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25-29 Ottobre 2021

2ª Settimana
22-26 Novembre 2021

Steel / Roll reactivity during continuous annealing

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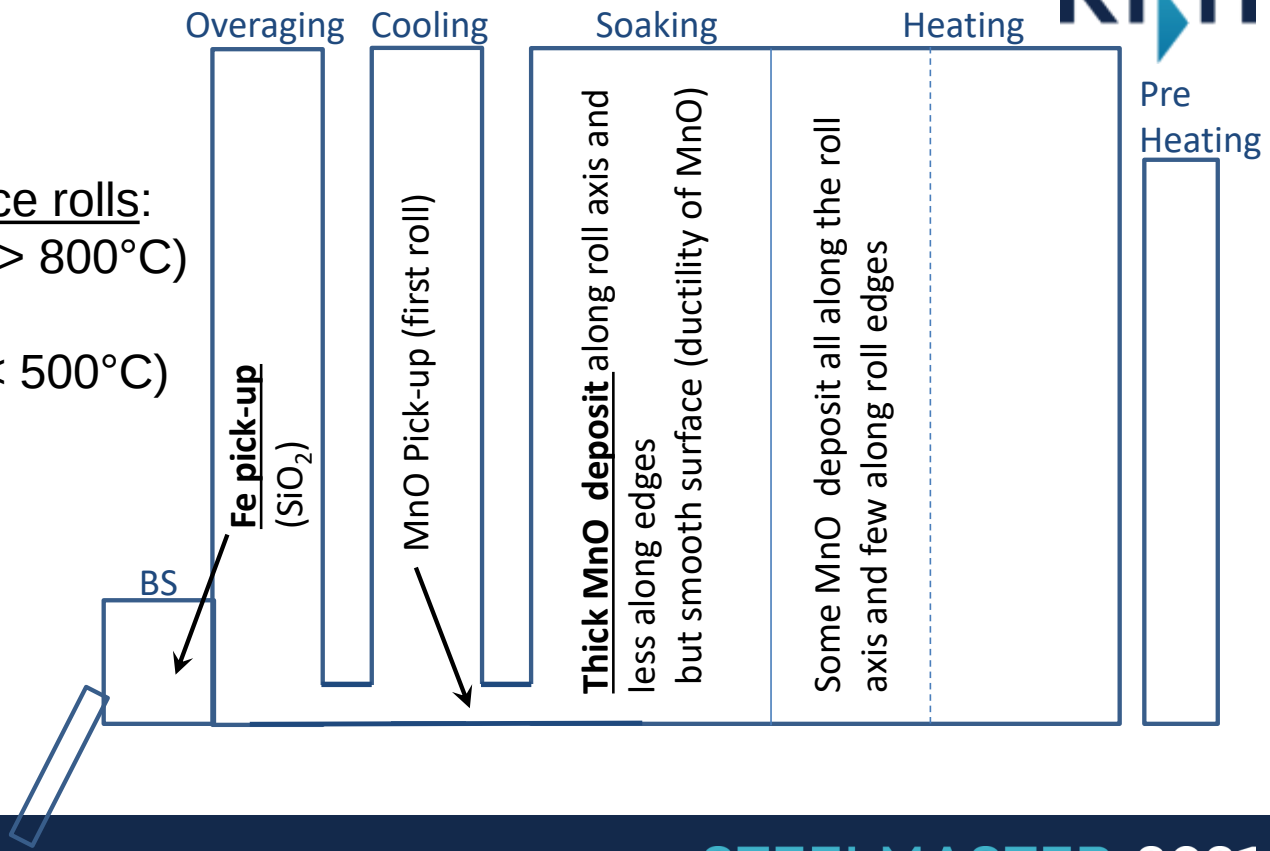
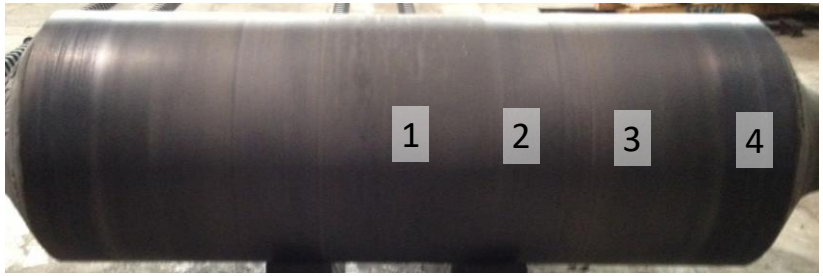
Introduction

2 main pick-up on furnace rolls:

- At high temperature (> 800°C)
  → Mn oxide
- At low temperature (< 500°C)
  → Fe fines (SiO_2)

