The effect of groove welding on mechanical properties and microstructure of wear resistance steel plate by Submerged Arc Welding

by Hendro Sumual

Submission date: 21-Jun-2023 10:51AM (UTC+0700)
Submission ID: 2120096167
File name: THE_EFFECT_OF_GROOVE_WALDING.pdf (657.74K)
Word count: 3126
Character count: 16317

IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

The effect of groove welding on mechanical properties and microstructure of wear resistance steel plate by Submerged Arc Welding

To cite this article: Zuldesmi Mansjur *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **694** 012027

IOP Conf. Series: Materials Science and Engineering **694** (2019) 012027 doi:10.1088/1757-899X/694/1/012027

The effect of groove welding on mechanical properties and microstructure of wear resistance steel plate by Submerged Arc Welding

Zuldesmi Mansjur[1], Hendro M Sumual[2] and I P Tamba[3]

[1] Mechanical Engineering Study Program, Engineering Faculty, Manado State University
[2,3] Mechanical Engineering Education Department, Engineering Faculty, Manado State University

E-mail: zuldesmi@unima.ac.id

Abstract. Aim of this research is to analyze the mechanical properties and microstructure of wear resistance steel plates joined by Submerged Arc Welding at different grooves welding. The welding current of 300 Ampere, voltage of 28 Volt and travel speed of 38 cm/min was applied. The microscopical examination method were used for weld zones. Impact toughness and rockwell hardness test were obtained from the weld metal, heat affected zone and the base metal samples. The fracture surfaces were examined by using optical microscope. As results, there was no difference of hardness and microstructure among three grooves welding. The significant differences were detected at the weld zones. Base metal had the highest hardness value. Ferrite and pearlite phases were obtained at three weld zones, but the heat affected zone had coarser grain structure than the base metal. Weld metal volume and electrode length significantly affected the impact toughness of joint, where the larger of the weld metal volume and length of electrode fill in the groove welding, the higher of impact toughness. The lowest impact energy and toughness value were attained at V groove and the highest was at I groove. The fracture surfaces at all groove welds showed ductile fracture dominantly.

1. Background

The wear resistant steels are typically used in various challenging high-stress wear conditions, such as mineral haulage and crushing, slurry transportation, dredging, demolition of concrete structures, and forest industry. In many applications, the wear environment is very complex and contains different wear mechanisms. Moreover, the wear resistant steels are not standardized and the generally used hardness based grading does not completely describe nor predict their wear behavior [1]. Thus, well-planned and multifaceted application oriented wear testing of the steels as a part of the material selection process is highly recommended for achieving a proper correlation to practical applications.

Sometimes, repairs of the wear resistant steels are required due to possible damage during during application and service. These parts repairs which involve welding are particularly critical in applications where high quality and/or precision are required. The submerged arc welding process is commonly used for repairing surface due to its easy applicability, high current density and its ability to deposit multiple filler wire at the same time, especially in restoration of worn parts, which is of great importance to manufacturers [2]. Submerged arc welding is suitable for welding of all weldable steels.The successful application of a welding the process mainly depends on the effective understanding of the temperature distribution in the weldment that can be helpful to estimate the evolution of the metallurgical microstructures and its subsequent influence on the mechanical properties [3]. However, many premature failures of a component, such as micro-fissures and residual stress corrosion cracking, are related to the microstructure and strength of the weld [4,5]. Thus, it is important to evaluate the microstructure and mechanical properties of joints made from wear resitant plate.

