Jurnal Rekayasa Mesin
p-ISSN: 1411-6863, e-ISSN: 2540-7678
Vol.21, No.2, August **2026**, hal. 273-284

Strength Analysis of Dissimilar Welded Joints Applied to Hydraulic Excavator Rod Arm

Abdul Choliq*, Fifit Astuti, Nur Rohmat
Mechanical Engineering, University Pamulang
Komplek Witanaharja No 1b West Pamulang, South Tangerang, Banten
*E-mail: dosen02127@unpam.ac.id

Submitted: 10-03-2026; Accepted: 13-08-2026; Published: 31-08-2026

Abstract

Dynamic workloads during hydraulic excavator operations frequently cause the joint between the shaft rod and the rod end to crack or even fracture. Although welding is often selected for economic reasons, the strength of this joint must be tested to ensure the operational safety of the heavy equipment. This study evaluates the mechanical characteristics of a dissimilar weld joint between AISI 1045 and AISI 4340 materials using the Gas Metal Arc Welding (GMAW) method with a current of 90 Amperes and a voltage of 19 V and varying filler metals: ER70S-6 and ER110S-G. Tensile test specimens were prepared in accordance with the ASTM E8/E8M-13a standard, featuring a length (L) of 50 mm and a diameter (D) of 12 mm. The welded samples subsequently underwent hardness testing using the Vickers method. Test results indicate that samples using ER70S-6 filler metal exhibited an average tensile strength of 544 N/mm^2 and a yield strength of 484 N/mm^2. Meanwhile, samples using ER110S-G filler metal showed an average tensile strength of 766 N/mm^2 and a yield strength of 613 N/mm^2. Hardness test results for the ER70S-6 samples showed average values of 279 HV in the AISI 1045 Heat-Affected Zone (HAZ), 358 HV in the AISI 4340 HAZ, and 167 HV in the weld metal. Conversely, the ER110S-G samples recorded average hardness values of 238 HV in the AISI 1045 HAZ, 383 HV in the AISI 4340 HAZ, and 280 HV in the weld metal. In conclusion, the ER110S-G filler metal resulted in a greater increase in both tensile strength and joint hardness compared to ER70S-6. This condition is driven by the characteristics of ER110S-G as a high-strength, low-alloy (HSLA) steel weld metal containing nickel (Ni), chromium (Cr), and molybdenum (Mo). The combination of these alloying elements produces a solid solution strengthening mechanism that results in a significantly more robust weld metal matrix structure.

Keywords: dissimilar welding; filler metal; HAZ; tensile strength; vickers hardness

Abstrak

Beban kerja dinamis selama operasi ekskavator hidrolik sering kali menyebabkan sambungan antara poros batang (*shaft rod*) dan ujung batang (*rod end*) mengalami retak hingga patah. Meskipun pengelasan banyak dipilih karena alasan ekonomis, kekuatan sambungan ini harus diuji guna menjamin keamanan operasional alat berat. Penelitian ini mengevaluasi karakteristik mekanis sambungan las berbeda jenis (*dissimilar welding*) antara material AISI 1045 dan AISI 4340 menggunakan metode *Gas Metal Arc Welding* (GMAW) dengan arus 90 Ampere dan tegangan 19 V, variasi logam pengisi ER70S-6 dan ER110S-G. Spesimen uji tarik mengikuti standar ASTM E8/E8M-13a, panjang (L) 50 mm dan diameter (D) 12 mm. Sampel lasan kemudian diuji kekerasannya menggunakan metode Vickers. Hasil pengujian menunjukkan bahwa sampel dengan logam pengisi ER70S-6 memiliki kekuatan tarik rata-rata 544 N/mm^2 dan kekuatan luluh 484 N/mm^2. Sementara itu, sampel dengan logam pengisi ER110S-G memiliki kekuatan tarik rata-rata 766 N/mm^2 dan kekuatan luluh 613 N/mm^2. Hasil uji kekerasan pada sampel ER70S-6 menunjukkan nilai rata-rata 279 HV pada area HAZ material AISI 1045, 358 HV pada HAZ material AISI 4340, dan 167 HV pada logam las (*weld metal*). Sebaliknya, sampel ER110S-G mencatatkan kekerasan rata-rata 238 HV pada HAZ material AISI 1045, 383 HV pada HAZ material AISI 4340, dan 280 HV pada logam las. Sebagai kesimpulan, logam pengisi ER110S-G memberikan dampak peningkatan kekuatan tarik dan kekerasan sambungan yang lebih besar dibandingkan ER70S-6. Kondisi ini dipicu oleh karakteristik ER110S-G sebagai logam las baja paduan rendah kekuatan tinggi (*High-Strength Low-Alloy*) yang mengandung unsur nikel (Ni), kromium (Cr), dan molibdenum (Mo). Kombinasi unsur paduan ini menghasilkan mekanisme penguatan larutan padat (*solid solution strengthening*) yang membentuk struktur matriks logam las menjadi jauh lebih kokoh.

Kata kunci: pengelasan berbeda jenis; bahan pengisi; HAZ; kekuatan tarik; kekerasan

1. Introduction

An excavator is a type of heavy equipment used for excavation, mining, dredging, demolition, land clearing, and material movement. This equipment allows for faster, more practical, and more efficient work [1]. During operation, almost all attachments on a hydraulic excavator actively move. One component that actively moves is the rod assembly. The rod assembly is part of the hydraulic cylinder that moves in and out of the cylinder to move the excavator's bucket, arm, and boom. The rod assembly consists of a rod axle and a rod end. Due to workload and vibration over a long cycle, the rod assembly can experience cracks. Ultimately, these cracks cause the rod assembly to fracture due to fatigue. The fracture occurs at the connection between the rod axle and the rod end. Replacing the rod assembly is the best solution, but it's expensive. Welding repairs are an alternative, though they require more complex work [2]. Welding between the rod axle and rod end is called dissimilar welding, which is the process of joining two different types of metal. Generally, rod assy materials are AISI 1045 and AISI 4340. AISI 1045 is known to be able to be joined dissimilarly with several types of metal [3][4]. Dissimilar welding is currently undergoing development by combining welding types and core metals (filler). Dissimilar welding methods can be performed using several welding methods [5], but it is more effective to do it with Gas Metal Arc Welding (GMAW) [6]. This welding method can be used for both ferrous and non-ferrous metals. GMAW produces a more accurate weld quality than other welding methods.

