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Erosion Problem for Granular Tungsten Targets Using Circulating Fluidized Beds

Experimental Investigation of Surface Damage

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Background:

To enable high beam power, and resulting higher particle yields, alternative target technologies are being considered. Among these is the circulating fluidized bed target, in which granular media is conveyed along the target container using a fluidizing gas. The unique erosion conditions created by the flow of dense media is poorly understood and requires experiment to fully characterise. Understanding erosion conditions will enable construction of a fluidized bed target.

Objectives

1. Understand operating conditions of wear surfaces in a fluidized tungsten target
2. Investigate the theoretical effect of particle shape and impingement angle on wear features
3. Create and develop an erosion test method suitable for dense erosion media
4. Analyse wear resulting from erosion in a variety of conditions
5. Make recommendations for design of a fluidized target

2. Erosion Theory:

- Erosion occurs due to the deformation, cutting or cracking of a surface by an impinging particle. Deformation and cutting are the two significant mechanisms for most materials [2].

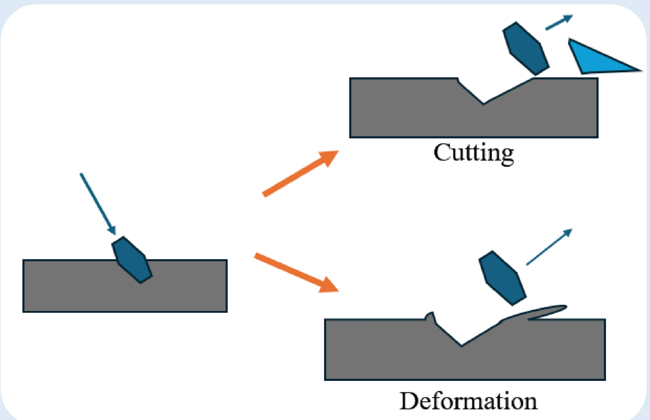

Figure 2: Dominant erosion mechanisms

- At low angles, a form of deformation wear called ploughing will occur. Ploughing displaces material to the side of the impact site

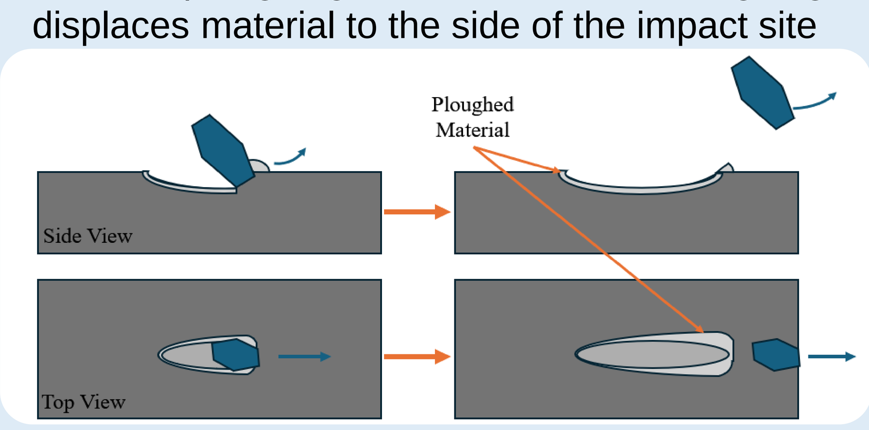

Figure 3: Ploughing of material from low angle impact

- Material hardness and ductility dominate the size and form of indentations generated. Softer materials deform more for the same impact energy. More ductile materials are more readily deformed than cut.
- Ductile materials erode most severely at moderate angles, typically ~10°
- Brittle materials erode by cracking, with worst erosion at 90° to the surface. Most conventional "brittle" materials behave in a ductile fashion for small particles

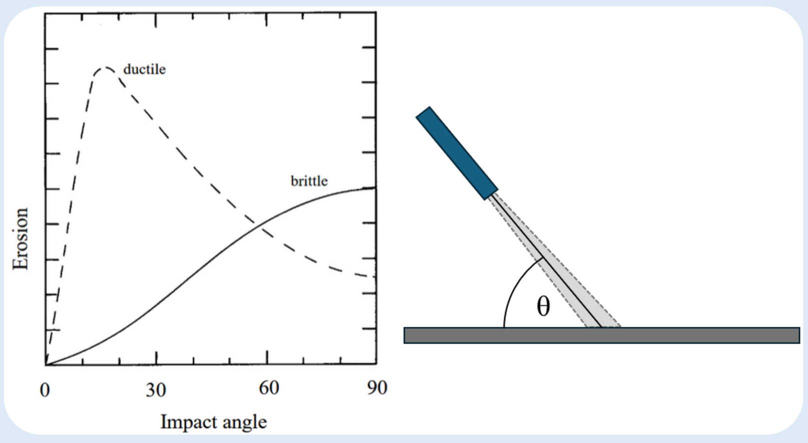

Figure 4: Rate of erosion for brittle and ductile materials at different impingement angle [3]