In the wear resistant carbon steels, the decomposition of austenite leads to textured microstructure composed of ferrite and pearlite bands. This is connected to the higher concentration of manganese in interdendritic regions that stabilize the austenite at lower temperatures. Consequently, ferrite grains are preferably nucleated in regions with a low concentration of manganese. Additionally, the carbon is segregated from the ferrite as it grows, concentrating on the regions of high manganese, where the perlite is formed [6]. This microstructure usually contains elongated inclusions that are responsible for the anisotropy of ductility and impact energy. Some properties may also be affected, such as: i- machinability, ii- hydrogen-induced embrittlement, in particular,in the heat affected zone of weld beads. The occurrence of heterogeneous microstructures (bands of ferrite and pearlite) may lead to the breaking of teeth during the fabrication of gears in the forging process [7]. It is crucial to recognize the microstructures of the weld zone in order to predict the hardness and impact toughness of the welded joint.

In this experimental investigation and relevant analyses, the influence of groove welding on mechanical properties of wear resistant plate was systematically investigated. In order to determine these parameters; the current, voltage and wire speed between the applicable ranges were tried in the welding laboratory, and then according to the penetration and visual tests the acceptable welding parameters were selected. Thus, the microstructural and mechanical properties of submerged arc welding (SAW) welds of 10 mm thick wear resistant steel plate according to the selected parameters were found out, instead of comparing the different weld zones.

2. Materials and Methods

Wear resistance plates were welded by using submerged arc welding process. For the microstructural investigation, microscopical examination methods were used in weld zones (weld metal, heat affected zone and base metal). Different samples obtained from the weld metal and the base metal, were subjected to hardness and impact toughness tests. Fracture surfaces were examined by optical microscope. Charpy impact toughness tests were made for the samples with three types of welding grooves.

2.1. Materials

The material used in this study was wear resistance plates of 10 mm thick with three groove welding types (I, V and U). Table 1 lists the chemical composition (wt %) of the wear resistant plate.

Table 1. Chemical composition (wt %) of the wear resistant plate

C	S_{max}	P_{max}	Cr	Mn	Mo
0.14	0.01	0.01	0.5	1.2	1.25

2.2. Welding conditions

The welding process for each groove was otomatic submerged arc welding with parameters as shown in Table 2.

Table 2. Welding parameters of the SAW.

Voltage (V)	Current (A)	Welding speed (cm/min)	Heat input energy (kJ/cm)
28	300	38	13.263

Before welding, the samples were preheated at temperature of 100^{0}C in order to prevent an initial hardening on the heat affected zone and residual stress on the thick plates. Then, they were polished with a brush and thoroughly washed with acetone to remove any greasy dirt and impurities.

The SAW process was realized automatically in the laboratory setting for hardness, impact toughness and microstructural investigations by using reversed polarity and multilayer welding at V and U grooves. For I groove, single layer of filling process was applied on two sides (upper and lower) of surface with root gap of 2 mm.

2.3. Microstructural investigation

Submerged arc welded joints of wear resistant plate were cross-sectioned perpendicular to the welding direction. In the first step, specimens were prepared with standard metallographic preparations like grinding, polishing and etching with Picral (4gr picric acid + 100 ml ethanol) for 10–15 seconds at room temperature. In the second step, the weld zones were investigated as micrographs by Optical Microscope with magnifications of 20X.

2.4. Hardness

As an additional destructive test method, Rockwell C hardness measurement (HRc) was carried out under a load of 150 Kg over cross sections on vertical (the welding centerline) and horizontal lines 1 mm distance between each indentation on metallographic specimen taken from each welded plate with Tokyo testing machine type RH-3N MFG. The Figure 1 shows the point of hardness testing.

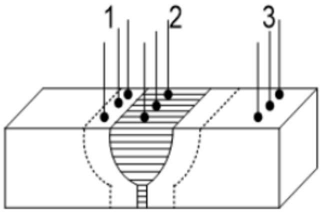

Figure 1. Test point of the hardness test samples ; (1). Heat Affected Zone (HAZ), (2). Weld Metal (WM) and (3). Base Metal (BM)

2.5. Notch impact toughness test

The direct notch impact testing was implemented to all welded specimens with three groove types as shown in Figure 2.

