



LOW APPLICATION TEMPERATURE FUSION BONDED EPOXY COATINGS

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ABSTRACT

Low application temperature has always been a desirable attribute to the application of fusion bonded epoxy (FBE) due to these advantages: (1) energy saving, (2) suitability for high strength steel (X80 or above) pipes, and (3) improvement of production throughout for 3LPE/PE. LAT-FBE has been a “hot” development product for different suppliers for several years. ShawPipe / Bredero Shaw has worked closely with powder suppliers in the LAT-FBE development and conducted a few production runs with different LAT-FBE coatings. This paper will discuss the benefits of using LAT-FBE and describe the continuous preheat temperature monitoring adopted in LAT-FBE coating productions.

Keywords: LAT-FBE, high strength steel pipes, fusion bonded epoxy, 3LPE, 3LPP.

INTRODUCTION

Fusion bonded epoxy (FBE) coatings have been widely used in pipeline corrosion protection for more than three decades. They are commonly used as stand-alone coatings, as well as the based layer of dual or multi-layer coatings for steel pipelines. FBE is a powder coating, which melt, fuse and flow (wet) in liquid form (state) with heat and react/crosslink to form a solid protective coating. In the pipe coating industry, FBE powder is applied by spraying onto preheated steel pipes. The key to achieve proper adhesion between the steel pipe and the coating is the melt-flow-wet process, which is mainly governed by the temperature of the pipe and the melt-fuse characteristics of the FBE. Typical application temperatures for conventional FBE coatings are generally in excess of 230°C.

In North America, Arctic regions have become the main focus for pipeline activities. In order to effectively and safely transport oil and gas in these geographically challenged areas, pipeline companies have put much effort in developing strain based design pipelines. The high strength steel line pipe (X80 or above) is suitable for cold environments and rough terrain because of its high strain and improved toughness. However, the pipe preheat temperatures of conventional FBE can reduce the elongation at yield of these high strength steel pipes, causing some pipeline companies to limit preheat temperatures to under 200°C when such pipes are being used. With the increasing popularity of using high strain steels in pipe construction projects and increasing energy prices, it has been in the suppliers' great interest to develop low application temperature FBE for the last several years.

In addition to energy saving and suitability to high strength steel pipes, using a lower application temperature can presumably improve the production throughout for 3LPP/PE and reduce material usage.

Bredero Shaw has worked closely with powder suppliers in the LAT-FBE development and has conducted a few production runs with TransCanada Pipelines to demonstrate the effectiveness of different coating systems with LAT-FBE. These systems included single layer and dual powder system (DPS) for the North Central Corridor project in Alaska, and single layer and High Performance Composite Coating (HPCC) for the Godin Lake Loop project in Northern Alberta [1]. Furthermore, a 3-layer PE system (YJ2K) consisting of a low application temperature FBE was trialed for Mackenzie Gas Pipeline.

This work discusses the benefits for using LAT-FBE and describes the continuous preheat temperature monitoring adopted in LAT-FBE coating productions.

ADVANTAGES OF USING LAT-FBE

Energy Saving

For FBE pipe coating application, steel pipes are usually preheated by induction heating for large diameter pipes. A successful coating application with FBE requires proper preheat temperature to (1) properly melt the FBE powder, so it can flow and properly wet the anchor profile of the pipe surface; and (2) generate sufficient heat for curing to achieve optimal properties. The coating adhesion is mainly determined by the flow-ability and wettability of the FBE melt, which is predominately governed by the melt viscosity and reactivity of FBE [2]. FBE formulators have formulated LAT-FBE with a lower melt viscosity and adjusted reactivity to allow lower application temperature. As mentioned before, typical application temperature for conventional FBE is in excess of 230°C, while LAT-FBE applies on substrate preheat of <200°C. The minimum 30°C difference in preheat temperature can provide a significant decrease in energy consumption from preheating and quenching processes. Depending on other parameters, such as pipe size, pipe wall thickness, line speed, etc., the energy savings can be as high as approximately 20% due to the lower preheat temperature from using LAT-FBE.

