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NDT Testing with Visual Testing Method in the Inside Upper Frame 6015 Area with GMAW Welding Based on 1E0099

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Abstract

The Upper Frame is the most important component of the excavator because it acts as an engine mount or hose holder connected to the main control valve. So for the welding process, special attention is needed for the frame center which aims to avoid weld distortion between the right side and the left and also as a cable holder from the engine. Therefore, the welding results require special attention starting from the size of the weld and the arrangement of defects in the weld results. The welding process on the Upper Frame uses the GMAW (Gas Metal Arc Welding) process with Lincoln Merit ER70S-6 wire, where the wire size is 1.320 mm and the welding results will be tested using the NDT (Non-Destructive Testing) method, namely Visual Testing. This study aims to determine the results of visual tests in the inside Upper Frame 6015 area using the 1E0099 standard. 1E0099 is the welding procedure used at PT Caterpillar Indonesia Batam. Visual test results from GMAW (Gas Metal Arc Welding) welding are expected to be free of weld defects. If there are still weld defects found, the welding results are still within the acceptance criteria based on internal code 1E0099.

Keywords: *Automation, example, embedded system, water-based vehicle, dynamic system*

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INTRODUCTION

Welding is the process of joining two or more metal materials with a heat process that melts the two specimens and then unites [1]. There are several welding methods in the manufacturing industry, one of which is GMAW welding (Gas Metal Arc Welding). GMAW welding is a semi-automatic welding process in which the welding wire is pushed through the wire feeder unit along with the protective gas that comes out through the nozzle then the welding wire meets the parent material to be connected and then produces arc welding [2]. One of the main variables influencing the welding process' productivity is the solid wire's melting rate [3]. In the GMAW welding process, the melting rate is thought to be influenced by the welding speed and welding current. The process used in all manual operations is the same for making butt welded joint. Welded joint quality criteria is multifaceted, such as geometric quality, absence of defect and strength quality criteria [4]. Each such criterion estimates only certain areas of weld quality. Both benefits and drawbacks come with GMAW welding. This welding technique offers several benefits, including good weld outcomes (weld strength), no slag production, and high processing efficiency. But the cost of this welding is substantial [5].

Visual inspection (VT) is the oldest and most widely used NDT method. It involves visual observation of the surface of the specimen to evaluate the presence of surface weld discontinuities such as irregularities, undercuts, porosity, overlaps and cracks [6]. Visual testing can be done by viewing the test piece directly, or by using optical instruments such as magnifying glasses, mirrors, borescopes, and computer-aided vision systems [7]. Visual can be applied to inspect casting, forging, welding and is used in all branches of industry. Weld beads can be tested visually, although interior irregularities cannot be found [8].

In this case the role of a welder must be able to produce quality welds that meet the requirements and criteria and must also pass various forms of testing, one of which is nondestructive testing or commonly known as NDT (Non-Destructive Test), for that a welder is expected to be able to fulfill it all even in restricted areas or for example in the Inside Area Upper Frame 6015 as seen in figure 1, which is a difficult position even to do limited work movement.

1E0099 is an internal manufacturing standard issued and set by the Caterpillar Inc company which regulates the welding procedure qualification process (Welding Arc) even for the evaluation of some defects that are still allowed [9]. In 1E0099 there are references for each process such as welding simulation, welding symbols and welding result testing. The welding result testing process that will be applied is NDT (visual testing, magnetic particle testing, ultrasonic testing). For this research, testing of welding results will be shown and discussed for one method only, namely NDT (visual testing).

Figure 1. Upper frame 6015.

Welding is required to produce very high-quality products, so it is carried out at the joint frame inside center to base plate welding in a restricted area where the welding area is only one meter in size and for the Base Plate to Frame joint and weld defects often occur. So Visual Testing to ensure the inside area of the joint to base plate to frame and sidewall is free from discontinuities in welding in the inside center area, then repairs or rewelding can be made so as to produce welding that meets quality.

Based on the description above, this research entitled "NDT Testing with Visual Testing Method in Inside Upper Frame 6015 Area with GMAW Process based on 1E0099" aims to find out the advantages of Visual Testing. Especially in the Inside Upper Frame Area so that it can see more clearly what defects are still left from the GMAW welding.

METHODS AND ANALYSIS

This research methodology NDT "Visual Testing" is taken from one international standard reference, namely 1E0099 [10]. Figure 2 show research illustration of visual inspection.