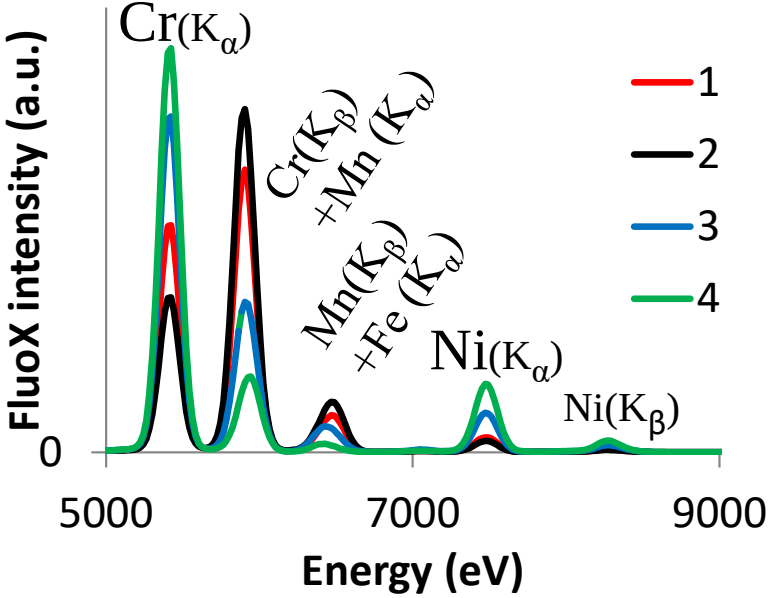


Introduction



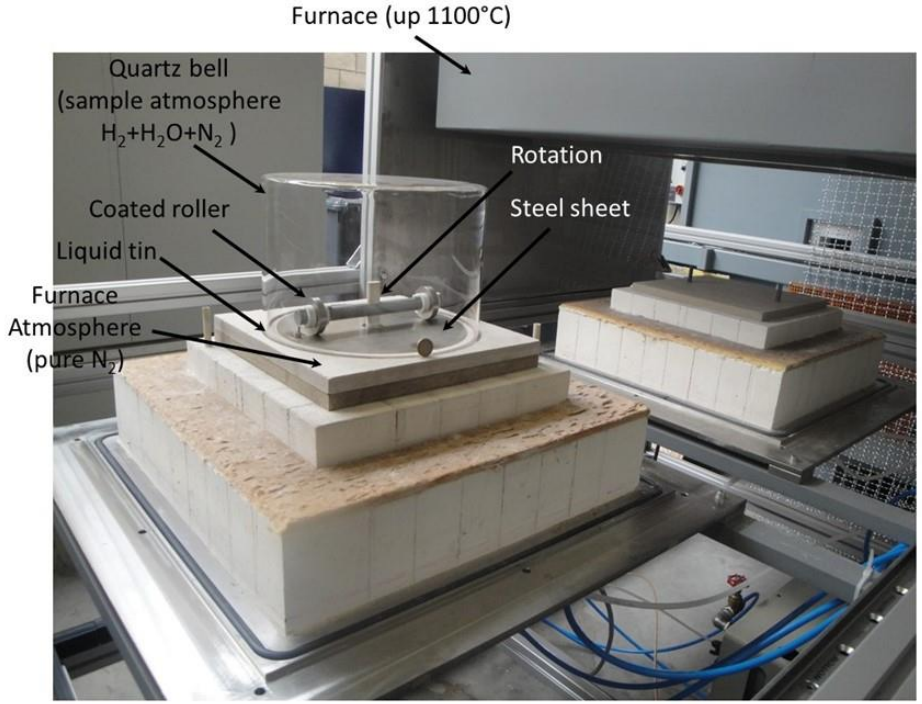
Example of pick-up measured by X-ray fluorescence on an industrial roll located in the soaking area

(Cr carbides / Ni coating)



Experimental procedure

Identification of roll-steel interaction by laboratory static and cyclic tests



Roll coating simulator: friction of a coated roll on a steel sheet in controlled atmosphere

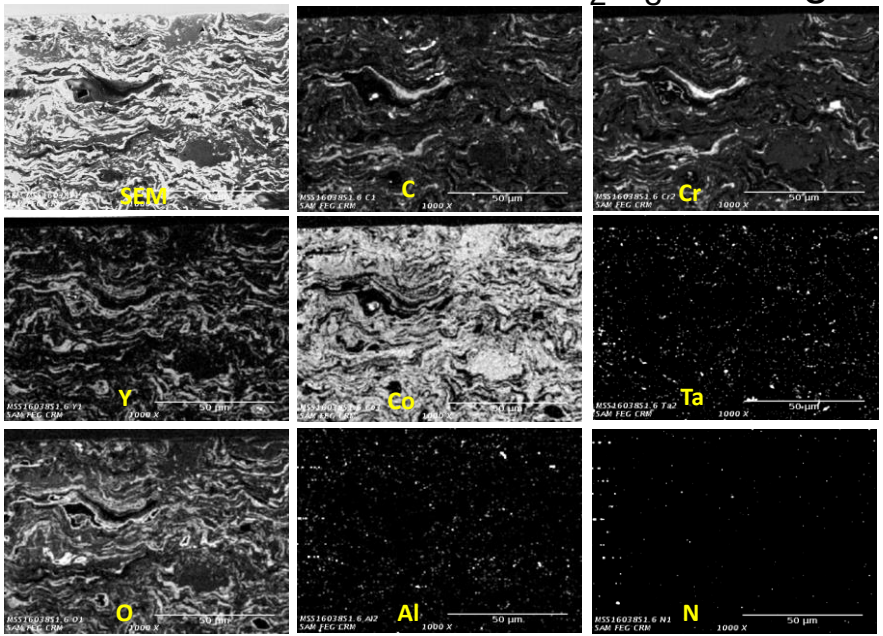
Reactivity and pick-up at high temperature

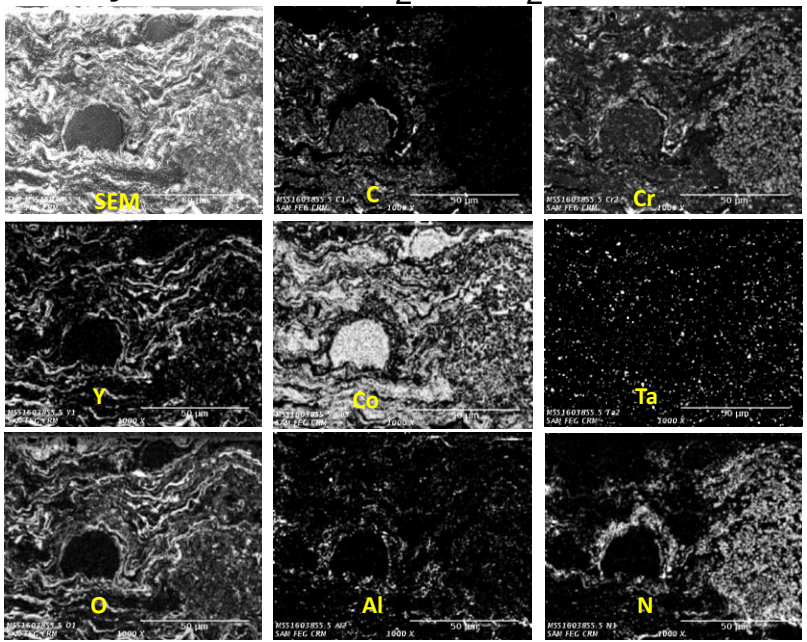
Gas – coating reactivity at high temperature

