

**OPTIMIZATION ELECTRICAL CURRENT OF THE SPOT TIG  
WELDING ON THE TENSILE STRENGTH OF MATERIAL MILD STEEL  
SPCG 250 USING FUZZY LOGIC METHOD**

By

Rahayu Budi Prahara

21952058

MASTER'S DEGREE

in

MASTER OF MECHANICAL ENGINEERING – MECHATRONICS

Concentration

FACULTY OF ENGINEERING & INFORMATION TECHNOLOGY



SWISS GERMAN UNIVERSITY

The Prominence Tower

Jalan Jalur Sutera Barat No. 15, Alam Sutera

Tangerang, Banten 15143 - Indonesia

February 2021

**Revision after Thesis Defense on January 28<sup>th</sup>, 2021**

### STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Rahayu Budi Prahara

\_\_\_\_\_  
Student

\_\_\_\_\_  
Date

Approved by:

Dr. Ir. Widi Setiawan

\_\_\_\_\_  
Thesis Advisor

\_\_\_\_\_  
Date

Dr. Ir. Henry Nasution, M.T

\_\_\_\_\_  
Thesis Co-Advisor

\_\_\_\_\_  
Date

Dr. Maulahikmah Galinium, S.Kom, M.Sc

\_\_\_\_\_  
Dean

\_\_\_\_\_  
Date

---

Rahayu Budi Prahara

---

## ABSTRACT

### OPTIMIZATION ELECTRICAL CURRENT OF THE SPOT TIG WELDING ON THE TENSILE STRENGTH OF MATERIAL MILD STEEL SPCG 250 USING FUZZY LOGIC METHOD

By

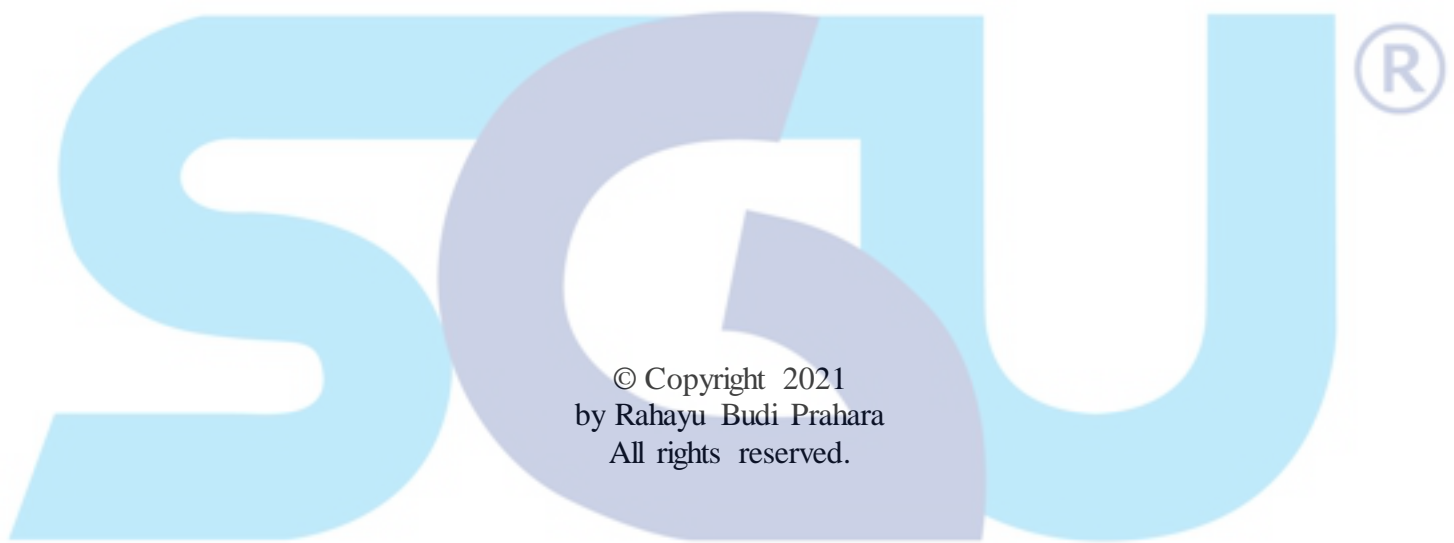
Rahayu Budi Prahara  
Dr. Ir. Widi Setiawan, Advisor  
Dr. Ir. Henry Nasution, M.T Co-Advisor