Plate Fit Up

Before carrying out the welding process, one of the preparations is fit up [11], where the first adjustment process is carried out starting from adjusting the gap distance and straightness of the base metal and then doing spot welding (tack weld) so that the distance that has been set does not change when welding. The details of the materials used are mentioned in table 1.

Dimensional Check

This dimensional check is carried out after Fit Up by a quality to see the results of the fit up of the material before the welding process is carried out. Dimensional check can be seen in table 2. Checking usually uses tools, namely the roll meter and taper gauge. For checking dimensions, among others:

1. Distance between material to datum
2. Flatness of the material.

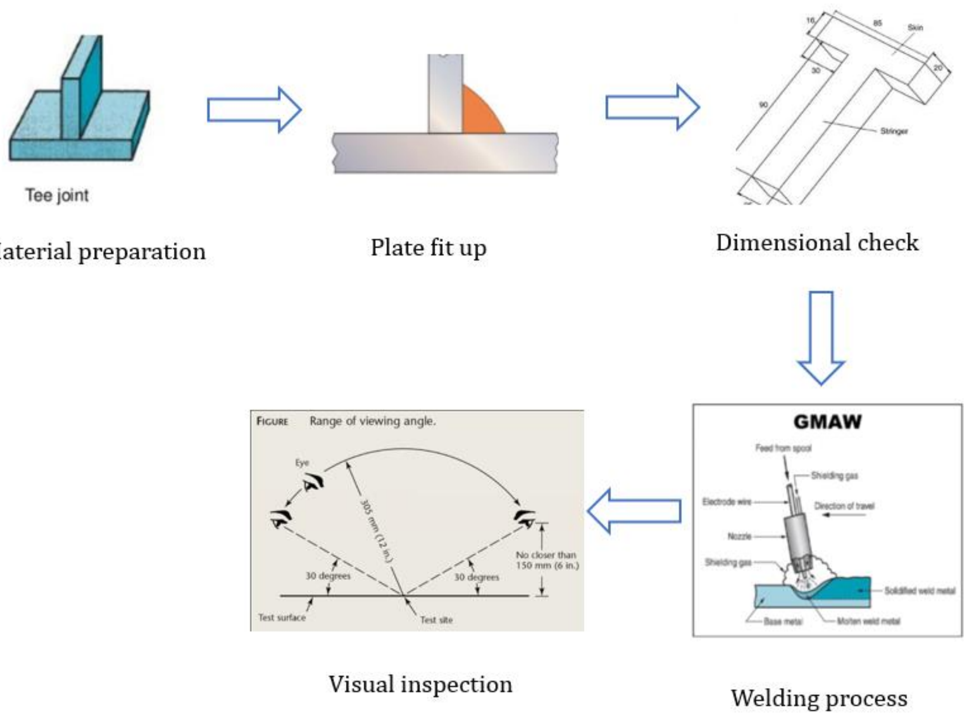


Figure 2. Research illustration of visual inspection.

Table 1. Materials used

Details	Design of welding process 1	Design of welding process 2
Plate Number	465-6222	465-6197
Material 1	Base plate carbon steel (S355)	Sidewall plate RH/LH carbon steel (S355)
Material Sizes	Length: 6395 mm material thickness: 50 mm	Length: 5411 mm material thickness: 50 mm
Joint Design	Tee joint fillet weld with 16 mm weld toe size	Tee joint fillet weld with 16 mm weld toe size
Material 2	Base plate carbon steel (S355)	Base plate carbon steel (S355)
Material Sizes	Length: 1058 mm material thickness: 25 mm	Length: 1058 mm material thickness: 25 mm
Joint Design	Tee joint fillet weld with 16 mm weld toe size	Tee joint fillet weld with 16 mm weld toe size

Table 2. Dimensional Check

	Distance between material to datum	Flatness of the material
Dimensional Check		

Table 3. Welding Parameters

Run number	Welding process	Welding position	Wfs	Volt	Travel speed mm/min
First Layer	GMAW	2F	8-10	30-32	415-760
Second Layer	GMAW	2F	8-10	30-32	415-760
Third Layer	GMAW	2F	8-10	30-32	415-760

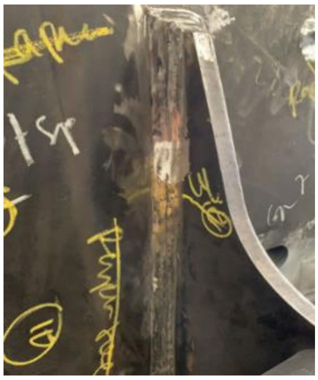
Welding Process

Welding process to be used is Gas metal arc welding (GMAW) using a mixed protective gas 75% Argon and 25% CO_2 [12]. For the first welding process with 2F welding position in the inside frame area with filling from the first layer to the third layer with a total of 6 passes each pass has a size of 5 mm and a total of 16 mm welding size calculated from the foot of the weld leg, the welding parameters used are mentioned in table 3.