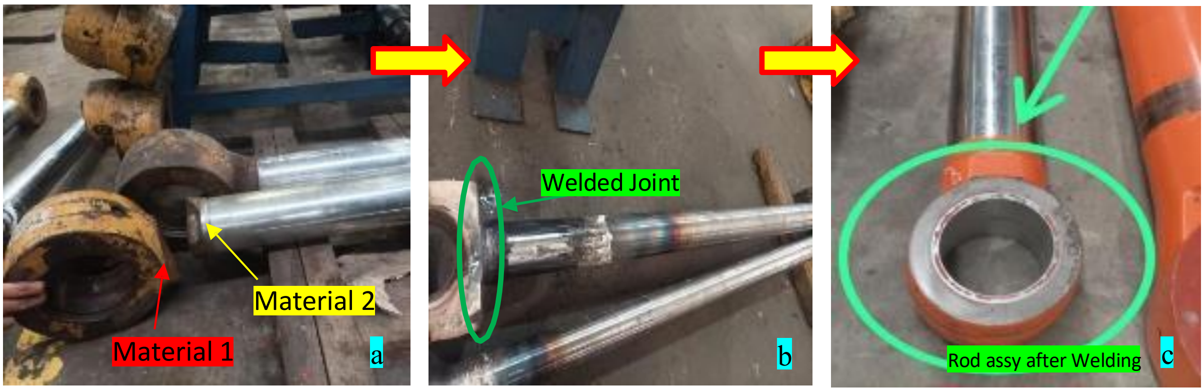


Figure 1. Rod assy cylinder before (a) and after connection (b, c)

The selection of filler and welding current greatly affects the quality of the weld [4]. The quality of the welded joint can be assessed from the deep penetration capability of the weld and the speed of filler melting into the metal which is useful for increasing the mechanical strength of the material being welded [7]. In several studies that have been conducted, dissimilar method connections have been carried out between AISI 1045 and AISI 316 L material samples with ER70S-6 and ER 308 L fillers and a current of 90 A using GMAW welding. The results, of all samples with the two types of fillers, the highest tensile strength value of the joint sample was 350 Mpa and a hardness of 111HRB [8].

Previous research successfully joined AISI 1045 and AISI 316L materials using a 90 A current with ER70S-6 and ER308L filler metals. However, the tensile strength of the resulting joint remained limited to 350 MPa. The novelty of this study lies in the utilization of higher welding current variations and different filler metal combinations to overcome this strength limitation. Through this method, the microstructure at the joint interface can be controlled to prevent brittleness, while simultaneously achieving deeper weld penetration and more seamless fusion. Consequently, this research successfully establishes a new welding parametric framework that yields significantly stronger joints compared to previous methods.

2. Material and Method

Based on the research, this study will analyze the results of dissimilar welding experiments between AISI 1045 and AISI 4340 material samples using ER70S-6 and ER-110S-G fillers and the welding method used is Gas Metal Arc Welding (GMAW). Based on the research, this study will analyze the results of different welding experiments between AISI 1045 and AISI 4340 material samples using ER70S-6 and ER-110S-G filler materials and the Gas Metal Arc Welding (GMAW) welding method. To measure the strength of the weld joint between AISI 1045 and AISI 4340 materials with two different filler metals, tensile testing was conducted using ASTM E8/E8M-13a standards and joint hardness testing using the Vickers

(HV) method. This, in turn, can determine whether these methods can be applied to connecting rod assemblies in hydraulic excavator cylinders. It should be noted that AISI 1045 and AISI 4340 steel are medium carbon steels with a carbon content of 0.4-0.5%. For other elements combined can be seen in the following table 1.

Table 1. Chemical Composition of Rod Assy Material [9][10]

No	Material Grade	Element (%)									YS (N/mm^2)	UTS (N/mm^2)	Hardness (HRB)
		Fe	C	P	S	Mn	Ni	Cr	Mo	Si			
1	AISI 1045	98.51 - 98.98	0.42 - 0.50	≤ 0.04	≤ 0.05	0.60 - 0.90	.-	.-	.-	<0.1	310	565	90
2	AISI 4340	95.19 - 96.33	0.38-0.43	0.035	0.04	0.60-0.80	1.65-2.00	0.70-0.90	0.20-0.30	0.15-0.35	470	745	96

From several sources it is known that the ER70S-6 MIG and ER-110S-G fillers have a C content between 0,06 % to 0,15 % [11]. A complete list of other blending elements contained in the filler can be seen in Table 2 below.

Table 2. Chemical Composition of Filler [11].

No	Filler Grade	Element in %									YS (N/mm^2)	UTS (N/mm^2)	Hardness (HRB)
		Fe	C	P	S	Mn	Ni	Cr	Mo	Si			
1	ER70S-6 MIG	-	0,06 ~ 0,15	≤ 0.025	≤ 0.035	1.40 ~ 1.85		≤ 0.15		0.80 ~ 1.15	400	≥ 480	91
2	ER-110S-G	-	0.08	<0.015	<0.015	1.60	1.50	0.7 - 0.9	0.30	0.60	470	745	95

The first stage is the preparation of tools including sandpaper, cutting grinder, Gas Metal Arc Welding (GMAW) machine and wire brush. Preparation of materials in the form of AISI 1045 and AISI 4340 steel. Filler ER70S-6 and ER-110S-G. Preparation of AISI 1045 and AISI 4340 steel materials follows the ASTM E8/E8M-13a sample standardization [12], the number of samples is 3 samples each.