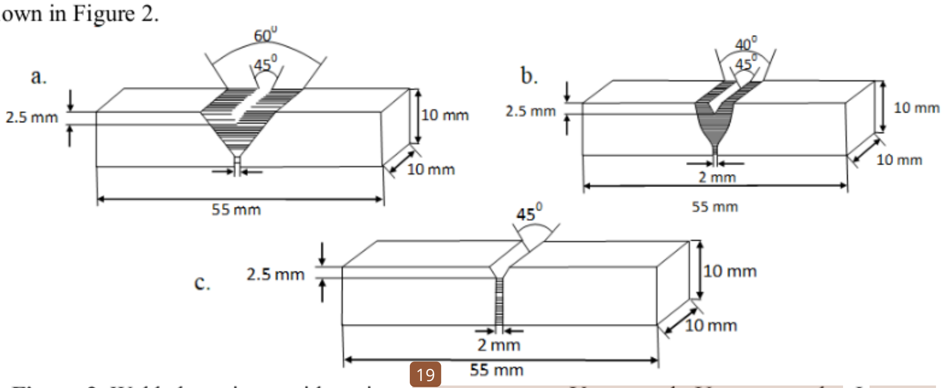

Figure 2. Welded specimen with various groove types; a. V groove, b. U groove and c. I groove

3. Results and Discussions

3.1. Rockwell Hardness test

The hardness evaluation was made on metallography specimens for single layer (I groove) and multiple layer (V and U grooves), in order to present results from the point of heat input effect on hardness as shown in Figure 3.

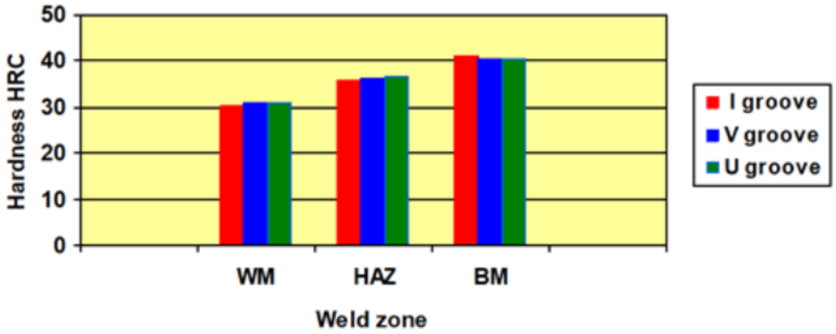

Figure 3. Hardness comparison among three welded zones: WM, HAZ and BM

In Figure 3, the variation of grooves welding are not contribute differences of hardness significantly for each weld zones. However, the differences are clearly distinguished in comparing to the three weld zones. Base metal hardness of the welds varied between 40.16 and 41.38 HRc and this value was the highest among the weld metal zone and HAZ. This conditions is owing to occurring of recrystallization condition and cooling rate. Besides, at the base metal zone, there was no heat affect occured at the samples and material compositions also influence the changes of hardness. The hardness of HAZ (36-36.66HRc) are close to the base metal. The grain growth was observed in HAZ due to during the welding process, the high heat transfer from the base metal through to the heat affected zone until the austenite phase was formed and slowly cooling was taken place. Because of the grain coarsening occurred at the HAZ interface, the hardness values were decreased. On the other hand, minimum hardness values 30.38-31.05 HRc were measured at the weld metal.

3.2. Microstructural investigation

The microstructural examination on the samples of welded joint was carried out using Optical Microscope and with 20x magnification. As displayed in Figure 4, ferrite (light color) and pearlite (dark color) phases were noticed in all weld zones, but the base metal had finer grain structure than the others. This fine grain structure lead to higher hardness of the base metal. The pearlite phase was appeared dominantly in this zone. Meanwhile, the grain became coarse and ferrite phase become visible primarily in HAZ. The change of grain size was probably because of hot operation during welding process with lower cooling rate. Meanwhile, in the weld metal zone, the cooling rate become lower till to room temperature and the phase turn into an initial phase. The ferrite phase be revealed mainly with a clear grain boundary in the weld metal zone.

