RESEARCH ARTICLE OPEN ACCESS

Analysis of Laser Welding On Trip 780 Material

Eshita G. Kulkarni, Sneha C. Patil, Prakash G.Bhosale

Marathwada Mitra Mandal's College of Engineering, Pune

ABSTRACT

With the aim of investigating a laser-welded dissimilar joint of TWIP and TRIP steel sheets, the microstructure was characterized by means of OM, SEM, and EBSD to differentiate the fusion zone, heat-affected zone, and the base material. OIM was used to differentiate between ferritic, bainitic, and martensitic structures. Compositions were measured by means of optical emission spectrometry and EDX to evaluate the effect of manganese segregation. Microhardness measurements and tensile tests were performed to evaluate the mechanical properties of the joint. Residual stresses and XRD phase quantification were used to characterize the weld. Grain coarsening and martensitic areas were found in the fusion zone, and they had significant effects on the mechanical properties of the weld. The heat-affected zone of the TRIP steel and the corresponding base material showed considerable differences in the microstructure and properties.

KEYWORDS-Laser beam welding, martensite materials, annealing.

Date Of Submission: 20-10-2019 Date Of Acceptance: 03-11-2019

INTRODUCTION

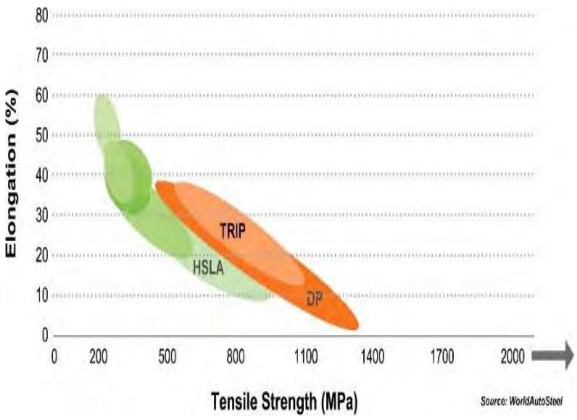
Automobile industries demand lightweight materials without compromising the strength. Many materials have been competing in the race to accomplish the requirement of automotive industries but advanced high strength steels (AHSS) have been the winner. Because, AHSS reduce the vehicle weight leading to reduced fuel consumption and increase the passenger safety due to higher energy absorption and stiffness of the body. AHSS is commonly referred to dual phase (DP), transformation induced plasticity (TRIP), complex phase (CP), and martensitic (M) steels which are characterized as steels with a yield strength above 300 MPa and a tensile strength higher than 600 MPa [1,2]. Among all the AHSS, TRIP steels have high strength combined with good uniform elongation due to hard–soft composite structure given by its various structural constituents like ferrite, bainite, martensite and carbon enriched retained austenite [3–6]. TRIP steel is commonly alloyed with, apart from Mn, Si or Al to suppress cementite formation thus forcing more carbon into retained austenite as both Si and Al are insoluble in cementite [1,2]. The mechanical properties of the TRIP steels have been the special attention for the possible implementation in industries. No difference in mechanical properties of TRIP steels is observed when all the Si in it is replaced by Al [7]; but interestingly C–Mn–Al TRIP steel exhibits a remarkable TRIP effect during tensile testing compared to C–Mn–Si TRIP [8]. In this regard, TRIP steel alloyed with both Si and Al are being considered based on concept of partial replacement of Si by limited amount of Al [9]. Automotive industries adopt various welding techniques to join steel sheets for the assembly of car bodies and various structural components [10–18]. However, resistance spot welding (RSW) is currently one of the dominant methods for manufacturing autobody structure [10,11,17,19–22]. In welding research, studies on welding of TRIP steels have been reported earlier by different processes [11–18]. For example, in laser beam welding (LBW) C–Mn–Si TRIP revealed a singlephase martensite microstructure in the fusion zone [12–14]; whereas C–Mn–Al fusion zone formed a multiphase microstructure containing skeletal ferrite, bainitic ferrite, martensite and retained austenite [14–16]. Like in laser welding, C–Mn–Si fusion zone in RSW also formed single phase microstructure of martensite [11,17]. Although there are reports on evolution of fusion zone microstructure in C–Mn–Al TRIP and C–Mn–Si steel in different welding processes, there is lack of report on combined effect of Al and Si on the metallurgical and mechanical properties of the fusion zone in TRIP steel in RSW or any other welding. Laser welding is a non-contact process that requires access to the weld zone from one side of the parts being welded. The weld is formed as the intense laser light rapidly heats the material-typically calculated in milli-seconds. Welding can be defined as any process in which two or more pieces of metal are joined together by the application of heat, pressure, or a combination of both. Most of the processes may be grouped into two main categories: pressure welding, in which the weld is achieved by pressure; and heat welding, in which the weld is achieved by heat. Heat welding is the most common welding used now a days.High energy density welding processes are those that focus the energy needed for welding to an extremely small size area. This allows for very low overall heat input to the work piece, which results in minimal BM degradation, residual stress, and distortion. Welding speeds can be very fast. The two main processes known for extreme energy Densities are laser and Electron Beam Welding (EBW).

