**////Title: Investigating Thermal Spraying Methods for Preventing Maritime Corrosion**

**////Standfirst:**

Every year, the combined effects of corrosion and wear cause a huge amount of damage to coastal and offshore machinery, incurring huge costs for repair and maintenance. While there are various types of coating that offer protection from wear and corrosion, the way in which that they are applied can massively impact their effectiveness. Dr Tai-Cheng Chen and his team at the Institute of Nuclear Energy Research, Taiwan, have been analysing these methods, in order to determine the best way to protect maritime infrastructure.

**////Main text:**

In many industries that are based around the coast and at offshore sites, corrosion from seawater can cause significant issues. It can damage both stationary and moving parts of machinery, leading to huge maintenance costs later down the line. While certain alloys, such as stainless steel, offer some resistance to corrosion, they are not immune to corrosion from seawater. Therefore, other methods are required to provide these materials with the defence they need to resist corrosion.

In addition, many moving components with machinery, such as valves, gears and bearings, are vulnerable to the effects of wear over time. The combined effects of wear and corrosion are therefore a serious issue for coastal and offshore machinery.

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A common solution to this problem is simply to spray vulnerable components with a protective coating. This provides the base material with an extra level of defence, helping it to remain operational for a longer period. There are various types of coatings available, ranging from synthetic polymers to metal-based materials.

Metal-based coatings are usually applied using a technique called thermal spraying. In this process, the solid metal is fed into the system – usually as powders or wires – and is quickly heated to a molten state. The molten metal is then sprayed onto the base material, and cools to form a protective layer. This provides the base material with an extra level of protection, significantly lengthening its lifespan.

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However, this process isn’t without its limitations. While applying a suitable coating can massively increase the lifespan of steel and other materials, the degree of protection can vary significantly. One of the biggest factors at play is the way in which the coating is sprayed, as this can sometimes lead to oxides, pores and cracks in the final product. These defects can reduce the protection offered by the coating, and ultimately lead to corrosion occurring down the line.

Therefore, it is important that research is conducted to understand the factors affecting the quality of the coating, and how these factors ultimately affect the ability of the coating to withstand corrosion and wear. Dr Tai-Cheng Chen and his team at the Institute of Nuclear Energy Research, Taiwan, have been investigating this phenomenon using a very interesting material known as Inconel-625 [**in**-kuh-nell six twenty-five].

Inconel-625 is a nickel-based alloy, which can be applied as a coating to protect metals such as stainless steel. While previous research demonstrates that Inconel-625 offers very good protection against corrosion and wear, the team wanted to determine the best method of applying it.

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Dr Chen and his colleagues decided to investigate four different methods of thermally spraying Inconel-625 onto stainless steel, and to assess the quality of the coatings produced using each of the four techniques. The first was flame spraying, where the coating is melted and atomised by a hot oxygen flame. They then tested arc spraying, where the coating is melted by the energy released in an electrical arc. The third method they explored was plasma spraying, where the material is melted by a plasma of an unreactive gas, such as nitrogen, helium or argon.

Finally, the team investigated high-velocity oxygen-fuel spraying, where a mixture of fuel and oxygen is first fed into a sprayer, where it is ignited. The burning gas mixture has immense pressure, and can therefore be ejected through a nozzle at an extremely high speed. A powdered form of the coating material can then be injected into the high-speed gas stream, where it fully melts. Then, the stream of gas and powder is aimed at the base material, where it is deposited to form a protective layer.

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Dr Chen and his colleagues used each method to apply Inconel-625 to several stainless-steel samples, and examined the quality of each coating using electron microscopy. This allowed the researchers to obtain detailed images of each sample, through which they were able to see all defects created during spraying.

The team found that the sample that was coated using flame and arc spraying contained significant oxide layers, cracks and pores on a microscopic scale, leading to a lower quality coating layer. The sample treated with plasma spraying had fewer oxide layers and thinner cracks within the coating, but still had a relatively high porosity. Out of all the methods, the high-velocity oxygen-fuel spraying technique produced the best finish, with the fewest oxide layers, cracks and the lowest porosity.

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Dr Chen then decided to analyse the corrosion-wear resistance provided by the four spraying methods. His team did this by abrading each sample using a wear apparatus. In each case, they tested the samples while under deionised water, or in salty water, to properly simulate the effects of corrosion caused by the sea.

Interestingly, the sample treated with high-velocity oxygen-fuel spraying, which had the highest hardness value, had lower overall corrosion-wear resistance than the other three samples. Dr Chen explains that, in the other cases, a protective oxide layer is formed within the coating, especially when high temperatures and oxygen are involved in spraying. When high-velocity oxygen-fuel spraying is used, the particles move so fast that there is less time for an oxide layer to form. The lack of an oxide layer ultimately gives the coating less wear resistance.

This is a significant breakthrough, as oxide layers are typically considered to be undesirable in this context. However, Dr Chen’s results clearly show that the presence of an oxide layer greatly enhances the ability of the coating to withstand corrosion and wear.

In addition, the samples that were abraded while under salty water actually suffered less wear than those abraded under deionised water. This was another surprising finding, as it is generally accepted that the corrosion-wear resistance of materials is worse in salty water compared to pure water. However, the results of the team’s study suggest that the presence of chloride in the salt solution lubricates the wear apparatus, reducing the amount of corrosion and wear.

Through their intriguing discoveries, the team has paved the way for further research, which will lead to the more effective use of Inconel-625, as well as other types of protective coating.

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Dr Chen and his team have collected impressive data that clearly show the effects of different methods of applying Inconel-625 as a protective coating. By establishing a clear link between the spraying method and the final coating performance, the team has paved the way for further research, which will ultimately help to reduce damage to coastal and offshore infrastructure.

This SciPod is a summary of the paper ‘A comparative study on the tribological behavior of various thermally

sprayed Inconel 625 coatings in a saline solution and deionized water’ from *Surface and Coatings Technology.* [doi.org/10.1016/j.surfcoat.2020.125442](https://doi.org/10.1016/j.surfcoat.2020.125442)