

# Tribological characterisation of NiP and NiP/TALC layers

M.-T. POPESCU<sup>a,b</sup>, A.-G. PLĂIAȘU<sup>b\*</sup>, M. ABRUDEANU<sup>b</sup>, N. POPA<sup>b</sup>, R.-N. DOBRESCU<sup>b</sup>, J. DENAPE<sup>c</sup>, M. M. DICU<sup>b</sup>

<sup>a</sup>Registrul Auto Român, DN 65B, Bradu, 117140, Pitești, Romania

<sup>b</sup>University of Pitești, Targu din Vale, No 1, 110040, Pitești, Romania

<sup>c</sup>ENI Tarbes, Azereix, no. 4, BP 1629 - 65016 Tarbes CEDEX, France

Increasingly, parts of the mechanical systems demand complex properties like: friction, abrasion, corrosion, shock resistance, local heating. In this context, industrial strategy aims to improve the performance and extend the life of mechanical systems by applying thermal and thermochemical treatments, including coatings with metallic materials (such as hard chroming) or composite (such as NiP layer), resistant to friction. These can be applied by electrochemical or electromagnetic field (PCM process). In this paper one attempts to analyze the behavior of the friction in air for NiP and the composite layer(NiP/talc) at room temperature.

(Received January 15, 2013; accepted June 13, 2013)

**Keywords:** Wear resistance, Friction, Layers, Composite, Talc

## 1. Introduction

To increase the reliability of parts in friction and life of equipment, engineers propose various solutions for optimizing the design, choice of materials, processing surfaces and lubrication. Challenge to security and economy cars often pass prior validation testing before integrating new solutions into the system, especially in transport and energy production. Choosing a representative tribological test method for real systems is an essential step for the success of the overall project. Due to their excellent properties, such as corrosion and wear resistance, low friction and environmental approachability, the amorphous and nanocrystalline Ni–P alloys have been extensively engaged by the industries [1,2]. High hardness and high wear resistance at ambient-to-moderate temperatures make the electrodeposited Ni–P alloys a good candidate for replacing pure nickel as a protective coating on copper for continuous casting of steel. The electrodeposition process of Ni–P alloys has been extensively studied, especially for deposits having high phosphorus content and also the tribological characterization was developed for the future applications.[2-4]. In our paper the challenges were to analyze the comportment of the friction in air for NiP and the composite layer(NiP/talc) at room temperature.

## 2. Materials and experimental methods

Spectral analysis of selected steels as the substrate (36NiCrMo16, EN 10025) revealed the following chemical composition: 0.33% C, 0.30% Si, 0.40% Mn, 1.75% Cr, 0.45% Mo; 4.00% Ni and Fe as balance. Pawn used to wear the attempts made by rubbing dry layer is

fabricated of alloy tool steel (100Cr6) with the following chemical composition, determined also by spectral analysis: 1.1% C, 0.214% Mn, 0.225% Si; 1.484% Cr, 0.025% Mo. To have a resistance to wear by friction as possible, pawn was heat treated (quenching + low return, the final structure is martensite of return).

Wear resistance of the composite layer deposited was determined by dry friction wear tests at room temperature.

Attempts to wear under dry friction were performed on samples with a standard rotating disk, brought into contact with a flat pion (Figure 1) alloy steel 100Cr6, under constant stress: normal force applied the pawn is  $F_n = 100$  N, the disc rotating at a speed of 1.5 m / s during each test: 3 hours (180 min).