Laser and EBW processes are used in a wide variety of industry sectors. Very high weld speeds are possible, and the welds are usually aesthetically pleasing. Laser welding is very adaptable to high-speed production, so it is common in the automotive sector. The ability to precisely locate welds on smaller sensitive components with minimal heat input makes laser welding very attractive to the medical products industry. Advanced High-Strength Steels Application Guidelines When welding with high energy density processes, the laser or EB is focused along the joint line of the work pieces to be welded. The extreme power density of the beam not only melts the material but causes evaporation. As the metal atoms evaporate, forces in the opposite direction create a significant localized vapor pressure. This pressure creates a hole, known as a keyhole, by depressing the free surface of the melted metal. The weld solidifies behind the key hole as it progresses along the joint. This method of welding known as keyhole welding is the most common approach to laser and EB and produces the characteristic welds of high depth-to-width ratio. There are some cases where the keyhole mode is not used. This mode is known as conductive mode welding. Conductive mode welds have a weld profile closer to that of an arc weld.

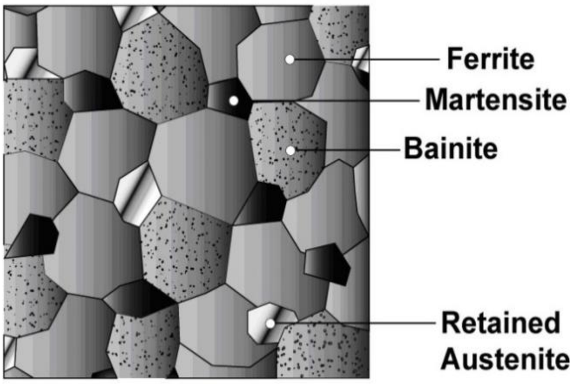
Transformation Induced Plasticity (TRIP)

The base metal microstructure of TRIP steels consists of a ferrite matrix with traces of martensite, bainite, and retained austenite. Austenite is transformed into martensite during plastic deformation (TRIP: Transformation Induced Plasticity effect), making it possible to achieve greater elongations and these steels their excellent combination of strength and ductility.