- Many erosive impacts will generate a new surface texture by deforming and removing material

4. Analysis

- Surface roughening visible to the naked eye
- Under SEM, a clear difference between materials is visible which shows titanium and stainless steel behaving similarly, and Inconel exhibiting much less deformation

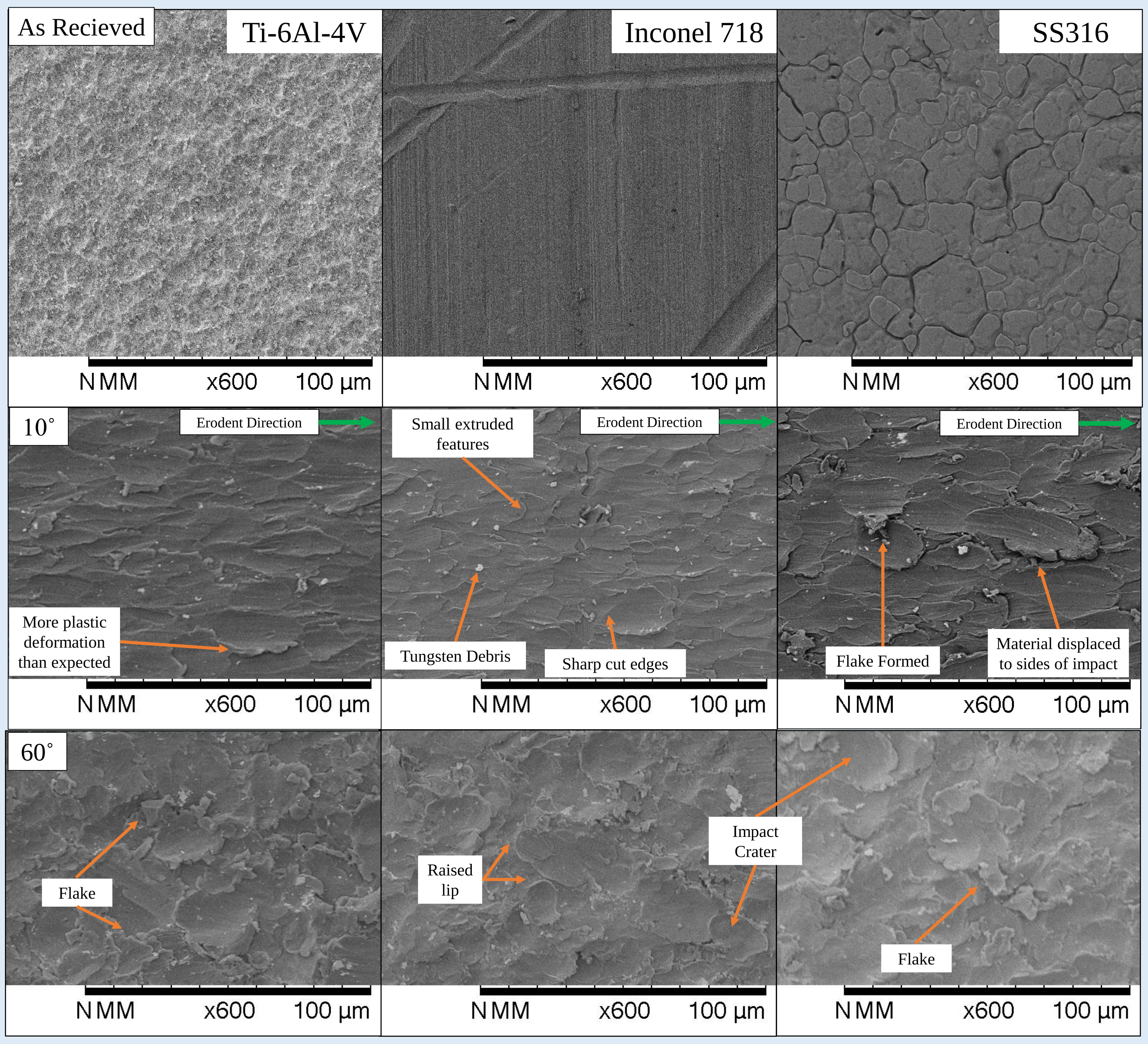

Figure 9: Surface damage from angular particle erosion for different metals and angles