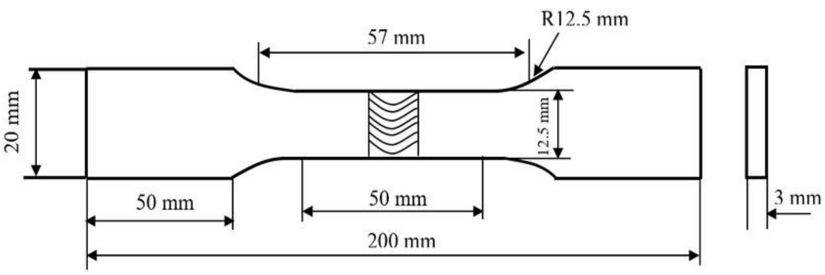


Figure 3. ASTM E8 standard tensile test sample

Surface cleaning is strictly performed to remove contaminants and prevent welding defects, while machining all specimens to ASTM standards ensures precise dimensions and reliable statistical data during tensile testing.

Figure 4. (a) Cutting, (b) Cutting results, (c) Turning (d) Sample.

The second stage involved welding AISI 1045 and AISI 4340 steel samples using gas metal arc welding (GMAW) with ER70S-6 and ER-110S-G filler metals (electrodes). The welding current was set at 90 Amperes and the voltage at 19 V as recommended by the company for ER70S-6 and ER-110S-G electrodes [13]. This controlled welding parameter setting aims to minimize heat input, prevent excessive thermal distortion in the dissimilar metal joint, and ensure the formation of optimal weld penetration free from microscopic defects prior to further mechanical testing [14]. After welding, all samples were subjected to tensile testing and hardness testing.

1. Tensile strength testing was conducted to determine the yield point and ultimate tensile strength of the welded joint. The tensile test specimens were based on the ASTM E8/E8M-13a standard [15] (See Figure 5). All test specimens were precisely machined in the transverse direction of the weld to ensure the gauge section encompasses the fusion zone, heat-affected zone, and parent metals uniformly.

Tensile Testing Process (a), Tensile Testing Results (b)

2. Hardness testing using the Vickers method with a load of 10 Kgf converted to Rockwell B to facilitate comparison of test results to more easily determine the hardness value of the measured samples (Figure 6). This conversion process enables seamless cross-referencing with standard industry benchmarks, providing deeper insights into the mechanical durability, structural integrity, and material performance of the tested specimens.

Figure 6. Hardness Testing Process

(a) Hardness Test, (b) ER70S-6 Hardness Test Results, and (c) ER110S-G Hardness Test Results

3. Results and Discussion

After conducting tensile tests on dissimilar weld samples and continuing with hardness tests on AISI 1045 and AISI 4340 materials in the HAZ area and filler metal, the following results were obtained:

a. Results of tensile test of welded samples with ER-70 metal filler.

Dissimilar welding between AISI 1045 and AISI 4340 steel samples, Gas Metal Arc Welding (GMAW) type, 90 A current and 19 V voltage, ASTM E8/E8-13a standard sample dimensions in three different samples: L gauge = 50 mm and D = 12 mm, filler types ER70S-6 and ER110S-G.

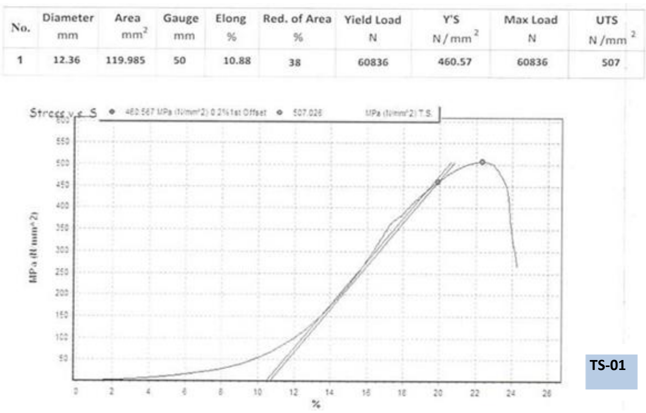
Table 3. Tensile test results of samples with ER-70 filler

Material	Filler	Sampel	Diameter (mm)	Area (mm^2)	Gauge Length	Elongation (%)	Reduction of Area (%)	Yield Strenght (N/mm^2)	Tensile Strenght (N/mm^2)	Location of Failure
AISI 4340 to AISI 1045	ER 70	TS-1	12,36	119,98	50	10,88	38	450,57	507	BBGM
		TS-2	12,49	122,52	50	9,60	29	430,49	509	BBGM
		TS-3	12,48	122,32	50	10,46	23	484,34	544	BBGM
Average						10,31	30	455,13	520	

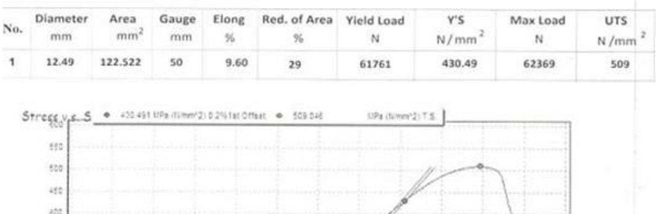
Testig Machine : Computer Servo Hydraulic Universal Testing Machine, Model: HT-9501, S/N: 1773

