# Technical Bulletin

Tungsten Carbide – Chromium Carbide – Nickel

# Cobalt-free option with excellent wear and oxidation resistance

## Introduction

Carbide powders containing both Tungsten Carbide and Chromium Carbide effectively bridge the performance gap between WC-based powders on one hand and CrC-NiCr powders on the other. HVOF- or HVAF-sprayed, WC-CrC-Ni coatings achieve similar hardness and wear resistance as WC-Co coatings in many conditions. Moreover, they are more oxidation-resistant and thermally stable up to 750 °C depending on application conditions. In terms of corrosion performance, WC-CrC-Ni coatings exhibit properties comparable to those of WC 10Co 4Cr coatings.

HVOF-sprayed coatings of WC-CrC-Ni are widely used in Oil & Gas applications where parts are exposed to both wear and corrosion. Mud motor rotors (MMR), along with ball and gate valves, compressor shafts, pump parts, and various other oil field equipment, are typical applications for these coatings. Given their superior thermal stability and oxidation resistance, these coatings also find applications on parts exposed to elevated temperatures, including furnace rolls and other process rolls in steel production.

As both the powder and coatings are Cobalt-free, WC-CrC-Ni emerges as a healthier and more environmentally friendly alternative to materials containing Cobalt.

## Powder Properties and Typical Applications

Höganäs' carbide portfolio encompasses various grades of agglomerated & sintered WC-CrC-Ni powders with different binder contents and carbide sizes (Figure 1).

Dense coatings from WC 20CrC 7Ni (**Amperit 551** and **Amperit 555**) are the right choice for applications requiring excellent wear resistance, along with good corrosion and oxidation resistance, even at elevated temperatures up to 750 °C. HVOF and HVAF are recommended processes to achieve the best coating quality (Figure 2).

WC-CrC-Ni coatings offer excellent cavitation protection. Given its coarser WC and adjusted particle morphology, **Amperit 555** can achieve higher deposition efficiency and produce denser coatings when sprayed with kerosene-fueled HVOF systems.

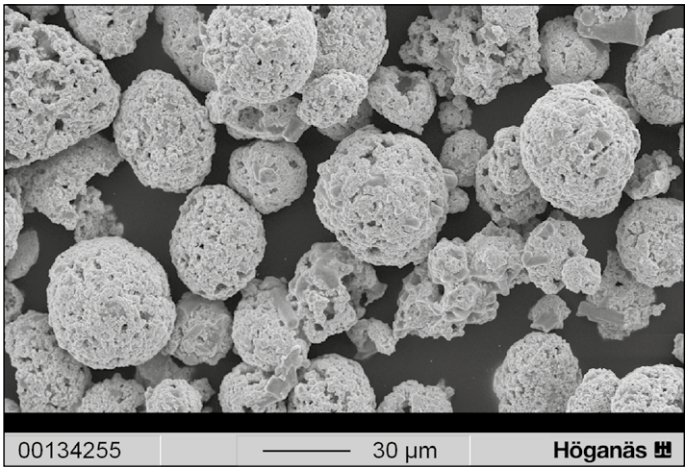
With its higher binder content, **Amperit 543** coatings are extremely dense and more ductile compared to other WC-based materials. The Young's modulus of less than 250 GPa aligns well with the characteristics of most steel substrates. The lower WC content and remarkably high deposition efficiency of 55% in kerosene-fueled HVOF make **Amperit 543** a cost-effective alternative to galvanic hard chrome overlays. Particularly suitable for applications like hydraulic cylinders or piston rods, it offers excellent corrosion resistance, coating ductility, and good wear resistance.