1. Operating Conditions:

- Many varied conditions will be faced by target container components
  - Dense flow through the target will behave like abrasion of the pipe walls
  - High velocity flow through the powder lift will impact the walls with high energy at low surface angles
  - Flows around bends will be at high angles to the surface, with a large amount of energy contributing to particle impingement
- Previous work at RAL has uncovered erosion to be a major concern for the design of a fluidized target system [1]
- A wide range of conditions should be investigated to understand the risks components face and how to avoid them

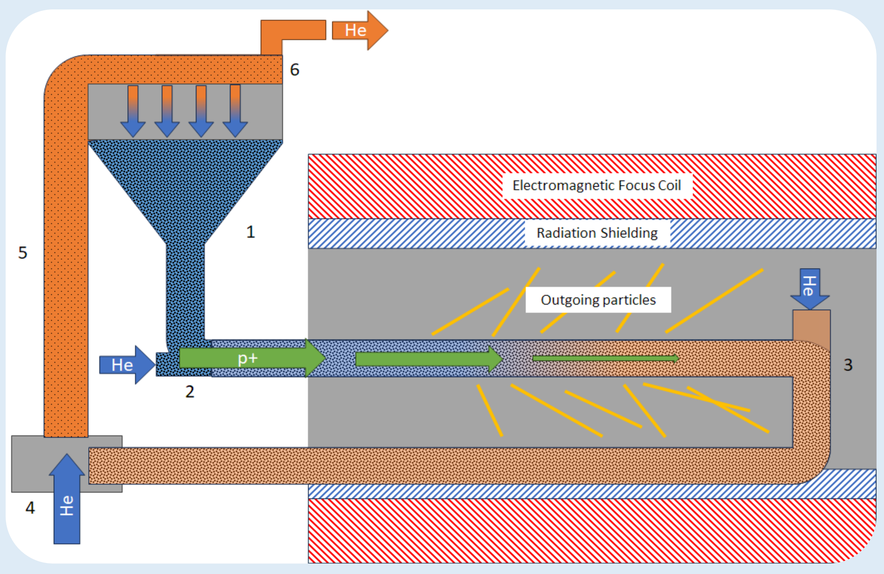

Figure 1: Fluidized bed target concept for a Muon Collider, in which the tungsten particles are conveyed by helium gas.

3. Test Procedure:

- Sand blaster type erosion tester used, where tungsten is propelled by 6bar air through nozzle
- Impingement angle is variable through adjusting sample height and nozzle angle. This maintains a fixed distance between nozzle and sample

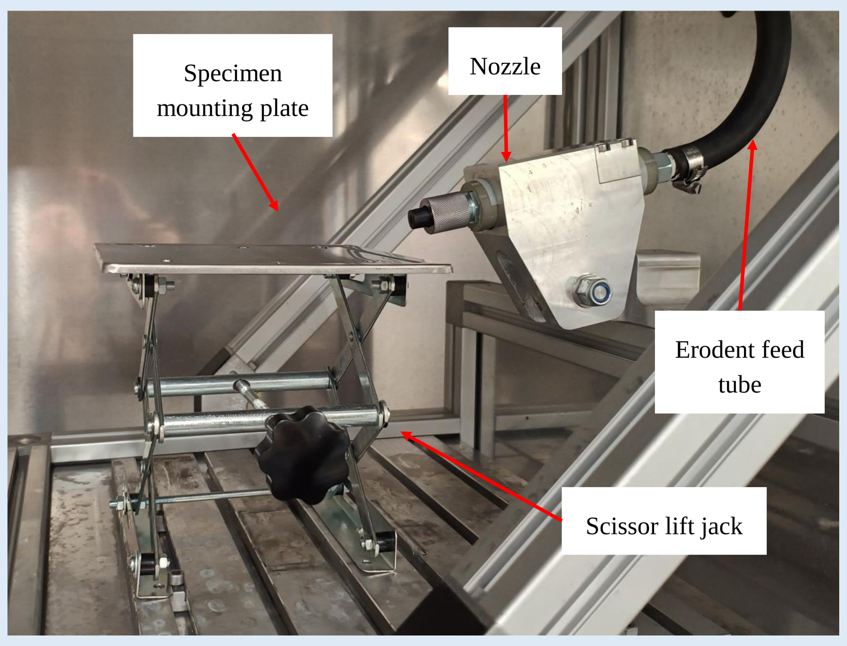

Figure 5: Erosion rig test enclosure.