Used Capacity : 500kN

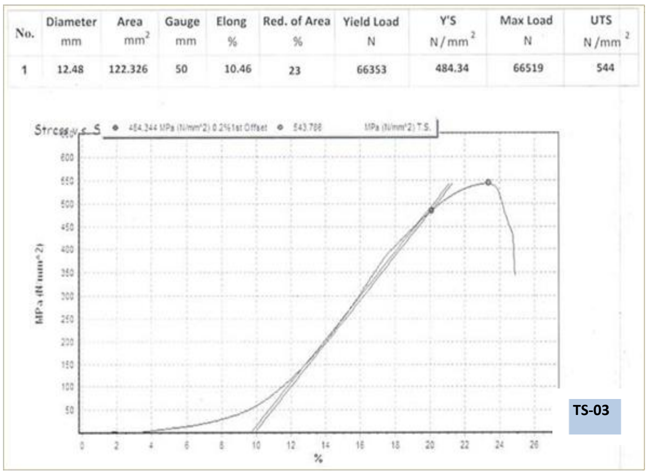
Remark : ***BBGM****: Broke Between Gauge Marks;* ***BOGM****: Broke Outside Gauge Marks*



The tensile test The tensile test results on sample 1 with a gauge length of 50 mm, a diameter of 12,36 mm, an area of 119,98 mm^2 showed a yield strength of 450,57 N/mm^2, a tensile strength of 507 N/mm^2, an elongation of 10,88%, a reduction area of 38%, and a fracture type of Broke Between Gauge Marks with a maximum load of 60836 N. The weld metal hardness is 158 HV or 80 HRB (Table 5).



The tensile test results on sample 2 with a gauge length of 50mm, a diameter of 12,49 mm, an area of 122,52 mm^2 showed a yield strength of 430,49 N/mm^2, a tensile strength of 509 N/mm^2, an elongation of 9,60%, a reduction area of 29%, and a fracture type of Broke Between Gauge Marks with a maximum load of 61761 N. Weld metal hardness of 178 HV or 86,7HRB (Table 5).



The tensile test results on sample 3 with a gauge length of 50mm, a diameter of 12.48 mm, an area of 122.32 mm^2 showed a yield strength of 484.34 N/mm^2, a tensile strength of 544 N/mm^2, an elongation of 10.46%, a reduction area of 23%, and a fracture type of Broke Between Gauge Marks with a maximum load of 66519 N. Weld metal hardness of 162 HV or 82 HRB (Table 5).

Figure 7. Stress and strain curves of samples with ER-70 filler

The tensile test results on sample 2 with a gauge length of 50 mm, a diameter of 12,49 mm, and an area of 122.52 mm^2 showed a yield strength of 430,49 N/mm^2, a tensile strength of 509 N/mm^2, an elongation of 9,60%, a reduction in area of 29%, and a fracture type of Broke Between Gauge Marks with a maximum load of 62369 N. The weld metal hardness is 178 HV or 86 HRB (Table 5).

The average tensile strength of the three joint samples with ER-70 filler was 520 N/mm^2. Compared to the tensile strength of AISI 1045 steel (565 N/mm^2) and AISI 4340 steel (745 N/mm^2) (see Table 1), the maximum tensile strength of the resulting joint is lower than that of AISI 1045 and AISI 4340 steel. However, this difference is not significant and is considered reasonable considering the tensile strength of ER-70 filler is 480 N/mm^2. Therefore, the strength of the ER-70 filler joint is considered close to that of the two materials and is considered adequate for repair.

b. Tensile test results of samples with ER-110 fille

Dissimilar welding between AISI 1045 and AISI 4340 steel samples, Gas Metal Arc Welding (GMAW) type, current 90 A and voltage 19 V, ASTM E8/E8-13a standard sample dimensions in three different samples, L gauge = 50 mm and D = 12 mm, filler ER70S-6 and ER110S-G.

Tabel 4. Tensile sample test results with ER-110 filler

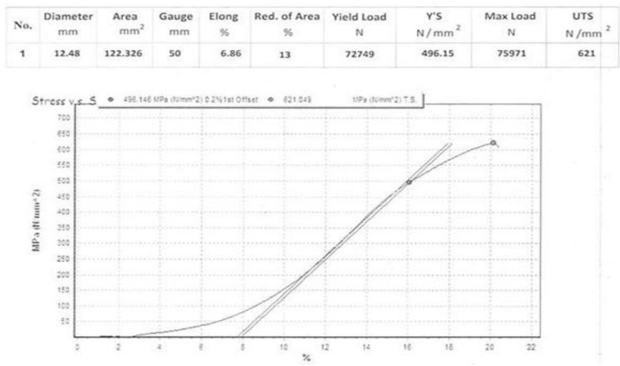
Material	Filler	Sampel	Diameter (mm)	Area (mm^2)	Gauge Length	Elongation (%)	Reduction of Area (%)	Yield Strenght (N/mm^2)	Tensile Strenght (N/mm^2)	Location of Failure
AISI 4340	**ER 110**	TS-1	12,48	122,32	50	6,86	13	496,15	621	BBGM
to		TS-2	12,42	121,15	50	21,32	63	612,79	766	BBGM

AISI 1045		TS-3	12,37	120,17	50	11,76	8	472,62	746	BBGM
Average						13,31	28	527,18	711	

Testig Machine : Computer Servo Hydraulic Universal Testing Machine, Model: HT-9501, S/N: 1773