As received CoAlCrTa-Y_2O_3 coating

6days – 920°C-N_2 5%H_2 / DP-30°C

Mapping close to the top surface



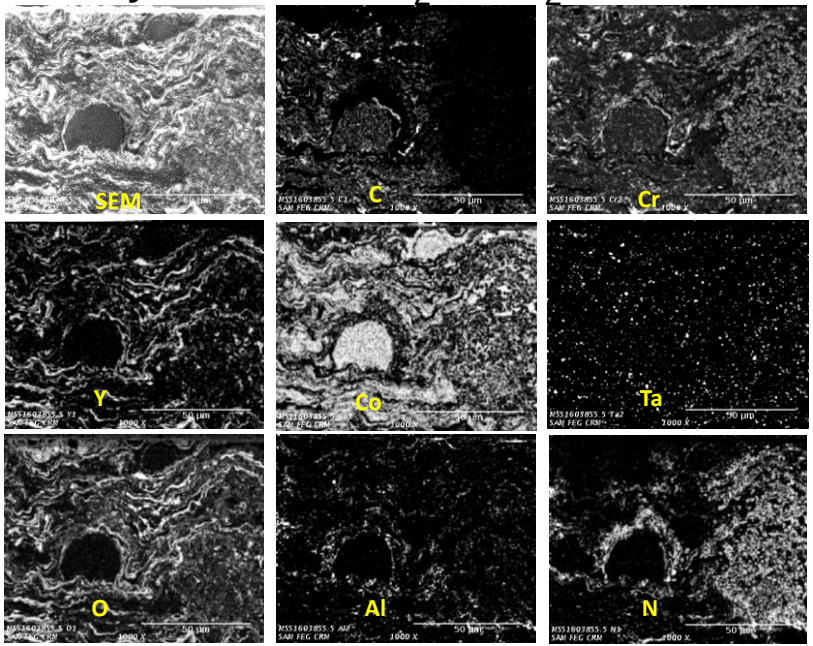


$CrCx+N_2 \rightarrow CrNx + C$ and $C+H_2O \rightarrow CO+H_2$

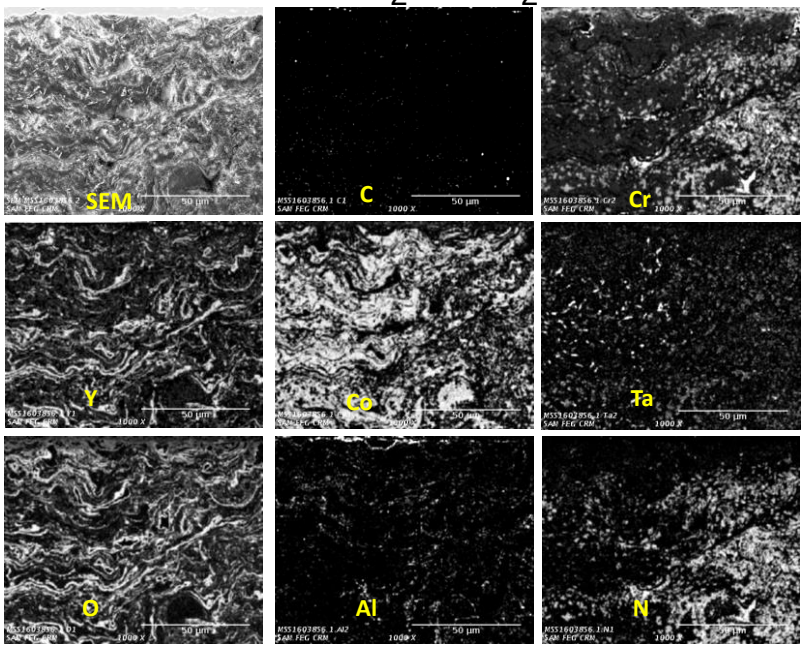
Reactivity at high temperature

Auger mapping on cross section

6days – 920°C-N_2 5%H_2 / DP-30°C



1month – 920°C-N_2 5%H_2 / DP-30°C

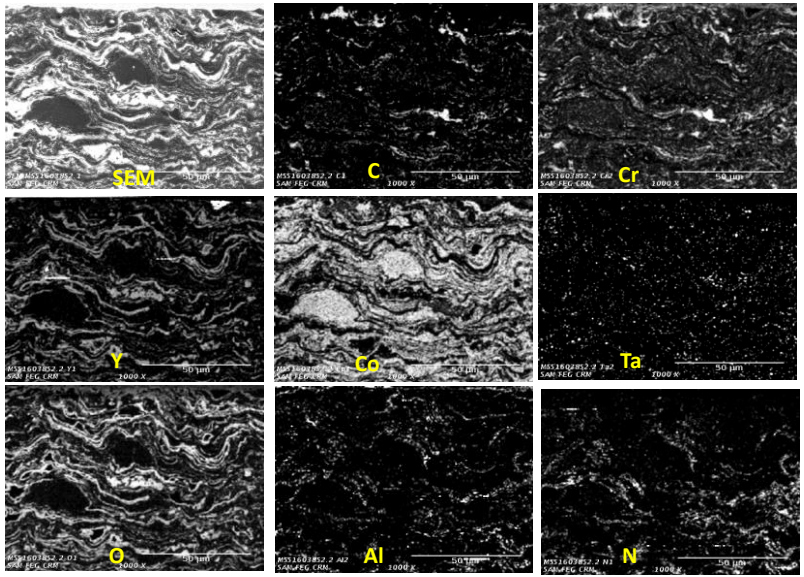


Complete decarburizing after heating 1 month in classical furnace atmosphere

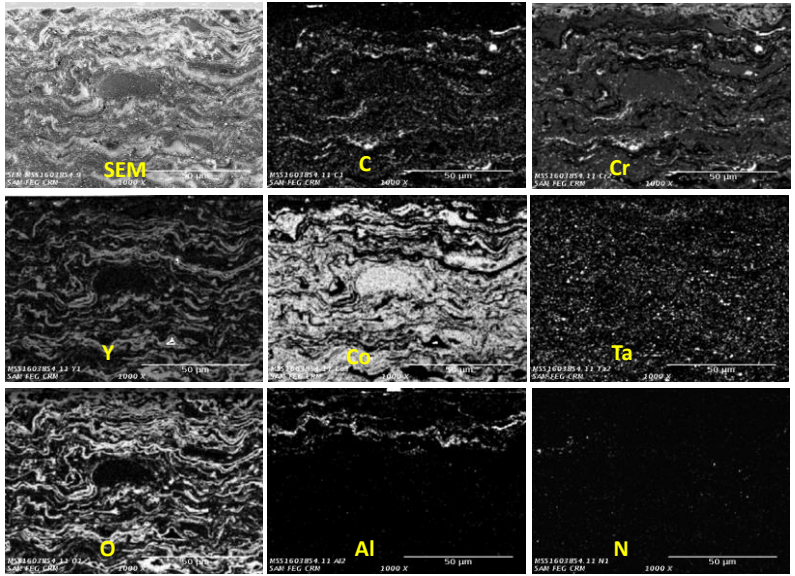
Reactivity at high temperature

Auger mapping on cross section

6days – 920°C- $\underline{N_2}$ 5%H_2 / DP0°C



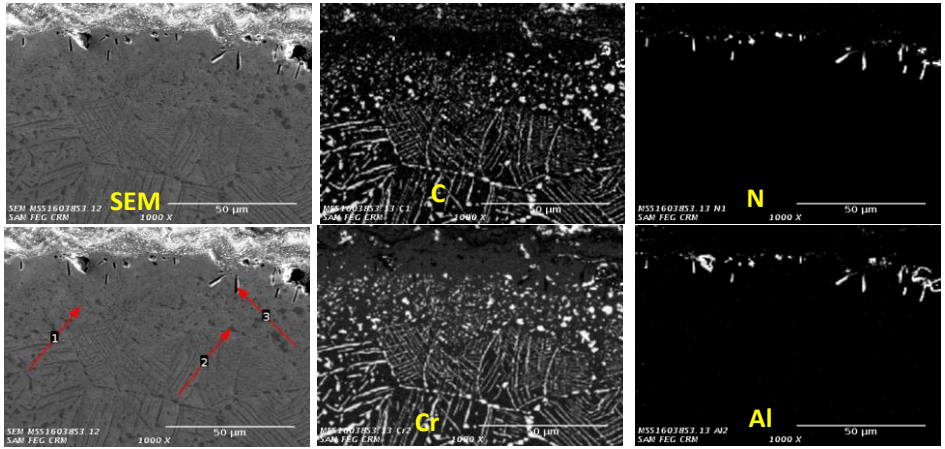
6days – 920°C- $\underline{Ar}$ 5%H_2 / DP0°C