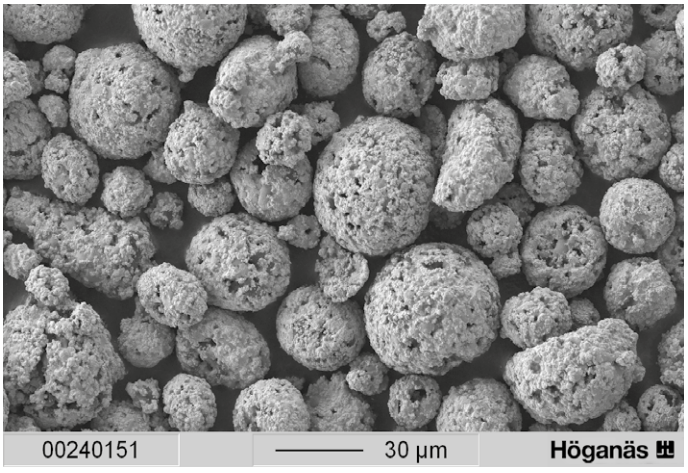
## Corrosion Performance

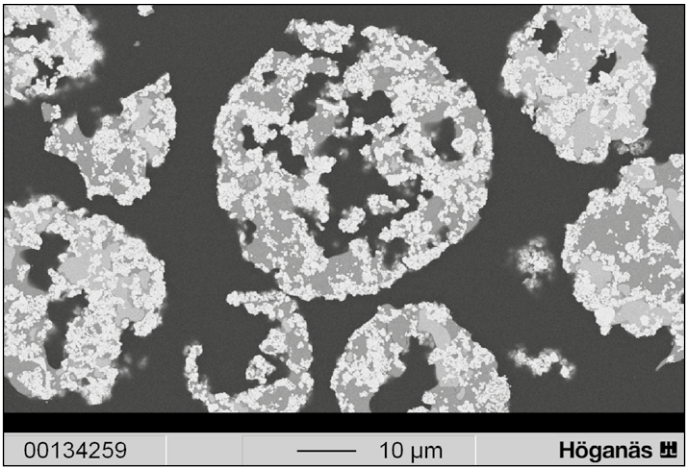
The corrosion behavior of coatings depends not only on the environment but also on factors such as coating quality, microstructure, phase composition, and substrate material, all of which significantly influence corrosion performance. Carbide coatings generally demonstrate excellent corrosion resistance against neutral and moderately alkali aqueous media. In acidic conditions, the metallic matrix may undergo corrosive attack, facilitated by a contact corrosion cell formed between the carbide and the matrix.

At room temperature, dense and crack-free HVOF/HVAF-sprayed coatings of Amperit 551, 555, 543 provide excellent corrosion protection in environments containing NaCl. Additionally, in various alkali and aqueous acidic environments (such as 1 M NaOH, 0.5 M citric acid, 0.5 M $H_2SO_4$), relatively good corrosion resistance can be achieved under ideal conditions. However, like other carbide coatings, the use in HCl-containing environments is critical and needs to be evaluated on a case-by-case basis.

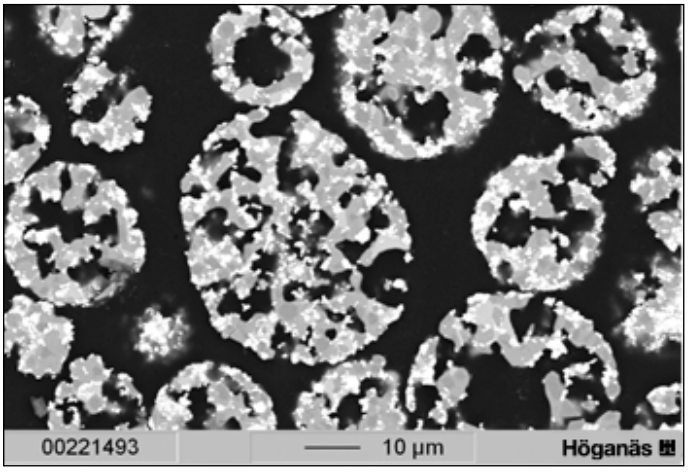
## Figure1: Typical Powder Morphology



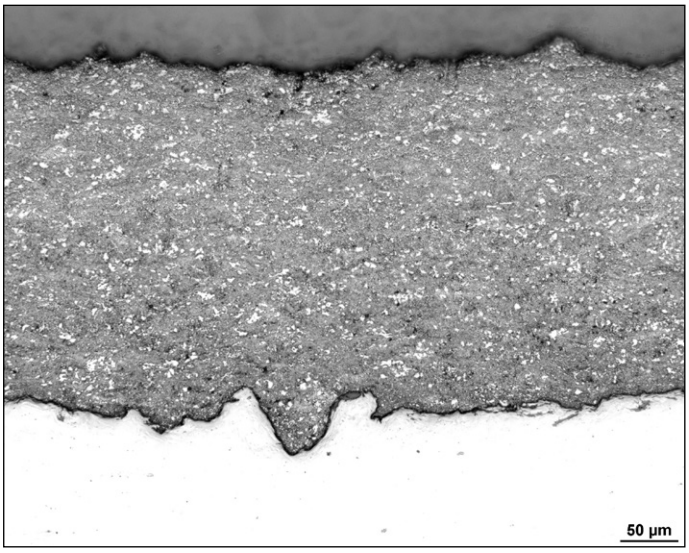




**Amperit 551.074**
Agglomerated & Sintered, WC 20CrC 7Ni

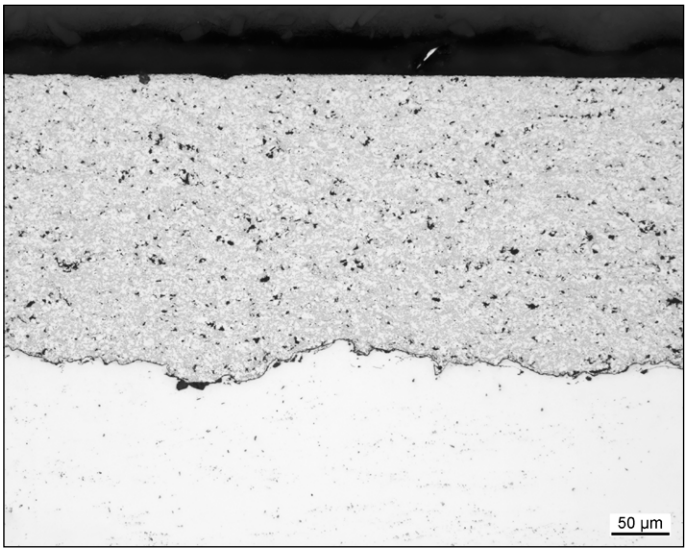



**Amperit 543.074**
Agglomerated & Sintered, WC 42CrC 16Ni

## Figure 2: Microstructures (LOM) of Typical Coatings




**Amperit 551.074**
Sprayed with liquid-fueled HVOF, etched cross-section




**Amperit 543.074**
Sprayed with liquid-fueled HVOF, unetched cross-section

## Typical Properties of HVOF- and HVAF-Sprayed Coatings

HVOF/HVAF-sprayed coatings of **Amperit 551** and **Amperit 555** typically outperform most other thermal spray coatings in terms of hardness, general wear resistance, as well as bond strength and other mechanical properties.