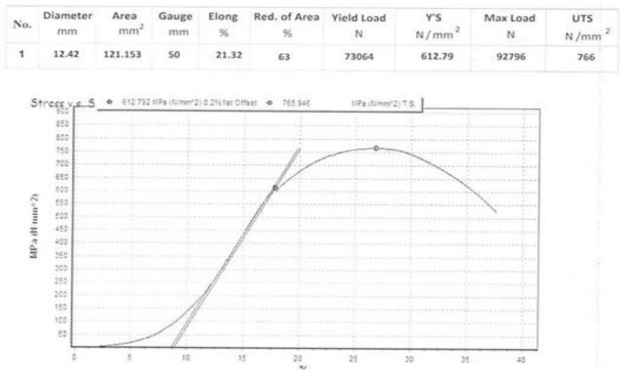
Used Capacity : 500kN

Remark : ***BBGM**: Broke Between Gauge Marks; **BOGM**: Broke Outside Gauge Marks*



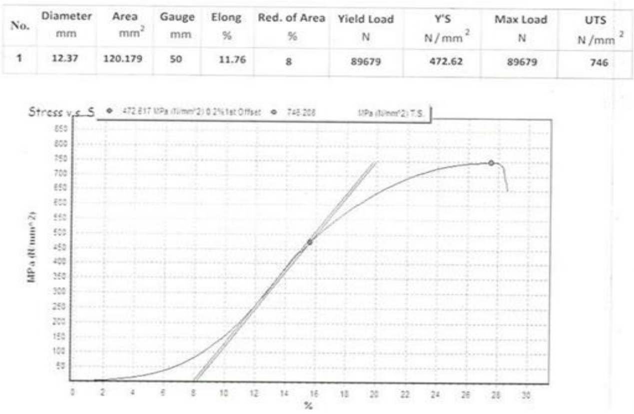
No.	Diameter mm	Area mm^2	Gauge mm	Elong %	Red. of Area %	Yield Load N	Y'S N/mm^2	Max Load N	UTS N/mm^2
1	12.48	122.326	50	6.86	13	72749	496.15	75971	621

The tensile test results on sample 1 with a gauge length of 50 mm, a diameter of 12.48 mm, and an area of 122.32 mm^2 showed a yield strength of 496.15 N/mm^2, a tensile strength of 621 N/mm^2, an elongation of 6.86%, a reduction of area of 13%, and a fracture type of Broke Between Gauge Marks with a maximum load of 75971 N. The hardness of the weld metal is 272 HV or 103 HRB (Table 6).



No.	Diameter mm	Area mm^2	Gauge mm	Elong %	Red. of Area %	Yield Load N	Y'S N/mm^2	Max Load N	UTS N/mm^2
1	12.42	121.153	50	21.32	63	73064	612.79	92796	766

The tensile test results on sample 2 with a gauge length of 50 mm, a diameter of 12.42 mm, an area of 121.153 mm^2 showed a yield strength of 612.79 N/mm^2, a tensile strength of 766 N/mm^2, an elongation of 21.3%, a reduction of area of 63%, and a type of fracture (Broke Between Gauge Marks) with a maximum load of 92796 N, Hardness of the weld metal 259 HV or 102 HRB (Table 6).



No.	Diameter mm	Area mm^2	Gauge mm	Elong %	Red. of Area %	Yield Load N	Y'S N/mm^2	Max Load N	UTS N/mm^2
1	12.37	120.179	50	11.76	8	89679	472.62	89679	746

The tensile test results on sample 3 with a gauge length of 50 mm, diameter of 12.49 mm, an area of 122.22 mm^2 showed a yield strength of 472.62 N/mm^2, a tensile strength of 746 N/mm^2, an elongation of 11.76%, a reduction of area of 8% and a fracture type of Broke Between Gauge Marks with a maximum load of 89679 N, Hardness of the weld metal 317 HV or 107 HRB (Table 6).

The average tensile strength of the three joint samples with E-110 filler was 711 N/mm^2. Compared to the tensile strength of AISI 1045 steel (565 N/mm^2) and AISI 4340 steel (745 N/mm^2) (see Table 1), the maximum tensile strength of the resulting joint is closer to that of AISI 4340 steel. The smaller difference in tensile strength values is due to the higher tensile strength of ER-110 filler compared to ER-70. Therefore, the strength of the ER-110 filler joint is considered more adequate and safer for repair.

c. ER-70 Filler Joint Hardness Test Results

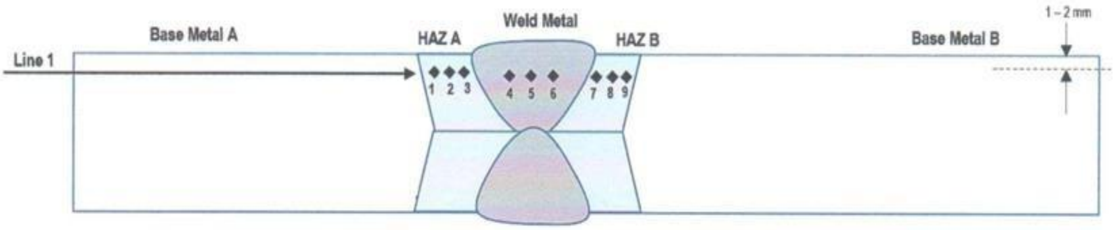


Figure 9. Sketch of hardness test

Table 5. Hardness test results for samples with ER-70 filler

Vickers Hardness Number (HV), Test Load Applied 10 Kgf										
Material Specification		AISI 4340			Weld Metal			AISI 1045		
Sample Filler ER-70	Location	HAZ A						HAZ B		
		1	2	3	4	5	6	7	8	9
	Sample I	374	362	357	159	158	155	229	249	242
	Sample II	443	467	452	187	178	178	348	344	343
	Sample III	268	263	243	163	162	168	256	254	249
Average		361	364	350	169	166	167	277	282	278
		358			167			279		