Visual Inspection

Visual testing is part of NDT (Non-Destructive Test) testing carried out on welds without damaging the material or by looking and observing the welds with the eye or with other assistance, to see the outside of the welds, visual testing is one of the most widely used inspection methods, visual testing does not require special equipment and because in terms of cost it is relatively cheap as well as fast and easy to implement. This test has the disadvantage that there is a limited vision of an inspector and cannot ensure the quality that is in the surface of the welds so that if there are defects in the weld results cannot be detected. The before-after visual inspection appearance for each material can be seen in table 4.

Table 4. Visual Inspection

Visual inspection	Material 1	Material 2
Welding Profile before Quality check		
Welding Profile after Quality check		

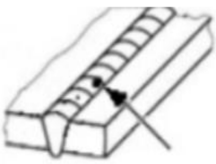
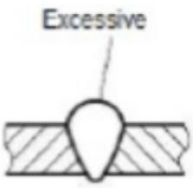
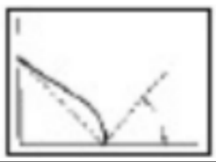
Visual inspections that use tools to measure and see, tools used such as welding gauges, inspection torches, solid markers as mentioned in table 5 [13].

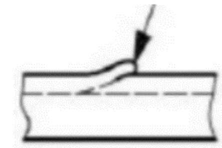
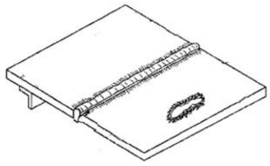
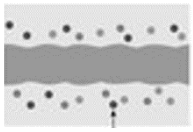
In 1E0099, which is a standard code from the Caterpillar company regarding visual testing, there are criteria regarding the results of weld tests that are allowed and vice versa, which are mentioned in table 6.

Table 5. Inspection Equipment

No.	Inspection Equipment
1.	Welding Gauge 
2.	Torch Light 
3.	V WAC Gauge 

Table 6. Visual Criteria of Welds Based on 1E0099

Weld defects	Figure	Description	Standard defect limits	Strict defect limit
Porosity on the surface		• Minimum diameter that can be seen • Maximum diameter at single pore hole • Maximum number of visible pores, there is every 300 mm weld length	1 mm (not minimum in flocking) 2 mm 6 mm	Not allowed
Material consumed (undercut)		Maximum depth measured from the surface of the plate regardless of length	0.5 mm	5% of plate thickness, maximum depth 0.5 mm
Excess weld metal (Convex)		• Weld surface width 20 mm • Surface width > 20 mm but < 30 mm • Weld width of 30 mm or more	2mm 3mm 4mm	2mm 3mm 4mm
Overlap weld metal		Expressed as a minimum to the angle (applies to the leg of the weld	90°	110° (Fillet weld)

		and the intersection of adjacent stacks)		150° (V-shape weld)
Bad start (tie in)		Measured from the excess weld metal	Not allowed	Not allowed
Deviated arc of the weld (arc strike)			Not allowed without repair	Not allowed without repair
Scattered weld spots (Spatter)			Not allowed without repair	Not allowed without repair

Notes:

(1) The criteria of strict weld defects apply to high body types made by Caterpillar starting from HMS 6060, HMS 6040, HMS 6030 to HMS 6020 other than these types using standard weld defect criteria (HMS 6015, Truck body 793, and Truck body 797).
(2) Measurement of leg length using Welding Gauge.

RESULTS AND DISCUSSIONS

The welding profile in the first welding design is a tee joint with a welding position of 2F and a welding size of 16mm and the welding profile in the second welding design is a Tee joint on plate number 465-6222 with a welding position of 2F and a welding size of 16 mm. One- or two-sided fillet welds that were completed from the web-sheet side are typically seen in welded T-joints. Nevertheless, for every construction, accessibility to the joint from the web-sheet side is not guaranteed. As a result, welding T-joints from the face-sheet side can occasionally be quite difficult. The web sheets must be precisely positioned and fixed in order to use these so-called concealed T-joints [14].