The grain size is a parameter which directly affects the mechanical properties of metals and alloys. In fine grained materials, mechanical properties are high due to increase of grain boundary. During the welding process, high temperature values in HAZ are observed because of the high heat input. The grain coarsening is seen in the microstructure and also the mechanical properties decrease. At the same time, the alloying elements in the structure of these steels form finely dispersed carbides. The dissolution of alloy carbides takes place on account of the high heat input effect during welding. It causes a reduction in mechanical properties. Additionally, because of the carbide dissolution, grain boundaries are released and grain growth during welding becomes easier. It is seen that the micro hardness results are compatible with the literature [8,9].

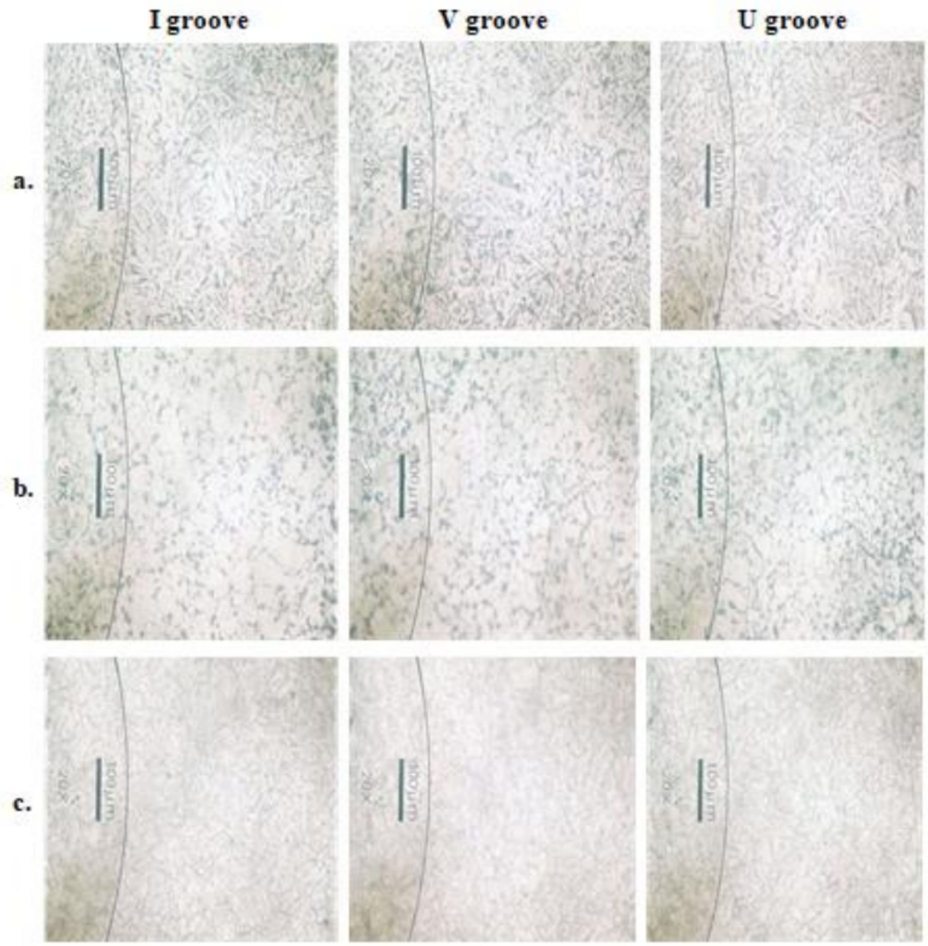

Figure 4. Microstructure photograph of specimen with three types of groove welding: I, V and U grooves at three welded zones: a. BM, b. HAZ and c. WM

3.3. Notch impact toughness test

In order to compare three grooves welding, 55mm × 10mm × 10mm test pieces were used. The tests were carried out at room temperature (~28°C). The notch impact values pointed out in joule/mm^2 are presented in Table 3.