The results of the hardness test on the weld metal made of ER-70 filler showed that the average hardness in the HAZ of AISI 1045 was 279 HV (109 HRB), a slight increase from the hardness value of AISI 1045 without heat treatment, namely 90HRB (See table 1 again.) While in the HAZ area of AISI 4340 the average hardness was 358 HV (110 HRB) an increase from the hardness without treatment, namely 95HRB (see table 1 again). In the weld metal the average hardness that occurred was 167 HV (85 HRB) and was not much different from the hardness of the ER-70 filler, namely 91 HRB, (see table 2). Thus, this connection increases the hardness of the steel in the HAZ area and maintains the hardness of the fill metal (ER-70 filler).

d. ER-110 Filler Joint Hardness Test Results

Table 6. Hardness test results for samples with ER-110 filler

Vickers Hardness Number (HV), Test Load Applied 10 Kgf										
Material Specification		AISI 4340			Weld Metal			AISI 1045		
Sample Filler ER-110	Location	HAZ A						HAZ B		
		1	2	3	4	5	6	7	8	9
	Sample I	371	499	500	272	272	271	237	247	241
	Sample II	303	403	361	257	259	256	235	226	205
	Sample III	277	325	415	314	317	311	241	250	246
Average		317	409	425	281	282	279	237	241	230
		383			280			238		

The results of the hardness test on the weld metal made of ER-110 filler showed that the average hardness in the HAZ of AISI 1045 was 238 HV (98 HRB), an increase from the hardness value of AISI 1045 without heat treatment, namely 90 (See table 1 again.) While in the HAZ area of AISI 4340 the average hardness was 383 HV (111 HRB) an increase from the hardness without treatment, namely 96 HRB (see table 1 again). In the weld metal the average hardness that occurred was 280 HV (104 HRB) and increased above the hardness of the ER-110 filler, namely 95 HRB, (see table 2). Thus, thiconnection increases the hardness of the steel being joined in the HAZ area and slightly increases the hardness of the fill metal (ER-110 filler).

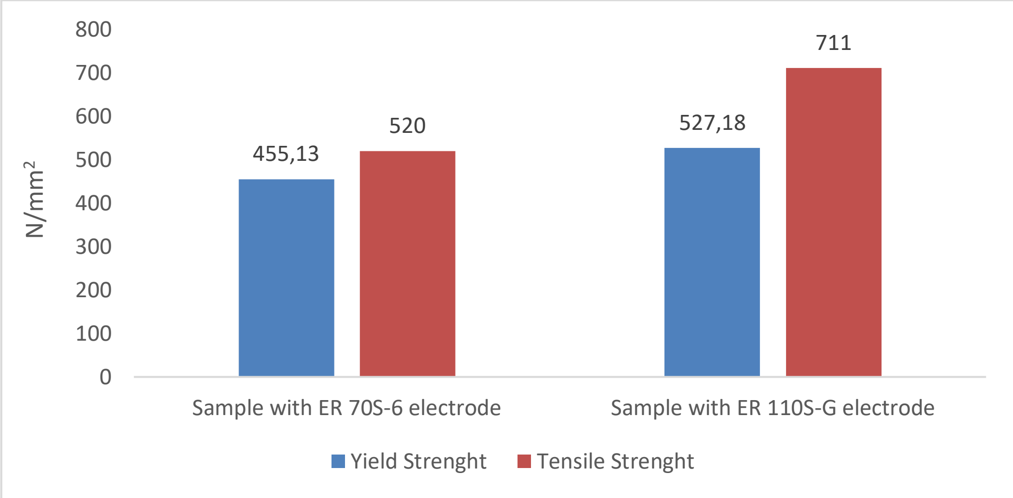


Figure 10. Comparison Graph of Tensile Strength of Filler Types ER70S-6 and ER110S-G.

The graph above is a comparison of the strength values of the dissimilar joint results from variations of the two types of fillers ER70S-6 and ER110S-G. The data generated after conducting tensile testing of this type of filler with dimensions of L gauge = 50.8 mm and D = 6 mm produces the same area value of 122 mm^2 but different tensile strength values of the material. The Ultimate Tensile Strength (UTS) value of the joint with the ER70S-6 filler reaches a value of 544 N/mm^2, while the ER110S-G reaches a higher value of 766 N/mm^2, there is a difference of 222 N/mm^2. The Yield Point (YP) value of the joint with the ER70S-6 filler is 484 N/mm^2 and for ER110S-G it has a value of 613 Mpa, there is a difference of 128 N/mm^2. Comparison of the elongation value of the material at break (elongation), in the connection with the ER70S-6 filler the elongation that occurred was 10% and in the ER110S-G it was 21%, there was a difference in the elongation value of 11%.

It can be analyzed that the results obtained are in accordance with the literature, namely that the ER110S-G filler produces a higher tensile strength value compared to the ER70S-6 filler. This is because the ER110S-G filler has several advantages including a softer arc, a stable combustion process, low welding spatter results and has a high toughness value with a maximum tensile strength (UTS) of 745 N/mm^2 [16]. While the ER70S-6 maximum tensile strength is only 560 N/mm^2 [see table 2 again].

