover plates using both materials

Table -3 MRR of 316SS and A203 LAS

S.No	POSITION	316L SS (avg) (mm^3/min)	A203 LAS (avg) (mm^3/min)
1.	Dwell	1.8088	1.5899
2.	Slot	2.3335	2.1415
3.	Arc	1.6294	1.5793
	Total Average	1.9239	1.7702

IV. SEM TESTING

Keyhole fractures, while rare, represent an entity deserving of contemplation when sharp force wounds happen to the skull. It requires minimum force of 10 kgf to cause a keyhole fracture, and if force exceeds 20.5 kgf it creates a Basilar skull fracture. The fracture force cannot be characterized as impact but rather an acus form of gradual load. This can be better elucidated as a needle like focused sharp load as said in Aaron M. Jackson, Keyhole fracture of the skull, Military medicine Radiology Corner.

Since, the load is required to be acus point type load, it must be applied on the burr cover plate at a particular point to simulate the condition of a keyhole fracture. Hence, the load is given load by the Vicker's hardness tester to get accurate results.After the plates are applied with load, the loaded segment of the burr cover plate is cut to the size 1 cm x 1 cm for SEM testing.

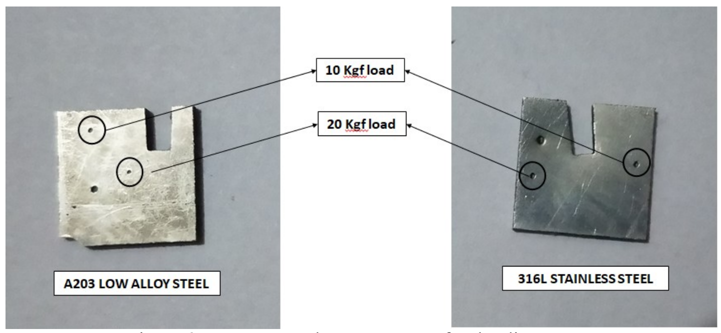

Figure 3. Burr cover plate segments after loading

When acute loads of 10 kgf anf 20 kgf are applied on the burr cover plate specimens, micro fractures are expected to occur at those points. The loaded burr cover plate segments are magnified to 20µm to get a clear view of the micro fractures formed at the point of action of load.

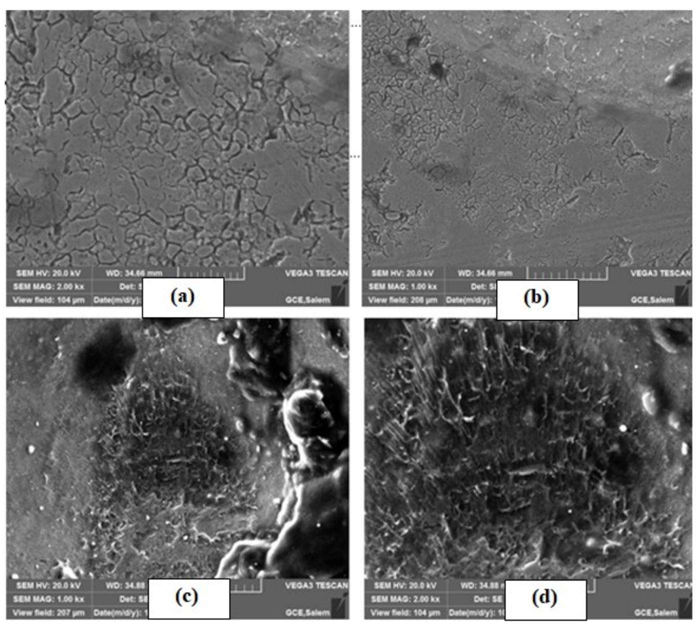

Figure 4. 20µm enlarged portion of (a) 10kgf loaded point A203 LAS (b) 20 kgf loaded point A203 LAS, (c) 10 kgf loaded point 316L SS, (d) 20 kgf loaded point 316L SS.

V. INTERPRETATION OF SEM RESULTS

From the SEM images we can see two types of micro fractures in the burr cover plate specimens, 1) intergranular cracks and 2) transgranular cracks. An intergranular break is a sort of crack where the split engenders along the grain limits of the material, generally when these grain limits are debilitated. Intergranular crack can happen in a wide assortment of materials, including steel compounds, copper composites, aluminum combinations, and earthenware production. It is a fracture that follows the grains of the material.Intergranular fracture characteristics:

1. Passes along grain boundaries
2. Interconneted to each other and
3. Docehedral shaped

Transgranular fracture is caused by crack which does not follow grain boundaries and hence transcends from one grain to another grain. The fracture follows the pattern of grains in the individual lattices of the material. This is one type of brittle fracture. In intergranular fractures, when grains are equiaxed (dodecahedral-shaped), this reduces the further propagation of cracks in the material, whereas the transgranular cracks in the material are more vulnerable to crack formation since it reduces the plasticity of the material. Transgranular fracture characteristics:

1. Passes through grain boundaries
2. Parallel to each other
3. Forms a hayform texture

Determination of Microfracture length

Determining the length of the microcracks are very important to find its effects on the material. ImageJ programming is utilized to quantify the length of the microfractures. ImageJ is a Java-based picture preparing program created at the National Institutes of Health and the Laboratory for Optical and Computational Instrumentation (LOCI, University of Wisconsin). ImageJ can show, alter, break down, procedure, spare, and print 8-piece shading and grayscale, 16-piece number, and 32-piece skimming point pictures. It can peruse many picture record positions including TIFF, PNG, GIF, JPEG, BMP, DICOM, and FITS, just as crude arrangements.