The TRIP investigated in this study contains a relatively high amount of aluminum (1.8 wt-%). Aluminum is a ferrite stabilizer and (when above approximately 0.8 wt-%) can allow ferrite to remain stable at temperatures approaching the melting point of the material. TRIP steels offer an outstanding combination of strength and ductility as a result of their microstructure. They are thus suitable for structural and reinforcement parts of complex shape. The microstructure of these steels is composed of islands of hard residual austenite and carbide-free bainite dispersed in a soft ferritic matrix. These steels have high strain hardening capacity. They exhibit good strain redistribution and thus good drawability. As a result of strain hardening, the mechanical properties, and especially the yield strength, of the finished part are far superior to those of the initial blank.TRIP steels also exhibit a strong bake hardening (BH) effect following deformation. The TRIP range of steels comprises 2 cold rolled grades in both uncoated and coated formats (TRIP 690 and TRIP 780) and one hot rolled grade (TRIP 780), identified by their minimum tensile strength expressed in MPa. [2] The microstructure of TRIP steels is retained austenite embedded in a primary matrix of ferrite. In addition to a minimum of fivevolume percent of retained austenite, hard phases such as martensite and bainite are present in varying amounts. TRIP steels typically require the use of an isothermal hold at an intermediate temperature, which produces some bainite. The higher silicon. The microstructure of TRIP steels is retained austenite embedded in a primary matrix of ferrite. In addition to a minimum of five volume percent of retained austenite, hard phases such as martensite and bainite are present in varying amounts. TRIP steels typically require the use of an isothermal hold at an intermediate temperature, which produces some bainite. The higher silicon and carbon content of TRIP steels also result in significant volume fractions of retained austenite in



the final microstructure.



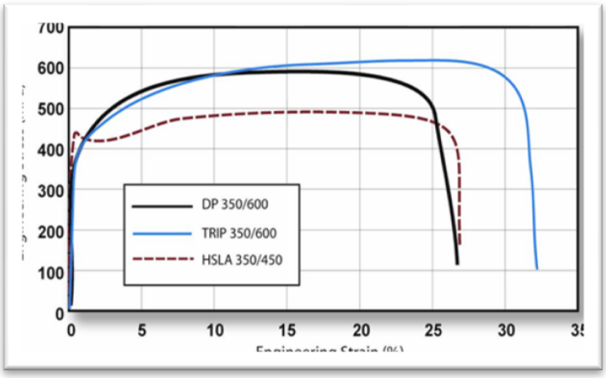
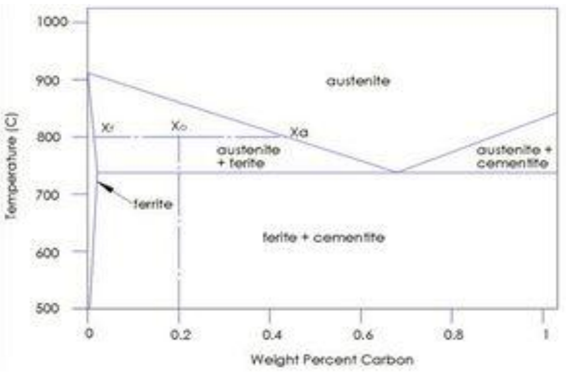


Fig Stress Vs Strain

During deformation, the dispersion of hard second phases in soft ferrite creates a high work hardening rate, as observed in the DP steels. However, in TRIP steels the retained austenite also progressively transforms to martensite with increasing strain, thereby increasing the work hardening rate at higher strain levels. This is illustrated in Figure 2.B-8, where the engineering stress-strain behavior of HSLA, DP and TRIP steels of approximately similar yield strengths are compared. The TRIP steel has a lower initial work hardening rate than the DP steel, but the hardening rate persists at higher strains where work hardening of the DP begins to diminish. Additional engineering and true stress-strain curves for TRIP steel grades are located in Figure The work hardening rates of TRIP steels are substantially higher than for conventional HSS, providing significant stretch forming. This is particularly useful when designers take advantage of the high work hardening rate (and increased bake hardening effect) to design a part utilizing the as-formed mechanical properties. The high work hardening rate persists to higher strains in TRIP steels, providing a slight advantage over DP in the most severe stretch forming applications. TRIP steels use higher quantities of carbon than DP steels to obtain sufficient carbon content for stabilizing the retained austenite phase to below ambient temperature. Higher contents of silicon and/or aluminum accelerate the ferrite/bainite formation. These elements assist in maintaining the necessary carbon content within the retained austenite. Suppressing the carbide precipitation during bainitic transformation appears to be crucial for TRIP steels. Silicon and aluminum are used to avoid carbide precipitation in the bainite region. The strain level at which retained austenite begins to transform to martensite is controlled by adjusting the carbon content. At lower carbon levels, the retained austenite begins to transform almost immediately upon deformation, increasing the work hardening rate and formability during the stamping process. At higher carbon contents, the retained austenite is more stable and begins to transform only at strain levels beyond those produced during forming. At these carbon levels, the retained austenite persists into the final part. It transforms to martensite during subsequent deformation, such as a crash event. For conventional materials, a strength increases leads to a decrease in ductility and vice-versa. However, developed materials such as TRIP, TRIP XP and TWIP offer a combination of both high strength and ductility.

