Technical Memo – TITRIX® Coating on AISI 1018 plain Carbon Steel Substrate using Additive Friction Stir Process (AFSP):

Summary

IAP Research Inc and Aero Probe Corp. have successfully shown the feasibility of creating wear and corrosion resistant coatings using TITRIX ® powders on steel substrates. IAP manufactures and sells wear and corrosion resistant TITRIX ® powders for coating applications. Aero Probe Corp. deposits coatings using Additive Friction Stir Process (AFSP). In our trials , ~ 870 microns thick coatings using TITRIX ® powders were successfully applied onto steel substrates. The interface between TITRIX ® coating and steel substrate was excellent and no interface de-laminations of any kind were evident under optical microscopy imaging. The hardness enhancement of TITRIX ® coating was very good with a value of 47.6 HRC (pure titanium hardness lies in 30-32 HRC range). The following paragraphs provide technical details of the coating trials and the results obtained.

Processing Details and Results:

IAP has supplied five samples of TITRIX® probes to Aero Probe along with 1018 plain carbon steel substrates for wear resistant coatings of TITRIX® trials. Coatings were deposited on as-purchased steel plates without any special substrate preparation. The sintered material (97.7% density) prepared from TITRIX® powders was used as a probe for the AFSP coating process.

Different process conditions such as probe RPM, translational speed, and feed rate were used by Aero Probe for TITRIX® coatings. Table 1 shows the processing conditions used for the coatings. Figure 1 shows the photograph of the coatings on steel. All coatings were deposited in an Argon atmosphere. The high-level of plastic deformation imparted into the coating and interface during AFSP process yields a homogenous, fine-grained microstructure and diffuse interface as shown in figure 1. The circular probe marks in the coatings are typical of AFSP and processing conditions of deposition could be fine tuned to obtain smoother coating surface.

Table1: Sample and processing condition description

1018 Carbon Steel substrate	TITRIX- TiC wt %	Probe Feed Rate	Probe Translation Rate	Probe RPM
1	6%	.02	1	500
5	12%	0.4	2	350
6	12%	0.3	3	350
7	12%	0.3	2.5	350
8	12%	0.2	2.5	250
9	6%	0.3	3	250

Figure 1: Photo of coatings of TITRIX on 1018 plain carbon steel substrate.

Results:

The preliminary analysis of the results were carried out on one of the sample # 5. The coated sample #5 from Table 1 with 12 wt % TiC was sectioned lengthwise and mounted and polished in accordance with ASTM Standard E3. The hardness was evaluated using a Mitutoyo 5104 microhardness tester in accordance with ASTM Standard E384 with a 500 gram load for 15 second load application. The bond line, microstructure and layer thickness were evaluated by reflected light microscopy in accordance with ASTM Standard E883 using a Nikon Epiphot 200 inverted metallograph.

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The following paragraphs summarize the preliminary results. The average measured thickness of TITRIX® layer on steel was 821.4 microns with an layer average hardness of 47.6 HRC. Microstructural analysis of the TITRIX® coated layer is shown in figures 2 and 3 where the interface between steel substrate and TITRIX® coated layer was found to be excellent with no lamellar cracks or debonding at the interface.

I. Layer Thickness Evaluation:

Reading	Thickness (µm)	Reading	Thickness (µm)
1	904.9	14	919.7
2	994.7	15	746.3
3	1035.9	16	718.8
4	1020.1	17	705.1
5	998.9	18	704.0
6	803.4	19	705.1
7	871.0	20	715.6
8	921.8	21	506.3
9	953.5	22	487.3
10	1035.9	23	576.1
11	986.3	24	648.0
12	872.1	25	743.1
13	961.9		

Avg.	821.4
Std. Dev.	166.5
Min	487.3
Max	1035.9

II. Microhardness Evaluation:

Reading	HV_{500}	HRC
1	476.7	47.4
2	544.1	52.0
3	471.9	47.1
4	456.2	45.9
5	453.3	45.6
Avg.	480.4	47.6

