Transforming the inferior metal alloy by electroless Ni-P/SiC deposit

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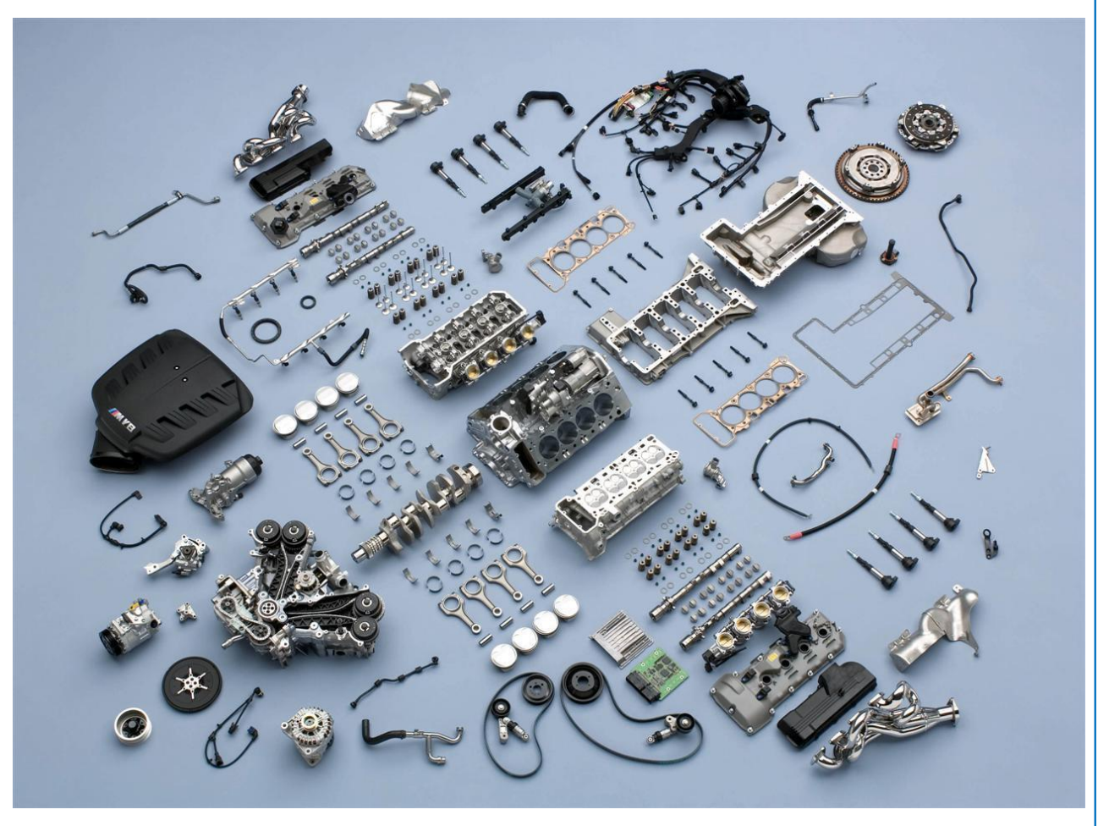
Transforming the inferior metal alloy by electroless Ni-P/SiC deposit

M. Franco[1], W. Sha[1], S. Malinov[2], T.L. See[3], H. Liu[4], Z. Liu[3] , G. Aldiç[5], H. Çimenoğlu[5]
[1]School of Planning, Architecture and Civil Engineering, Queen’s University Belfast, Belfast BT7 1NN, UK
[2]School of Mechanical and Aerospace Engineering, Queen’s University Belfast, Belfast BT7 1NN, UK
[3]Corrosion and Protection Centre, School of Materials, The University of Manchester, Manchester, M13 9PL, UK
[4]Light Industry Equipment Advanced Manufacturing and Measurement and Control Technology Provincial Key Laboratory, School of Mechanical and Automotive Engineering, Qilu University of Technology, Ji'nan 250100, P. R. China
[5]Department of Metallurgical and Materials Engineering, Istanbul Technical University, 34469 Maslak, Istanbul, Turkey

1. Introduction

Surface modification by metal deposition onto inferior material is of paramount importance for many engineering applications. A type of metal coating by electroless technique is versatile owing to its promising material properties and characteristics. Heat treatment of electroless nickel coating is important owing to the properties enhancement such as increase in microhardness, tribology and phase transformation [1].