Table 3. The impact test results of three groove welding samples

No	Specimen	α (^{0})	β (^{0})	T (^{0}C)	IE (Joule)	Average IE (Joule)	IT (J/mm^2)	Average IT (J/mm^2)
1	U. 1	156	62	28	205.96	205.34	2.74	2.73
2	U. 2		63		204.10		2.72	
3	U. 3		62		205.96		2.74	
4	V. 1		64	28	201.77	203.32	2.69	2.71
5	V. 2		63		204.10		2.72	
6	V. 3		63		204.10		2.72	
7	I. 1		30	28	265.60	266.48	3.54	3.55
8	I. 2		28		268.25		3.57	
9	I. 3		30		265.60		3.54	

The specimen with I groove contributed the highest impack toughness values of 3.55 J/mm^2 and it achieved the best absorbed energy about 266.48 J, following U groove (impack toughness of 2.73 J/mm^2 and absorbed energy of 205.34 J) and V groove (impack toughness of 2.71 J/mm^2 and absorbed energy of 203.32 J). Weld metal volume and length of electrode influence the strength and toughness of joint crucially, especially for V and U groove samples. By increasing the welding metal volume and length of electrode, the strength of welding become increase. However, these variables were not affect to I groove sample. The highest impack toughness of I groove sample was mainly caused by the welding process. During the welding process, filler metal was applied onto both sides (upper and lower) of surface with root gap of 2 mm. It was carried out because at I groove, a penetration was not trough the surface actually.

The fractured surfaces are presented in Figure 5. The I groove samples with high impact energy showed almost fully ductile fracture (~89%) and , as shown in Figure 5c. The fractured specimens of U groove (Figure 5b) had two different fracture surfaces in a ductile (~78.6%), and a brittle manner over part (~ 21.4%) and its impact value was relatively lower. The V groove specimens gave the lowest values, and it had smaller ductile zone about ~75% and broader brittle zone about ~ 25% , as presented in Figure 5a.

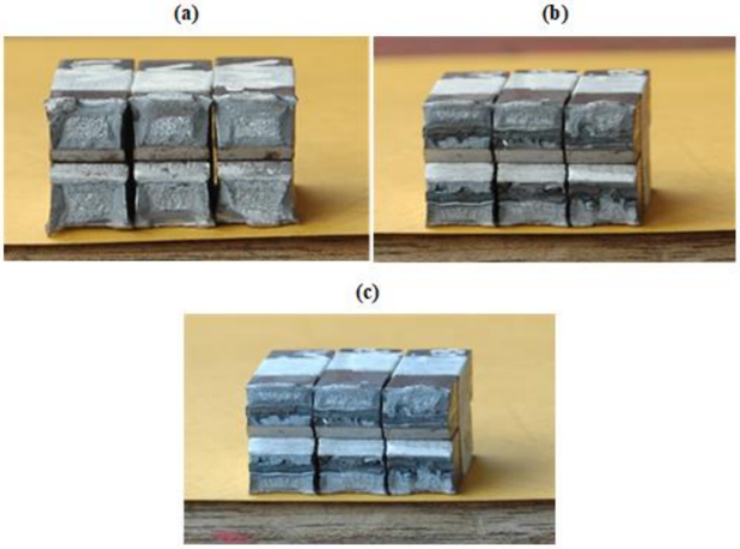

Figure 5. Fracture surface of impack thougness of test samples with (a) V, (b) U and (c) I grooves

During the welding process of wear resistant steel plate, preheating, temperature between passes, heat input should be controlled strictly in keeping with the declared standards, in order to keep away from cold cracks and possible failures, and to achieve the required properties of welded structures. Inadequate heat input mostly influences hardness and the strength of these structures. Moreover, the hydrogen dissolution and residual stresses in the weld may result in cold cracks, while minimizing deformability and enhancing sensitiveness to embrittlement [10].

