CURTISS-WRIGHT

PEO coated lightweight aluminium brake disc

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Advanced PEO coated lightweight aluminium brake disc for solving non-exhaust emission challenges

With legacy of history for innovation in aviation, naval, nuclear and energy sectors, Curtiss-Wright is now looking into solving a next global challenge with issues on automotive particle emissions.

Vast majority of cars still use grey cast iron (GCI) as friction brake discs that are quite heavy. The high 'unsprung-mass' and additional rotational inertia impacts on fuel consumption, ride comfort, damage to roads or battery efficiency in the case of electric-vehicles (EVs). Increased fuel consumption leads to higher CO_2 or exhaust emissions (EE). GCI disc is also prone to corrosion when it is left stationary for a long period of time. Corrosion on the surface of the brake disc can lead to an increase in noise, vibration and harshness (NVH) and reduce braking efficiency. Furthermore, brake dust released as non-exhaust emission (NEE) from cast iron disc and pad wear system comprises of nano-particles. Particulate matter PM_{10} in urban air pollution has been linked to a range of acute health conditions[i], including effects on the respiratory and cardiovascular systems, asthma[ii], even Alzheimer's disease[iii iv v], premature deaths and reduction in life-expectancy. NEE particles from the UK road traffic is now having a greater public health impact than the exhaust particles that contributes to an effect equivalent to around 29 000 deaths across the country annually[vi]. NEE issues from tyre, road abrasion and brake wear have hardly been addressed and are expected to remain unchanged till 2030 if actions are not taken today[vi].

Fig.1. GCI disc (left) and PEO-Al disc (right).

How CWST are pushing the boundaries of materials science

Curtiss-Wright are proposing the use of light-weight alternatives such as aluminium brake discs to replace the heavy iron discs, subsequently reducing vehicle weight by up to 20kg (for mid-size car) and deliver considerable fuel savings. Furthermore, reducing unsprung mass and rotational inertia through lighter discs, leads to better handling performance, improved acceleration or deceleration, and less damage to road surfaces. The main challenge for using an aluminium alloy as a friction brake disc is the maximum operating temperature (MoT) limitation as well as poor tribological properties and susceptibility to excessive corrosion and wear. The growth in EVs is adding another dimension to this problem and relates to their regenerative-braking systems (RBS). The RBS generator resistance acts to slow the vehicle, thereby reducing the demands on the friction brake system. Reduced demand means cast-iron discs are colder and damper for longer, significantly increasing corrosion susceptibility. As a result: 1) the corroded discs produce even higher levels of particulate emissions; and 2) they are prone to seizure following such periods of inactivity. The reduced braking demands and the pronounced issues of cast-iron discs in EVs creates an even greater need / opportunity for a lighter, wear resistant alternative.

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Keronite

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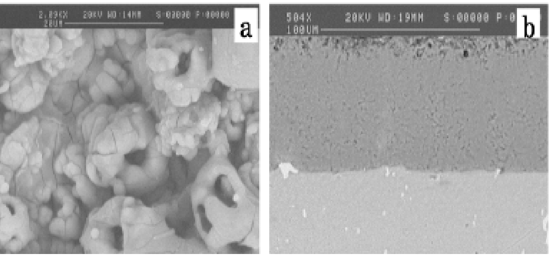

Fig.2 SEM images of the PEO ceramic coating, surface (left) and cross-section (right).

The Innovation

The innovation is based on the application of a unique, proprietary Keronite Plasma Electrolytic Oxidation (PEO) process to a light-weight aluminium brake disc (Fig.1). The PEO converts the brake disc's surface layer into a dense and super-hard crystalline Al_2O_3 ceramic coating (Fig.2), capable of surviving temperature extremes, corrosion, extreme wear and thermal stresses. PEO is a conversion layer (rather than a deposited ceramic coating or brazed ceramic layer), and offers excellent adhesion to the substrate metal, which makes the ceramic coating extremely robust and able to withstand relatively high coefficient of thermal expansion (CTE) mismatch.

