



**Cost Estimation and Optimization of Welding
Activities in Industrial Projects**

Prepared By

Haitham Abdullah Nsaif

Supervisor

Dr. Karim Aljebory

**This Thesis Was Submitted as Partial Fulfillment of the Requirements
for the Master Degree of Engineering Project Management (E.P.M.)**

**Faculty of Engineering
Isra University**

2018



**Establishing and Developing
Computer Application (Software)
For
Industrial Projects**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿ وَأَنْزَلْنَا الْحَدِيدَ فِيهِ بَأْسٌ

شَدِيدٌ وَمَنْفَعٌ لِلنَّاسِ ﴾

صَدَقَ اللَّهُ الْعَظِيمُ

COMMITTEE DECISION

This Thesis (**Cost Estimation and Optimization of Welding Activities in Industrial Projects**) Was Successfully Defended and Approved on: 09 / 08 / 2018.

Examination Committee

Signature

Dr. Karim Aljebory, (Supervisor)
Assoc. Prof. of Computer Control Eng.

.....

Dr. Walid Hasan, (Member)
Assoc. Prof. of Structure

.....

Dr. Sultan A. Tarawneh , (Member)
Prof. of Construction Engineering Management
(Mutah University of Jordan)
Karak – Jordan

.....

DEDICATION

To the soul of my father and mother

To my wonderful wife

To my children Ali zain al abdeen and Safa

To my great family

With love

ACKNOWLEDGEMENTS

First of all, I would like to present my sincere thanks and appreciation to my supervisor Dr. Karim Aljebori for his continuous guidance, encouragement and follow-up, without which I would not have been able to accomplish this thesis.

Furthermore, my thanks and gratitude are extended to Professor Dr. Rami A. Maher for his valuable assistance and information which were essential for the completion of this work.

My thanks and appreciation are also presented to all professors who taught me at the faculty of engineering at Isra University.

My gratitude and appreciation are also due to Dr. Abd Al-Karim Jawad from the University of Jordan for his valuable advices and actual guidance and assistance to accomplish this effort.

Last, but not least, I would like to extend my sincere thanks to An-Nejem Company for Engineering Contracting with all its administrative and technical cadre for their valuable help during conducting the practical experiments included in this work, as well as to my family and nice colleagues and friends who gave me their support and encouragement.

TABLE OF CONTENTS

COMMITTEE DECISION	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF ABBREVIATIONS	xi
ABSTRACT	xii
Chapter One: Introduction	1
1.1 Preface	2
1.2 Research Objectives and Hypotheses	4
1.4 Scope of Research.....	5
1.5 Research Importance and Methodology	5
1.6 Importance of Costing	7
1.7 Thesis Layout and Structure	8
1.8 Limitations of the Study	9
Chapter Two: Literature Review	10
2.1 Introduction.....	11
2.2 Review of Articles	11
Chapter Three: Fundamentals of Welding and Cost Estimation	24
3.1 Introduction.....	25
3.2 Objectives of Cost Estimation	27
3.3 Components of a Cost Estimate.....	28
3.3.1 Labour Cost	29
3.3.2 Cost of Raw Materials.....	29
3.3.3 Overhead Costs	30
3.4 Cost Estimation Procedure.....	30
3.5 Elements of Cost.....	31
3.6 Cost Estimation of Welding Process	32
3.7 What Is Welding?	35
3.7.1 The Welding Process	36
3.7.2 Welding Process Classification	37