1.1 What is the purpose?
For automotive and aerospace industries light weight aluminium alloys are the back bone for any great designs and structure. But these alloys are vulnerable to wear, erosion, corrosion etc. Electroless nickel coating reinforced with hard particles can transform the surface behaviour of the substrate. With optimal heat treatment the coating properties can further be enhanced.

1.2 Research aim
The present work aims to develop and understand the composite coating Ni-P/SiC by electroless technique. The characterisation such as phase structure, morphology and properties like microhardness, friction and wear are investigated systematically.

2. Experiments

Aluminium alloy LM24 (Al-8%Si-3.5%Cu alloy) was used as substrate. It underwent pretreatment as shown in Table 1. Each step is followed by tap water washing and deionised water rinsing. The composite coating process parameters are shown in Table 2. The hard particles were introduced and stirred for 30 minutes prior to the plating process started. Upward and downward of the pH adjustment was done using ~50 % NH_4OH and ~10 % H_2SO_4, respectively.

Table 1. Pretreatment conditions and parameters [2]

Process	Chemicals	Temperature	Time	Degree of agitation
Degreasing	C_6H_6O (acetone)	Room	3-5 min.	None
Alkaline cleaning	5.75 g/l Na_3PO_4, 5.75 g/l Na_2SiO_3	60-65 °C	~3 min.	Mild
Acid neutralising	13 % vol. HNO_3 (initial conc. ≥65 %)	Room	~20 sec.	Mild
Zincating	100 g/l ZnO, 525 g/l NaOH	Room	~20 sec.	Mild

Table 2. Plating process parameters [2]

Parameter	Value
pH	4.8-4.9
Temperature	88±2 °C
Time	80 min.
SiC concentration	2-18 g/l
Agitation	Magnetic stirrer along with sample rotator

Heat treatment was done in furnace and for vacuum all the samples were sealed in glass before placing in the furnace. XRD analysis on coated samples was carried out at room temperature using PANalytical X-ray diffractometer applying CuK_α radiation. The step size of scans was 0.02°. Energy dispersive X-ray (EDX) run by Aztec version 2.0 software was used for chemical composition analysis. Microhardness by microhardness tester using load of 100 gf. Tribology behaviour was tested using wear tester with load of 20 N rotating in a circular track of 8 mm diameter at a rotational speed of 200 rpm with the ball diameter of 5 mm. And also in-situ (200 °C) monitoring using 2 N load with ball diameter of 6 mm and track diameter of 11 mm was performed using different pin-on-disk wear tester.

3. Results and discussion

The coating uniformity and the distribution of the reinforcing particles are shown in Fig. 1. The particles are evenly distributed in the coating which also follows the contour of the substrate [3].