| Typical Properties of HVOF- and HVAF-Sprayed Coatings | | |
|---|---|---|
| Deposition Efficiency: | 30–60 % | |
| Roughness as-sprayed, Ra: | 3.0–7.0 µm,<br>3.0 µm or below achievable, using fine powders such as 30/5 µm | |
| Bond Strength (on steel): | > 70 MPa | |
| Hardness HV0.3: | **Amperit 551, Amperit 555,** | 1100–1400 |
| | **Amperit 543** | 900–1250 |
| Wear (ASTM G65, mod): | **Amperit 551, Amperit 555,** | < 3 $mm^3$ |
| | **Amperit 543** | < 4 $mm^3$ |

**Typical data. For more details, please contact us at: www.hoganas.com/en/contact/*

## Table 1: Overview of Höganäs' WC-CrC-Ni Portfolio

| Amperit | Particle Size (µm) | Carbide Size | APS | HVOF | HVAF | Special Features and Typical Applications |
|---|---|---|---|---|---|---|
| **WC 42CrC 16Ni, Agglomerated & Sintered:** | | | | | | |
| **543.059** | 30/5 | Fine WC / Medium $Cr_3C_2$ | | X | X | • Higher oxidation and corrosion resistance than pure WC-Ni or WC-Co coatings<br>• Very dense coatings with very good stress tolerance and ductility and excellent high cavitation resistance<br>• Young's modulus of the coatings adjusted to match that of common steels<br>• Significantly higher deposition efficiency especially in kerosene-fueled HVOF makes the 543 products an economical alternative to WC-CoCr for selected applications, e.g., hard chrome replacement for hydraulic cylinders and piston rods<br>• Oil & Gas: mud motor rotors, pumps, and valve parts |
| **543.074** | 45/15 | | | X | | |
| **WC 20CrC 7Ni, Agglomerated & Sintered:** | | | | | | |
| **551.059** | 30/5 | Fine WC / Medium $Cr_3C_2$ | | X | X | • Higher oxidation and corrosion resistance than pure WC-Ni or WC-Co based coatings<br>• Smooth coatings with fine microstructure and high bond strength<br>• Oil & Gas:mud motor rotors, valve parts, seals, ball and gate valves<br>• Steel: furnace rolls, deflector, and other process rolls<br>• Paper: calander and dryer rolls |
| **551.074** | 45/15 | | | X | | |
| **551.088** | 53/20 | | X | X | | |
| **555.074** | 45/15 | Medium WC / Medium $Cr_3C_2$ | | X | | • Higher oxidation and corrosion resistance than pure WC-Ni or WC-Co coatings<br>• Coarser WC than Amperit 551 and adjusted particle morphology for improved coating density and deposition efficiency with kerosene-fueled HVOF<br>• Applications see Amperit 551 |

## Related Products

- For better abrasive wear protection, materials with only WC hard phase are recommended. The service temperature of these materials is limited to 450 °C. WC with a CoCr metal matrix material provide significantly better corrosion protection compared to WC-Co coatings. However, hardness and wear resistance of WC-Co coatings are in most cases higher. WC-Co-Cr products include Amperit 507, 554, 556, 557, and 558.
- $Cr_3C_2$ 20(Ni 20Cr) and $Cr_3C_2$ 25(Ni 20Cr), such as Amperit 578, 584, and 585, are recommended for applications at service temperatures up to 870 °C. Additionally, they offer better corrosion protection in saline, sulphuric, or alkaline environments.
- Amperit 538.074 (WC 30WB 10Co) is designed for special applications such as Zn-bath equipment or other scenarios involving contact with liquid metal.
- Nickel self-fluxing alloys with the addition of hard phases are widely used for hard facing applications. The coatings are mainly applied by flame spraying with a subsequent fusing treatment.
- Nickel self-fluxing alloys applied by HVOF can reach hardness levels of 400–600 HV0.3 and are suitable for moderate wear applications, offering good corrosion protection.
- Iron-based alloys, such as 3.50 and 3650-02, can be applied by HVOF, providing moderate wear protection and good corrosion resistance at hardness values in the range of 400–600 HV0.3.

## Handling and Safety Recommendations

- Store in dry location.
- Open containers should be stored in a drying oven to prevent moisture pickup.
- Tumble powder prior to use to prevent segregation.
- For information related to health, safety and the environment, please refer to the respective Safety Data Sheets.

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