Improving Autoclave Agitator Mechanical Seal Performance

• Choosing Optimum Face Materials

White Paper by Tim Kent
**Introduction**

In many process industries Mechanical Seals are the first choice (in many cases the only choice) to seal rotating equipment. One such case is when dealing with high temperature water based reactions which take place in autoclaves. Typical examples are:

- Pressure Oxidation (POX) used to recover copper, platinum and gold from refractory ores.
- Hydrogen reduction and ammonia leaching used in nickel and cobalt refining.
- High Pressure Acid Leach (HPAL) used to recover nickel and cobalt from laterite ores.

Processes such as these typically involve temperatures of over 200°C. While the high temperature greatly increases reaction speed, this elevated temperature does necessitate high pressures to prevent the water boiling away.

The ore being treated is in the form of suspended solids so must be constantly agitated to prevent settling out. Also mixing of process reagents such as sulphuric acid in HPAL, ammonia & hydrogen gas in nickel refining and oxygen gas in POX is required. This agitation and mixing is most commonly provided by large shaft diameter top entry mixers which must be sealed to prevent steam and process fluids escaping to the atmosphere.

Double mechanical seals are employed to seal the rotating shafts, typically 150mm diameter and often larger. Although the shafts rotate slowly, the equipment is very large; the operating conditions are extreme with high pressure & temperature.

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**Brick Lined Autoclave with Five Top Entry Mixers**

Each shaft is sealed by a double mechanical seal.

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**Autoclave Agitator with Mechanical Seal**
Choosing Optimum Seal Face Materials

Mechanical seals have been around since the turn of the 20th century, becoming widely used in automotive applications in the 1940's. For many years a carbon face and a much harder seat were used. More recently hard ceramic face materials have been developed and employed with advantages over carbon faces. This is particularly true in the case of autoclave agitator seals where carbon materials often perform badly.

The problem - blistering of carbon faces
Carbon face materials are limited in application due to not only very low mechanical strength but also very poor heat transfer properties; this is why high duty seal applications, including high pressure autoclave applications are best sealed with hard seal face materials.

Frictional heat – is created between the seal faces when they operate. The speed of the agitator is low so the amount of heat is relatively low, but it is confined between the seals faces in a fluid film around 2 to 3µm (microns) thick. By comparison a hair is around 90µm thick as below. If heat build-up is excessive then the very thin fluid film boils or flashes, this allows the faces to contact, in turn creating more heat until the seal faces are damaged.
Carbon’s low heat transfer – makes it a very effective insulator. To illustrate, performance motorcycles are now fitted with carbon fiber exhaust cans that feel just warm to the touch after racing laps! This insulation property is great for motorcycles but highly undesirable in a seal face as it traps the frictional heat in the 2 to 3 µm fluid layer escalating the fluids likelihood to flash.

Surface damage (blisters) – a second resultant from the low heat transfer property of carbon is heat is trapped only at the surface of the seal face. If the surface heat becomes too high, this then leads to differential expansion within the carbon. Carbon has a relatively high expansion rate, similar to most metals in fact. However carbon is brittle unlike metals which are ductile.

Due to the low heat transfer the face expansion is of course confined to the surface layer only, which being part of a brittle rather than ductile material leads to cracking at the surface and spot blisters to form where the heat is the highest.

The mechanism of blistering is similar to when concrete is heated with a blow-torch; it spalls & cracks at its surface.
### Alternate Face Materials

To combat the poor flexural strength, thermal conductivity problem and low chemical resistance of carbon it is required to use a material with better thermal properties.

**Tungsten carbide (TC)** is an older hard face material. While having good strength and high conductivity it is attacked chemically in severe processes such as acid leaching. This is because the tungsten carbide is bound together with a small % of metallic binder, typically nickel or cobalt. When the binder is exposed to a process designed to leach nickel it’s not hard to see it is dissolved.

**Silicon carbide (RB sic / Ssic)** is often used in mechanical seals, it is strong, has good thermal properties but it has poor frictional properties when used in a pair of hard faces. This limits its use in autoclave seals, particularly if using a low lubricity fluid like de-mineralised water.

Carbon does of course have good frictional properties and is to some extent self lubricating. If carbon graphite is combined with a hard material such as silicon carbide, GSic a hard material with good friction properties is produced. The following chart shows the properties of this material compared to carbon and common hard face materials.

<table>
<thead>
<tr>
<th></th>
<th>B carbon</th>
<th>A carbon</th>
<th>Gsic</th>
<th>Ssic</th>
<th>TC</th>
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</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>85 shore</td>
<td>100 shore</td>
<td>1000 HV</td>
<td>2500 HV</td>
<td>1500 HV</td>
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<tr>
<td>Compressive strength</td>
<td>207 Mpa</td>
<td>350 Mpa</td>
<td>740 Mpa</td>
<td>3800 Mpa</td>
<td>high</td>
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<tr>
<td>Flexural strength</td>
<td>64 Mpa</td>
<td>90 Mpa</td>
<td>170 Mpa</td>
<td>390 Mpa</td>
<td>high</td>
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<tr>
<td>Modulus of elasticity</td>
<td>23 Mpa</td>
<td>26 Gpa</td>
<td>260 Gpa</td>
<td>400 Gpa</td>
<td>550 Gpa</td>
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<tr>
<td>Thermal conductivity</td>
<td>21 W/m*K</td>
<td>9 W/m*K</td>
<td>158 W/m*K</td>
<td>80 W/m*K</td>
<td>high</td>
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<tr>
<td>Boundary Lubrication</td>
<td>V Good</td>
<td>V Good</td>
<td>Good</td>
<td>Poor</td>
<td>Average</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td>Poor to acid</td>
<td>Poor to acid</td>
<td>Good</td>
<td>V Good</td>
<td>binder leaching</td>
</tr>
</tbody>
</table>

### Typical seal face material properties

**Upgrade of Existing Seals**

The good news is older mechanical seals can often be upgraded using improved seal face materials and technology. The cost of upgrading is a fraction of a change to new mechanical seals. Please contact WCIS for further details if we can help you to increase the performance of your agitator seals with minimal cost and risk.

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For further information, initial enquiries can be made to the author at tim.kent@wcis.com.au. Alternatively, please contact our offices on the details below, or visit our website at www.wcis.com.au.