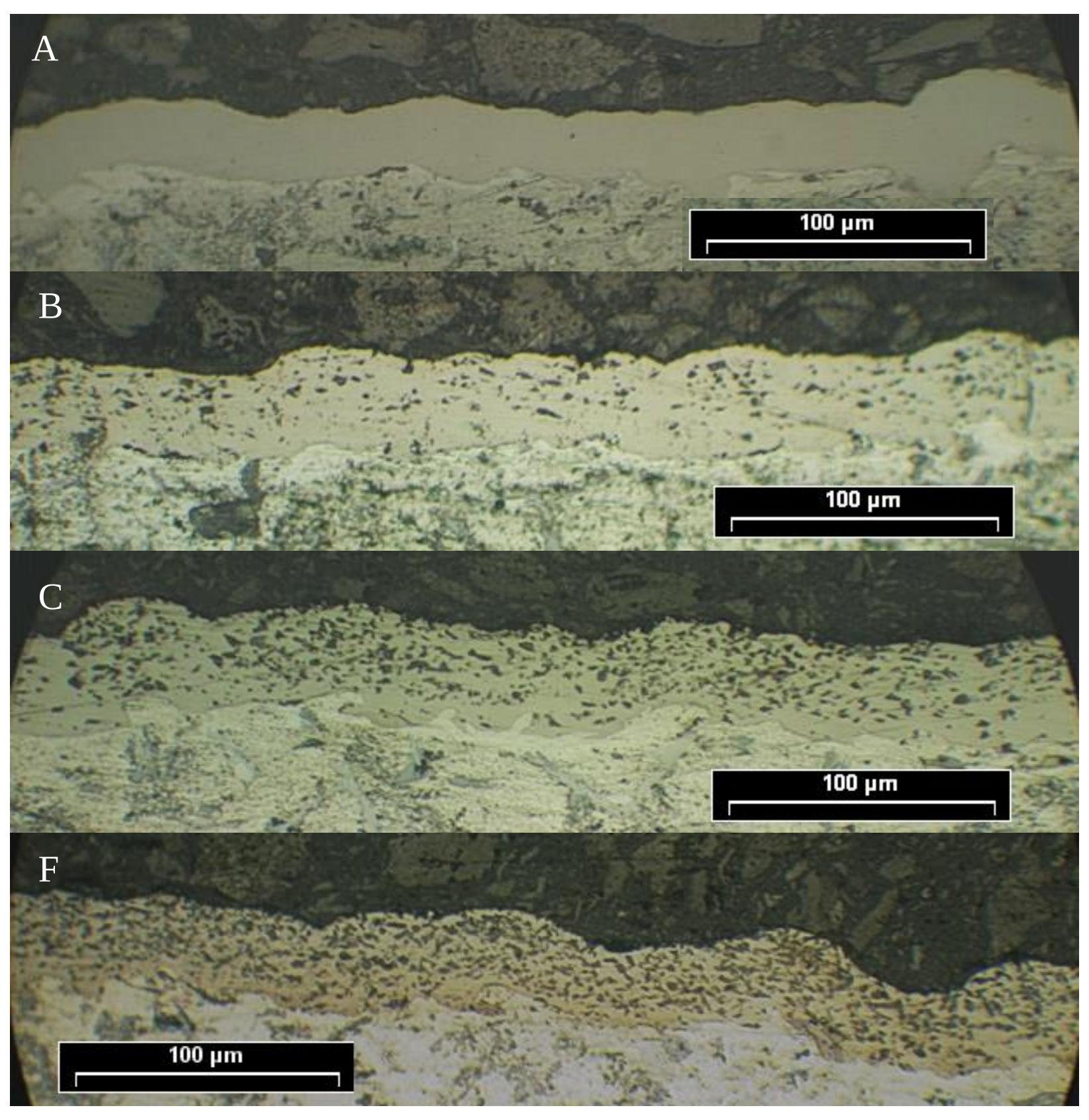


Fig.1. Cross section of the coatings of different SiC concentrations A (0 g/l), B (2 g/l), C (6 g/l) and F (18 g/l)