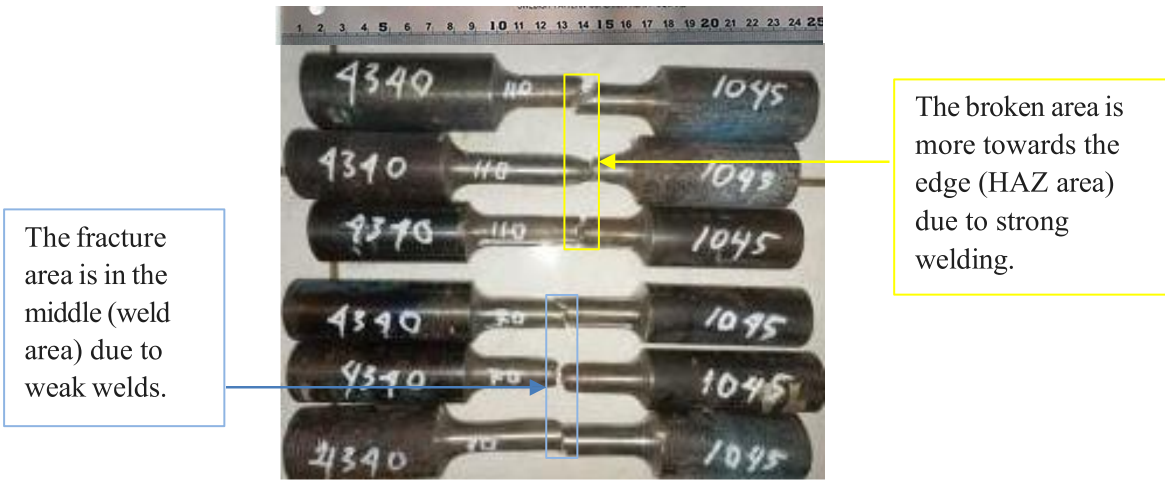


Figure 11. Sample fracture area

Visual analysis in Figure 7 shows that the weld fracture with ER110S-G filler occurred in the HAZ of AISI 1045 steel, not in the weld zone. While the weld fracture with ER70S-6 filler occurred in the weld zone, not in the HAZ of the material. This concludes that using ER110S-G filler results in stronger welds than welds using ER70S-6. Welds with ER110S-G improve the joint properties, even when using two different materials. This is due to ER110S-G's high-strength shielding gas, a smooth arc, a stable combustion process, low spatter, and higher toughness compared to ER70S-6 filler.

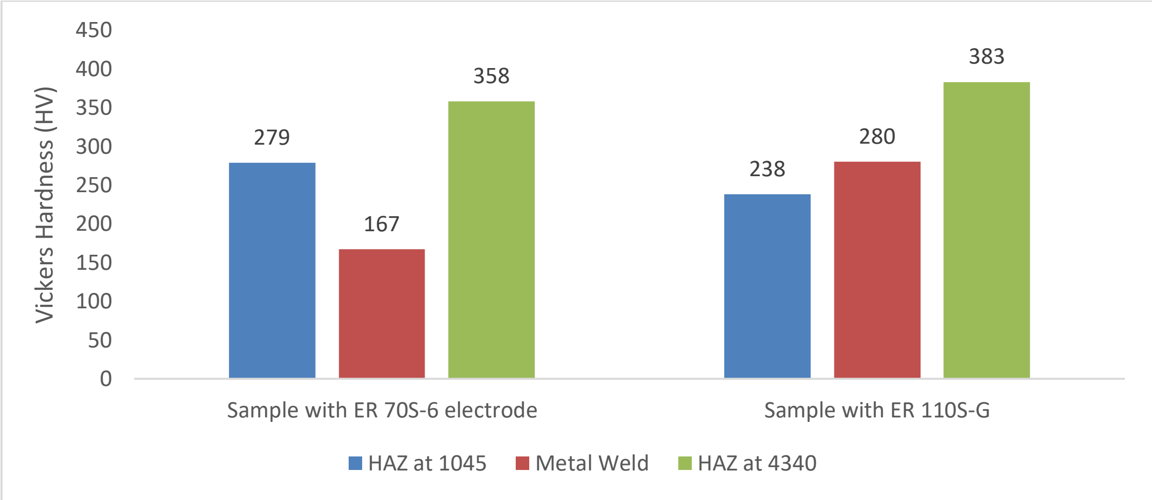


Figure 11. Comparison Chart of Hardness of Filler Types ER70S-6 and ER-110S-G

Figure 11 shows a comparison graph of the hardness values of the dissimilar joints of AISI 1045 steel and AISI 4340 steel from variations of the two types of fillers ER70S-6 and ER110S-G. The data shows that the welded joint with the ER70S-6 filler produces a hardness value in the HAZ 1045 area of 109 HRB (279 HV), Weld Metal 85 HRB (167 HV) and HAZ 4340 is 110 HRB (358 HV). While the welded joint with the ER110S-G filler in HAZ 1045 is 98 HRB (238 HV), Weld Metal 104 HRB (280 HV) and HAZ 4340 111 HRB (383). The hardness of the welded joint with ER110S-G has a harderness than ER70S-6, one of the forming factors is the different chemical composition of the two fillers (table 1). The elements C, Mn, Cr, and Si in ER110S-G are higher than ER70S-6. These alloying elements increase the tensile strength and hardness of the filler [17]. In this case, for greater accuracy, it is necessary to carry out chemical composition tests on the material using a spectrometer or SEM (*Scanning Electron Microscope*) and EDS (*Energy-Dispersive X-ray Spectroscopy*) to determine the chemical composition in detail [18].

Based on these data, the dissimilar joint between AISI 1045 and AISI 4340 materials using ER110S-G filler produced a strength similar to the results of previous joint experiments between AISI 1045 and AISI 316 L materials, which produced a hardness value of 111HRB. Therefore, rod assembly repair with dissimilar welded joints can be used as an alternative repair without having to replace the rod assembly with a new one, thus saving costs.

4. Conclusion

The results of the study on the connection of different types of AISI 1045 and AISI 4340 steel using ER70S-6 and ER110S-G filler materials which were tested for tensile strength with ASTM E8 / E8M-13a standards, and tested for hardness with ASTM E92 / ISO 6507-1 standards resulted in the following conclusions:

1. The tensile strength of joints using ER 70S-6 filler resulted in an ultimate tensile strength (UTS) of 544 N/mm^2 and a yield strength (YS) of 484 N/mm^2, with an elongation of 10%. Meanwhile, joints using ER 110S-G filler resulted in an ultimate tensile strength (UTS) of 766 N/mm^2 and a yield strength (YS) of 613 N/mm^2, with an elongation of 21%. ER110S-G filler provided a higher tensile strength when applied to dissimilar joints of AISI 1045 and AISI 4340 compared to ER70S-6.
2. The results of the hardness test on the weld using the ER 70S-6 filler were 85HRB, while the ER 110S-G filler was 104HRB. The effect of the ER110S-G filler was higher on the hardness of the dissimilar joint material of AISI 1045

with AISI 4340. So it can be interpreted that the ER110S-G filler is better for the dissimilar joint of AISI 1045 steel with AISI 4340.