- Erodent speed is measured indirectly using a rotating slot time-of-flight device [4]. This produced a repeatable single line on the solid disc- a near constant speed of 22m/s

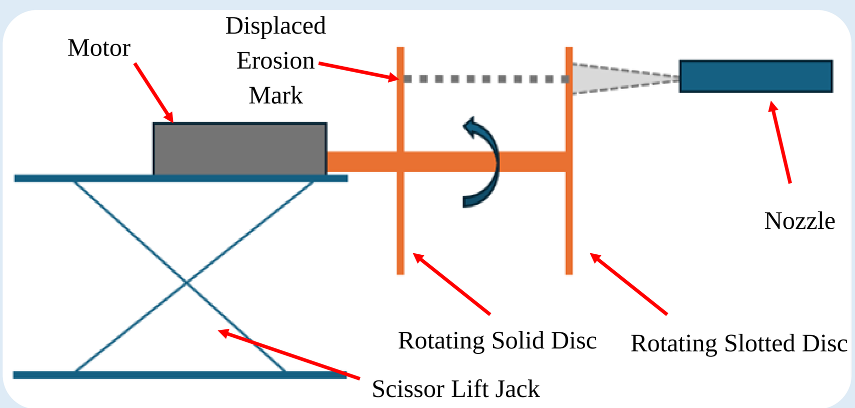

Figure 6: Time of Flight particle velocity meter

- Two sizes of angular tungsten tested

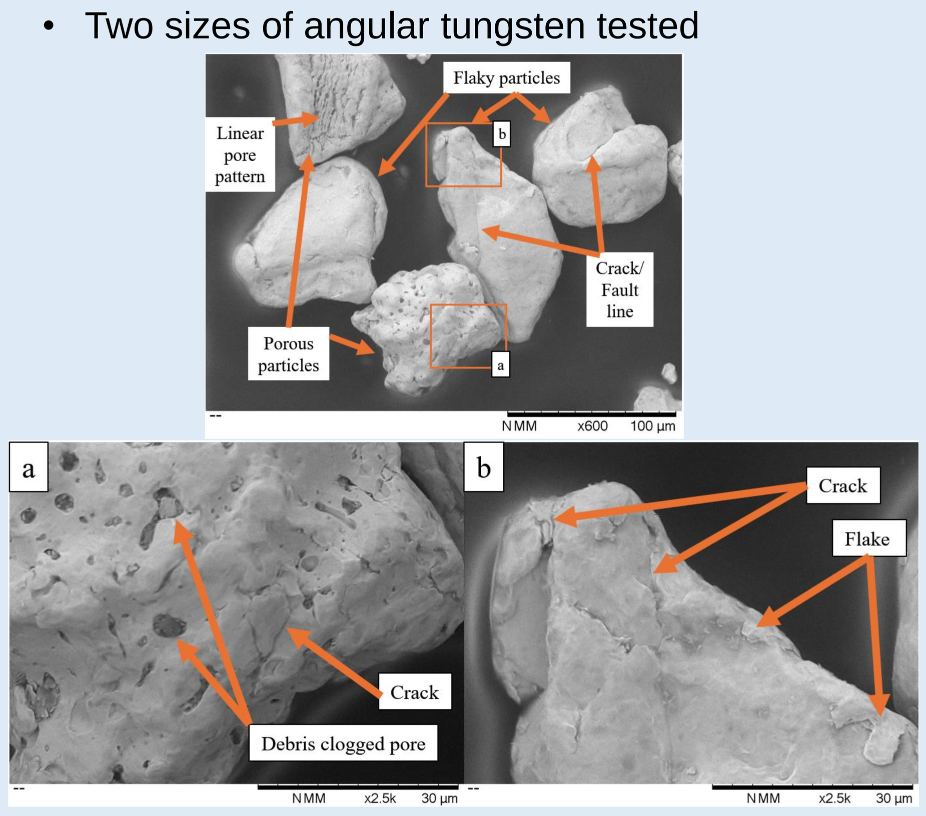

Figure 7: Angular Erodent SEM images

- One size of spherical tungsten tested

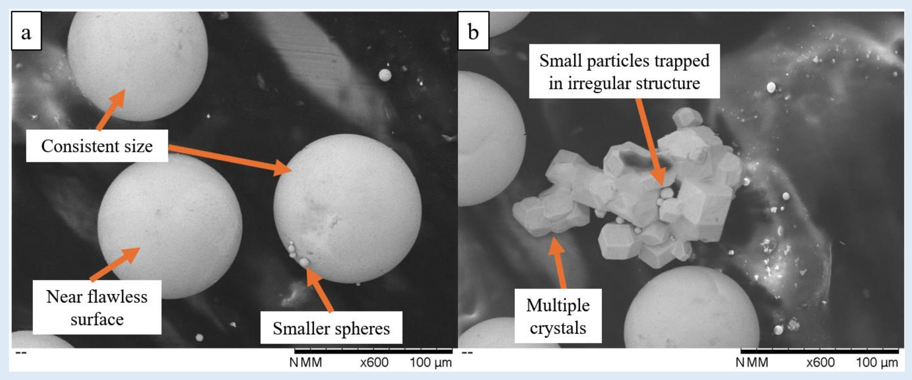

Figure 8: Spherical Erodent SEM Image

- 300g of tungsten was propelled at samples of Ti-6Al-4V, stainless steel 316, and Inconel 718
- Surfaces were tested for hardness using Vickers and ASTM scratch hardness standards. Titanium was the hardest surface, with SS316 the softest.
- Surfaces were examined by SEM and optical profilometry before and after erosion

