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Anti-pick-up Coatings for furnace rolls in CALs & CGLs

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Design of anti-pick-up coatings

The design of pick-up resistant coating solutions were outlined according to the different pick-up type and the formation mechanism at low and high temperatures :

- **At low temperatures: mechanical bonding and sintering of Fe particles** induced by coating's surface roughness and by metal friction due to the presence of a metallic binder in cermet coatings. → **Coatings for cooling & overageing sections.**
- **At high temperatures: Chemical interaction** of MnO/SiO_2 (from steels) due to the presence of Cr_2O_3 / Al_2O_3 (from coatings) forming sticky spinels. → **Coatings for heating & soaking sections.**
- For both applications, **hardness** must be improved for avoiding **wear defects**.

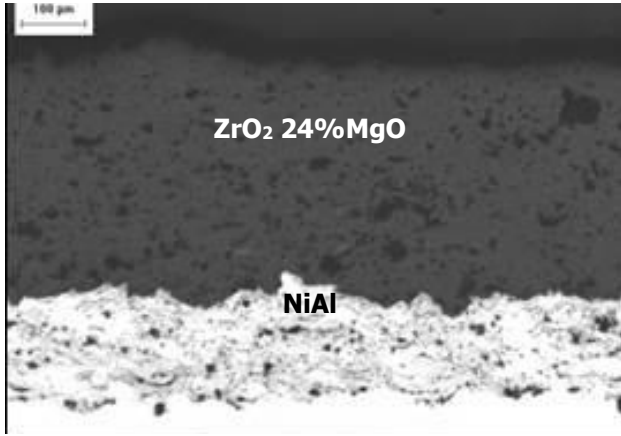
Roll coatings for low temperature applications

- Chemical interactions between rolls and strip oxides are not an issue: kinetics is too slow at temperatures < 500°C;
- Mechanical interactions occur: coating's surface roughness should be as low as possible;
- Sintering between Fe debris and the metal binder in the coating can occur making Fe pick-ups very adherent: the amount of metal in the coating must be limited.

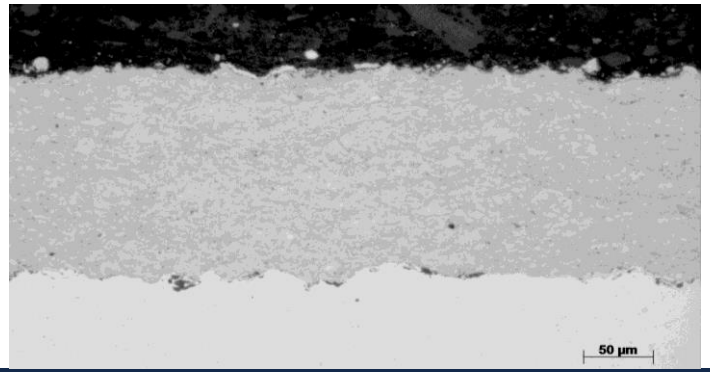
Coatings must be smooth, dense, with no or lowest possible metal and characterized by a high hardness.

Roll coatings for low temperature applications

- WC-CrC-Ni (73%-20%-7%) cermet coating has a low metal binder.
- Cermet coatings deposited by High Velocity Air Fuel (HVAF) instead of High Velocity Oxygen Fuel (HVOF). **HVAF** can form a more uniform and finer dispersion of ceramics in a denser metallic matrix → higher hardness
- Ceramic oxide coatings with bond coats, i.e. ZrO_2–MgO coating



Measurement	Value
Thickness (µm)	170
Porosity (%)	0,35
Oxides (%)	0,2
Microhardness (HV 0.3)	1200

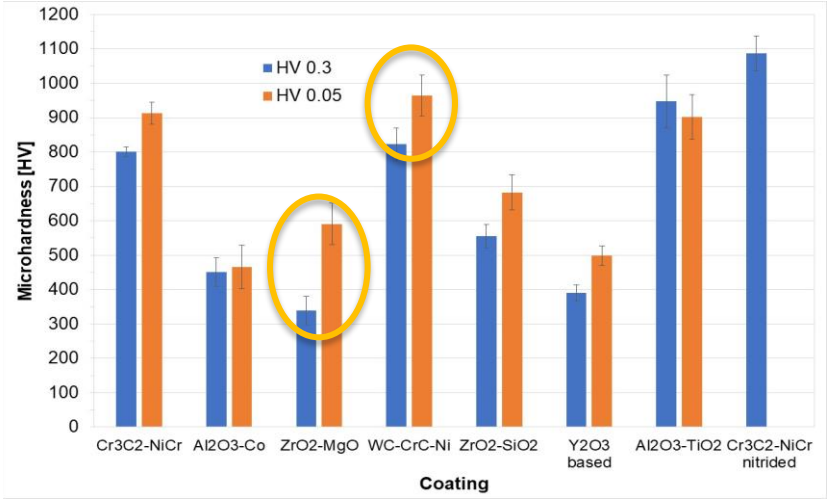


	substrate	Bond-coat	Top coat
	AISI 304	NiAl	zirconia
CTE	$17x10^{-6}$ °C^{-1}	$13x10^{-6}$ °C^{-1}	11-13x 10^{-6} °C^{-1}

Roll coatings for low temperature applications

Coating type	Powder Composition
Cermet	Cr_3C_2 in NiCr *
	Al_2O_3 in Co (Cr, Al, Ni, Nb) *
	WC-CrC-Ni
	plasma nitrided Cr_3C_2 - NiCr
Ceramic	ZrO_2-MgO
	ZrO_2-SiO_2
	Al_2O_3 TiO_2
	Y_2O_3 based

* reference coatings



- ZrO2-MgO coating has a low hardness this behaviour rules out its application.
- The WC-CrC-Ni **cermet coating** deposited by HVAF having only 7% Ni and appropriate hardness appears to have the best characteristics. Moreover, it has a Co free metallic matrix that complies with the latest REACH regulations.