Improvement of Production Throughout and Reduction of Material Usage

The water quench process is important for production efficiency to protect operators and the coating from damage [2]. The polyethylene or polypropylene topcoat could be damaged by the conveying wheels if the topcoat did not cool fast and hard enough to be supported by the conveying wheels. Since PE/PP is known to be good insulator, more energy is required to cool the insulated hot pipes from >200°C to approximately 40-60°C for safe handling. With the use of low application temperature, the quenching time can be reduced (as well as the energy consumption for chilling the quenched water), and thus increase the production throughput of 3LPO coating.

In order to ensure the total thickness requirement in 3LPE/PE coating process, a thicker polyolefin topcoat is usually applied to compensate the thinning at the weld bead area. Since the polyolefin topcoat would thin out more at a higher pipe temperature, a thicker polyolefin topcoat would be required to maintain the over thickness which also translate to a higher PO material usage/wastage. In this case, LAT-FBE with at least 30°C less than conventional preheat temperature would help to reduce the wastage of PO material. PO material usage can be reduced by approximately 10-30%, depending on pipe size, line speed, height of raised weld, etc. with the use of LAT-FBE. A side-wrapped over HPCC project [3] demonstrated that using LAT-FBE in combination with HPCC and internal cooling on raised welded pipes can achieve a reduction of PE material usage up to 40%. Figure 1 shows the comparison of coating thickness between the weld seam and body with (a) the conventional 3LPE and (b) a side-wrapped over HPCC using LAT-FBE. It is apparent that there was a significant thickness difference with the conventional 3LPE coating. Furthermore, the LAT SW-HPCC can eliminate the “weld tenting” problem, which is common in 3LPE coating (Figure 1a).