Table -4 Crack lengths observed in 316LSS

S.No	Label	Angle (º)	Length (µm)
1		-60.751	15.784
2		-52.595	11.829
3		-66.194	20.275
4		-84.174	13.363
5		-52.595	11.612
6		-47.643	12.483
7		-66.251	14.82
8		-82.674	19.087
9		-41.468	15.697
10		-59.036	9.685
11	Mean	-61.338	14.463
12	SD	14.005	3.36
13	Min	-84.174	9.685
14	Max	-41.468	20.275

Table -5 Crack lengths observed in A203 LAS

S.No	Label	Angle (º)	Length (µm)
1		-53.13	5.417
2		-48.814	4.348
3		-26.565	7.51
4		-97.125	5.465
5		-74.32	8.061
6		-35.362	5.059
7		33.275	5.208
8		-60.781	9.137
9		-105.124	10.468
10		-100.305	6.056
11	Mean	-56.825	6.673
12	SD	41.821	2.019
13	Min	-105.124	4.348
14	Max	33.275	10.468

VI. RESULTS AND DISCUSSION

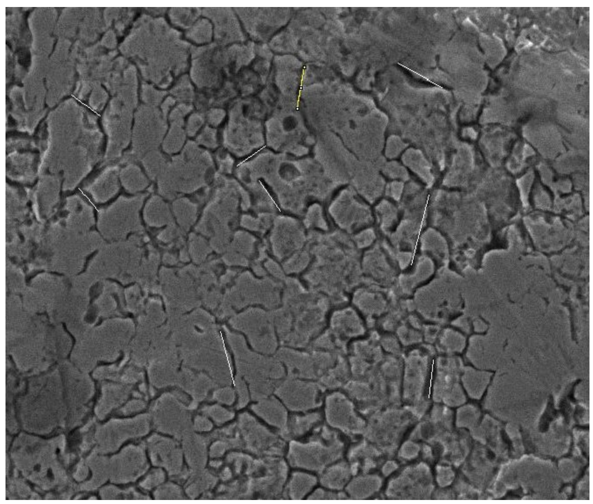

Figure 5. Intergranular cracks in A203 LAS

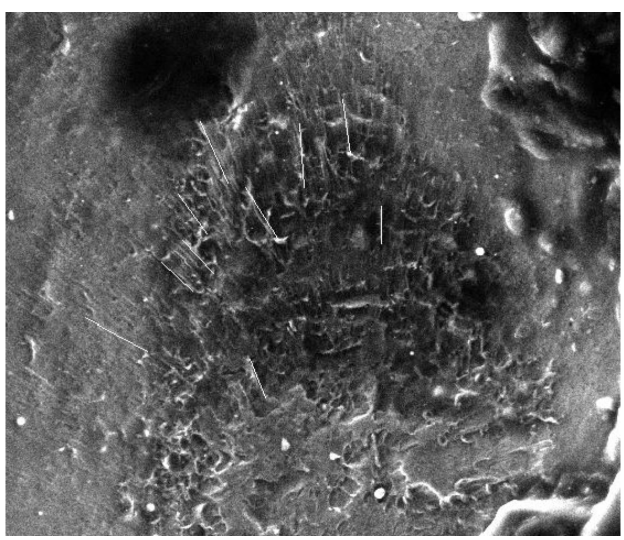

Figure 6. Transgranular cracks in 316l SS

A203 LAS sample,

Max length - 10.462 µm
Min length - 4.348 µm
Mean length - 6.673 µm
Intergranular fracture characteristics:

1. Passes along grain boundaries
2. Interconneted to each other and
3. Docehedral shaped

316L SS sample,

Max length - 20.287 µm
Min length - 9.685 µm
Mean length - 14.463 µm
Intergranular fracture characteristics:

1.Passes through grain boundaries
2.Parallel to each other
3.Forms a hayform texture

- Mean Fracture length in 316L SS specimen – 14.463 µm (>10.2 µm)
- Mean Fracture length in A203 LAS specimen – 06.673 µm (<10.2 µm)

Microfractures of length above 10.2 µm are not suitable for angiogenesis which is key to osseointegration **[27]**. Osseointegration is the direct basic and utilitarian association between living bone and the outside of a heap bearing counterfeit embed. Angiogenesis is the physiological procedure through which fresh recruits vessels structure from prior vessels, framed in the previous phase of tissue development. In intergranular fractures, have less propagation rate thantransgranular cracks regardless of the material, whereas the transgranular cracks in any material are more vulnerable to crack formation since it induces emrittlement and increases the plasticity of the material **[1]**.

This makes A203 low alloy steel more suitable than 316L SS for making Burr cover plate for key hole fracture implants.

VII. CONCLUSION

A203 low alloy steel was chosen as the biocompatible material to make burr cover plate. Burr cover plates machined from both 316L SS and A203 LAS were applied keyhole fracture load (10 kgf and 20 kgf) and were tested for microcrack formation in SEM microscope. It was found that transgranular cracks formed in 316L SS obstructs osseosynthesis in the implanted site. Hence, A203 low alloy steel is proved to be more suitable to make for keyhole fracture implants than 316L Stainless Steel.

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