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16. Abstract

Traffic signal mast arm baseplate connections are particularly susceptible to fatigue. The top of traffic signal mast arm welds experience fluctuating tensile stresses when wind and traffic gust loads cause the mast arm to oscillate. It has been postulated that UIT application to mast arm weld toes during the fabrication process will delay fatigue crack initiation. Successful UIT application during the fabrication process will extend fatigue lives of traffic signal mast arm welds in the field. Since mast arm welds are the weakest spot in the traffic signal structure, increased weld life translates into increased traffic signal life. Previous research claims that UIT is light, quiet, and easy to learn. Critical areas under scrutiny during UIT application at the fabrication plant are: time lost due to training workers, time lost during the UIT application, and efficiency of the treated poles. This report investigates the first two issues by documenting the application of UIT to fabricated mast arms at the TransAmerican Power Products facility.

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UIT Application During Fabrication

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INTRODUCTION

Traffic signal mast arm to baseplate connections are particularly susceptible to fatigue. The weld at the top of traffic signal mast arms experience fluctuating tensile stresses when wind and traffic gust loads cause the mast arm to oscillate. It has been postulated that UIT application to mast arm weld toes during the fabrication process will delay fatigue crack initiation [1]. Successful UIT application during the fabrication process will extend fatigue lives of traffic signal mast arm welds in the field. Since mast arm welds are the weakest spot in the traffic signal structure [1], increased weld life translates into increased traffic signal structure life.

UIT must be applied after hot-dip galvanization, since temperatures above 300^{o}C have proven to undo the benefits of UIT, probably because extreme heat relaxes the beneficial compressive stresses induced by UIT [2, 6]. Hence, UIT is the final step of the fabrication process at the fabrication plant. Galvanization removed during UIT application is repaired with a zinc-rich paint, which has no effect on the UIT. [2, 3].

Previous research claims that UIT is light, quiet, and easy to learn [3, 4, 5, 6, 7, 8]. Critical areas under scrutiny during UIT application at the fabrication plant are: time lost due to training workers, time lost during the UIT application, and fatigue performance of the treated poles. Proprietary tests performed for TransAmerican Power Products indicated that UIT treatment significantly improved the fatigue performance of their traffic signal structures. Therefore, this report investigates only the first two issues by documenting the application of UIT to fabricated mast arms at the TransAmerican Power Products facility.

TRAINING SESSION

UIT training took place at the TransAmerican Power Products, Inc. fabrication yard, located at 2427 Kelly Lane, Houston, TX 77066. The observed training began on October 12, 2004. UIT training covers application technique and basic theory behind UIT. UIT training was lead by a trained Applied Ultrasonics technician. Applied Ultrasonics is currently the only UIT vendor in the US.

During the morning training of October 12, 2004, the Applied Ultrasonics technician met with the Vice President of TransAmerican, TransAmerican's Quality Control person, two TxDOT inspectors, and the author. The two workers that would actually perform the treatment were not present at this morning presentation. Since everyone in the group, with the exception of the Quality Control person, was familiar with UIT, the Applied Ultrasonics technician presented a shortened version of the UIT background information presentation, which only lasted one and a half hours. The information presentation for a group that is not familiar with the process usually lasts the entire morning of a daylong UIT training session.

The presentation introduced the concept of increasing fatigue life, using UIT, showed the equipment, proper application settings and techniques, and stressed that already cracked materials cannot be treated. The TransAmerican Quality Control person, the only person at the presentation not familiar with UIT, asked many questions, and the Applied Ultrasonics technician had no problem answering all the questions. The TransAmerican Quality Control person has an extensive background on other weld fatigue life improvements, and after the presentation he understood UIT to be a process similar to shot peening.

AFTERNOON FABRICATION YARD UIT APPLICATION TRAINING

The UIT application training took place in the TransAmerican yard over a few days. The first day is documented in this section.

Test Setup

Since UIT is the last step in the fabrication process, the mast arms to be treated were already galvanized and stockpiled in the TransAmerican fabrication yard. Figure 1 shows the stockpiled mast arms in the fabrication yard.

Figure 1 Stockpiled Mast Arms at the TransAmerican Fabrication Yard

A crane moved mast arms in the TransAmerican yard from their stockpiled location to the fixed testing stand. The mast arms were stockpiled near the fixed testing stand, so that the crane did not have to move, only rotate, during transportation of the mast arms. After the training was complete, the crane was replaced by a forklift for the routine treatment of the arms.