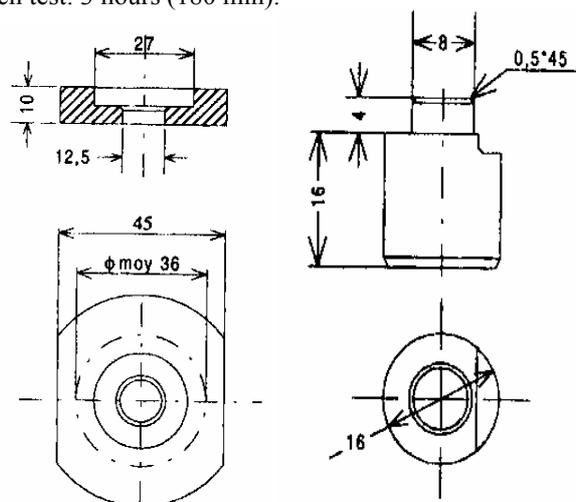


Fig. 1. Sample ring (a) and pion (b) used in dry friction tests on samples coated with NiP composite with and without talc

In the tests carried out were determined: volume of material lost through friction, friction coefficient, friction slope roughness, chemical composition of the areas affected by tribological tests. For this work, dry friction wear tests at various temperatures and with various speeds of rotation were conducted on environmental tribometer LGP. These are the type tribometer pawn - disc.

The microscopic images were obtained with a scanning electron microscope and chemical compositions were analyzed by EDX method.

### 3. Results and discussions

Wear tests were carried out at ambient temperature only analyzing the changes produced by this type of request (dry friction), in terms of deposits morphologies and chemical composition, depending on the absence or presence of talc in the composite layer. The microscopies are analyzed in correspondence with spectrometric tests.

In the case of NiP coated samples (without talc), chemical deposition of NiP is always present in the wear track in a layer thick enough not to see the iron in the substrate, which layer is slightly worn. There is an exfoliation inside edge of the track (Fig. 2).

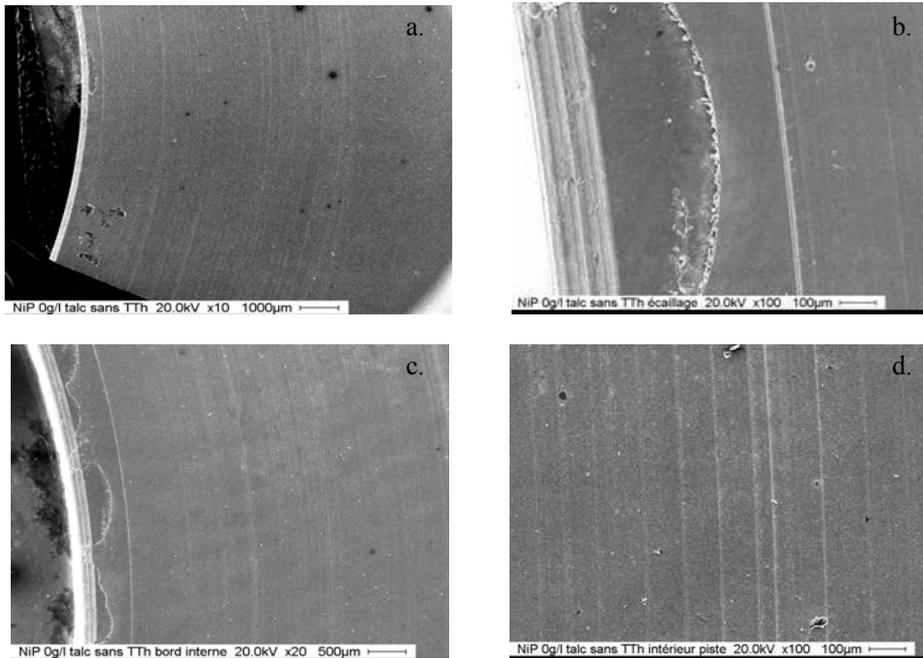


Fig. 2. Runway friction test with NiP layer: a - general view; b - degradation inner edge (magnification 100 ×); c - inner edge of the track (magnification 20 ×); d - track friction (magnification: 100 x)

Spectrometric analysis of Fig. 3 shows the occurrence indeed wear iron content is high, in fact, appears 36NiCrMo16 chromium from the substrate, but this is

unique because the deposition of NiP reappears immediately.