Table yy is a list of the steel grades that were evaluated, along with the nominal gauge thickness and coating type of each. Table 2 lists the chemical composition of each steel. The chemical compositions of the DP 780 and TRIP 780 steels were determined by inductively coupled plasma (ICP) analysis, while the composition of the DP 980 steel is that which was provided in the manufacturer's certification. TRIP steels therefore can be engineered or tailored to provide excellent formability for manufacturing complex AHSS parts or exhibit high work hardening during crash deformation for excellent crash energy absorption. The additional alloying requirements of TRIP steels degrade their resistance spot-welding behavior. This can be addressed somewhat by modification of the welding cycles used (for example, pulsating welding or dilution welding).

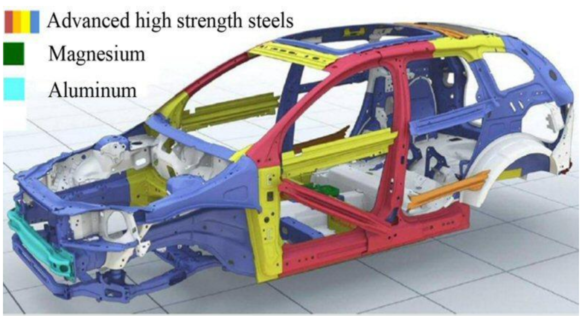
Therefore, tempered surfaces and insert blocks harder than 60 HRC are needed to withstand the forming loads with an acceptable service life expectation. Another problem to be faced by die manufacturers is the occurring of errors coming from die deformation due to their asymmetrical shape. These deformations are relatively small compared to die size but can become bigger than the allowed tolerance for the final produced part. In this context, different approaches were proposed e.g. design and control of variable binder force for stamping dies, spring back compensation, the use of newly developed utilities in the preparation stage and the elaboration of CNC programs using CAM software, a knowledge-based system for intelligent stamping process planning and an intelligent feature based DFS (design for stamping) system for implementing the stamp ability evaluation. The TRIP 780 welds had a continuous structure of ferrite grains along the fusion boundary. The presence of ferrite along the fusion boundary can be explained with the equilibrium phase diagram shown in Fig. 12.