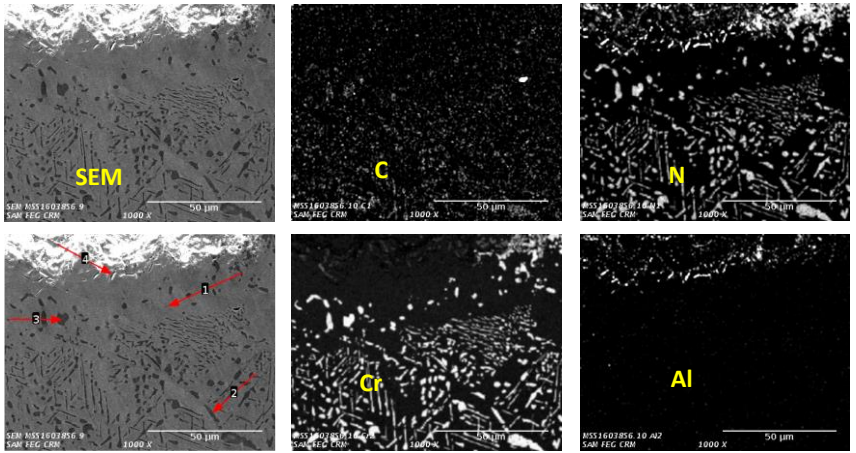
Lower nitriding at DP 0°C and No nitriding after annealing in Ar atmosphere