5. Conclusions and Recommendations

- Tungsten behaves visually similarly to more common erodents in literature, but more work is necessary to quantify wear for comparison
- Roughening of surfaces varies greatly with impingement angle for all cases
- Surface deformation from erosion is not correlated to hardness values
- Localised heating from erodent impact can be significant, resulting in a softer, more ductile erosion condition. This effect is likely amplified by high density erodent
- Titanium may not be the material of choice for long term performance- Inconel seems more resilient to surface damage
- Longer tests should be conducted to develop erosion to a steady state.

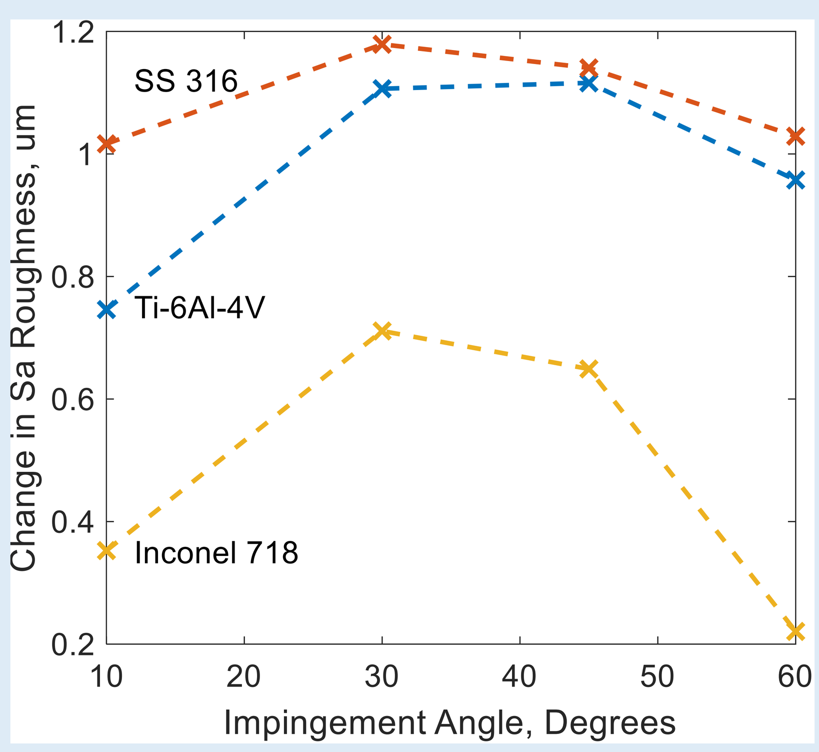

Figure 10: Surface roughening from erosion by angular particles

References

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