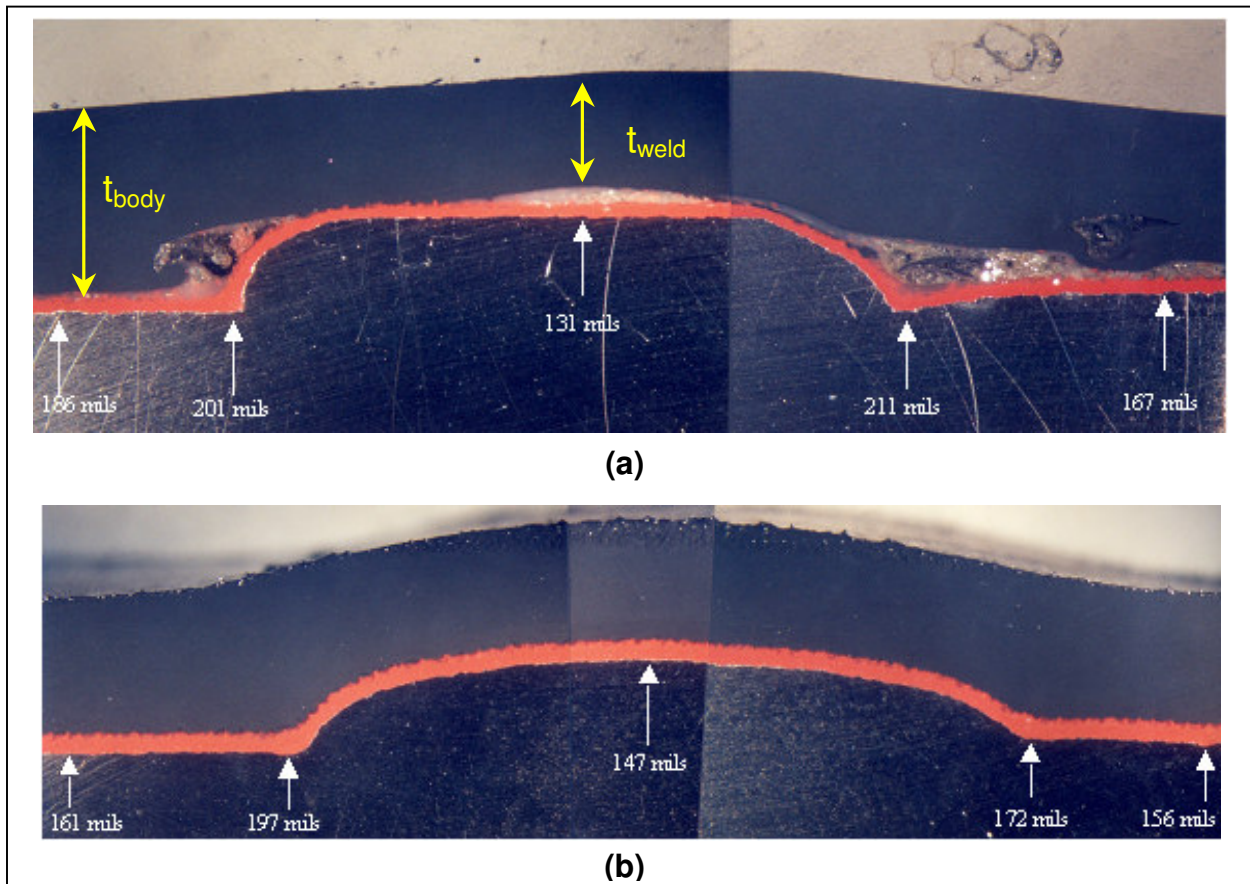


Figure 1 – Cross section of weld seam obtained from (a) conventional 3LPO coating process. Thickness of body is 30-40% higher than thickness at weld area; (b) LAT SW-HPCC.

Suitability of High-Strength Steel Pipe (X80 or above)

As the demand for oil and gas increases, the development of new oil and gas reservoirs in more remote locations becomes more needed. The major reservoirs discovered in recent years tend to be in very remote regions, where pipeline construction must take place in winter conditions [1]. In order to safely install and operate in severe environments, the demand of strain based design pipelines using high strength steel (X80, X100 and X120) have increased [4-5]. With high strength steel, the wall thickness of linepipe can be reduced significantly which can result in reductions of pipe laying costs with respect to transportation and welding time [6]. However, high strength steel pipes present application challenge with the conventional FBE powder as some key properties of these high strength steel pipes, especially X100 and above, can change (e.g. reduction in the tensile elongation at yield) when subjected to conventional FBE coating process. This issue led to the development of a low application temperature FBE coating, which has comparable or better performance than the conventional FBE. The application temperature for the new LAT-FBE is targeted to avoid exceeding 200°C, and preferably to be able to apply at even lower temperature.

PROJECTS, TEST RESULTS AND DISCUSSION

In the past several years, trials and production runs were conducted with different coating systems consisting of LAT-FBE. These coating systems were qualified in the accordance with CSA Z245.20/21 as well as some additional stringent requirements based on different projects. Most projects required high integrity coatings to provide reliable performance in Arctic environments and to ensure safe handling and construction with temperatures in the range of -40°C to -50°C. The following lists the key projects coated with LAT-FBE in the last several years:

- Stand-alone LAT-FBE for North Central Corridor Project (9km, NPS42)
- LAT Dual-layer for North Central Corridor Project (1km, NPS42)
- Side-wrap over LAT-HPCC for Peerless Lake III Project (2.5km, NPS24)

Table 1 shows the comparison of test results between stand-alone conventional FBE and LAT-FBE (from NCC project). Results demonstrate that LAT-FBE provide performance virtually identical to those with well-proven conventional FBE powders. Test results from LAT dual-layer and LAT-HPCC also confirmed that systems with LAT-FBE, which were applied within a temperature window of 175°C to 200°C, have performance equivalent to conventional powders designed to be applied at the conventional 230°C to 250°C application temperature.

Table 1 – Comparison of test results between Conventional standard FBE and LAT-FBE.