Fig.3. Component immersed in the electrolyte bath showing plasma discharge during the Keronite PEO process.

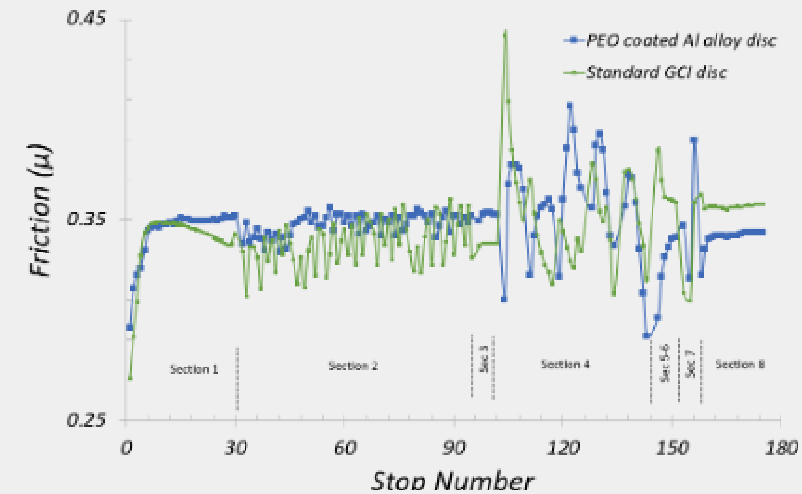

Fig.4 Average CoF values of PEO/Al disc vs GCI disc at 100°C IBT during AK Master test.

What is Keronite PEO?

- PEO technology is essentially plasma-assisted anodising in an environmentally safe, low-concentration alkaline electrolyte that is free of Cr, heavy metals, volatile organic compounds and strong acids.
- Millions of very short-lived plasma discharges, like microscopic bolts of lightning on he surface of a component (Fig.3) transform the surface layer into materials such as Corundum (Al_2O_3) on Aluminium.
- Similar to anodizing, but employs much higher potentials (typically 400V-1000V), so that discharges occur and the resulting plasma modifies (and enhances) the structure of the oxide layer.
- Due to very high hardness and a continuous barrier, these coatings offer enhanced protection against wear, corrosion as well as electrical/thermal insulation in addition to many other properties.

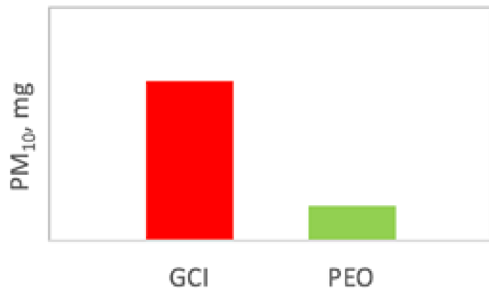

Fig.5. Decrease in PM_{10} emissions by 78% for PEO-Al compared to GCI (Courtesy: Fabian Limmer PhD work at the University of Leeds).

i Dizdar S. et al: 'Grey Cast Iron Brake Discs Laser Cladded with Nickel-Tungsten Carbide - Friction, Wear and Airborne Wear Particle Emission', Atmosphere 2020, 11, 621; doi:10.3390/atmos11060621.
ii UK DEFRA and DTI, 'The costs of reducing PM10 and NO2 emissions and concentrations in the UK.'
iii Maher et al, 'Magnetite-pollution-nanoparticles in the human brain', 2016.
iv Pankhurst et al, 'Increased-levels-of-magnetic-iron-compounds-in-Alzheimer's disease. J. of Alzheimers Disease 13(1), p.49-52, 2008.
v Kirschvink et al., 'Magnetite bio-mineralization in the human brain. Proc. Natl. Acad Sci. USA 89 (16), 1992, p.7683—7687.
vi COMEAP Report, 2010. ISBN 978-0-85951-685-3.

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