3.8 Welding Methods.....	38
3.8.1 Shielded Metal Arc Welding (SMAW)	38
3.8.2 Gas Shielded Arc Welding.....	41
3.8.3 Submerge Arc Welding	45
3.9 Welding Codes and International Standards.....	46
3.9.1 Welding Procedure Specification (WPS).....	47
3.9.2 Qualifying the Welding Procedure Specification	48
3.10 Factors Affecting Cost Estimation of Welding.....	48
3.10.1 Joint Design	48
3.10.2 Weld Metal Cost.....	54
3.10.3 Deposition Rate	55
3.10.4 Deposition Efficiency.....	55
3.10.5 Operation Factor	56
3.10.6 Electric Power	59
3.10.7 Welder Skill and Welding Position	60
3.10.8 Labour and Overhead	66
Chapter Four: Methodology Implementation.....	67
4.1 Introduction.....	68
4.2 Cost and Time Estimating Model	68
4.3 Weld Assemblage Modeling.....	70
4.4 Decomposition of a Mechano-Weld Structure	70
4.5 General Cost Function	71
4.6 Indirect Cost Estimation	72
4.7 Direct Cost Estimation.....	73
4.8 Geometric Modeling	73
4.9 Welding Time Estimation.....	75
4.10 Welding Cost Estimation	77
4.11 Experimental Analysis of Deposition Rate.....	80
4.11.1 Experimental Hypotheses	80
4.11.2 Experimental Objectives.....	81
4.11.3 Experimental Procedure and Results	81
4.11.4 Hypothesis Testing	85
4.11.5 Regression Analysis.....	88
4.11.6 The Effect of Welding Position on Metal Weight	94

4.11.7 Experimental Conclusion	96
Chapter Five: Software Development.....	97
5.1 Introduction.....	98
5.2 Software Validation and Results.....	106
5.3 Manual Estimation of Cost by the Company	109
5.4 Comparison of Results.....	109
5.5 The Benefits of Software in Company Management Departments	112
Chapter Six: Conclusions and Recommendations.....	115
6.1 Conclusions.....	116
6.2 Recommendations.....	117
6.3 Future work.....	118
References.....	خطأ! الإشارة المرجعية غير معرفة.
Appendices.....	122

LIST OF TABLES

NUMBER	TABLE CAPTION	PAGE
2.1	Importance of papers usage	23
3.1	Reference numbers for some fusion welding methods	38
3.2	Basic weld types and their symbols	53
3.3	Operating Factor for different Welding processes	57
4.1	Experimental data for electrode diameter	83
4.2	Experimental data for electrode diameter	84
4.3	SPSS results for explore test	85
4.4	SPSS results for explore test	86
4.5	SPSS results for independent samples test	86
4.6	SPSS results for independent samples test	87
4.7	SPSS results for linear regression	88
4.8	SPSS results for linear regression	90
4.9	Statistical analysis steps	93
4.10	Required melt weight in different welding positions (Welding handbook, 18th edition, ESAB)	94
4.11	SPSS results for linear regression for the metal weight	95
5.1	Comparison of results between manual and program estimation	109
5.2	Time and cost estimation from software (pressure vessel)	110
5.3	Time and cost estimation from software (storage tank)	111

LIST OF FIGURES

NUMBER	FIGURE CAPTION	PAGE
1.1	The main four constraints of project management	2
1.2	Thesis layout diagram	8
3.1	The Freiman curve	26
3.2	Elements of total cost	32
3.3	Some important welding processes	37
3.4	An illustration of the SMAW system	40
3.5	SMAW welding arc	41
3.6	GMAW equipment	43
3.7	Gas- shielded metal arc welding	44
3.8	Schematic of submerged arc welding system	46
3.9	Calculation of weld requirements depending on joint design	50
3.10	Increasing weld size increases the welding cost	51
3.11	Different kinds of lap joints	52
3.12	Different types of butt joints	53
3.13	Deposition efficiency	56
3.14	Deposition rate (high deposition rates are desirable)	58
3.15	Scheme of placement of components to be welded for flat welding	60
3.16	Scheme of placement of components to be welded for horizontal welding	61
3.17	Scheme of placement of components to be welded for vertical welding	62
3.18	Scheme of placement of components to be welded for different types of welding positions, including overhead welding	63
3.19	Pipe horizontal rolled position	63
3.20	Pipe horizontal fixed position	64
3.21	Pipe vertical position	64

