Postcrack Propagation of Tensile Shear Test: Analyzing the Carbon Steel Welds, Stainless Steel Welds, and Both Steels Mixed Welds in Resistance Spot Welding

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Postcrack Propagation of Tensile Shear Test: Analyzing the Carbon Steel Welds, Stainless Steel Welds, and Both Steels Mixed Welds in Resistance Spot Welding

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Abstract Conducting tensile shear test for the spot-welded specimens is a common practice in resistance spot welding as it helps to understand the loading behavior and its corresponding effect. Two categories of weld failures are conventionally regarded, as to distinguish the sound weld over a poor one. This approach has severe drawback from early days and therefore the postcrack propagation (PCP) method is carried out as an alternative in this experimental study. With the PCP experimental results in hand, the tensile shear test is simulated using ANSYS to observe the corresponding strain distribution. Based on the visual inspection of simulation and practical results, three classifications (IF, PF, and TF) are consequently categorized; so that the weld failures of tensile shearing test can now be accurately distinguished by means of cracking patterns. Moreover, some degrees of fractures have regularly been noticed by other fellow researchers within these three categories and thereby the fractures have been named after the degrees of cracking severity. Carbon steel welds, partially corroded carbon steel welds, stainless steel welds, and mixed steel welds have been parallelly analyzed for the PCP modes and the results obeyed the categorization very well.

Keywords Crack initiation · Postcrack propagation · Weld failure · Failure modes

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Introduction

Spot welds are the primal joining components that hold any car body for its elegant shape. An average of 6000 spot welds, to date, is being used for a luxurious car to connect its mechanical assembly, apart from other joining techniques. Usually, any car body has higher tendency of facing crashes when accident happens. This issue lays the foundation for failure analysis of postcrack propagation (PCP) and therefore examining the ultimate load bearing capacity becomes an important measure to determine the integrity or trust worthy of spot welds. Conventionally, the crack initiation is what has always been taken into consideration, when the spot welded specimens are subjected to the analysis of bonding strength during tensile shearing test [1–4]. This approach creates the ultimate tensile strength (UTS) as a common referencing model, of which, the maximum force that initiates cracks is assumed to be the maximum bonding strength of that particular welded pair [5–7]. Based on this empirical assumption, there would only be two possible outcomes that can be sustainable, as of either a sound weld or an insufficient weld [8–10]. This prediction limits the cracking patterns into two category but as a matter of fact, it yields various degrees of weld failures under the tensile shearing test [11–13]. As to overcome the anomalies of failures categorization, the postcrack propagation analysis (PCP) is carried out in this investigation. Figure 1 illustrates the entire loading curves of PCP from poor to expulsion limits. In PCP, the loading behavior is continued until the complete separations between welded counterparts are noticed. With this experimental concept, the carbon steel welds, corroded carbon steel welds, stainless steel welds, and both steels combined welds are investigated for various levels of loading effects that generate complete separation between welded spots [14, 15].

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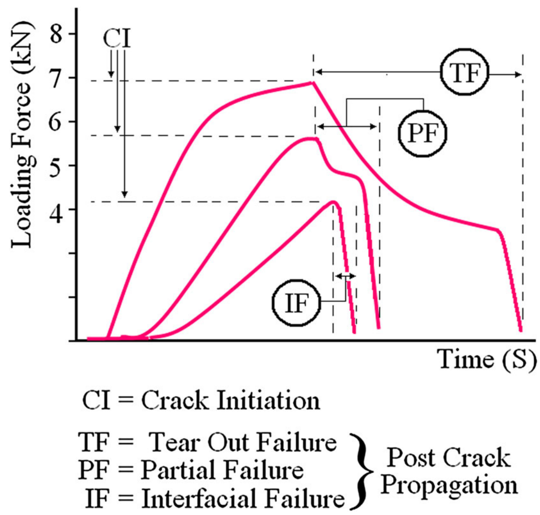

Fig. 1 Crack initiation and the postcrack propagation of tensile shear test (1 mm sheets)