For TRIP 780, at temperatures near the liquidus, ferrite is the only thermodynamically stable phase. For all locations within the TRIP 780 HAZ, the fraction of ferrite in the microstructure is greater for the welds produced with low cooling rate compared to high cooling rate. The microstructure of the low cooling rate weld at the point of peak HAZ hardness consists of predominately ferrite grains separated by regions of degenerate martensite. As previously noted, the term degenerate martensite is used to describe regions that appear to be martensite at optical microscopy levels but may contain tempered martensite and/or bainite constituents. The microstructure in the high cooling rate weld at the location of peak HAZ hardness consists of a mixture of martensite and large ferrite grains. In both cases, the fraction of ferrite in the HAZ microstructure increases from the point of peak HAZ hardness to the location of minimum HAZ hardness. The microstructure of the high cooling rate weld has greater hardness at each HAZ location between the points of minimum and peak hardness. The microstructure evolution in the HAZ of TRIP steels can be separated into two different regions. The regions that heated above the AC1 temperature (700°C) and the regions heated below the AC1 temperature. Referring to Fig. 12, the regions heated above the AC1 do not entirely transform to austenite due to increased stability of ferrite. As a result, the regions heated above the AC1will remain in a two-phase (austenite + ferrite) region throughout the heating cycle. Depending upon the peak temperature, the ferrite fraction may increase from the original level. This often resulted in a continuous necklace of ferrite along the weld interface of the welds produced on the TRIP 780 steel. Similar microstructural observations have been noted for multiphases self-shielded gas metal arc welds. As the HAZ starts cooling, a small fraction of the austenite may be retained, but the larger fraction decomposes into either bainite or martensite. The rate of cooling will determine the nature of this microstructure mixture. This is supported by the HAZ microstructure of welds made with both the nominally high and low cooling rate conditions.At a given location of the far HAZ, the martensite formed from the retained austenite, as well as that present in the as-received base material, may undergo tempering. The degree of martensite tempering is dependent on the weld thermal cycle at the given location. Based on the measured hardness of the welds produced with both cooling rate conditions, lesser degrees of martensite tempering are expected in the welds made with the high cooling rate condition. The extent of softening appears to decrease with an increase in distance from the AC1 boundary. The base metal microstructure of TRIP steels consists of a ferrite matrix with islands of martensite, bainite, and retained austenite. The TRIP 780 investigated in this study contains a relatively high amount of aluminum (1.8wt-%). Aluminum is a ferrite stabilizer and (when above approximately 0.8wt-%) can allow ferrite to remain stable at temperatures approaching the melting point of the material. The results of this investigation verified that retained ferrite is present in all regions of the TRIP 780 HAZ. Because the microstructures of the DP and TRIP steels are substantially different, the results for these steels are discussed separately.

APPLICAION

As a result of their high energy absorption capacity and fatigue strength, TRIP steels are particularly well suited for automotive structural and safety parts such as cross members, longitudinal beams, B-pillar reinforcements, sills and bumper reinforcements. ArcelorMittal has extensive data on the forming and service characteristics of the TRIP family of steels. To integrate these steels at the design stage, team of experts is available to carry out specific studies based on modeling and experimental, tests. B-pillar reinforcement in electrogalvanized TRIP,780 Bumper cross member in electrogalvanized TRIP 780.