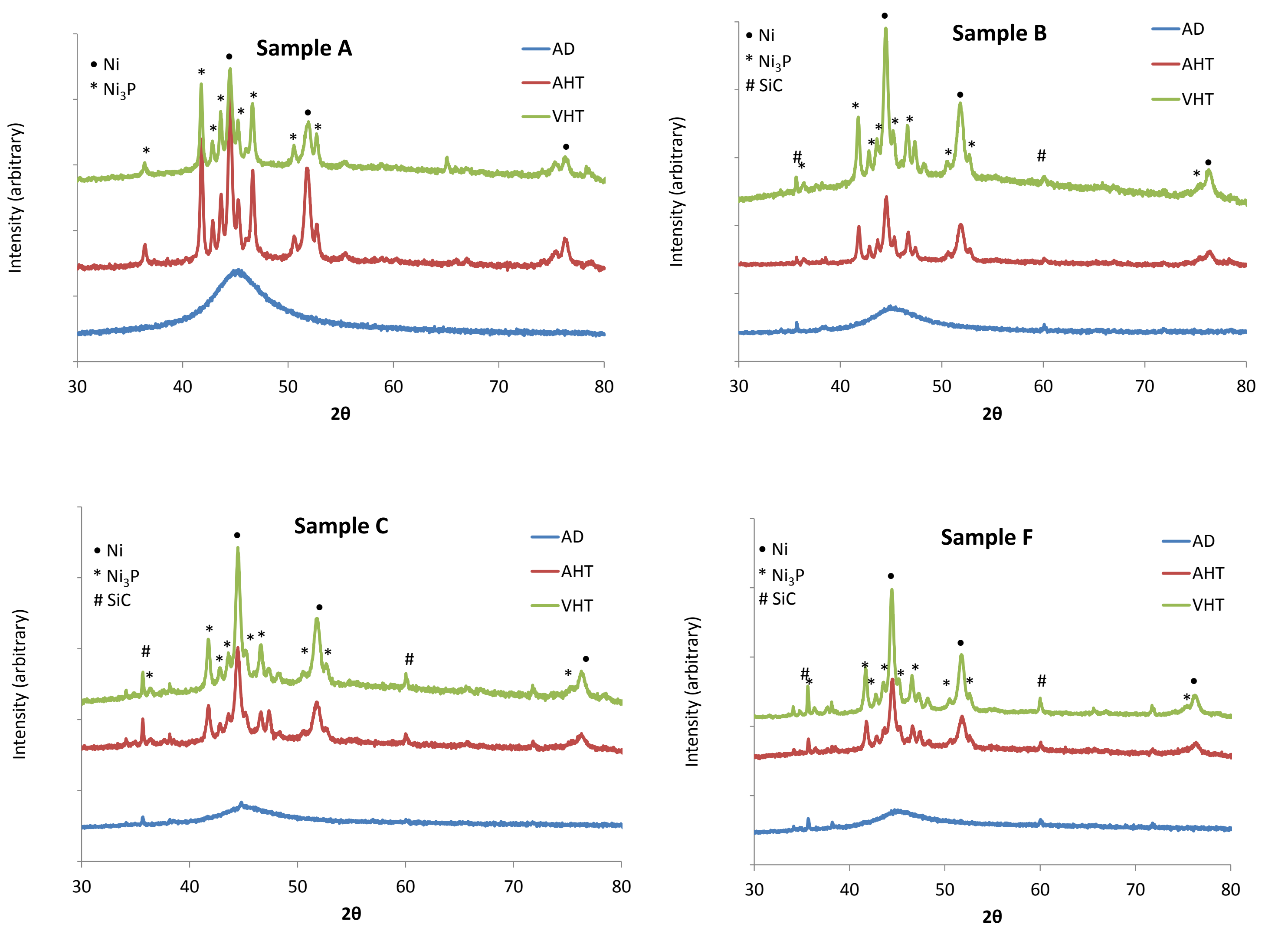


Fig. 2. XRD patterns for samples A, B, C and F

3.1 Phase structure
The broad peak for the as-deposited state (AD) of the coating shows the amorphous structure for all the samples. The heat treated states both in atmospheric (AHT) and vacuum (VHT) conditions show well defined sharp peaks mainly from the crystallite Ni and Ni_3P with SiC peak for composite coatings. Oxide peaks are not observed for the two types of heat treated samples.