Test	Test Parameters	Acceptance Criterion	Standard FBE	LAT-FBE
Adhesion – Hot Water Immersion	24 hours at 75°C	Rating 1-3	Avg. 1	Avg. 1
	2 days at 75°C		Avg. 1	Avg. 1
	28 days at 75°C		Avg. 2	Avg. 1
	24 hours at 95°C	Rating 1-3	Avg. 1	Avg. 1
	28 days at 95°C		Avg. 2	Avg. 1
Cathodic Disbondment (Disbondment Radius)	28 days at 23°C	8.0 mm max [6.5 mm TCPL]	Avg. 5.0 mm	Avg. 5.2 mm
	28 days at 50°C	11.5 mm max	Avg. 7.9 mm	Avg. 6.9 mm
	1 day at 65°C (3.5V)	4.5 mm max	Avg. 3.4 mm	Avg. 2.3 mm
	2 days at 65°C (3.5V)	5 mm max [4.5 mm TCPL]	Avg. 3.3 mm	Avg. 3.9 mm
	28 days at 65°C	15 mm max [13.5 mm TCPL]	Avg. 11.2 mm	Avg. 10.2 mm
	28 days at 80°C	15 mm max [16.5 mm TCPL]	Avg. 12.9 mm	Avg. 9.8 mm
Flexibility	-30°C	2.5%/pd with no cracking	Pass	Pass
	0°C		Pass	Pass
	20°C		Pass	Pass
Impact	-40°C	1.5J with no holiday	Pass	Pass
	-30°C		Pass	Pass
	-10°C		Pass	Pass
	0°C		Pass	Pass
	20°C		Pass	Pass
	50°C		Pass	Pass
Porosity	Cross-section	Rating 1-4	2	1
	Interface		2	1

Process Monitoring for LAT-FBE Production

LAT-FBE are found to be more sensitive to surface preparation, especially the preheat temperature, when compared to conventional FBE powder. In other words, the application temperature window of LAT-FBE for achieving optimal performance is narrower than conventional FBE. In view of the importance of the application temperature, a tighter preheat process control was adopted when coating LAT-FBE.

In a LAT-FBE trial which was held in 2008, the preheat temperatures throughout the whole pipe were continuously monitored during the coating process. Figure 2 shows the application temperature profiles of three different LAT-FBEs. The target application temperature ranges for LAT-FBE A and B, and LAT-FBE C were 185-200°C and 175-190°C, respectively. Qualification tests were conducted with samples obtained from trail ends in accordance with CSA and TCPL's requirements as summarized in Table 2.

Based on the performance as shown in Table 2, two LAT-FBEs were selected from our customer for production runs – LAT-FBE B and LAT-FBE C. It is noted that LAT-FBE B received some borderline results (as indicated in blue in Table 2) which may have been due to a low preheat temperature at the trail (approximately 180°C).

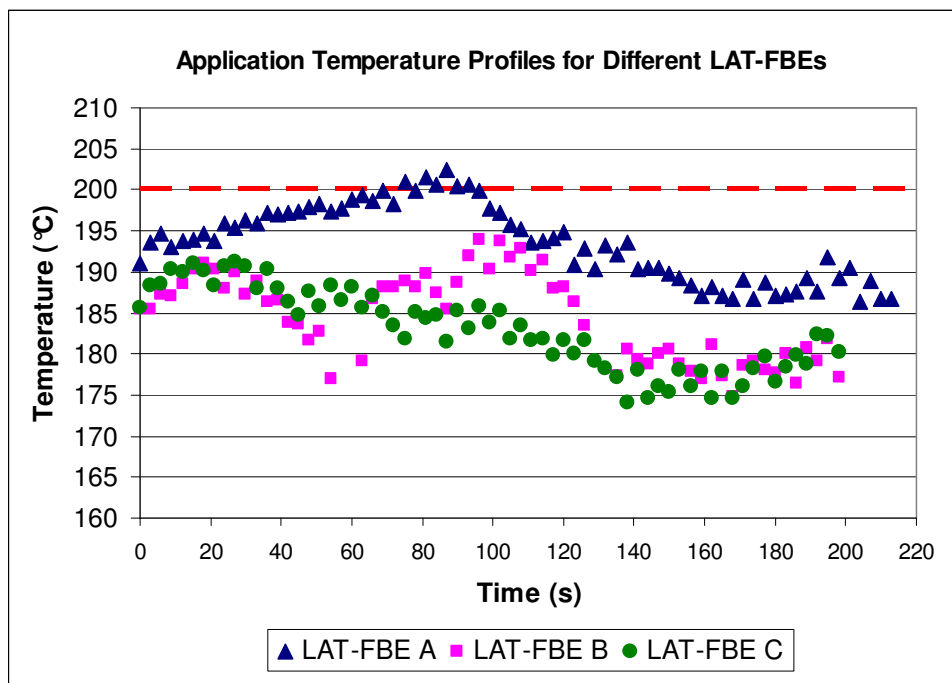


Figure 2 – Application temperature profiles measured by a contact pyrometer for 3 LAT-FBE obtained from plant trials.