3.22	Pipe 45° inclined position	65
3.23	Pipe 45° inclined position with a restricting ring	65
4.1	Model adopted for welding cost estimation	69
4.2	Approach for decomposition of “welding features” and “preparing features”	71
4.3	The geometric modeling approach of a welding section	73
4.4	Geometric modeling of a welding feature "end- to- end" in V groove shape	74
4.5	Welding time calculating methodology	76
4.6	Single V butt joint	81
4.7	the Scatter diagram between vertical and flat deposition rates	89
4.8	Relationship between vertical and flat deposition rates	90
4.9	the Scatter diagram between vertical and flat deposition rates	91
4.10	Relationship between vertical and flat deposition rates	92
4.11	Relationship between vertical and flat metal weight	96
5.1	Software flowchart diagram	99
5.2	User windows ≠ 1	100
5.3	User windows ≠ 2	101
5.4	User windows ≠ 3	103
5.5	User windows ≠ 4	104
5.6	User windows ≠ 5	105
5.7	User windows ≠ 6	106
5.8	Diagram for pressure vessel	107
5.9	Diagram of storage tank	108
5.10	Histogram explaining the difference between software program estimation and manual estimation	112
5.11	Software report in management process	113

LIST OF ABBREVIATIONS

Abbreviation	Meaning
WPS	Welding procedure specification
DOE	Design of experiment
ANOVA	Analysis of variance (One way ANOVA)
FSW	Friction stir welding
GMAW	Gas metal arc welding
ANN	Artificial neural network
SMAW	Shielded metal arc welding
GMAW-C	Gas metal arc welding with CO ₂
GMAW-M	Gas metal arc welding with mixed gas
FCAW	Flux cored arc welding
MCAW	Metal cored arc welding
SSFCAW	Self- shielded flux cored arc welding
SAW	Submerged arc welding
GTAW	Gas tungsten arc welding
RW	Resistance welding
OFW	Oxy fuel gas welding
AW	Arc welding
MIG	Metal inert gas
TIG	Gas tungsten arc welding
ASME	American society of mechanical engineers
AWS	American welding society
PQR	Procedure qualification record
SPSS	Statistical package for the social sciences

Cost Estimation and Optimization of Welding Activities in Industrial Projects

**By
Haitham Abdullah Nsaif**

**Supervisor
Dr. Karim Aljebory**

ABSTRACT

Cost estimation is an essential work for the efficient management of any enterprise. It gives very useful information for the preparation of financial accounts. The problem of estimating the cost of welding activities within industrial engineering projects can be attributed to the existence of a number of variables that affect this task, which renders it more complicated. As a result, it is necessary to develop mathematical models and find optimized solutions to estimate the costs of different welding activities, including direct and indirect costs. In addition, the difficulties in welding cost estimation can be overcome by the implementation of a computer program that calculates the direct and indirect cost of welding. Activities and compares the different welding methods in terms of efficiency time and cost. The program is expected to compare the different processes and take the appropriate decision on how to implement the welding activities, thus, several departments at factories and corporations will benefit from the inclusion of such program. The current study delivers a theoretical model that optimizes the cost of welding activities based on all variables involved in affecting the total costs. It also develops computer software, which is capable of accurately calculating welding cost and time. Furthermore, particular experiments are conducted to determine the deposition rate of welding metal in different positions (vertical, flat). Through experiments conducted, it was found that there are differences in deposition rate in different welding positions (vertical, flat). It was also found that more deposition metal weight is required in the vertical welding position compared with flat welding position. A vertical pressure vessel and horizontal fuel storage tank were taken as case studies. Simple projects were considered in this study because of time consideration. Welding cost and project completion time for the selected projects have been calculated by using the developed computer program and the results obtained compared with those obtained manually by a factory. The results revealed that the computer program developed in this study was very efficient in accurately calculating industrial project welding cost and completion time compared with manual methods of welding costs and time estimation. Finally, this research study concludes with proposing a number of recommendations which are of benefit to researchers, factories and decision makers. It is highly recommended to use software program to calculate the welding costs of industrial projects and the time required to accomplish them, in addition to conducting more experiments to extract the deposition rate and compare different deposition rates for different welding positions.

Keyword: Welding, Cost Estimation, Welding Process, Welding Cost.