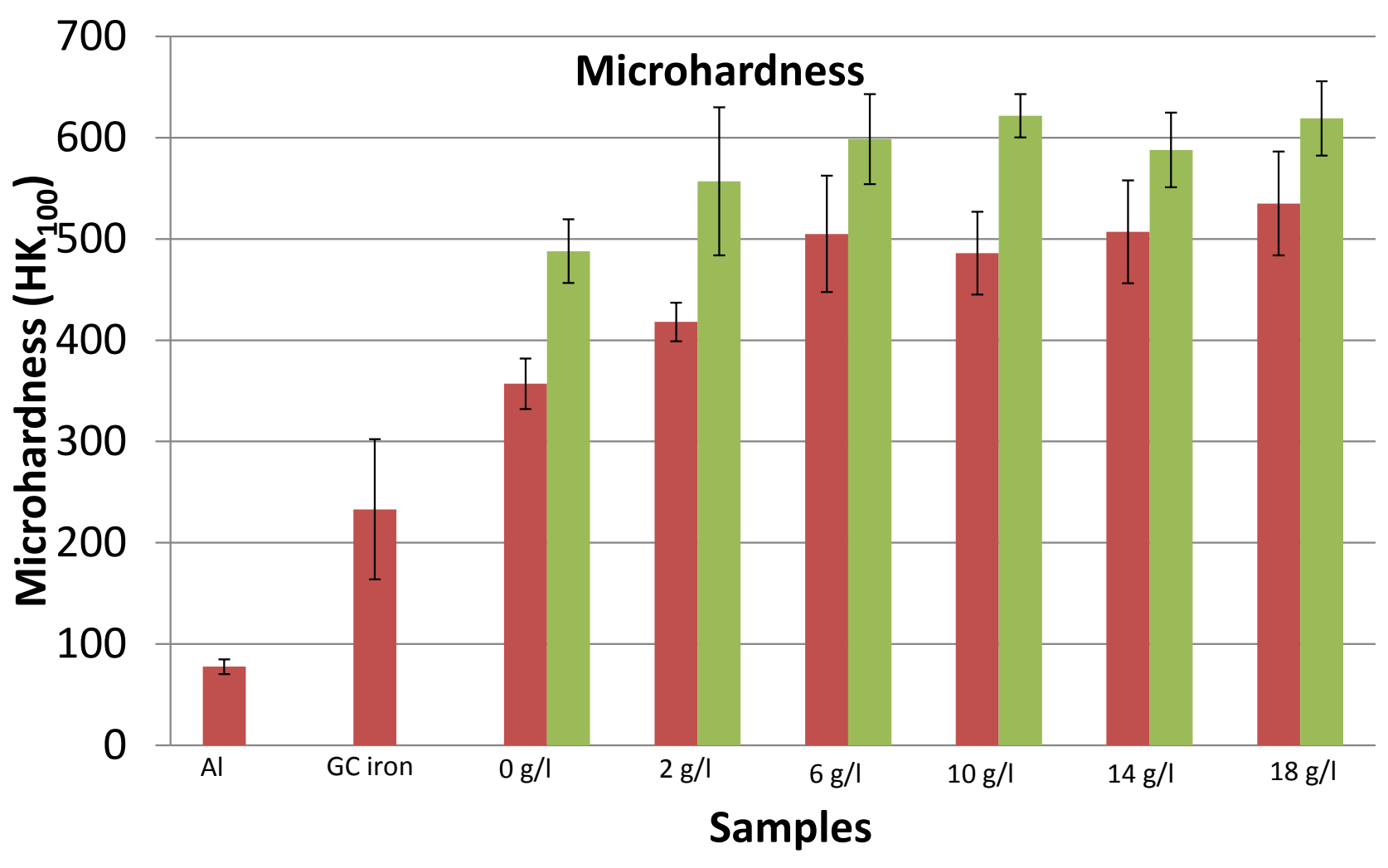


Fig. 3. Microhardness for bare aluminium, grey cast iron and coated samples (heat treated in light green colour)

3.2 Microhardness
Significant increase in microhardness post coating as compared to the bare Al substrate (Fig. 3) is observed. Upon heat treatment the microhardness further increases. Reference grey cast iron was taken as it is the conventional material for cylinder liner in engine system.