SWISS GERMAN UNIVERSITY

This research explains about the optimization of electric current TIG spot welding on the tensile strength of SPCG 250 mild steel using a fuzzy logic system. In this study using 2 types of fuzzy, namely Mamdani FIS and Sugeno ANFIS. By combining these 2 fuzzy types, the error value is 11.8712. In addition, regression analysis was also carried out on the input variable parameters of the output variable. From the results of the regression analysis, it is known that the parameters that influence it are electric current and holding time. The validation process is carried out by matching the results of fuzzy output, ANFIS output and real data to the mechanical properties of the materials which is 320 MPa, so the optimization value at current 80 A and holding time 10 with a value of 342.92 MPa is obtained. To the tensile strength test results, a decision-making system with fuzzy logic can be used using the ANFIS method.

*Keyword: Spot TIG welding, Fuzzy logic, ANFIS, Optimization, Current, Holding time, Mild steel SPCG 250, MATLAB.*

**COPYRIGHT**



**SWISS GERMAN UNIVERSITY**

---

## DEDICATION

I dedicate this work to my beloved wife, sons and daughters who always encourage and inspire me, patiently wait and give the best prayers for my struggle.

Allah is the One Who created seven heavens in layers, and likewise for the earth. The divine command descends between them so you may know that Allah is Most Capable of everything and that Allah certainly encompasses all things in His knowledge. (Q.S. At-Talaq: 12)



---

## ACKNOWLEDGEMENTS

Praise and gratitude to Allah Subhanahu wa ta'ala for all blessings and guidance, so that until now they are still given the opportunity and health. By His will the writer is also able to complete the preparation of a thesis and complete study assignments in this beloved campus.

The author's gratitude goes to Dr. Ir. Widi Setiawan and Mr. Dr. Ir. Henry Nasution, M.T. for his patience and sincerity in guiding authors and always give advice like parents themselves. The author is very proud to study at this campus with the support of lecturers, employees and colleagues in the Master of Mechanical Engineering (Mechatronics) study program.

The author also expresses his gratitude to Mr. Ir. Tony Harley Silalahi, M.A.B., E.M.B.A., Mr. Tonny Pongoh, S.H., LL.M, Mr. Budi Hartono, S.T., M.T., and all colleagues at Astra Manufacturing Polytechnic who have provided opportunities and support so that this study assignment can be carried out and completed.

The author realizes that this thesis is still far from perfect, so the writer is open to constructive criticism and suggestions. Hopefully this thesis can be useful for Swiss German University students in general and Mechanical Engineering (Mechatronics) students in particular.

Tangerang, February 2021

Rahayu Budi Prahara

---

**TABLE OF CONTENT**

	Page
STATEMENT Y THE AUTHOR .....	2
ABSTRACT.....	3
COPYRIGHT.....	4
DEDICATION .....	5
ACKNOWLEDGEMENTS .....	6
LIST OF FIGURES .....	10
LIST OF TABLES .....	12
CHAPTER 1 – INTRODUCTION .....	13
1.1 Background .....	13
1.2 Research problem.....	15
1.3 Research objective.....	15
1.4 Significance of study.....	16
1.5 Research question.....	16
1.6 Hypothesis .....	16
CHAPTER 2 - LITERTURE RIVIEW .....	17
2.1 Theoretical perspectives .....	17
2.1.1 Tungsten Inert Gas (TIG) welding .....	17
2.1.2 Spot TIG welding.....	18
2.1.3 Welding parameter .....	20
2.1.4 Testing process.....	21
2.1.5 Fuzzy algorithm .....	21
2.1.6 Input and output variable .....	27
2.1.7 Fuzzy rule: If-Then rules.....	27
2.1.8 Logical operation .....	27
2.1.9 Fuzzification.....	28
2.1.10 Defuzzification.....	28
2.1.11 Adaptive Neuro Fuzzy Inference System (ANFIS) .....	32
2.1.12 Simple linear analysis .....	34
2.2 Previous study .....	35
CHAPTER 3 – RESEARCH METHODS .....	41