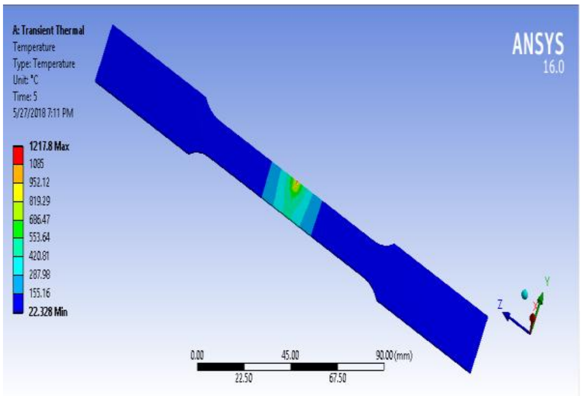
LASER BEAM WELDING

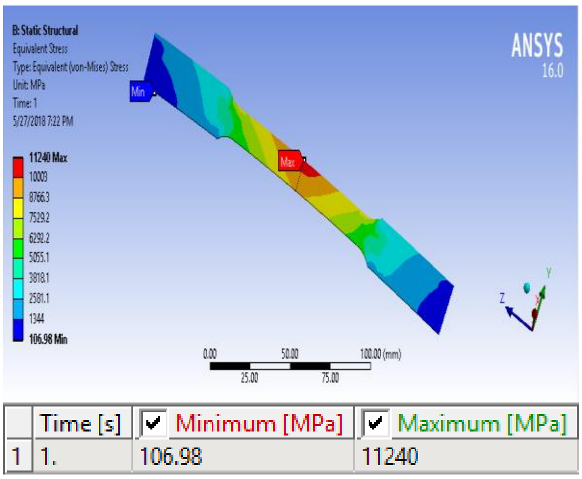
The word "laser" is an acronym for "light amplification by stimulated emission of radiation." Lasers produce a special form of light (electromagnetic energy) consisting of photons that are all of a single coherent wavelength. Light of this form can be focused to extremely small diameters allowing for the creation of the high- energy densities used for welding. The laser beam itself is not useful for welding until it is focused by a focusing lens. Lasers vary in the quality of the beam produced. A high-quality beam will diffract less when focused, providing for the creation of a smaller spot size. Reflective lenses are important to lasers as well since they are used in the optical cavity where the beam is generated, as well in the beam delivery systems for some lasers. For these reasons, optics play a major role in laser beam welding. Laser beam welding does not require additional filler metal and shielding gas is optional. When the beam hits the work piece. It melts and vaporizes metal atoms, some of which are ionized by the intense beam. This creates what is known as a plume (or plasma) over the weld area that can sometimes interfere with the beam. In these cases, shielding gas may be used to deflect the plume. The choice of laser type depends on cost, the type and thickness of material to be welded and the required speed and penetration. Lasers are distinguished by the medium used to generate the laser beam, and the wavelength of laser light produced. Although there are many types of lasers, common lasers for welding include the Nd:YAG, fibre, disk solid-state lasers, and the gas-based CO2 laser. The lasing medium in solid-state lasers are crystals (Nd: YAG and disk lasers) or fibres (fibre laser) that have material added (doped) that will "lase"when exposed to a source of energy, whereas the lasing medium in the CO2 laser is a gas blend consisting of CO2, He, and N2 gas. In all cases, "lasing" occurs when the atoms/molecules of the medium are excited to a higher energy state through the introduction of additional energy (known as pumping). When this occurs, photons are emitted, which, in turn, excite other atoms/molecules. This results in a cascade of photons that travel in coherent waves of a single wavelength, the two properties that laser light is known for. CO2 lasers produce wavelengths of 10.6 μm, while the wavelength of the solid-state lasers is 1.06 μm. CO2 lasers are generally less expensive, but the longer wavelength of light does not allow its beam to be delivered through fibre optic cables which reduces its versatility. Its light is also more reflective, which limits its use with highly reflective metals such as Al. The solid-state lasers are generally more compact and require less maintenance than the CO2 laser. They are more conducive to high-speed production since their beams can be delivered through long lengths of fibre optic cable which can then be attached to a robot. Some of the solid-state lasers such as the fiber laser produce beams of outstanding quality. However, the shorter wavelength of these lasers requires additional safety precautions regarding eye protection. The choices of focus spot size, focus spot location in the joint, and focal length are all important considerations when laser beam welding. Usually, a small focus size is used for cutting and welding, while a larger focus is used for heat treatment or surface modification. the location of the beam's focal point can also be varied based on the application. When welding, it is common to locate the focal point somewhere near the center of the joint. But cutting applications benefit from placing the focal point at the bottom of the joint. Weld spatter onto the focusing lens can sometimes be a problem, especially when there are contaminants on the surface of the parts being welded. Approaches tominimizing the spatter problem include choosing a long focal length lens which keeps the lens a safe distance from the weld area, or the use of an air "knife" to protect the lens. A-11, P-6.