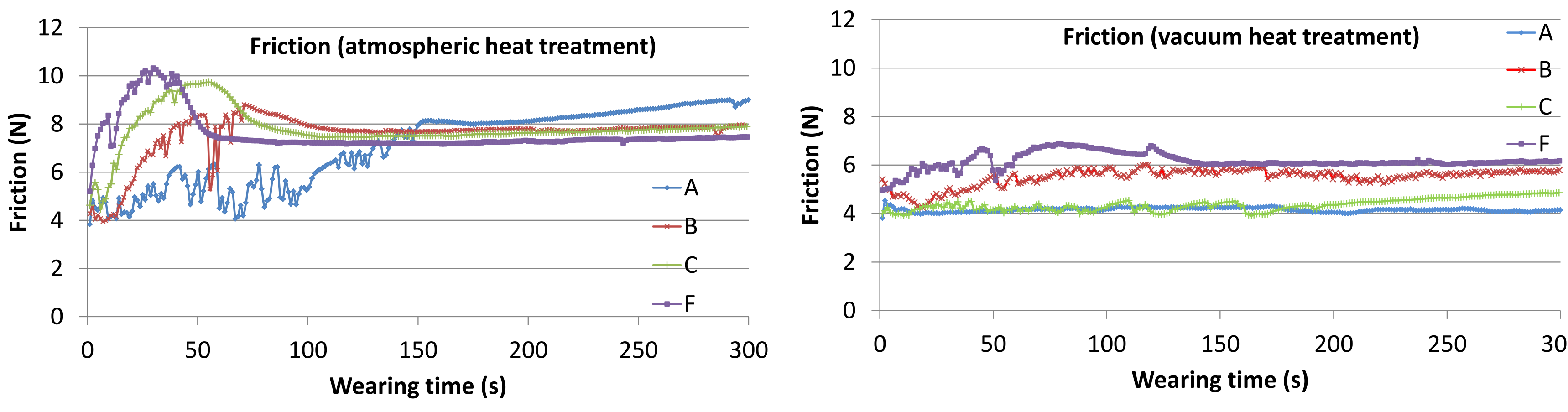


Fig. 4. Friction responses over sliding time.

3.3 Friction
There are substantial fluctuations in the friction graph especially in the early stage of the wearing time and then the friction becomes stable and smoother after this period of wearing time for atmospheric condition. Large significant difference is exhibited before and after a threshold. Such observation does not occur in the friction graph for the samples heat treated in vacuum condition (Fig. 4). However, some irregularities of friction are seen which gradually fades away as the wearing proceeds. The main differences in the friction behaviour obtained with different heat treatment conditions could be due to the considerable layer of oxide formation. The bluish appearance (visual inspection) on the surface of samples heat treated in atmospheric condition which is not seen for vacuum heat treated samples is the indication of the oxide formation. In-situ engine simulation (200 °C) friction responses suggest the coated samples exhibit lower friction as compared to grey cast iron as shown in Fig. 5.