---

3.1	Research design.....	41
3.2	Scope of study .....	42
3.3	Material and equipment.....	42
3.3.1	Low carbon steel.....	42
3.3.2	Equipment .....	43
3.4	Research preparation.....	46
3.4.1	Specimen preparation.....	46
3.4.2	Making research variables .....	46
3.4.3	Welding process .....	47
3.4.4	Tensile testing .....	50
3.5	Fuzzification.....	53
3.5.1	Input and output variable .....	53
3.5.2	Membership function input and output variable .....	55
3.5.3	Rule viewer design.....	58
3.5.4	Surface design .....	60
3.6	ANFIS model construction.....	60
3.6.1	Input and output variable .....	60
3.5.3	Fuzzy set of input variable .....	61
3.5.4	Rule viewer design.....	63
3.5.5	Surface design .....	65
3.6	Regression Analysis of input and output variable .....	66
3.6.1	Simple linier regression (SLR) .....	69
CHAPTER 4 – RESULT AND DISCUSSION .....		73
4.1	Specimen product trail analysis.....	73
4.2	Validation.....	74
4.2.1	First validation analysis .....	74
4.2.2	Second validation analysis .....	77
4.2.3	SLR analysis .....	80
4.3	Result combining.....	83
4.4	Validation result.....	84
CHAPTER 5 – CONCLUSIONS AND RECCOMENDATIONS .....		86
5.1	Conclusions .....	86

---



---

5.2 Recommendation.....	87
GLOSSARY .....	88
APPENDIX .....	89
REFERENCES .....	92
CURRICULUM VITAE.....	96



## LIST OF FIGURES

Figure	Page
Figure 2. 1 TIG welding process (Patel, 2014) .....	17
Figure 2. 2 The principle of welding spot TIG welding .....	18
Figure 2. 3 The principle resistance spot welding (Faozi, 2015) .....	18
Figure 2. 4 Triangular membership function .....	23
Figure 2. 5 Trapezoidal membership function .....	23
Figure 2. 6 Trapezoidal membership function– R Function .....	24
Figure 2. 7 Trapezoidal membership function– L Function .....	24
Figure 2. 8 Gaussian membership function .....	25
Figure 2. 9 Generalized Bell membership function .....	25
Figure 2. 10 Sigmoid membership function .....	26
Figure 2. 11 Fuzzy logical operations (Nasution, 2007) .....	27
Figure 2. 12 Maximum defuzzification method .....	29
Figure 2. 13 Centre of area defuzzification method .....	29
Figure 2. 14 Weighted average defuzzification method .....	30
Figure 2. 15 Mean- max method .....	30
Figure 2. 16 Center of sum method .....	31
Figure 2. 17 Largest area method .....	31
Figure 2. 18 First (or last) of maxima method .....	32
Figure 2. 19 Structure ANFIS (Azizah, Adi and Widodo, 2016) .....	33
Figure 3. 1 Research flow process .....	41
Figure 3. 2 Welding machine type OTC TIG ACCUTIG 300P (Daihen, 2002) ..	44
Figure 3. 3 Specification tensile strength machine (Shimadzu, no date) .....	45
Figure 3. 4 Tensile test machine SHIMADZU .....	45
Figure 3. 5 Test specimen dimensions .....	46
Figure 3. 6 Input-output parameters of fuzzy logic control model .....	54
Figure 3. 7 Membership function input variable (electrical_current) .....	55
Figure 3. 8 Membership function input variable (holding_time) .....	56
Figure 3. 9 Membership function output variable (strength) .....	57
Figure 3. 10 Optimization results with a current 40 A and a holding time of 5 seconds .....	58
Figure 3. 11 Optimization results with a current 60 A and a holding time of 10 seconds .....	58
Figure 3. 12 Optimization results with a current 80 A and a holding time of 10 seconds .....	59
Figure 3. 13 Fuzzy rule .....	59
Figure 3. 14 Graph of the effect of current and holding time on the results of the tensile strength test fuzzy model .....	60
Figure 3. 15 Train result of initial data ANFIS .....	61
Figure 3. 16 FIS properties of initial data .....	62