4. Conclusions

The effects of groove welding on the microstructure and mechanical properties of wear resistant plate were studied. The following are the main conclusions of this study:

1. By varying groove welding, hardnesses and microstructures of samples were not change significantly. However, their changes were appeared at three weld zones (base metal, heat affected zone, and weld metal)
2. The highest hardness was obtained at base metal zone (40.16-41.38 HRc) followed by HAZ (36-36.66 HRc) and weld metal zone (30.38-31.05 HRc).
3. As microstructure investigation, the base metal had finer grain size than HAZ and weld metal. The grain coarsening was occurred during the weld process because of the high heat input in HAZ.
4. The highest impact energy and toughness value were attained at I groove and the lowest was at I groove. The fracture surfaces at all groove welds showed ductile fracture dominantly.

References

[1] N. Ojala, K. Valtonen, V. Heino, M. Kallio, J. Aaltonen, P. Siitonen, V.-T. Kuokkala, Effects of composition and microstructure on the abrasive wear performance of quenched wear resistant steels, Wear 317 (2014) 225–232, https://doi.org/10. 1016/j.wear.2014.06.003
[2] B Gulenc, N Kahraman. Wear Behaviour of Bulldozer Rollers Welded using a Submerged Arc Welding Process. Materials and Design. 24 (2003) 537–542.
[3] D. V. Kiran, J. Cheon, N. Arif, H. Chung, S. J. Na, Three-dimensional Finite Element Modelling of Pulsed AC Gas Metal Arc Welding Process. Int. J. Adv. Manuf. Technol. 86 (2016) 1453–1474.
[4] A. Chamanfar, M. Jahazi, A. Bonakdar, E. Morin, A. Firoozrai, Cracking in fusion zone and heat affected zone of electron beam welded Inconel-713LC gas turbine blades, Mater. Sci. Eng. A 642 (2015) 230–240.
[5] A.H.S. Iyer, K. Stiller, G. Leijon, H.C.M. Andersson-Östling, M. Hörnqvist Colliander, Influence of dwell time on fatigue crack propagation in Alloy 718 laser welds, Mater. Sci. Eng. A 704 (2017) 440–447
[6] R.A. Grange, Effect of microstructural banding in steel, Metall. Trans. 2 (1971) 417–426, https://doi.org/10.1007/BF02663328.
[7] J. Krawczyk, B. Pawłowski, P. Bała, Banded microstructure in forged 18CrNiMo7-6 steel, Metall. Foundry Eng. 35 (2009) 45, https://doi.org/10.7494/mafe.2009.35. 1.45.
[8] Porter, D. A. Weldable High-Strength Steels: Challenges and Engineering Applications. IIW International Conference, 2-3 July, Helsinki, (2015) 1-14.
[9] Ada, H. Weldability of Pipes Produced for Crude Oil and Natural Gas Pipelines with The Method of Submerged and Spiral Arc Welding and Researching Their Mechanical Properties, M.Sc. Thesis, p. 145, Gazi University, Ankara. (2006).
[10] Dunđer, M., Vuherer, T., Samardžić I., 2014. Weldability of microalloyed high strength steels TStE 420 and S960QL. Metalurgija 53, 3, 335-338.