TransAmerican had a fixed testing stand made of steel that was connected to a concrete slab. The fixed testing stand had several sets of holes in it to allow for the different size base plates that TransAmerican fabricated. It took a total of 3 people to connect the mast arm to the test stand. Figure 2 shows a mast arm being bolted into place.

Figure 2 Mast Arm Being Connected to Fixed Testing Stand

Previous research by Koenigs shows that UIT application is most effective when applied under an imposed stress of 16.5 ksi at the treated weld toe [1]. The mast arms at TransAmerican have UIT applied under a nominal 16.5 ksi bending stress to simulate the stress in the arm under static service loading. There are two sets of design standards for TxDOT's cantilever traffic signal structures: Structures that are designed for 100 mph winds, and structures that are designed for 80 mph winds. TxDOT inspectors used the standards for structures designed for 100 mph winds when determining the load to place at the mast arm end that would induce a 16.5 ksi stress at the weld toe of a 20 foot mast arm. A 500-pound load was applied to the end of all mast arms before UIT application at the TransAmerican fabrication yard to produce the nominal 16.5 ksi stress at the weld toe. To simplify the application procedure, the same weight was used for all mast arms.

After the mast arm was bolted to the fixed testing stand it was loaded with a 500-pound circular weight, as shown in Figure 3 and Figure 4. Figure 3 shows the crane as it moved a 500-pound circular weight to the end of the mast arm. Figure 4 shows personnel securing the 500-pound weight in place. Figure 5 shows a close-up of the 6 inch tenon at the end of the mast arm that was used to support the 500-pound circular weight during UIT application.

Figure 3 Crane Moving the 500-Pound Circular Weight to the Mast Arm End

Figure 4 Placing the 500-Pound Circular Weight on the End of the Mast Arm

Figure 5 Mast Arm with 6-Inch Tenon at the End

Figure 6 shows the entire UIT application set-up in the TransAmerican fabrication yard prior to UIT application.

Figure 6 Entire Loaded and Fixed Mast Arm UIT Setup

UIT Application Demonstration

UIT application began after the mast arm was secured in the loading setup and loaded with the 500-pound weight. The Applied Ultrasonics technician demonstrated the UIT application procedure by applying UIT to the TransAmerican mast arm. The TransAmerican workers who were being trained observed the example application.

First, the power generator was turned on. The power generator supplied power to the UIT generator. Next, the water pump was turned on to cool the UIT generator. The UIT generator produces the ultrasonic oscillations that are utilized by the UIT tool to treat the steel weld. Then the UIT generator was turned on to maximum power, which corresponded to 80 volts. The UIT tool used 10 amps, so the power applied during UIT application was 800 watts. The UIT generator was set at maximum power for all mast arm applications. Figure 7 shows the UIT generator and the water pump. Figure 8 shows the UIT generator, the UIT tool, and the power generator.

Figure 7 UIT Generator (Blue Box on Left) and Water Pump (Red Box on Right)