Reactivity at high temperature at the stainless steel / coating interface

6days – 920°C- Ar 5%H_2 / DP0°C

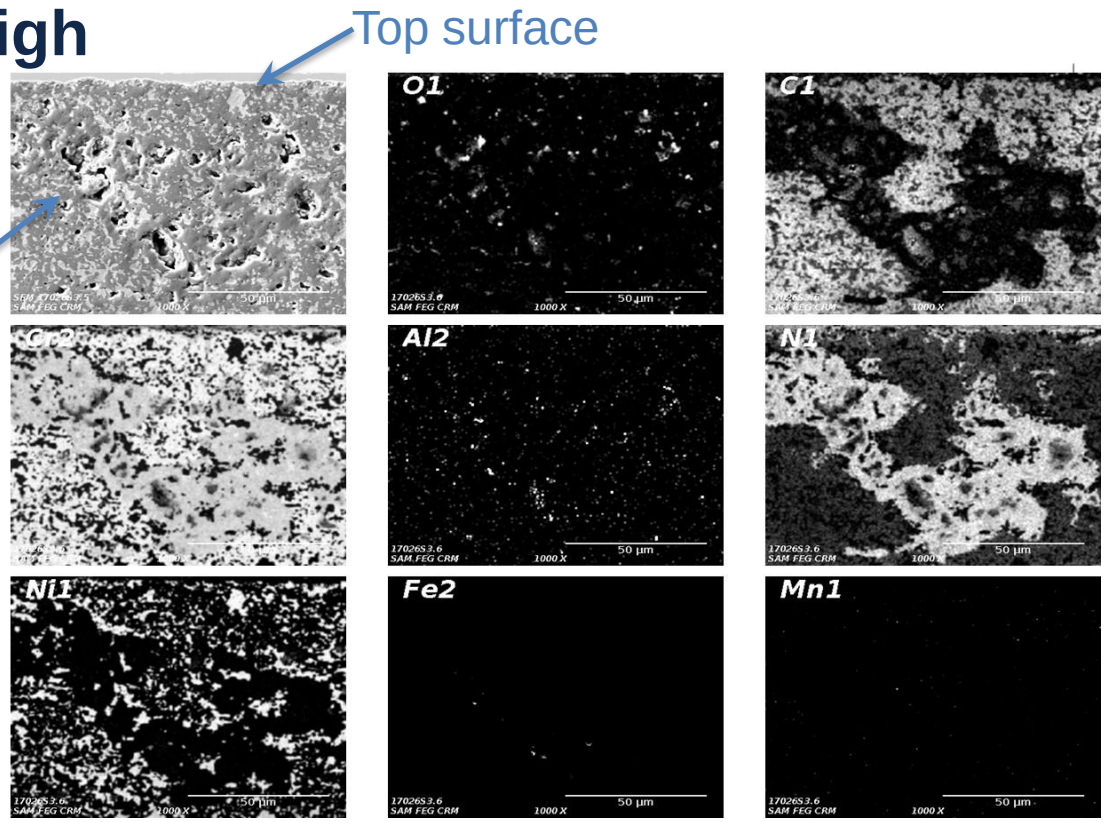


1month – 920°C-N_2 5%H_2 / DP-30°C



Stainless steel nitriding under the coating after annealing in N_2 atmosphere

Reactivity at high temperature

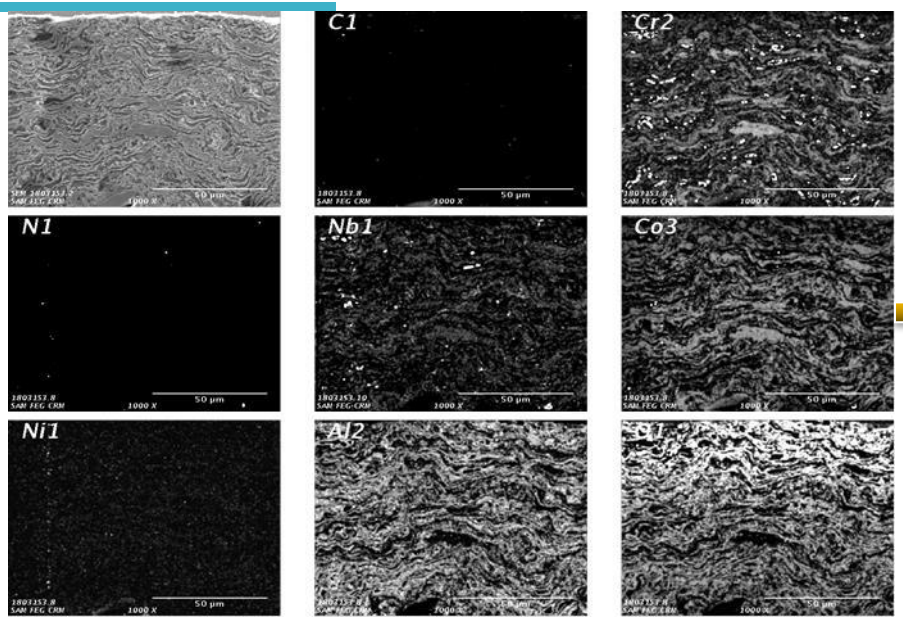


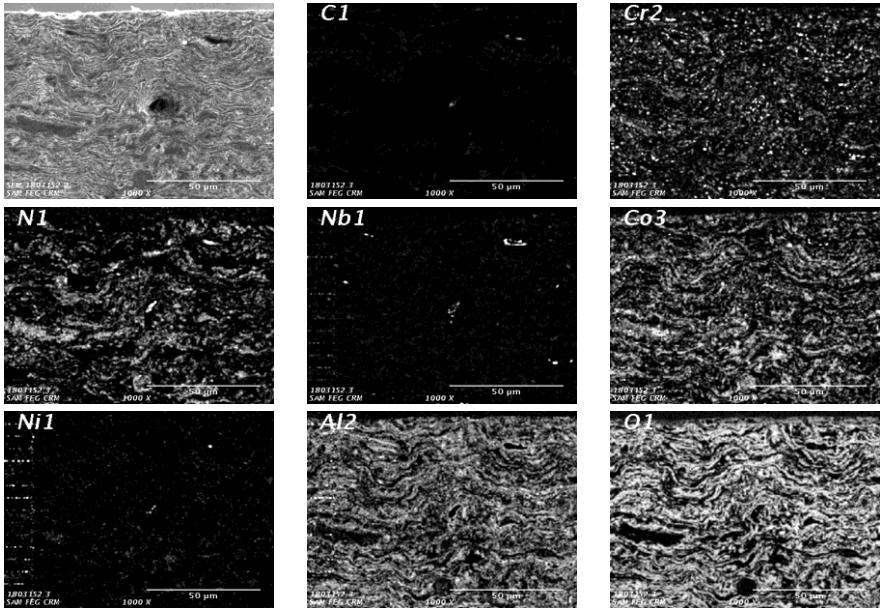
Auger mapping: cross section of a Cr carbide / Ni coating after 10 days at 870°C in N_2/5%H_2/DP-30°C: preferential nitriding along coating porosities

Cr nitriding

Before annealing

After annealing

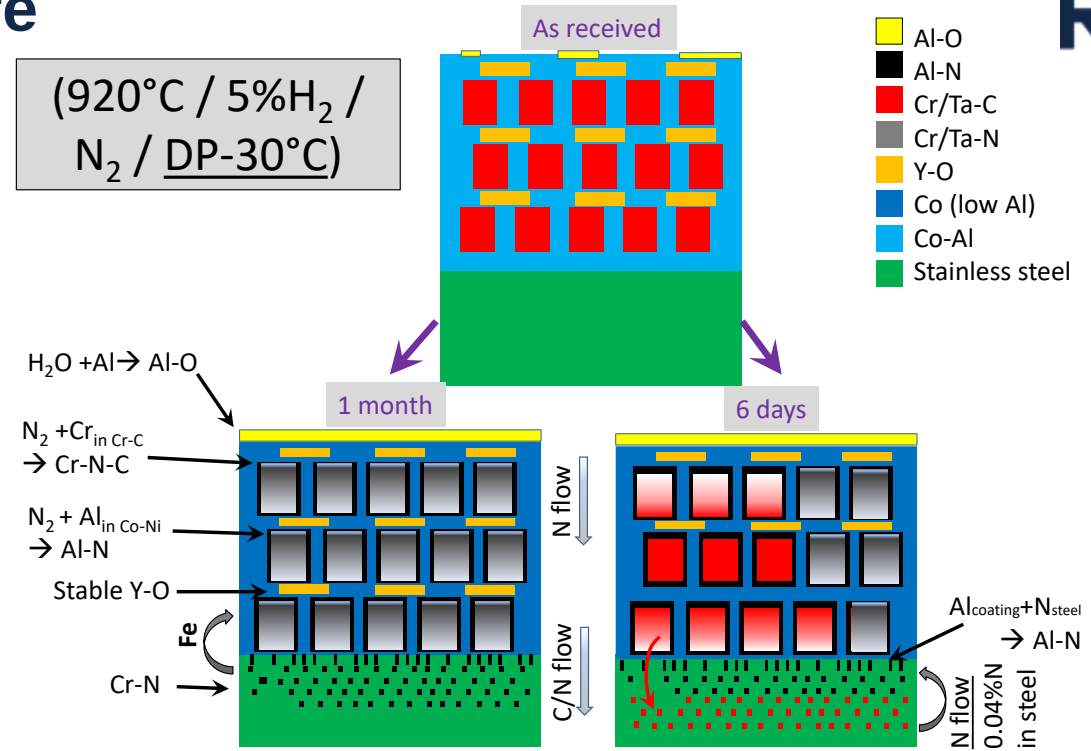




Auger mapping on the cross section of the Al_2O_3 in a Co (Cr, Al, Ni, Nb) coating after ageing during 7 days at 800°C in 1%H_2/DP-30°C atmosphere → Nitrided coating

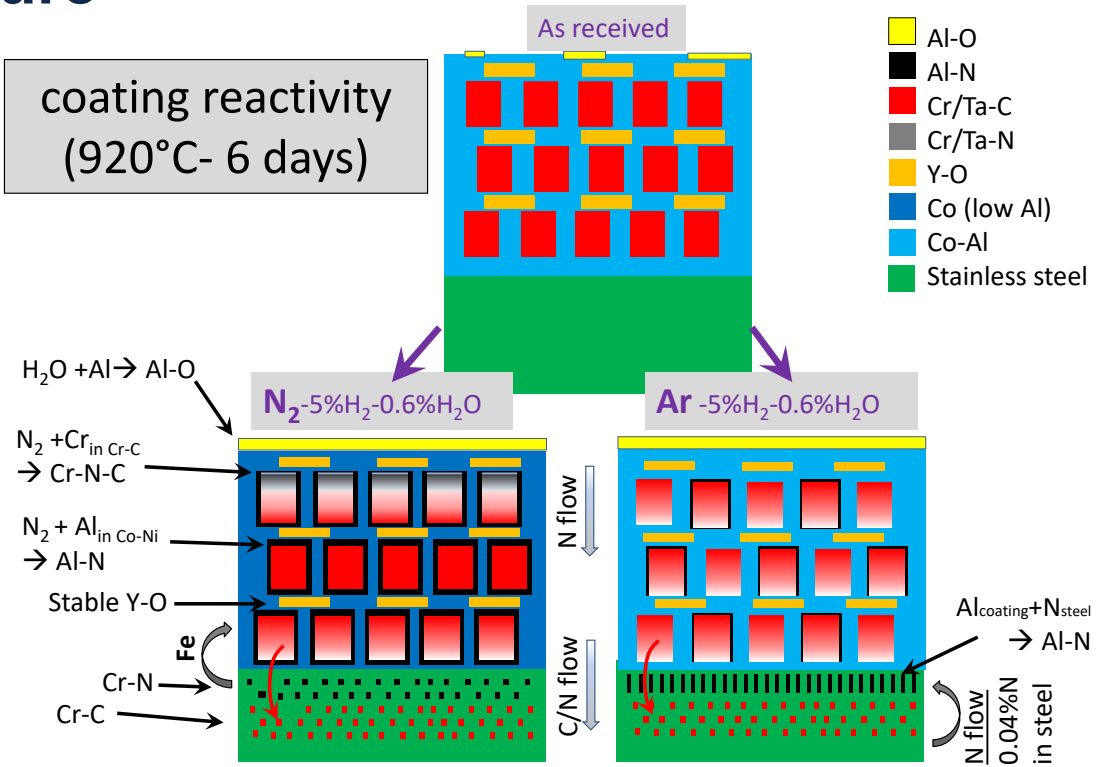
Conclusion for the reactivity at high temperature