The maximum allowable Weld Bead size of GMAW fillet welds made in a single pass for semiautomatic welding in the flat position should be 10 mm to 12 mm (based on wire diameter size) and 8 mm for the horizontal position. Variations 1E0099B, 1E0099M, 1E0099U, 1E0099V have a maximum single pass weld size limited to a weld swing width of 14 mm.

Each weld joint parent material has been visually inspected in advance in order to meet the requirements of the standard code 1E0099. The results of the visual inspection can be seen in figures 3 and 4 of the visual observations shown in these figures are then compared with the benchmark for the acceptability of the visual inspection results as shown in table 6, namely the table of visual testing criteria [9].

Figure 3 describes the undercut defect found in the visual test where the defect has a length of 450 mm and a depth of 2 mm as shown above. The visual inspection results can be seen in figure 3 and then compared with the benchmark for the acceptability of visual inspection results as shown in table 6, namely the table of visual testing criteria.

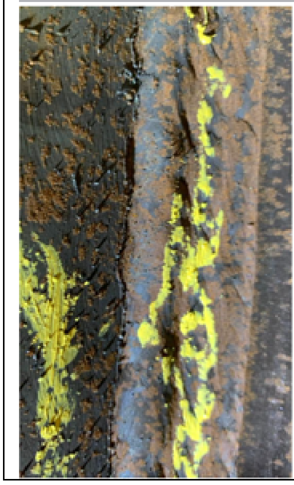
UPPER FRAME 6015	
FIRST DEFECT	ACCEPTANCE CRITERIA
 **UNDERCUT** Length: 450 mm Depth: 1.5 – 2 mm	Acceptance criteria for undercut – 1E0099 is 5% of the plate thickness with a maximum depth of 0.5 mm.

Figure 3. Undercut defect.

UPPER FRAME 6015	
SECOND DEFECT	ACCEPTANCE CRITERIA
 **SPATTER** Length: 200 mm Depth: 1 mm	Acceptance criteria for spatter – 1E0099 is spatter not allowed without repair.

Figure 4. Spatter defect.

Undercuts are typically a flaw in welding that can occur frequently or intermittently, particularly when welding quickly. Undercut formation is complicated and can happen in a number of ways, mostly because of melt flow mechanics and temperature [15]. Undercuts can severely reduce the fatigue characteristics of the welded workpiece [16]; hence efforts are made to prevent them—typically by overfilling or reducing the welding speed, but there are other solutions, such as selecting a better shielding gas or preheating the work piece before welding [17].

Figure 4 shows the risk of welding defect using the Gas Metal Arc Welding (GMAW) method. A quality problem with deep penetration laser welding methods is spattering which necessitates costly and time-consuming post-processing [18]. Causes of spatter including excessive welding current, increases of arc length, the polarity is off, improper gas shielding, the voltage is set too low, the electrode's operating angle is very steep, and the surface is polluted. Some preventions for spatter are cutting the welding current and arc length, adhering to the welding circumstances and using the appropriate polarity, and using appropriate gas shielding and raising the plate angle [19]. By adding jumped melts to a large molten pool, spattering also can be avoided [20].

In the code and standard 1E0099 for spatter problem are not allowed in the code and stated in table 6 is unacceptable.

CONCLUSIONS

After conducting visual testing on the welding process used in the inside area of the upper frame 6015 is GMAW (Gas Metal Arc Welding) using Lincoln Merit ER70S-6 wire size 1,320 mm and the results of the weld will be tested using NDT (Non Destructive Testing) methods, one of which is visual testing and the welding process on the part of the S355 carbon steel plate with plate number 171-4212 and thickness of 25mm and part of the 465-6222 carbon steel plate with a thickness of 50mm in the inside center area in accordance with the standards of code 1E0099. Based on the visual test results, it is known that there are two welding defects, the first is undercut as shown in Figure 5 with a defect depth of 2mm and a defect length of 450mm and the second is a spatter defect with a width of 1mm and a defect length of 200mm. All these defects have been declared reject or rejected based on the standard code 1E0099 used in Caterpillar.

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DECLARATION OF CONFLICTING INTERESTS

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