Table 2 – Test results obtained from LAT FBE Trials.

Test	Requirements	LAT FBE A	LAT FBE B	LAT FBE C
Thickness (mil)	14 – 16 mil (20 max)	15.5 ± 1.1	15.2 ± 0.9	16.6 ± 1.0
24hr – CDT @ 65°C	4.5 mm	2.1 ± 0.1 mm	2.5 ± 0.3 mm	2.3 ± 0.2 mm
48hr – CDT @ 65°C	4.5 mm	2.4 ± 0.3 mm	4.8 ± 0.5 mm	3.9 ± 0.8 mm
28d – CDT @ 23°C	6.5 mm	3.0 ± 0.8 mm	6.7 ± 0.8 mm	5.2 ± 0.9 mm
28d – CDT @ 50°C	11.5 mm	12.5 ± 0.7 mm	14.4 ± 4.1 mm	6.9 ± 1.0 mm
28d – CDT @ 65°C	13.5 mm	21.2 ± 0.6 mm	11.1 ± 2.4 mm	10.2 ± 0.7 mm
28d – CDT @ 80°C	16.5 mm	25.6 ± 7.4 mm	6.1 ± 0.5 mm	9.8 ± 1.4 mm
24hr HWS @ 75°C	Rating of 1-3	1, 1, 1	1, 1, 1	1, 1, 1
48hr HWS @ 75°C	Rating of 1-3	1, 1, 1	2, 2, 2	2, 1, 1
28d HWS @ 75°C	Rating of 1-3	1, 1, 1	3, 1, 1	1, 1, 1
24hr HWS @ 95°C	Rating of 1-3	1, 1, 1	1, 1, 1	1, 1, 1
28d HWS @ 95°C	Rating of 1-3	3, 1, 1	1, 1, 1	1, 1, 1
Impact @ -40°C	1.5J	Pass	Pass	Pass
Impact @ -30°C	1.5J	Pass	Pass	Pass
Impact @ -10°C	1.5J	Pass	Pass	Pass
Impact @ 0°C	1.5J	Pass	Pass	Pass
Impact @ 23°C	1.5J	Pass	Pass	Pass
Impact @ 50°C	1.5J	Pass	Pass	Pass
Flexibility 1.5° @ -30°C	No Cracking or Stretch Marks	Pass	Pass	Pass
Flexibility 2.5° @ -30°C	No Cracking	Pass	Pass	Pass
Interfacial Porosity	Rating of 1-4	Rating of 2	Rating of 2	Rating 1
X-Section Porosity	Rating of 1-4	Rating of 2	Rating of 2	Rating 1
ΔTg	< 3°C	4.31°C	1.68°C	-2.59°C
% Cure	> 95%	96%	99%	99%

Bredero Shaw has explored alternate non-contact temperature monitoring method to improve the preheat temperature monitoring capability during coating process. Application temperature was measured by a non-contact measuring device and results were comparable to the profiles obtained by the contact thermocouple.

In the North Central Corridor coating job, non-contact temperature measurement was employed in the production run for monitoring the pipe/application temperatures. Process capability analysis was performed with the temperature profiles from this job and results support that the preheat temperature process is capable of meeting specifications ($C_p > 1.3$) and also potentially capable of meeting specifications ($C_{pk} > 1.3$). All these results will be presented in the NACE 2010 regional meeting in Calgary.

CONCLUSIONS

Low application temperature FBE has been applied successfully as stand-alone coatings and base layers of dual-layer, HPCC and three-layer systems. Test results demonstrated that LAT-FBE applied in the range of 175-200°C provides virtually identical performance to conventional FBE applied at 230-250°C. The use of LAT-FBE has the following benefits:

1. Energy reduction during the coating process
2. Suitability for high strength steel pipes
3. Increased production throughout and reduction of polyolefin topcoat usage for three-layer.

Proper application temperature is the key factor in desirable coating adhesion and performance for LAT-FBE coating. It is important to ensure that the application temperature is maintained within the specified range. A non-contact preheat temperature monitoring by infrared was also successfully employed in LAT-FBE production runs.

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