I. RESULTS

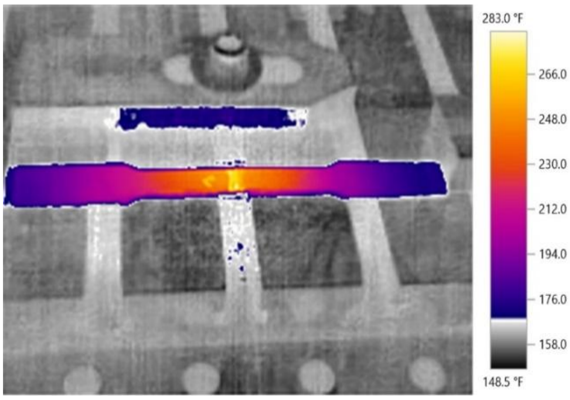
CFD ANLYSIS

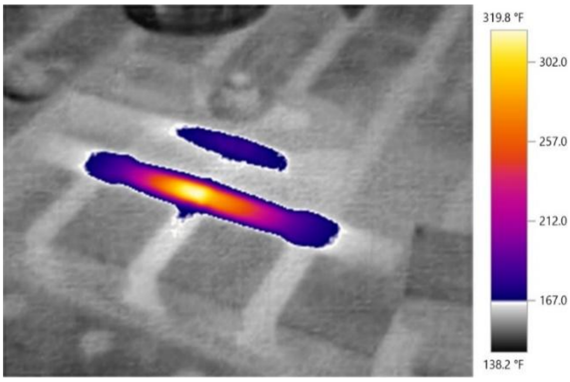
Condition	Yield Load	Avg Estimate Tensile Load	Gauge Length after Fracture	Avg, Yield Strength	Avg, Ultimate Tensile Strength	Avg % Elongation
N-N	2.75	4.76	51.8	141.45	247.53	3.6
N-W	3	5.56	52.8	156.99	290.95	5.6
N-A	3.32	4.88	51.8	172.2	252.85	3.6



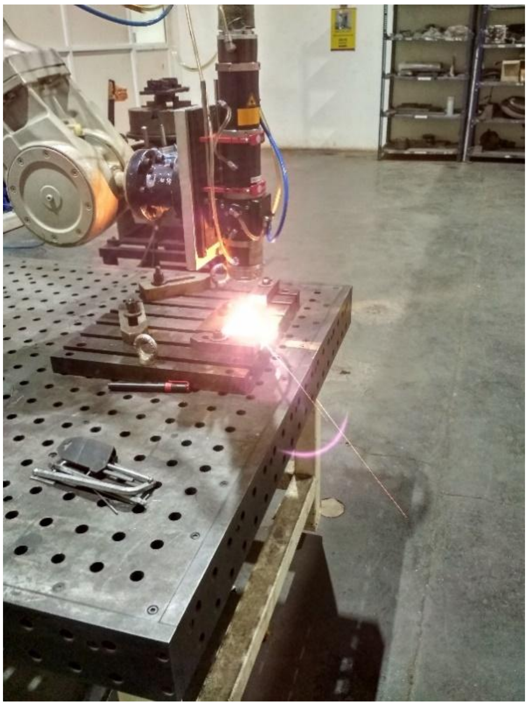


THERMAL CAMERA IMAGE





IMAGES OF LASER WELDING



II. CONCLUSION

We consider the above results from the perfect laboratory. The three condition which we considered pretty much gave very satisfactory results. The N-N (Normal-Normal) is the normal metal specimen without any heating conditions. It is welded in its normal state and then tested. The N-W (Normal-Water Quench) specimen is where normal specimen is welded with water quenched specimen. The specimen is preheated and rapidly cooled within short period of time. After watering quenching welding process is carried out and the tested. The N-A (Normal-Annealed) specimen is where normal specimen is welded with annealed specimen. The specimen is pre heated and the cooled in ambient temperature for long period of time. Laser welding is the followed by annealing.