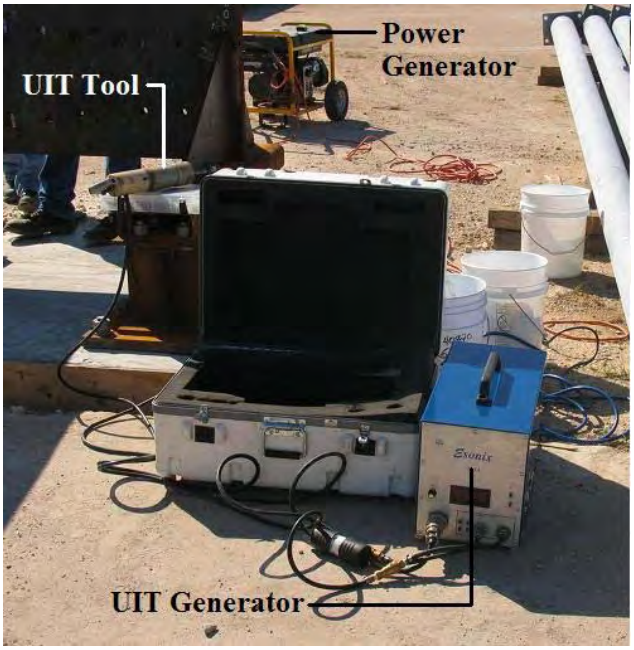

Figure 8 Front View of the UIT Tool, Power Generator, and UIT Generator

The technician applied UIT to both toes of the mast arm-base plate weld. The Applied Ultrasonics technician expressed that it is irrelevant which weld toe is treated first. Both weld toes were treated with UIT following the same procedure. UIT was applied to the mast arm weld toe with the multi-pin UIT tool held at a 45° angle from the mast arm. The angle that the UIT tool is held against the weld toe during application can range from 30° to 60°, but an effort to keep the tool at 45° to the weld toe should be made. The UIT application followed the weld toe so as to create a smoother transition from the weld to the mast arm or base plate. A maximum of four passes was made with the UIT tool. UIT with a 1/8 inch diameter pin should create about a 1/8 inch impression at the weld toe. In general, the groove created by UIT is expected to be about the size of the treatment pin.

The UIT tool used during application had a multi-pin head on the tool, with two 1/8 inch pins installed. Applied Ultrasonics has found that two pins perform better than three or four 1/8 inch diameter pins for application to 10 inch diameter mast arm weld. The reason that two pins give superior UIT application is that the small diameter of the mast arm prevents three or more pins from coming into contact during application. A flat plate, for example, would probably get superior UIT application from three or four 1/8 inch diameter pins in the multi-pin tool because all of the pins would be able to contact the steel during treatment. Figure 9 shows UIT application.

Figure 9 Application of UIT to a Mast Arm Weld Toe

The UIT was applied with a steady, yet light, pressure on the UIT tool. The application technique did not require a hard push. The UIT tool was moved over the length of the mast arm weld toe to be treated. The 6.6 pound weight of the tool and the action of the tool itself created the necessary contact force. The length of the UIT application along the mast arm weld toe extended 90° in each direction from the top vertical of the mast arm. Hence, the entire top 180° of the mast arm weld toes was treated with UIT. Since the mast arm had a 10 inch diameter, the mast arm had a weld toe circumference of 31.4 inches. The topmost 15.7 inches of the 31.5 inch mast arm weld was peened with UIT. The bottom 180^{o} of the mast arm does not need UIT application because previous tests indicate that fatigue cracking does not occur where the mast arm is in compression, namely, the bottom of the mast arm [1].

Figure 10 shows the mast arm-baseplate connection before UIT application. Figure 11 shows a 180^{o} application of UIT to the weld toe on the arm. Notice in Figure 11 that the treated area is shiny due to the galvanization flaking off during treatment which revealed the un-galvanized steel underneath. In Figure 11 the groove produced by the 1/8 inch diameter pins of the multi-pin UIT tool is also visible. Figure 12 shows application of UIT to the baseplate weld toe.

Figure 10 Mast Arm-Baseplate Weld Connection Before UIT Application

Figure 11 Completed Mast Arm Weld Toe UIT

Figure 12 Application of UIT to Baseplate Weld Toe

Inspection by a TxDOT Inspector

After the example UIT application by the trained technician, a TxDOT inspector inspected the groove produced by UIT application. One hindrance to perfect UIT application is when existing galvanization on the mast arm weld toe does not flake off from UIT application, or flakes off and then gets between the UIT tool pins and the mast arm weld metal. Pieces of galvanization can result in a barrier between the UIT tool and the metal to be treated. According to the Applied Ultrasonics technician, during past UIT applications, pieces of galvanization have prevented proper impact of the weld metal by the UIT tool. If either the galvanization does not flake off during treatment, or galvanization that has flaked off gets between the UIT tool and the area of treatment, gaps in proper UIT application will occur. The UIT application area must be cleared of any remaining galvanization after UIT application for inspection for incomplete treatment. The trained technician suggested using a screwdriver to remove galvanization after UIT application, if a screwdriver is available. Oil cannot be used to remove galvanization after UIT application, because oil will interfere with application of the zinc-rich paint to repair the galvanizing area after UIT application. TxDOT inspectors recommend using a wire brush for galvanization removal after UIT application. Figure 13 shows galvanization being removed with a wire brush.

Figure 13 Removal of Galvanization with a Wire Brush

After all galvanization was removed from the UIT application area, and the UIT application was complete, the UIT application depth was measured. Proper UIT application with 3 mm diameter pins in a multi-pin UIT tool usually produces a 1/8" (3 mm) diameter groove along the treated weld toe. The width of the UIT application groove and the maximum depth of the UIT application groove were difficult to measure. The depth of the UIT application groove can be measured either with a weld undercut measuring device, or by rolling a single 3 mm diameter pin from the UIT tool in the UIT application groove. Rolling the 3 mm diameter pin from the UIT tool in the UIT application groove is a good check of the UIT application groove's depth and width when more sophisticated tools are not available. Figure 14 shows the measurement of the UIT application groove using an undercut measuring device. Figure 15 shows a 3 mm diameter pin from the UIT tool rolled in the UIT application groove.