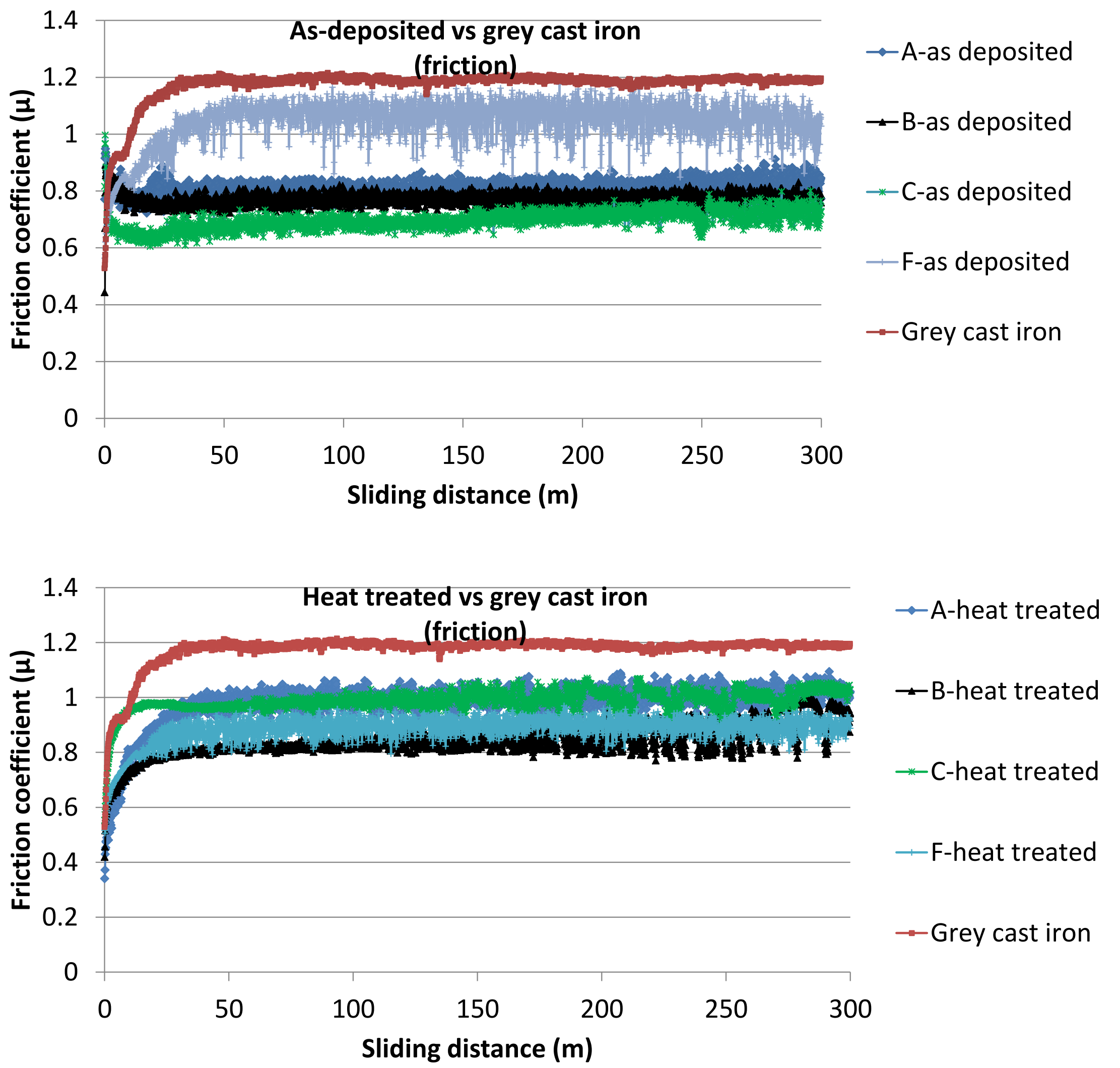


Fig.5. In-situ friction responses at high temperature

3.4 Wear
Wear characteristics of the bare aluminium and the coatings in terms of wear rate is tabulated in Table 3. Wear rate is lower after the coating. Wear resistance is improved on heat treatment as compared to as-deposited state.

Table 3. Tribology data from wear testing

Sample	Condition	Wear rate ($m^2·N^{-1}$)
Bare aluminium	-	$8.36×10^{-12}$
A	As deposited	$1.86×10^{-14}$
	400°C	$8.11×10^{-14}$
B	As deposited	$3.09×10^{-13}$
	400°C	$7.27×10^{-14}$
C	As deposited	$9.02×10^{-13}$
	400°C	$8.91×10^{-14}$
F	As deposited	$1.07×10^{-12}$
	400°C	$9.37×10^{-14}$

4. Concluding remarks

- Deposition of composite Ni-P/SiC onto aluminium alloy shows uniform coating and even distribution of reinforcing particles. SiC content increases on increasing in SiC concentration in the plating solution.
- XRD profile shows crystalline peaks from Ni and Ni_3P, and SiC peaks for composite samples in heat treated conditions and amorphous phase in as-deposited state.
- Microhardness increases after coating as compared to uncoated aluminium. Heat treatment further enhances the microhardness.
- Instability of the friction during the early stage of sliding is noticeable for atmospheric environment annealed samples of electroless nickel coating. No abrupt changes in the friction are found for vacuum heat treated samples
- High temperature friction of near engine environment shows lower friction for coated samples as compared to grey cast iron.
- Wear performance is better for coated samples in terms of lower wear rate. Heat treated samples exhibit better wear resistance as compared to as-deposited state.

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