REFERENCES

[1]. G. Frommeyer, U. Brüx, P. Neumann, ISIJ International 43 (3) (2003) 438 446.
[2]. O. Grässel, L. Krüger, G. Frommeyer, L.W. Meyer, International Journal of Plasticity 16 (2000) 1391–1409.
[3]. R. Petrov, L. Kesttens, A. Wasilkowska, Y. Houbaert, Materials Science and EngineeringA 447 (2007) 285–297.
[4]. A. Wasilkowska, R. Petrov, L. Kestens, E.A. Werner, C. Krempaszky, S. Traint, A.
[5]. Pichler, ISIJ International 46 (2) (2006) 302–309.
[6]. S. Zaefferer, J. Ohlert, W. Bleck, Acta Materialia 52 (2004) 2765–2778.
[7]. E. Girault, P. Jacques, P. Harlet, K. Mols, J. Van Humbeeck, E. Aernoudt, F. Delannay,
[8]. Materials Characterization 40 (1998) 111–118.
[9]. J. Maki, J. Mahieu, B.C. De Cooman, Proc. 5th Int. Conf. on Zinc and Zinc Alloy
[10]. Coated Steel Sheet (Galvatech 2001), Centre de Researches Meatallurgiques, Bruxelles, Belgium, 2001.
[11]. E. Giraulta, A. Mertensb, P. Jacquesb, Y. Houbaertc, B. Verlindena, J.V. Humbeecka, Scr. Mater. 44 (2001) 885.
[12]. P.J. Jacques, E. Girault, P. Harlet, F. Delannay, ISIJ Int. 41 (2001) 1061.
[13]. Committee on Automotive Applications, AHSS – Application Guidelines, International Iron and Steel Institute, Washington, DC, 2006.
[14]. V.H. Baltazar Hernandez, M.L. Kuntz, M.I. Khan, Y. Zhou, Sci. Technol. Weld. Joining 13 (2008) 769.
[15]. S. Daneshpour, S. Riekehr, M. Kocak, V. Ventzke, A.I. Koruk, Sci. Technol. Weld. Joining 12 (2007) 508.
[16]. T.K. Han, S.S. Park, K.H. Kim, C.Y. Kang, I.S. Woo, J.B. Lee, ISIJ Int. 45 (2005) 60.
[17]. M. Xia, Z. Tian, L. Zhao, Y.N. Zhou, ISIJ Int. 48 (2008) 483.
[18]. J. Chen, K. Sand, M.S. Xia, C. Ophus, R. Mohammadi, M.L. Kuntz, Y. Zhou, D. Mitlin, Metall. Mater. Trans. A 39A (2008) 593.
[19]. Advanced High-Strength Steels Application Guidelines Version 6.0 –
[20]. Technical Editors: Stuart Keeler-Sc.D.Mechanical Metallurgy , Menachem Kimchi-M.Sc.Welding Engineering , Peter J.Mooney-Managing Director,3S-Superior Stamping Solutions.LLC
[21]. Advanced High-Strength Steels Application Guidelines Version 5.0 - Technical Editors: Stuart Keeler-Sc.D.Mechanical Metallurgy , Menachem Kimchi-M.Sc.Welding Engineering
[22]. Standard Test Methods for tension testing of Metallic Materials1This standard is issued under the fixed designation E 8/E 8M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.
[23]. Investigation of the Formability of TRIP780 Steel Sheets - Yang Song - University of Windsor

[24]. Microstructure and mechanical properties of fibre laser welded medium manganese TRIP steel - N. Lun, D.C. Saha, A. Macwan, H. Pan, L. Wang, F. Goodwin, N. Zhou

[25]. Microstructure and mechanical properties of laser-welded joints of TWIP and TRIP steels - L. Mujicaa,b,∗, S. Webera,c, H. Pintob,d, C. Thomye, F. Vollertsene

[26]. Microstructure–hardness relationship in the fusion zone of TRIP steel welds - S.S. Nayaka,∗, V.H. Baltazar Hernandeza,b, Y. Okitaa,c, Y. Zhoua

XXXXX" Analysis of Laser Welding On Trip 780 Material"International Journal of Engineering Research and Applications (IJERA), vol. 9, no. 10, 2019, pp 01-08