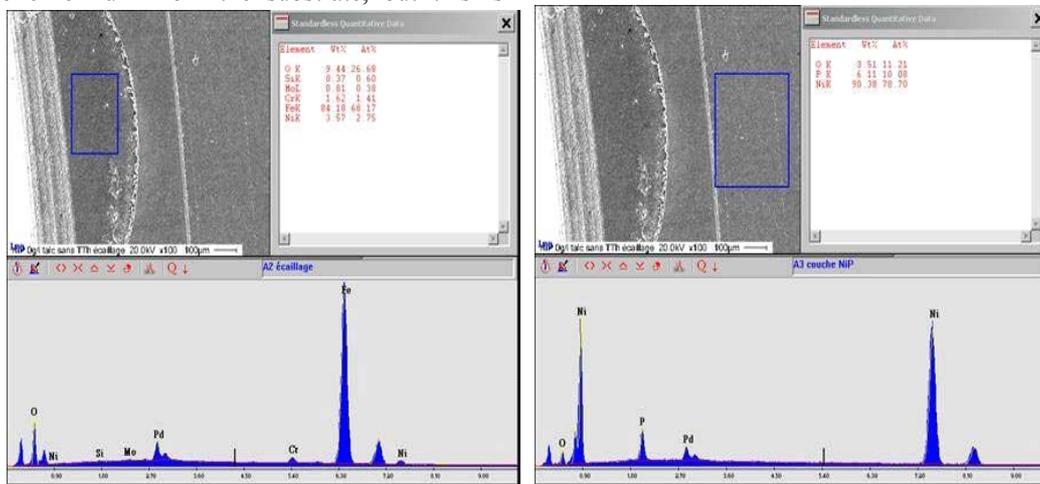


Fig. 3. Spectrometric analysis of samples with NiP layer: top - an area outside the friction track, bottom - a frictional area inside track.

For samples coated composite NiP + 40 g / l talc, exfoliation is observed on the inner edge of the runway friction (Fig. 4). Spectrometric analysis shows that this place was completely destroyed layer (worn). Depreciation

is stronger than the evidence NiP layer 0g / l talc, areas alternating with areas looking polished surfaces. Chemical analysis (Fig. 5) indicates significant presence of iron, which expresses an advanced wear layer composite.