III. Microstructural Analysis:

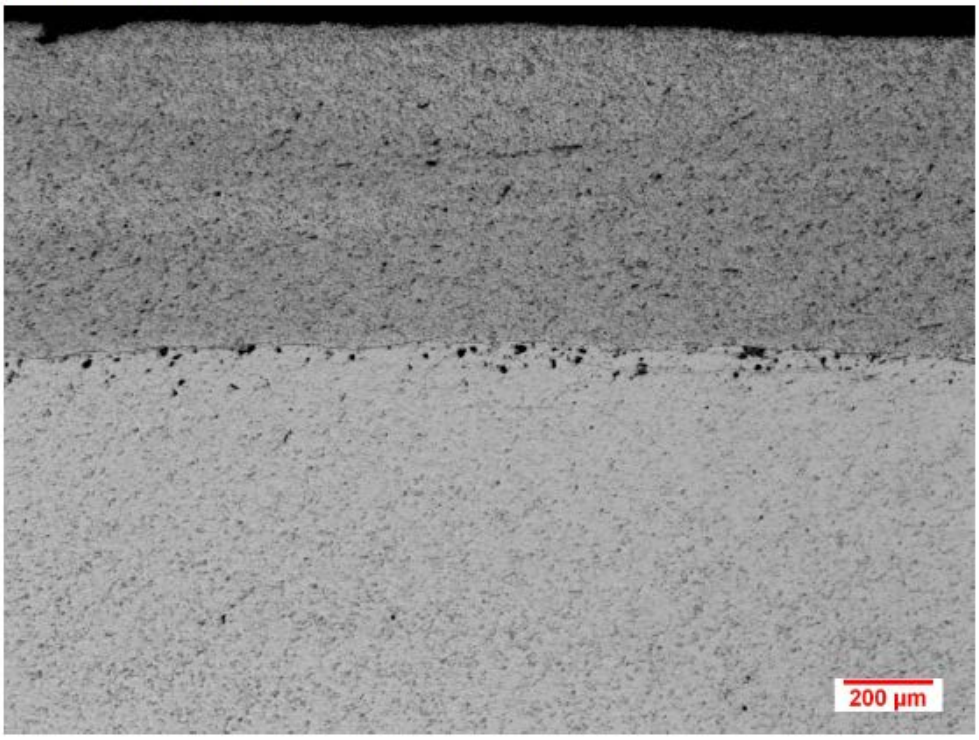

Figure 2: Representative image of the bond line between TITRIX® coated layer (top) and plain carbon steel (bottom). Aspolished magnification 50X.

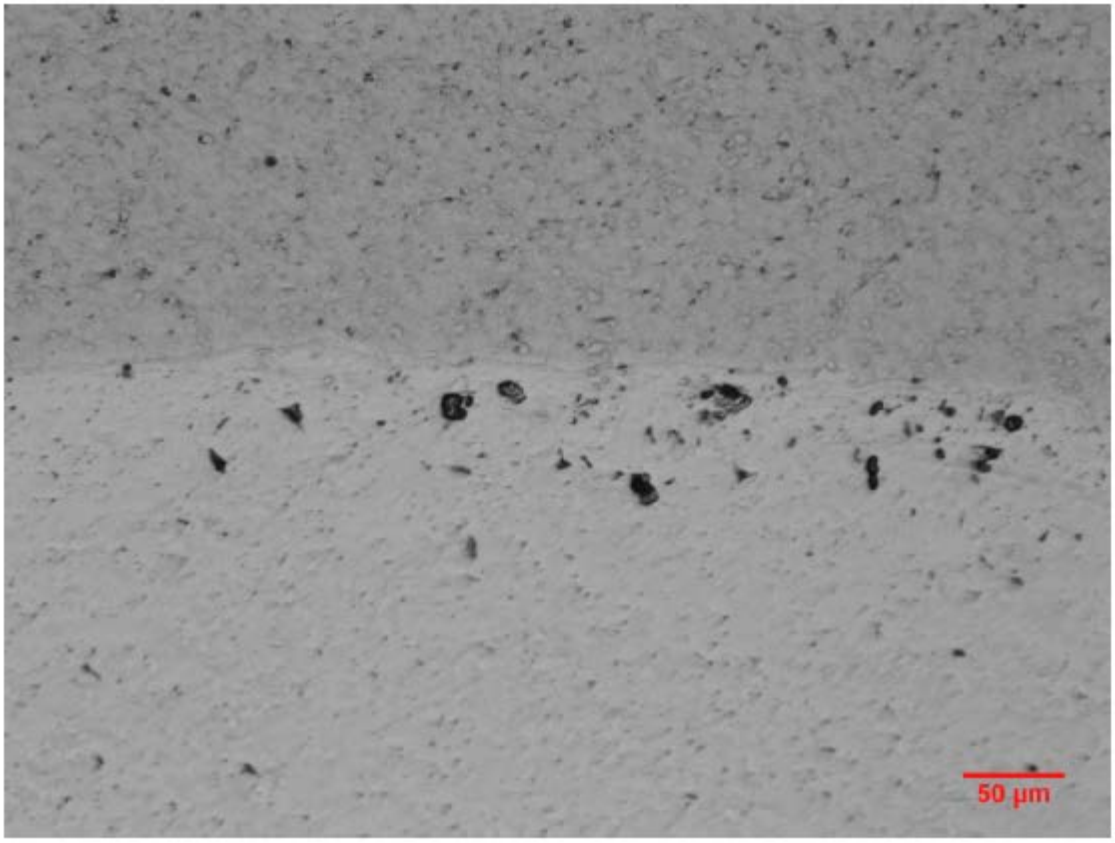

Figure 3: Representative image of the bond line between TITRIX® coated layer (top) and plain carbon steel (bottom). As-polished magnification 200X.

Currently high resolution Scanning Electron Microscopy (SEM) Analysis of the coated layer is in progress to determine the size of the TiC phases in the composite, and to identify presence of any other phases and details of any porosity.