Figure 14 Measurement of UIT Application Groove Using an Undercut Measuring Device

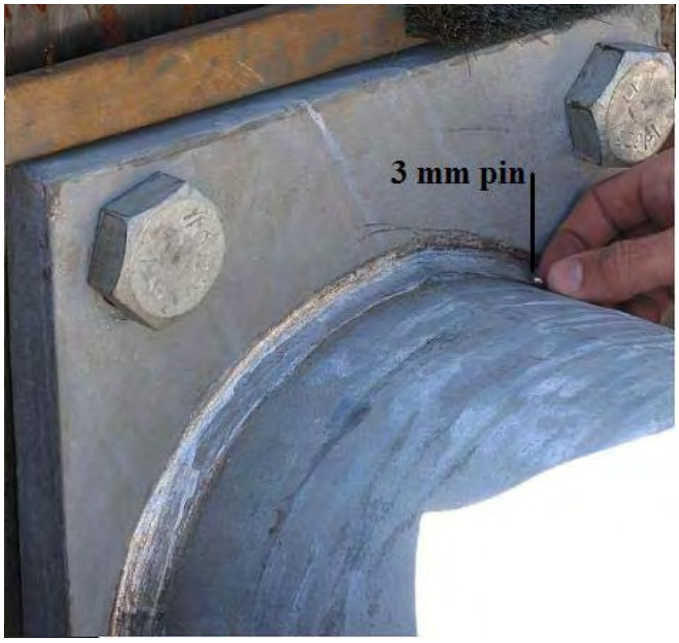

Figure 15 Measurement of UIT Application Groove by Rolling a 3 mm Diameter Pin from the UIT Tool in the UIT Application Groove

Repair of Galvanizing

After satisfactory inspection of the UIT application by a TxDOT inspector, a zinc-rich paint repair was applied in two coats by the TxDOT inspector. The first coat was allowed to dry before the second coat was applied. The zinc-rich paint used at the TransAmerican fabrication yard by TxDOT inspectors was Rust-oleum Cold Galvanizing compound, which contained 93%

pure zinc. Figure 16 shows the paint being applied. Figure 17 shows the area of UIT application while the paint is drying. Figure 18 shows a completed UIT application after repair is completely dried.

Figure 16 Application of Zinc-Rich Paint

Figure 17 Drying Zinc-Rich Paint

Figure 18 Mast Arm Weld After Completion

Removal of Mast Arm from Fixed Testing Stand

After both weld toes had UIT application and the galvanizing had been repaired, the crane removed the 500-pound weight from the end of the mast arm. The crane then supported the mast arm as three people removed the bolts from the testing stand. Two people aided the crane by guiding the un-bolted mast arm as the crane moved the mast arm from the testing stand to a storage area.

The finished mast arm treated in the demonstration was labeled for reference on what a correct UIT application to a mast arm weld should look like, and was set aside for future reference.

Applied Ultrasonics Technician Treatment Times

Table 1 lists the times for each phase of UIT application to a mast arm weld during the training demonstration

Table 1 Description of Phases of UIT Application

Phase	Description	Applied Ultrasonics Technician Times (minutes)
1	Move the mast arm with crane from stockpile to fixed testing stand, bolt the mast arm to the fixed testing stand, and apply the 500-pound circular weight with the crane to the end of the fixed mast arm.	15
2	UIT application to the mast arm weld toe.	6
3	UIT application to the base plate weld toe.	5
4	Inspection of both mast arm and base plate weld toes, removal of galvanization flakes and remaining galvanization, touch-up of UIT application, and application of zinc-rich cold-spray galvanization repair.	15
5	Unbolting the mast arm with UIT application and moving the mast arm by crane to a new stockpiled location.	4
Extra	Discussion and breaks.	7
	Total:	53

APPLICATION OF UIT BY TRAINED EMPLOYEES

The TransAmerican employees that were trained to apply UIT at the fabrication yard were present during the UIT application by the Applied Ultrasonics technician, but the employees were often not in the best position to view the UIT application technique. The employees that were being trained to apply UIT to the mast arm welds at the fabrication yard practiced first on a test plate weld. The test plate weld consisted of a small section of a base plate-mast arm connection. Figure 19 shows an employee practicing on the test plate.