Roll coatings for high temperature applications

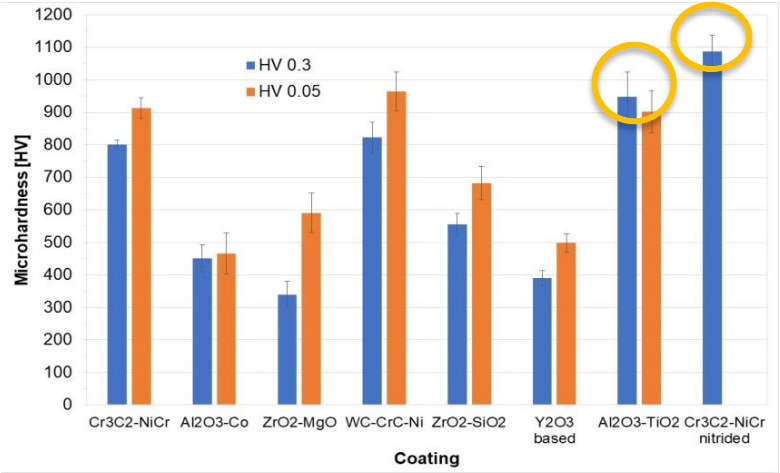
- Reactions between roll's surface oxides and strip oxides occur: to avoid the formation of sticky spinels, cermets with a metal binder containing mainly Ni and/or Co should be preferred.
- Cr and Nb (metallic or carbides) in the cermet coatings partly react in the typical annealing atmosphere (5-7% H_2/N_2, DP< -30°C) and are transformed into nitrides: it is suggested to directly incorporate in the coating stable nitrides by a controlled nitriding process aiming to transform partially Cr and CrC into CrN hard phases.
- ZrO_2 and other stable oxide coatings (i.e., Al_2O_3, Y_2O_3) have shown not to react with the selective oxidation layer on steels.

Roll coatings for high temperature applications

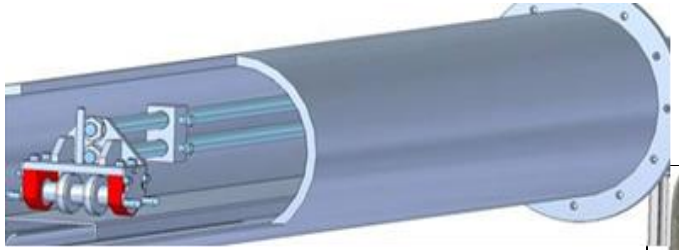
- **Cr_3C_2 - NiCr cermet coatings** submitted to a post-deposition **plasma nitriding** process in N_2 atmosphere for 24 h at 550°C for surface hardening.
- **Hard ceramic oxide coatings** with an alloy bond coat include, ZrO_2+(MgO or Y_2O_3), ZrO_2-SiO_2, Y_2O_3-based and Al_2O_3-TiO_2 coatings by plasma spraying with an innovative Water Plasma Torch (WPT).

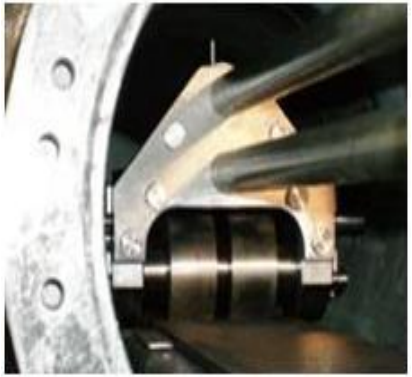
Coating type	Powder Composition
Cermet	Cr_3C_2 in NiCr *
	Al_2O_3 in Co (Cr, Al, Ni, Nb) *
	WC-CrC-Ni
	plasma nitrided Cr_3C_2 - NiCr
Ceramic	ZrO_2-MgO
	ZrO_2-SiO_2
	Al_2O_3 TiO_2
	Y_2O_3 based

* reference coatings



Dynamic interaction testing at high temperatures





Dynamic interaction test rig for simulating HSS strip / roll coating interactions at 900°C under controlled annealing atmosphere: 5%H_2/N_2; Dew Point -30°C

Cr_3C_2-NiCr	Al_2O_3–Co matrix	WC-CrC-Ni	Nitride Cr_3C_2-NiCr	ZrO2-MgO
				

- Cr_3C_2-NiCr and Al_2O_3–Co coatings form small randomly distributed pick-ups,
- nitride Cr_3C_2-NiCr, WC-CrC-Ni and ZrO_2-MgO coatings have few or no pick-ups
- Considerable powdering of the ceramic roll is due to its lower hardness, this behaviour rules out its application

NoStickRolls Project : rolls for testing

The coatings that appeared to have the aimed-for characteristics and hardness were selected for **laboratory tribological testing sequence** with the aim of identifying:

- the best ones for soaking zone application to be tested under **semi-industrial conditions** at the Roll Strip Interaction test bench
- the best one to coat rolls for **industrial trials** in the overageing zones in CAL & CGL.

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