EFFECT OF SHIELDING GASES ON MECHANICAL AND CORROSION PROPERTIES OF STEEL 316L USING FCAW

By
Engineer \ Mostafa Abdelhamid Abdelazim Abdelmotteleb

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
in
METALLURGICAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:
Effect of Shielding Gases on Mechanical and Corrosion Properties of Steel 316L Using FCAW

Key Words: **Flux Cored Arc Welding, Shielding Gases, Stainless Steel 316L, Corrosion Resistance, Microstructure, Strength**

Summary:
In this study, the influence of variation in the shielding gas composition on the mechanical properties and corrosion resistance of steel 316L was investigated. Seven different shielding gas compositions in addition to pure CO_2 were studied in this work using flux cored arc welding (FCAW) process. For bead-on-plate specimens, all the specimens appeared satisfactory under x-ray. It showed less spatter except using Ar/N 97/3 and $Ar/CO_2/N$ 82/15/3 shielding gases which resulted in higher number of spatter. Furthermore, for complete real welded joints, conditions 100% CO_2, Ar/CO_2 75/25, Ar/CO_2 80/20 and Ar/O_2 98/2 showed low porosity beside success by tensile test. Increase of carbon dioxide percentage lead to increase the depth of penetration. It led also to decrease in hardness, impact values and ferrite content. All specimens showed near values in corrosion resistance. So, it is recommended to use 100% CO_2, Ar/CO_2 75/25, Ar/CO_2 80/20 and Ar/O_2 98/2 for welding steel 316L by flux cored arc welding.

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ABBREVIATIONS

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Ar	:	Argon
CO_2	:	Carbon dioxide
N_2	:	Nitrogen
O_2	:	Oxygen
HAZ	:	Heat affected zone
SMAW	:	Shielded metal arc welding
GMAW	:	Gas metal arc welding
GTAW	:	Gas tungsten arc welding
FCAW	:	Flux cored arc welding
SAW	:	Submerged arc welding
PAW	:	Plasma arc welding
LBW	:	Laser beam welding
EBW	:	Electron beam welding
UTS	:	Ultimate tensile strength
DC	:	Direct current
ASME	:	American Society for Mechanical Engineers
AWS	:	American Welding Society
ASTM	:	American Society for Testing and Materials
DIN	:	Deutsches Institut für Normung “German Institute for Standardization”
EN	:	European Norm
ISO	:	International Organization for Standardization
UNS	:	Unified numbering system

ABSTRACT

This work aimed at studying the effect of the shielding gases on the weld metal by studying the mechanical and corrosion properties of steel 316L using flux cored arc welding by determining the most appropriate welding conditions in terms of optimum current and voltage. Then, different ratios of shielding gases were used to determine the most suitable gas/gas mixture to reach the best mechanical and corrosion properties.

Steel 316L was used where surface preparation for welding had been done. Then applying welding using flux cored arc welding process with changing the shielding gases. Then, each weld condition was evaluated either by visual inspection and mechanical tests such as tension, hardness and impact whereas metallurgical evaluation was done by optical microscope examination for the heat affected zone and weld metal. This is beside the corrosion test. Then, a comparison was made for all the obtained results to reach the optimum conditions.

The results lead to that the most suitable gas/gas mixtures are 100% CO_2, Ar/CO_2 75/25, Ar/CO_2 80/20 and Ar/O_2 98/2 which give the optimum mechanical and metallurgical properties for the weld.

Chapter (1)

Introduction

Chapter (1)

Introduction

This work is directed to study the effect of the shielding gases on the mechanical and corrosion properties of steel 316L using flux cored arc welding. FCAW is considered one of the most productive welding methods since it is used in the welding of metals with high thickness. For this reason it is used in the heavy industry and shipbuilding industry. Steel 316L is considered one of the most important kinds of austenitic steels which used in industry since it contains molybdenum, which gives it greater corrosion resistance in addition to its ability having high strength at low temperatures.

Stainless steel is one of the most versatile materials in today’s society. It can be produced with a wide range of properties and is used in millions of applications. Stainless steels are used for their corrosion resistance. Stainless steels are those alloys of iron and chromium, with or without other elements, containing at least 11% chromium. This is the minimum amount of chromium necessary to form a stable, passive chromium oxide film. It is this film that is the basis for the corrosion resistance of all stainless, and most nickel base, corrosion-resistant alloys. [1]

Austenitic stainless steels represent the largest of the general groups of stainless steels and are produced in higher tonnages than any other group. They have good corrosion resistance in most environments. The austenitic stainless steels have strengths equivalent to those of mild steel's, approximately 210 MPa (30 ksi) minimum yield strength at room temperature, and are not transformation hardenable. Low-temperature impact properties are good for these alloys, making them useful in cryogenic applications. Service temperatures can be up to 760°C (1400°F) or even higher, but the strength and oxidation resistance of most of these steels are limited at such high temperatures. Austenitic stainless steels can be strengthened significantly by cold working. They are often used in applications requiring good atmospheric or elevated temperature corrosion resistance. They are generally considered to be weldable, if proper precautions are followed.

Elements that promote the formation of austenite, most notably nickel, are added to these steels in large quantities (generally over 8 wt%). Other austenite-promoting elements are C, N, and Cu. Carbon and nitrogen are strong austenite promoters. Carbon is added to improve strength (creep resistance) at high temperatures. Nitrogen is added to some alloys to improve strength, mainly at ambient and cryogenic temperatures, sometimes more than doubling it. [2]

Stainless steel 316L is used in several applications such as automotive industry, construction industry, chemical industry, decorative applications and kitchen fittings, food and beverage industries, mechanical engineering, aerospace applications, medical and pharmaceutical applications.

The “L” grades are used to provide extra corrosion resistance after welding. The letter L after a stainless steel type indicates low carbon (as in 304L). The carbon