---

Figure 3. 17 Membership function input variable (current) .....	62
Figure 3. 18 Optimization results with a current 40A and a holding time of 5 seconds .....	63
Figure 3. 19 Optimization results with a current 60 A and a holding time of 10 seconds .....	64
Figure 3. 20 Optimization results with a current 80 A and a holding time of 10 seconds .....	64
Figure 3. 21 ANFIS rule .....	65
Figure 3. 22 Graph of the effect of current and holding time on the results of the tensile strength test ANFIS model .....	65
Figure 3. 23 Current 40 A and holding time 5s vs strength.....	66
Figure 3. 24 Current 60 A and holding time 5s vs strenght .....	66
Figure 3. 25 Current 80 A and holding time 5s vs strength.....	67
Figure 3. 26 Current 40 A and holding time 10s vs strength.....	67
Figure 3. 27 Current 60 A and holding time 10s vs strength.....	68
Figure 3. 28 Current 80 A and Holding time 10s vs Strength .....	68
Figure 3. 29 Current line fit plot (x=current, y=strength) .....	69
Figure 3. 30 Current line fit plot (x=current, y=strength) .....	71
Figure 4. 1 Test result of first validation data .....	74
Figure 4. 2 Training error result of 100 data with ANFIS .....	75
Figure 4. 3 Training data result of 100 data with ANFIS .....	76
Figure 4. 4 Result with design fuzzy (Current 60 A, Ht 10s) .....	78
Figure 4. 5 Result with design ANFIS (Current 60 A, Ht 10s) .....	78
Figure 4. 6 Result with design fuzzy (Current 80 A, Ht 10s) .....	79
Figure 4. 7 Result with design ANFIS (Current 80 A, Ht 10s) .....	79

## LIST OF TABLES

Table	Page
Table 2. 1 Fuzzy logic fault detector performance with different membership functions (Nasution, 2007).....	26
Table 3. 1 The chemical composition of low carbon steel SPCG 250 (Steel, 2018) .....	43
Table 3. 2 The mechanical properties of low carbon steel SPCG 250 (Steel, 2018) .....	43
Table 3. 3 Variation of welding current variables for holding time 5 seconds .....	46
Table 3. 4 Variation of welding current variables for holding time 10 seconds .....	47
Table 3. 5 Specimen 1 prior to the tensile test. ....	48
Table 3. 6 Specimen 2 prior to the tensile test. ....	49
Table 3. 7 Tensile test result data .....	51
Table 3. 10 Universe of discourse, domain, and membership range of input variable.....	63
Table 3. 11 Summary output SLR of current with holding time 5s .....	70
Table 3. 12 Summary output SLR of current with holding time 10s .....	71
Table 4. 1 The required spot TIG welding parameter with input current and holding time .....	73
Table 4. 2 Real output vs output fuzzy .....	75
Table 4. 3 Universe of discourse, domain, and membership range of Input variable from first validation .....	76
Table 4. 4 Real output vs output ANFIS .....	77
Table 4. 5 Output fuzzy.....	80
Table 4. 6 Regression data holding time 5s .....	81
Table 4. 7 Result data equation holding time 5s .....	82
Table 4. 8 Regression data holding time 10s .....	82
Table 4. 9 Result data equation holding time 10s .....	83
Table 4. 10 Data mechanical properties material mild steel SPCG 250 .....	84
Table 4. 11 Match table between real output, fuzzy output, ANFIS output .....	85