(920°C / 5%H_2 / N_2 / DP-30°C)

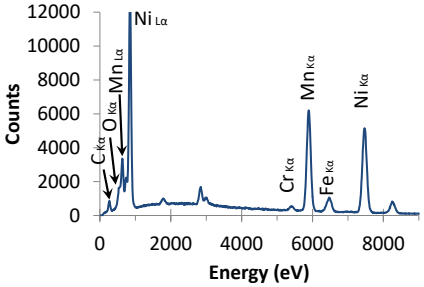


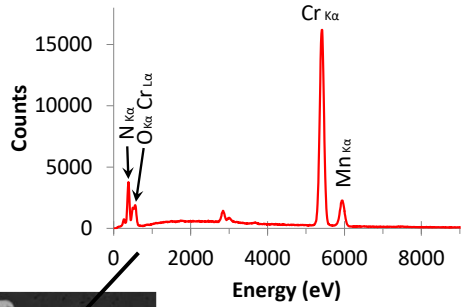
Conclusion for the reactivity at high temperature

coating reactivity (920°C- 6 days)

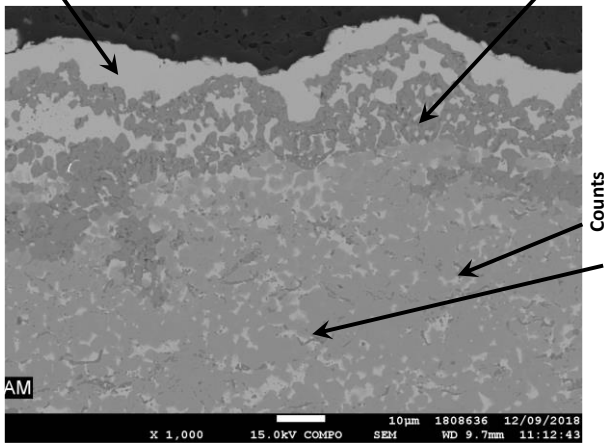


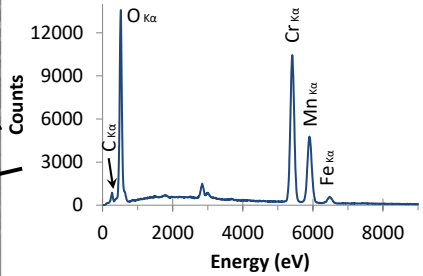
Reactivity at 900°C





SEM-EDX analyses after interaction (no friction) at 900°C of a TWIP steel with a coating made of Cr carbide in Ni (Cr) without any friction (4 days/900°C/5%H_2/DP-30°C).



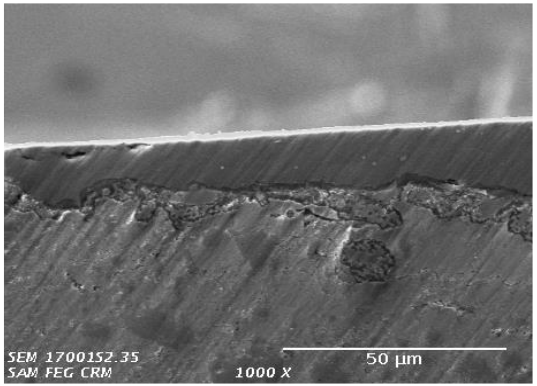


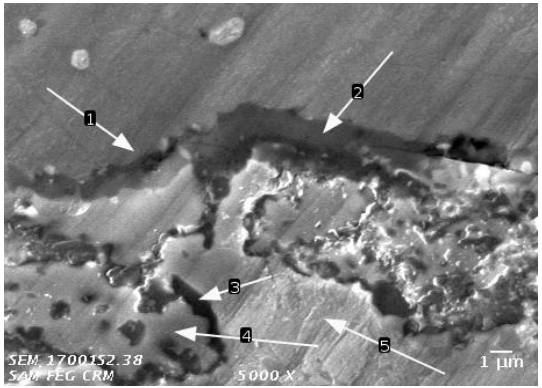
SEM cross section indicates:

- Nitriding + Mn diffusion inside the Ni binder + MnCr oxides

Pick-up at 920°C

After 6 days of friction on a TWIP steel on a CrC/Ni(CrAl) coating
920°C / N_2-5H_2 / DP-30°C