Figure 19 Employee Applying UIT to a Test Plate Weld

After the employees became comfortable with the UIT process, they started UIT application to a loaded mast arm weld in the setup. During the UIT application by the employee, the Applied Ultrasonics technician and Vice President of TransAmerican often had to stop the employee to show him by example the correct UIT application techniques. During the employee's first UIT application of a mast arm weld he made many more passes than was necessary, did not always hold the tool at 45^{o}, and was not able to keep the treatment along the weld toe. Figure 20 shows an employee applying UIT to the weld toe. The Uit tool is almost vertical, not at the desired 45^{o} angle.

Figure 20 Employee's First UIT Application to a Mast Arm Weld

TransAmerican Employee's UIT Application Times

The employee's UIT application to a mast arm weld involved the same phases as the Applied Ultrasonics technician, as listed in Table 1. The approximate times for the employee's UIT application are listed in Table 2 Phases such as UIT application to the mast arm weld toe and the baseplate weld toe overlapped at times, so times are approximate.

Table 2 Employee's First UIT Application to a Mast Arm Weld Times

Phase	Description	Applied Ultrasonics Technician Times (minutes)	TransAmerican Employee's Times (minutes)
1	Move the mast arm with crane from stockpile to fixed testing stand, bolt the mast arm to the fixed testing stand, and apply the 500-pound circular weight with the crane to the end of the fixed mast arm.	15	7
2	UIT application to the mast arm weld toe.	6	35
3	UIT application to the base plate weld toe.	5	35
4	Inspection of both mast arm and base plate weld toes, removal of galvanization flakes and remaining galvanization, touch-up of UIT application, and application of zinc-rich cold-spray galvanization repair.	15	20
5	Unbolting the mast arm with UIT application and moving the mast arm by crane to a new stockpiled location.	4	5
Extra	Discussion and breaks.	7	20
	Total:	53	102

By the end of two days of training the employees, TransAmerican employees could complete three to four UIT applications and paint repairs to mast arms per day. However, after two weeks the employees were able to complete 10 to 15 UIT applications per day, according to a Houston TxDOT inspector.

DISCUSSION

Applied Ultrasonics Technician Treatment vs Trained TransAmerican Employee Treatment

Figure 20 shows that the TransAmerican employee held the UIT multi-pin tool at an extreme angle to the weld toe, not at the recommended 30^{o} to 60^{o}. The employee used more than the recommended two 1/8 inch diameter pins in the multi-pin UIT tool. The shiny areas visible in Figure 20 show that the employee's UIT application strayed from the weld toe into the baseplate, mast arm, and weld metal by many millimeters. Excess UIT application is not in accordance with approved UIT application techniques, and the effects of excess UIT application are unknown. However, since compressive stresses and plastic deformation definitely take place, even in areas of excessive UIT application, it can be assumed that poor UIT application that results in excess UIT application area will still enhance the fatigue life of the mast arm weld. The UIT application by the Applied Ultrasonics technician, on the other hand, was in perfect accordance with the Applied Ultrasonics UIT application guidelines. The bolts attaching the mast arm to the testing setup hampered both the employee and Applied Ultrasonics technician during UIT application.

Treatment by the Applied Ultrasonics technician from start to finish took less than an hour, and would have been less if the focus had been pure UIT application instead of instruction. Treatment by an employee on his first day of training can last for one to two hours, although the employee will have UIT application times comparable to a trained Applied Ultrasonics technician after a few weeks. The TransAmerican employee did not understand English, which slowed the learning process at TransAmerican. A possible way to increase employee productivity would be to teach the UIT application technique in the employee's native language. Another possible way to expedite employee learning of UIT application is to have the employees being trained attend the morning presentation on UIT. By attending the morning UIT presentation, the employees being trained may feel more comfortable with the UIT tool when they begin their hands-on training.

UIT Application Concerns

A concern with UIT raised by the TxDOT inspectors is under-treatment. A concern that UIT needs to be applied entirely around the pole was raised, since cracks will find the new weakest spot in a connection. Since the mast arm-base plate connection is in compression on the bottom half of the mast arm, crack initiation in this area is not of concern.

Proper application of UIT requires that all galvanizing is removed during UIT application. Occasionally, UIT application does not remove galvanizing correctly. The problem of flaking galvanizing interfering with UIT application may be prevented by removing galvanizing prior to UIT application.

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