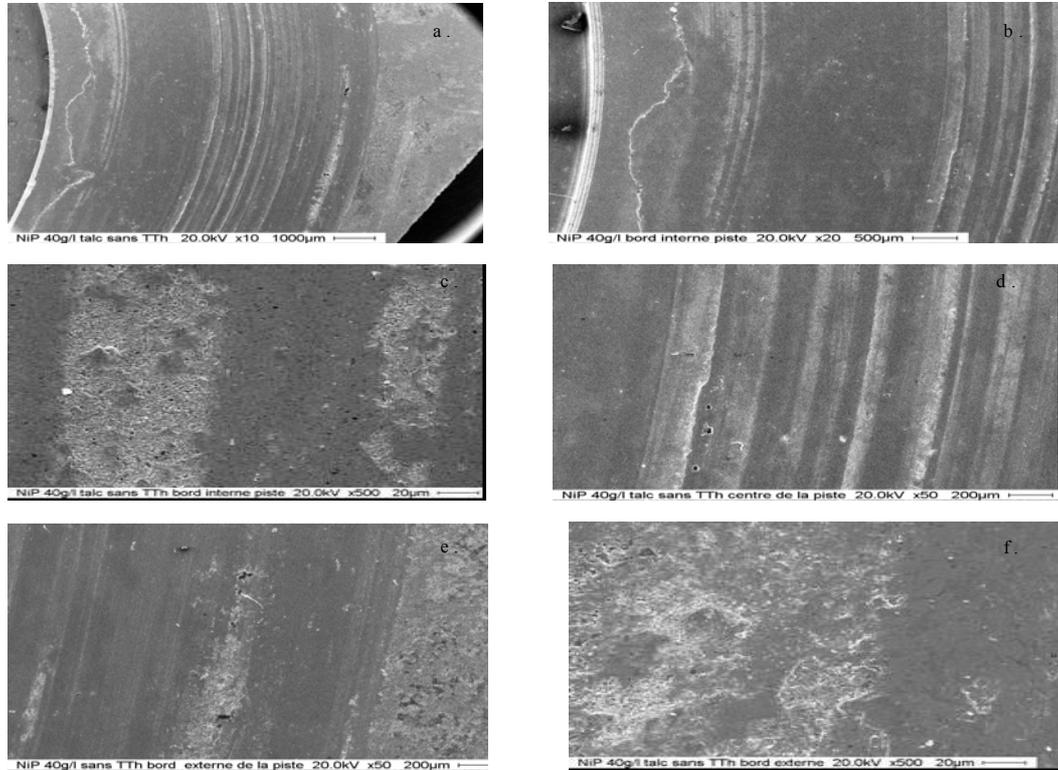


Fig. 4. Runway friction test with NiP layer + 40 g / l talc: a - overview; b - degradation of the inner edge of the track (magnification 20 ×) c - inner edge of the track (magnification: 500 ×) d - center runway friction (magnification 50 ×) e - outer edge of the track (magnification: 50 ×), f - the outer edge of the track (magnification: 500 ×).

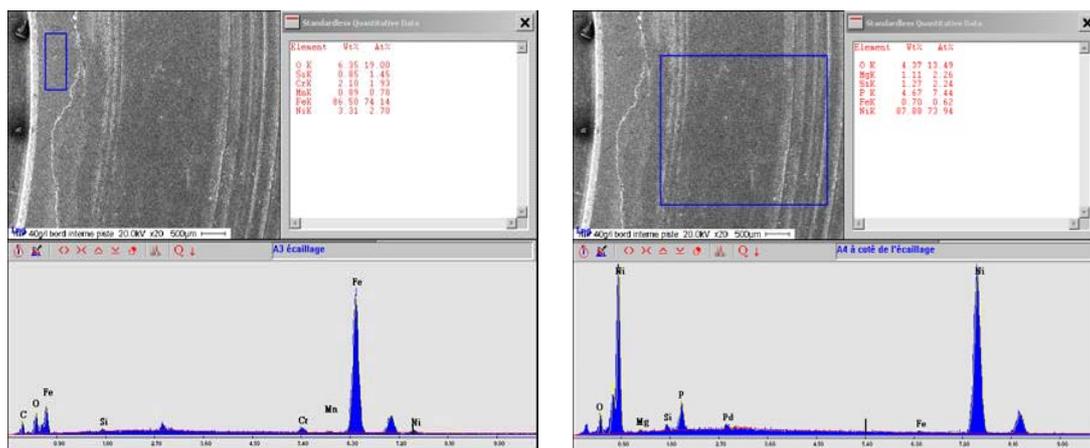


Fig. 5. Spectrometric analysis of samples with layer of NiP + 40 g / l talc: chemical composition of an area near the inner edge of the track, where there is the phenomenon of delamination.

Analyzing the NiP coated samples + 120 g/l talc, we can observe a very pronounced wear. The NiP composite is present all over the runway. In Fig. 6 talc protuberances and some cavities, the trigger points of wear are observed.

The NiP areas that have not attained the friction alternate with areas heavily used, especially to the outer edge of the runaway friction.