Atomic Concentration Table %

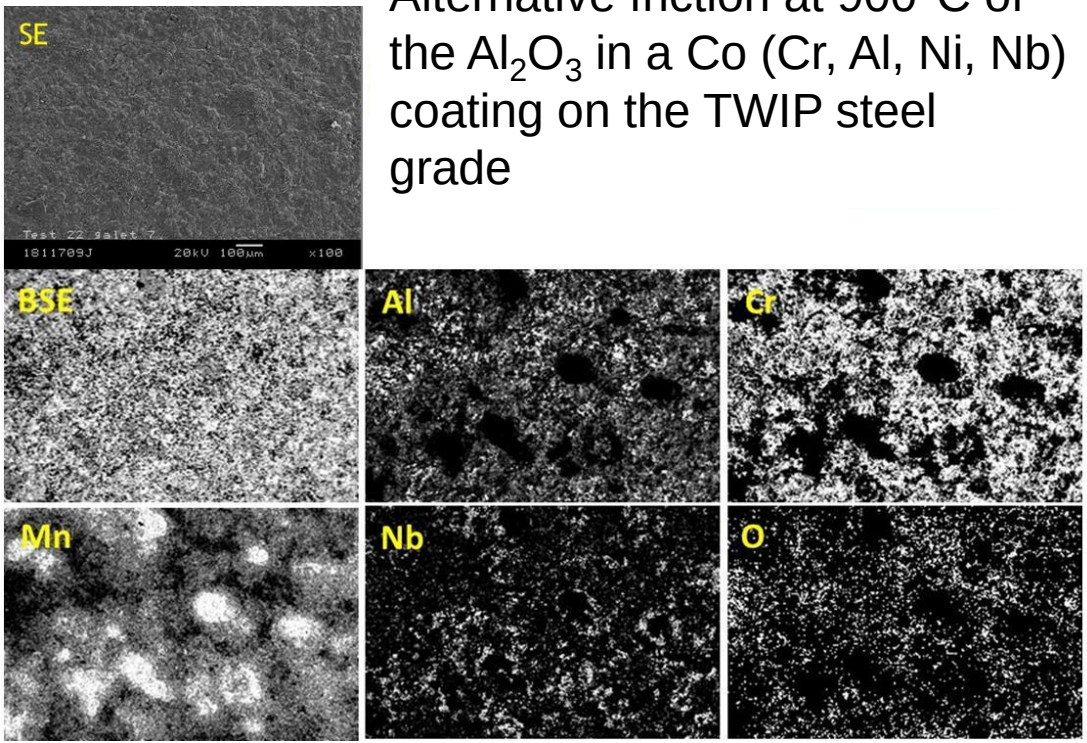
area	C c-carbu	N	O1	Al	Cr	Mn	Ni
1	-	-	50.0	-	-	50.0	-
2	-	-	47.4	52.7	-	-	-
3	-	40.2	-	59.8	-	-	-
4	19.5	-	-	-	80.5	-	-
5	-	-	-	17.7	7.2	-	75.1

Auger Cross section along a MnO embedding after the friction test.

→ Sticking without strong reactivity of the MnO selective oxidation with the Al oxide of the coating

→ The MnO follow the coating topography, which indicates a significant ductility/ reactivity

Pick-up at 900°C



Alternative friction at 900°C of the Al_2O_3 in a Co (Cr, Al, Ni, Nb) coating on the TWIP steel grade

SEM top view after the friction of the Al_2O_3 in a Co (Cr, Al, Ni, Nb) coating with the TWIP steel grade

Conclusion for the pick-up at high temperature

- Thick MnO pick-up is noticed on the roll coating.
- This peak-up however induces the formation of a smooth layer, probably due to the high ductility of the MnO at high temperature
- The adhesion of this oxide seems to be important due to the presence of a Cr_2O_3/ Al_2O_3 layer on the furnace roll. These oxides are formed by the selective oxidation of the Cr/Al contained in the Ni/Co binder.
- Mn from the TWIP steel (23%Mn) diffuses inside the Co/Ni binder of the coating.

Pick-up at 500°C

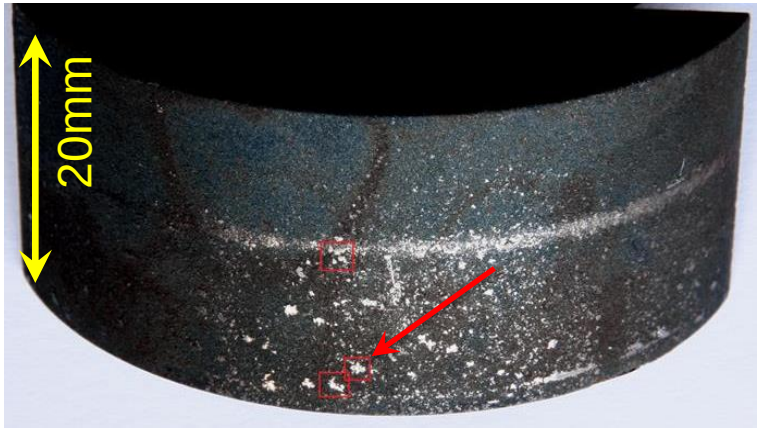
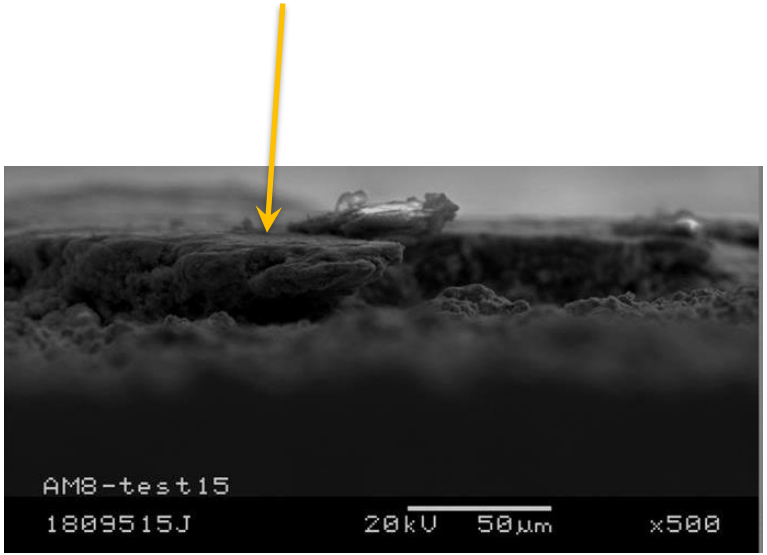
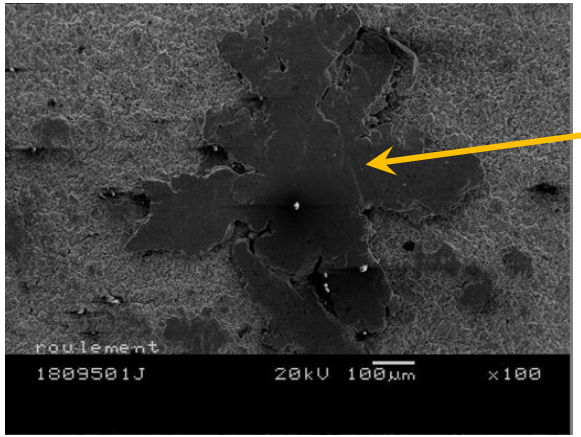


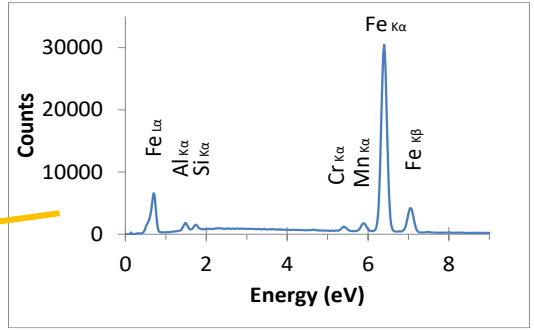
Photo of the roll with Cr_3C_2 / NiCr coating showing pick-up after 3 days of friction of a HSS at constant temperature (500°C) in N_2/3%H_2/DP-30°C atmosphere