The effect of groove welding on mechanical properties and microstructure of wear resistance steel plate by Submerged Arc Welding

ORIGINALITY REPORT

19%	14%	15%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	researchnow.flinders.edu.au Internet Source	2%
2	Jayanta Mondal, Karabi Das, Siddhartha Das. "An investigation of mechanical property and sliding wear behaviour of 400Hv grade martensitic steels", Wear, 2020 Publication	1%
3	www.rotterdamenwerk.nl Internet Source	1%
4	Pranjal Shukla, Srihari Chitral, Tinku Kumar, Degala Venkata Kiran. "The influence of GMAW correction parameters on stabilizing the deposition characteristics for wire arc additive manufacturing", Journal of Manufacturing Processes, 2023 Publication	1%
5	Gulenc, B.. "Wear behaviour of bulldozer rollers welded using a submerged arc welding process", Materials and Design, 200310	1%

Publication

6	www.dora.lib4ri.ch Internet Source	1%
7	Fabian Kies, Markus B. Wilms, Norbert Pirch, Konda G. Pradeep, Johannes H. Schleifenbaum, Christian Haase. "Defect formation and prevention in directed energy deposition of high-manganese steels and the effect on mechanical properties", Materials Science and Engineering: A, 2020 Publication	1%
8	jmrt.com.br Internet Source	1%
9	Submitted to University of Illinois at Urbana-Champaign Student Paper	1%
10	Behzad Shahedi, Mehrnoosh Damircheli, Ali Shirazi. "Experimental investigation of the effects of welding parameters and TiO2 nanoparticles addition on FSWed copper sheets", Materials Research Express, 2018 Publication	1%
11	Karacs, Gábor, and András Roósz. "Simulation of Isothermal Austenitization in Banded Pearlite Steels by Cellular Automaton", Materials Science Forum, 2015. Publication	1%

12	Yinxia Zhang, Shaoshuai Yuan, Xin Yang, Dong Wang. "Effect of process parameters on hardness and microstructure of 18CrNiMo7-6 carburized steel in high-speed cylindrical grinding", The International Journal of Advanced Manufacturing Technology, 2022 Publication	1 %
13	hrcak.srce.hr Internet Source	1 %
14	businessdocbox.com Internet Source	1 %
15	www.hjse.hitit.edu.tr Internet Source	1 %
16	Mehrnoosh Damircheli, Ali Shirazi. "Microstructural and mechanical properties of FSWed copper plates under usage of shielding gas for different welding parameters", Materials Research Express, 2019 Publication	<1 %
17	Shahriar Afkhami, Timo Björk, Jari Larkiola. "Weldability of cold-formed high strength and ultra-high strength steels", Journal of Constructional Steel Research, 2019 Publication	<1 %
18	hdl.handle.net Internet Source	<1 %

19	repozitorij.fsb.unizg.hr Internet Source	<1 %
20	abcm.org.br Internet Source	<1 %
21	mdpi-res.com Internet Source	<1 %
22	www.ijmerr.com Internet Source	<1 %
23	Jun Liu, Li-Liang Wang, Junyi Lee, Ruili Chen, Omer El-Fakir, Li Chen, Jianguo Lin, Trevor A. Dean. "Size-dependent mechanical properties in AA6082 tailor welded specimens", Journal of Materials Processing Technology, 2015 Publication	<1 %
24	patents.google.com Internet Source	<1 %
25	Suzuki, M.. "Assessment of the allowable maximum crack size in the toe HAZ of welded low alloy steel components", International Journal of Pressure Vessels and Piping, 197911 Publication	<1 %
26	Tingwei Zhou, Haifeng Xu, Xinyuan Ma, Zhenlin Xu, Hai Zhao, Yizhu He. "A Novel Carbide-Free Bainitic Heavy-Haul Wheel Steel	<1 %

with an Excellent Wear-Resistance under Rolling-Sliding Condition", Metals, 2023
Publication

27	electrochemsci.org Internet Source	<1 %
28	mit.imt.si Internet Source	<1 %
29	Kaushal Kishore, Pankaj Kumar, Goutam Mukhopadhyay. "Microstructure, Tensile and Fatigue Behaviour of Resistance Spot Welded Zinc Coated Dual Phase and Interstitial Free Steel", Metals and Materials International, 2021 Publication	<1 %

Exclude quotes	Off	Exclude matches	< 2 words
Exclude bibliography	Off		