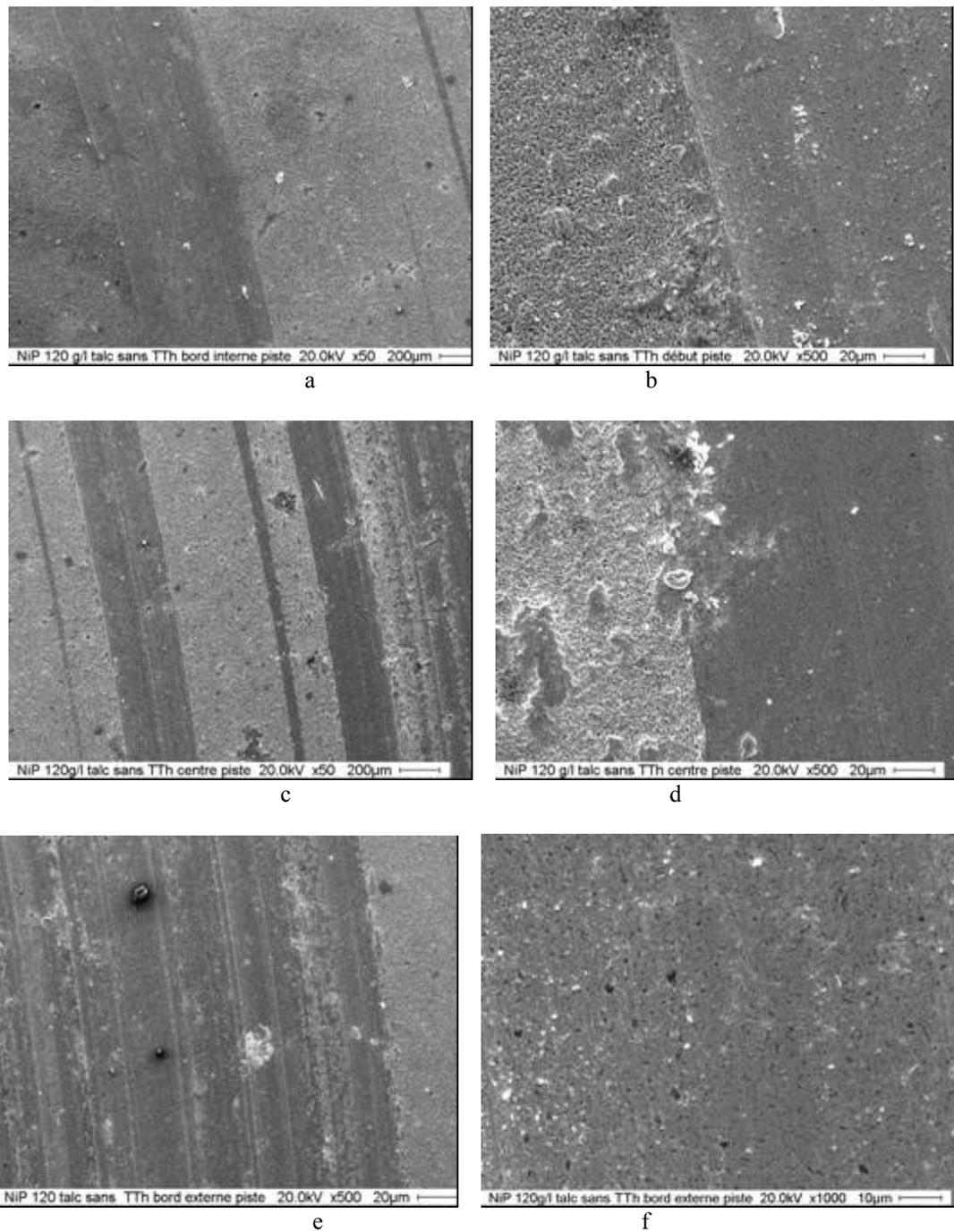


Fig. 6. Runway friction NiP coated sample + 120 g / l talc: a - inside edge of the track (magnification 50 ×) b - early runway friction (magnification: 500 ×) c - center runway friction (increase : 50 ×) d - center runway friction (magnification: 500 ×) e - the outer edge of the friction track (magnification: 500 ×) f - friction outer edge of the track (magnification: 1000 ×).