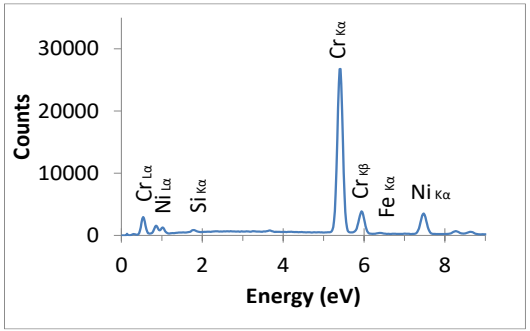
SEM lateral view of a pick-up



Pick-up at 500°C

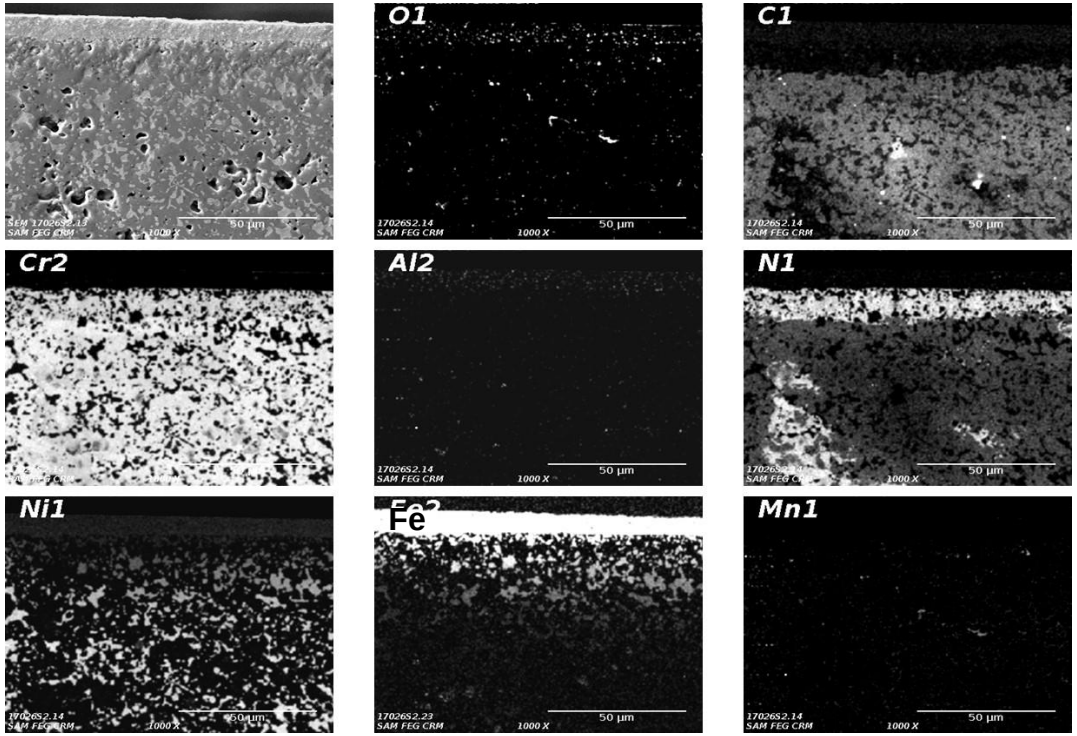






Top view of metallic iron pick-up identified by SEM-EDX

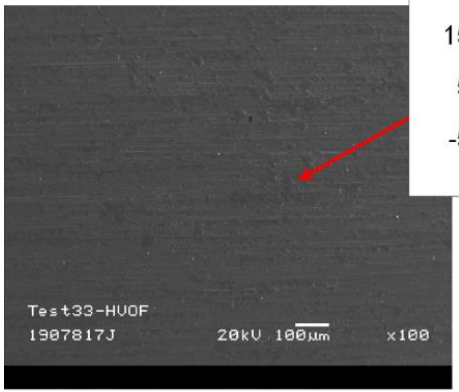
Pick-up at 500°C

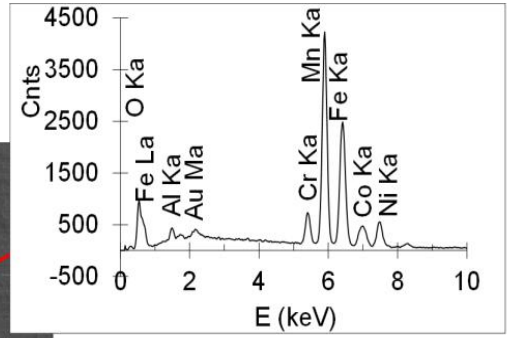


Auger mapping: cross section of the Cr carbide / Ni coating after 6 days at 920°C in N2/5%H2/DP-30°C with cyclic friction on a HSS at 500°C

Pick-up at 500°C

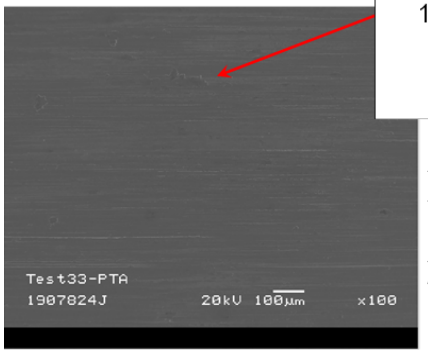
CoCrAlY-Al_2O_3 coating

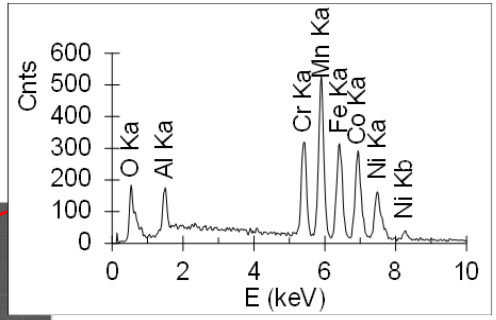




Steel: TWIP (23%Mn)
Coating: As received HVOF (Rina-CSM)
→ Axis position
Continuous friction:
4 days/500°C/2.5%H_2/DP-30°C

CoNiCrAlY coating





Steel: TWIP (23%Mn)
Coating: As received PTA (Rina-CSM)
→ Axis position
Continuous friction:
4 days/500°C/2.5%H_2/DP-30°C

Possibility to also have Mn oxide pick-up with pre-oxidized TWIP steels, but the amount is very limited on smooth roll surfaces

Conclusion

At low temperature (<500°C)

- Iron pick-up on furnace rolls is mainly observed during the process of high strength steel
- This iron pick-up is made of iron fines, which can sinter with the Ni/Co of the furnace rolls coating and make a strong adhesion.
- A smooth coating surface significantly reduces iron pick-up.
- Mn / Si oxides pick-up can also be noticed, but on very high alloyed steel grades (TWIP or electrical steels). Their adhesion is also weaker because no sintering occurs between this pick-up and the roll coating.

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