3. The strength and hardness produced by this dissimilar welding cannot match the original product from the factory. However, it at least helps with the work temporarily and saves costs.

References

[1] C. Hua, J. Zhou, B. Zhang, Y. Zhang, and J. Zhang, "Low-complexity tracking control of hydraulic excavator systems with asymmetric full-state constraints," *J. Franklin Inst.*, vol. 362, no. 1, pp. 1–15, 2025, doi: 10.1016/j.jfranklin.2024.107345.

[2] D. Purnama, G. A. Wardana, and N. S. Adicandra, "Mechanical Strength Analysis of AISI 4340 Material Against Welding Repair Using the SMAW Method," *J. Poli-Teknologi*, vol. 14, no. 3, 2016, doi: 10.32722/pt.v14i3.766.

[3] G. Carrillo, M. Gómez, J. Rodas, and R. Pimentel, "Design and construction of automated mechanical ventilation equipment," *Ingenius*, vol. 2022, no. 27, pp. 17–22, 2022, doi: 10.17163/ings.n27.2022.02.

[4] E. A. Gadallah, M. I. A. El Aal, A. Y. Mohamed, and H. H. El-Fahhar, "Effects of filler on the microstructure and corrosion of similar and dissimilar gas inert tungsten arc welding aluminum alloys joints," *Sci. Rep.*, vol. 13, no. 1, pp. 1–18, 2023, doi: 10.1038/s41598-023-44421-y.

[5] N. Singh Doad, A. Gill, and D. P. Dhiman, "An Experimental Approach to Study the Effect of Process Parameters on Tensile Strength of Friction Welded Interface of Dissimilar MetalsAISI304/4340," *Int. J. Adv. Res.*, vol. 4, no. 1, pp. 249–260, 2018, doi: 10.13140/RG.2.2.12337.84323.

[6] A. S. Baskoro, D. Ubaszti, and D. Benhur, "The Effect of Welding Parameters on Microstructure in Dissimilar Welding of Stainless Steel 316L and Structural Steel on Gas Metal Arc Welding (GMAW)," pp. 9–10, 2019.

[7] R. W. Lubis, S. Dharma, R. Rahmawaty, R. Sebayang, N. Bahri, and M. A. Aditya, "Analysis of the Effect of Filler Metal Variations on the GTAW Welding Process of Aluminum Alloys on Hardness Tests and Microstructure," *SINERGI POLMED J. Ilm. Tek. Mesin*, vol. 5, no. 2, pp. 42–51, 2024, doi: 10.51510/sinergipolmed.v5i2.1581.

[8] F. Viktor dan Bella, U. Wahid, and H. Semarang, "The Effect of Filler and Electric Current in Welding Dissimilar Metals (AISI 1045) with Stainless Steel (AISI 316L) on Mechanical Properties and Microstructure," *Pros. SNST ke-3*, no. 3, pp. 45–50, 2019.

[9] A. Calik, O. Sahin, and N. Ucar, "Mechanical properties of boronized AISI 316, AISI 1040, AISI 1045 and AISI 4140 steels," *Acta Phys. Pol. A*, vol. 115, no. 3, pp. 694–698, 2009, doi: 10.12693/APhysPolA.115.694.

[10] W. S. Lee and T. T. Su, "Mechanical properties and microstructural features of AISI 4340 high-strength alloy steel under quenched and tempered conditions," *J. Mater. Process. Technol.*, vol. 87, no. 1–3, pp. 198–206, 1999, doi: 10.1016/S0924-0136(98)00351-3.

[11] AWS, "Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding," *Am. Weld. Soc.*, p. 44, 2005.

[12] ASTM E8, "ASTM E8/E8M standard test methods for tension testing of metallic materials 1," *Annu. B. ASTM Stand. 4*, no. C, pp. 1–27, 2010, doi: 10.1520/E0008.

[13] American National Standard Structural Welding, *Aws D1 .1/D1 .1 M:2020*. 2020.

[14] P. Kah, R. Suoranta, J. Martikainen, and C. Magnus, "2014_Metals and Polymers CFRP," vol. 36, pp. 152–164, 2014.

[15] E. Ghio, E. Cerri, M. Riccio, and J. Sisti, "Mechanical properties and microstructure of Ti6Al4V Extra Low Interstitial alloy produced via laser and electron beam additive manufacturing processes," *Metall. Ital.*, vol. 113, no. 10, pp. 69–83, 2022.

[16] X. Yu, “Microstructure and Mechanical Properties of High-Strength, Low-Alloy Steel Thin-Wall Fabricated with Wire and Arc Additive Manufacturing Kaijie,” 2023.

[17] R. Kartikasari, R. Muhfidin, and S. Anshory, “Analysis of the Effect of Mn Content on the Microstructure and Mechanical Properties of Fe-Cr-Mn Alloy Castings,” *Majamecha*, vol. 6, no. 1, pp. 26–35, 2024, doi: 10.36815/majamecha.v6i1.3234.

[18] M. M. Ghanem and A. M. Sehsah, “Effect of Welding Parameters on Microstructure and Mechanical Properties of Dissimilar AISI 304 / Ductile Cast Iron Fusion Welded joints,” no. Dci, 2024.