The spectrometric analyses by EDX, from Fig. 7, in accordance with the microscopical aspects indicating the presence of iron only like hints.

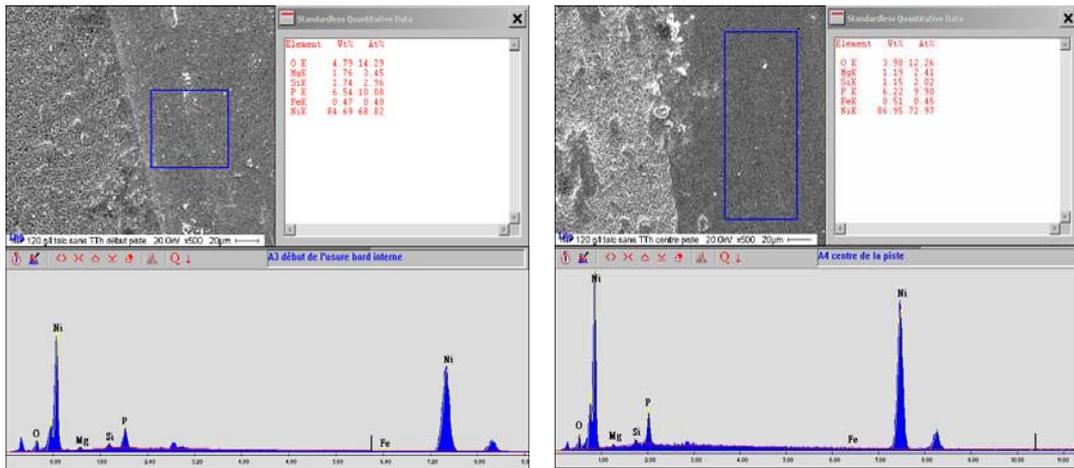


Fig. 7. Spectrometric analysis of samples with layer of NiP + 40 g / l talc: chemical composition of an area near the inner edge of the track and in the center

Fig. 8 shows the layers on 35NiCrMo16 steel after dry friction testing exhibits uniformity, which vary from

19,8-28,6µm for NiP, 25,6-30,2 µm for NiP/40talc and 23.9-27.2 µm for NiP/120talc.