تحسين وإيجاد الكلف التخمينية للفعاليات اللحامية بالمشروع الهندسي الصناعي

إعداد

هيثم عبد الله نصيف

المشرف

د. كريم الجبوري

الملخص

يعد تخمين الكلف عملاً أساسياً للإدارة الناجحة لأي مشروع، فهو يوفر معلومات مفيدة لإعداد الميزانيات والحسابات المالية بشكل عام وللمشاريع الهندسية الصناعية على وجه الخصوص. وتتبع المشكلة في تخمين كلف الفعاليات المختلفة لعملية اللحام والوقت اللازم لإنجازها من وجود عدد كبير من العوامل التي تؤثر في تلك المهمة، الأمر الذي يجعلها مهمة صعبة ومعقدة. لذا، فإن من الضروري تطوير نماذج رياضية وإيجاد الحلول المثلى لتخمين كلف الفعاليات المختلفة لعملية اللحام والوقت اللازم لإتمامها، على نحو يشمل الكلف المباشرة وغير المباشرة لتلك الفعاليات. من ناحية أخرى، يمكن تجاوز الصعوبات الكامنة في تخمين كلفة فعاليات عملية اللحام والوقت اللازم لإنجازها عن طريق تطوير برنامج حاسوبي يحسب الكلف المباشرة وغير المباشرة لفعاليات عملية اللحام ويقارن بين طرق اللحام المختلفة من حيث الكلفة والوقت والفعالية. ومن خلال التجارب تبين بأن هناك فرق بين معدل الترسيب للسلك باختلاف وضعيات اللحام المختلفة (الأفقية، العمودية) وكذلك زيادة الوزن المعدن المترسب في الوضعية العمودية مقارنة بالوضعية المستوية. ويتوقع من البرنامج أن يقوم بمقارنة العمليات المختلفة ويتخذ القرار المناسب حول تنفيذ كل فعالية من فعاليات عملية اللحام. ومن الجدير بالذكر أن العديد من الدوائر والأقسام في الشركات والمصانع المعنية بالمشاريع الهندسية الصناعية ستستفيد من هذا البرنامج الذي يمكن تطويره إلى قاعدة بيانات تحفظ فيها بيانات تلك المشاريع. في الدراسة الحالية، يتم تطبيق نموذج رياضي يقوم بحساب القيمة المثلى للكلف المباشرة وغير المباشرة لفعاليات عملية اللحام بناء على العوامل التي تؤثر في تلك الكلف وبالتالي في الكلفة الكلية لعملية اللحام. كما يتم تطوير برنامج حاسوبي يحسب بدقة تكلفة فعاليات عملية اللحام والوقت اللازم لإنجاز كل منها. كذلك فقد أجريت تجارب عملية لتحديد معدل الترسيب لمعدن اللحام في وضعيات مختلفة مثل (المستوي والعمودي). من ناحية أخرى، أجريت دراسة حالة على اثنين من المشاريع الصناعية الهندسية في شركة النجم للتعهدات الهندسية، وهما: وعاء ضغطي عمودي وخزان أفقي لتخزين الوقود، ولضيق الوقت، تم الاقتصار على مشاريع بسيطة. وقد جرى حساب كلفة اللحام والوقت اللازم لإتمام العملية باستخدام البرنامج الحاسوبي الذي تم تطويره في هذه الدراسة، ومقارنة نتائج البرنامج مع النتائج التي تم الحصول عليها من مصنع النجم باستخدام التخمين اليدوي. وقد أثبتت المقارنة فعالية البرنامج الحاسوبي المستخدم في هذه الدراسة الذي أعطى نتائج دقيقة لحساب كلفة فعاليات عملية اللحام والوقت اللازم لإكمالها؛ إذ كانت أفضل بكثير من نتائج التخمين اليدوي. واختتمت الدراسة بعدد من التوصيات التي من المأمول أن يستفيد منها الباحثون والمهتمون ومديرو الشركات والمصانع المعنية بالمشاريع الهندسية الصناعية وأصحاب القرار. وكذلك وجوب استخدام البرامج الحاسوبية لحساب وتخمين كلف اللحام المختلفة للفعاليات للمشروع الصناعي والوقت اللازم لهما وضرورة إجراء المزيد من التجارب لإيجاد معدل الترسيب للسلك في وضعيات اللحام المختلفة. الكلمات الدالة: اللحام، تخمين الكلف، عملية اللحام، تكلفة اللحام.