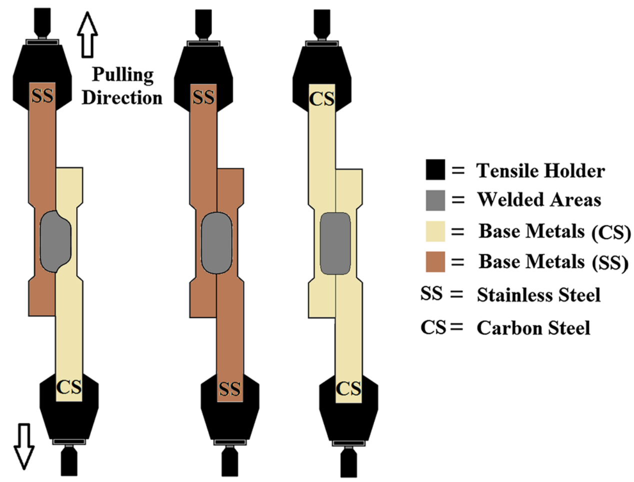

Fig. 2 Tensile shearing test of carbon steel, stainless steel, and both steel mixed welds

Experimental

Carbon steel and stainless steel materials are mainly used to prepare the welding materials as sheet coupons, having a size of 200 mm of length, 25 mm of width, and 1 mm of thickness. A Japanese model spot welding machine (75 kVA) is engaged to weld the coupons as lap joints, producing approximately 900 welded pairs. Process variant, the welding current has been primarily varied to weld these sheets together, forming the weld nuggets from poor to expulsion limits. The welded samples are consequently tested by a tensile machine as to understand the postcrack loading behavior and its corresponding effects. Pull-to-separate mode is carried out to observe the entire postcracking patterns. The tensile machine's gripping is set to hold about 40 mm of each side of welded samples using metal grippers (Fig. 2). Pulling speed of the machine is maintained around 50 mm per minutes and the continuous pulling mechanism which produces complete separation between welded pairs is considered as the PCP test. The entire welding process is conducted for more than 900 weld samples, but, only the appropriate samples are included in this paper for visual inspections.

Results and Discussion

Crack Initiation Versus Postcrack Propagation

Traditional approach of tensile test uses two distinctions in differentiating the weld joints such as the interfacial failure (IF), which represents prematurely failed welds; while the button pull-out (TF), represents better welds [16–18]. As for the interfacial failure, the complete separation happens at fusion zones without fracturing any other part of the base metals [19, 20]. In contrast, the button pull-out type fractures at the heat-affected zones as having a complete circle of tearing-off or so [21, 22]. As to challenge this empirical idea, deep focus has been put onto the categorization, and consequently three categories (IF, PF, and TF) are identified for the PCP modes with degrees of severity. Thus, the TF type failures have drawn the highest tensile shearing force, while pTF type failures held the second highest place in the loading forces consumption. TF represents the 1st degree while pTF represents the 2nd degree of most sound welds. Literally, the TF has torn with trails from weld button on both sides, tearing in the direction of tensile pulling levers. It seems to be the best weld joints of all, which draws highest tensile shearing forces and is denoted by TF (1st degree) or simply TF. The second degree of fracture in the same category, the TF (2nd degree) or simply the pTF represents the button pull-out failures in which the complete separation occurs around the welded nuggets. In other words, the button pull-out (pTF) type cracks radially at the heat-affected zone (HAZ) without causing any damages to the weld button itself. In traditional context of the tensile shearing test, pTF failures have been known as the best-bonded welds but not so in PCP analysis. These two failures (TF and pTF) are conventionally assumed to be the better weld joints, thus, having no difference in whatsoever mean. The two empirical failures are now significantly differentiated into severity of fractures. The partial failure (PF) type has occupied third rank and the interfacial failure (IF) type held the lowest level in the hierarchy of loading force consumption regardless of metal types. Moreover, a lower quality weld in comparison to the TF or pTF would normally initiate the fracture at HAZ and tear perpendicularly across the metal pieces rather than tearing-off radially. This type of failure