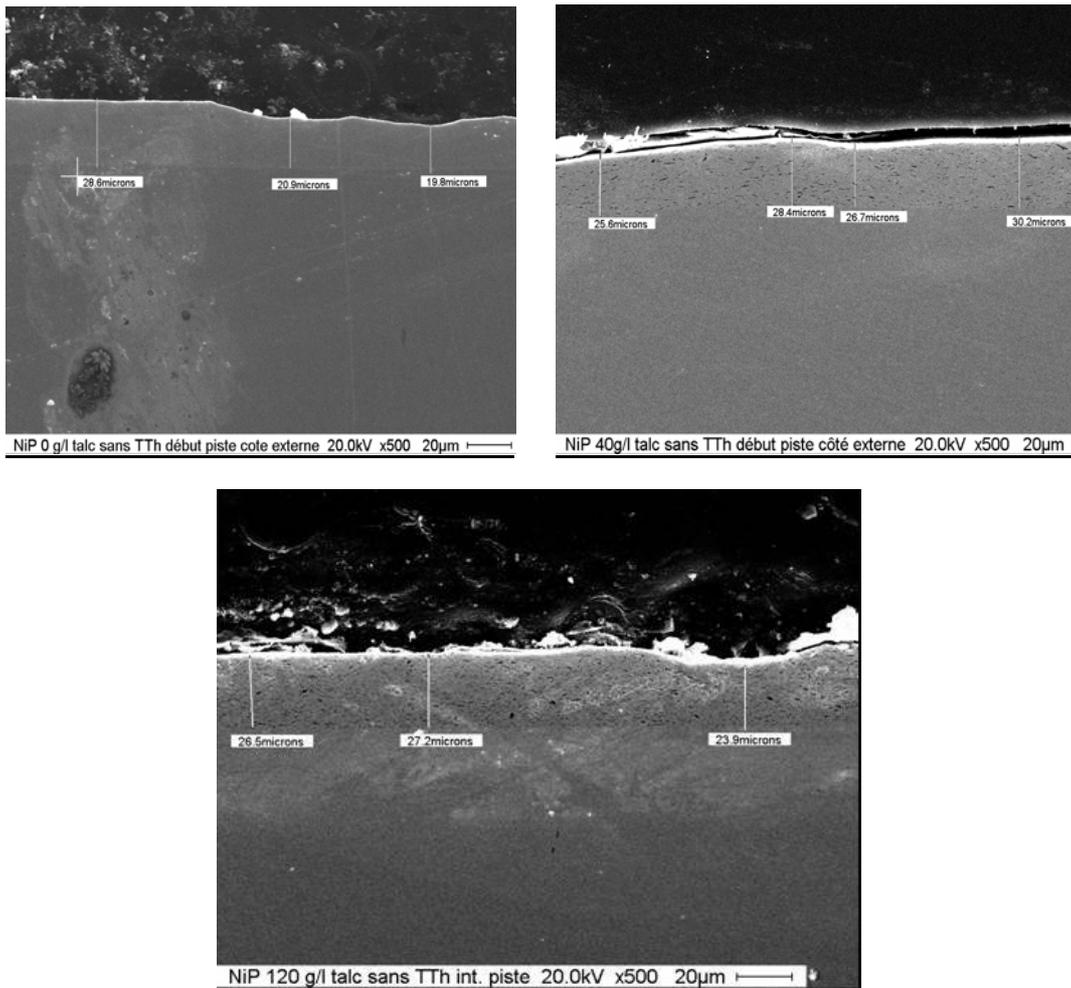


Fig. 8. Coating thickness variation in runway friction layer of a sample of a) NiP b) NiP + 40 g / l talc anc c) NiP + 120 g / l talc (to the outside of the track).

#### 4. Conclusions

Metallic NiP and NiP / talc composite samples were tested at room temperature and the wear behaviour was analyzed by electron microscopy coupled with EDAX analysis. The tribological tests allow studying the influence of talc particles in the friction process of the materials. It may be observed that incorporating talc particles in the coating did not improved the abrasion resistance for crude deposits developed. Indeed, assuming the low resistance of NiP matrix, the deposition layer is fast decaying and pawn remains relatively intact. It is expected that talc addition will have a benefit in mechanical behaviour at higher temperature and future tests have to be developed at different temperatures to put in evidence the impact of temperature on the process.

#### Acknowledgements

The authors acknowledge to Regional Council Midi Pyrenee for the financement of the project. The layers have been prepared and characterized with the

participation of researchers from the Institut Politechnique Toulouse/Ecole Nationale d'Ingenieurs of Tarbes led by Joel Alexis and Jean Pierre Bonino.

#### References

- [1] E. Felder, C. Angelelis, M. Ducarroir, M. Ignat, P. Mazot, *Annales de Chimie Science des Materiaux*, **23**(5-6), 791 (1998).
- [2] H. B. Lee, D. S. Wu, C. Y. Lee, C. S. Lin, *Tribology International* **43**, 235 (2010).
- [3] L. Chang, C.-H. Chen, and H. Fang, *Journal of the Electrochemical Society*, **155**(1), 57 (2008).
- [4] B. Etchevery, J. Alexis, J.Y. Paris, J.P. Bonino, J. Denape, J.A. Petit, *Tribologie et couplages multiphysiques*, 22 – 24 mai 2006, Lille, France, 159 – 168.

---

\*Corresponding author: [gabriela.plaiasu@upit.ro](mailto:gabriela.plaiasu@upit.ro)