EFFECT OF ANNEALING ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 0.06% CARBON STEEL

PHOUMIPHON NORDALA

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EFFECT OF ANNEALING ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 0.06% CARBON STEEL

by

PHOUMIPHON NORDALA

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the thesis entitles *"**Effect of Annealing on Microstructure and Mechanical Properties of 0.06% Carbon Steel**"*. I also declare that it has not been previously submitted for the award of any degree of diploma or other similar title of this for any other examining body or University.

Signature :

Name of Candidate : Phoumiphon Nordala

Matrix Number : P-GD0013/13(R)

Date :

Witness by

Signature:

Main-Supervisor : Assoc. Prof. Ahmad Badri Bin Ismail

Date :

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LIST OF SYMBOLS

%	Percentage
%C	Percentage of Carbon
%wt	Weight Percentage
%EL	Percentage of Elongation
F	Ferrite
M	Martensite
P	Pearlite
$>$	More Than
$<$	Less Than
~	Approximately/ About
ºC	Degree Celsius
K	Kelvin
g	Gram
Min	Minute
MPa	Megapascal
mm	Milimeter
µm	Micrometer
Nano	Nanometer
Fe_3C	Cementite/Carbide
γ	Austenite (gamma)
α	Ferrite (alpha)
λ	Wavelength of the Rays
θ	Angle between the Incident Rays and the Surface of the Crystal

D	Spacing between the Layers of Atoms
T_m	Melting Temperature
M_s	Martensite Start
M_f	Martensite Finish
ε_{eq}	Equivalent Strain
n	Total Number of Rolling Passes
r	Reduction at Each Pass

LIST OF ABBREVIATIONS

DP	Dual Phase
UFG	Ultrafine Grain
SPD	Severe Plastic Deformation
ECAP	Equal Channel Angular Pressing
ARB	Accumulative Roll-Bonding
HPT	High Pressure Torsion
MDF	Multidirectional forging
ASTM	American Society for Testing and Materials
AISI	American Iron and Steel Institute
SAE	Society of Automotive Engineers
FCC	Face Centered Cubic
BCC	Body Centered Cubic
BCT	Body Cetered Tetragonal
IT	Isothermal Transformation
TWIP	Twinning-Induced Plasticity
AC	Air-Cooling
IWQ	Ice-Water Quenching
SQ	Step-Quenching
CR	Cold Rolling
OM-IA	Optical Microscopy Analysis with attached Image Analyzer
XRD	X-ray Diffraction
FESEM	Field Emission Scanning Electron Microscopy
EDX	Energy Dispersive X-ray

HV	Vickers Hardness
RD	Rolling Direction
TD	Transverse Direction

KESAN PENYEPUHLINDAPAN KE ATAS MIKROSTRUKTUR DAN SIFAT-SIFAT MEKANIKAL BAGI KELULI KARBON 0.06%

ABSTRAK

Kajian ini bertujuan untuk mengkaji mikrostruktur dan sifat mekanik keluli rendah karbon (0.06% C) terhadap beberapa proses rawatan haba dan kerja sejuk. Proses ini bermula dengan tiga rawatan haba yang berbeza; Penyejukan Udara (AC), Pelindapkejutan Air dan Ais (IWQ), dan Penyepuhlindapan Bertingkat (SQ) sebelum 75% pengelekkan-sejuk. Semua spesimen tergelek-sejuk disepuhlindap pada suhu sub-genting dan inter-kritikal. Keputusan menunjukkan bahawa IWQ adalah kaedah terbaik untuk memulakan mikrostruktur awal berbanding dengan kaedah AC dan SQ. Suhu penyepuhlindapan optimum sub-genting adalah pada 525ºC. Pada suhu ini (525ºC), butiran ferit ultra-halus diperolehi (~ 500 nm). Kekuatan tegangan dan mikro-kekerasan adalah lebih tinggi daripada keadaan diterima kira-kira 89% dan 79% masing-masing. Tambahan pula, didapati bahawa suhu penyepuhlindapan inter-kritikal yang optimum adalah pada 800ºC. Pada suhu ini (800ºC), kombinasi ferit dan martensit yang terbaik terbentuk. Kekuatan tegangan dan mikro-kekerasan adalah lebih tinggi daripada spesimen yang diterima lebihkurang 81% dan 104%, masing-masing.

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ABSTRACT

The present study is aimed to examine the microstructure and mechanical properties of low-carbon (0.06% C) steel against several heat treatment and cold worked processes. The process was started with three different heat treatments; Air Cooling (AC), Ice-Water Quenching (IWQ), and Step Quenching (SQ) prior 75% cold rolling. All cold-rolled specimens were subcritical and intercritical annealing. The results show that the IWQ is the best method to start initial microstructure compared to AC and SQ method. The optimum of subcritical annealing temperature is at 525ºC. At this temperature (525ºC), ultrafine ferrite grains are obtained (~ 500 nm). Tensile strength and microhardness are higher than as-received condition about 89% and 79%, respectively. Furthermore, it was found that the optimum intercritical annealing temperature is at 800ºC. At this temperature (800ºC), a good combination of ferrite and martensite are formed. The tensile strength and microhardness are higher than the as-received specimen about 81% and 104%, respectively.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

In general terms, iron and steel are often confusing. Iron is a chemical element (atomic number 26 on the periodic table). The symbol of chemical 'Fe' is from the Latin word for iron, Ferrum. The word steel is used to describe almost all alloy of iron and it is often mentioned that steel is an alloy of iron and other elements, primarily carbon (Hosford, 2012). The basic material in human development is steel. An adequate quantity of quality steel materials is essential for the realization of industrial development of countries all over the world and for supplying conditions for the modern lifestyle of humanity. Steel is a necessary component of all machinery used for the manufacture of all our goods (Weng, 2009). The study of steels is essential because of the steel represents by far the most extensively-utilized metallic materials, basically due to steel can be manufactured cheaply in large quantities to accurate specifications (Bhadeshia et al., 2011). On the other hand, the wide range of desirable properties which can be managed easily by altering the elemental composition and processing.

The increasing rapidly of motor vehicles worldwide and the associated environmental impact, lightweighting automobile has become an urgent global initiative. In order to provide automobile market requirements such as lightweight materials to improve vehicles with high fuel efficient. The automobile industry has developed steels which are advanced high strength steels (AHSS) together with dual-phase (DP) steels. These steels display both high strength and excellent formability with weight reduction (Cornette et al., 2001; Shaw et al., 2001). The most common steels used in the automobile industry are mild steels, which are low-carbon steels due to it is cheap and excellent deep draw ability.

Figure 1.1 is a schematic of the Ford Car-2014 model, displaying the dissimilar types of materials that used for designing the body of the car. It can be seen that the bulk of the car body consists of dual-phase steels and mild steels which are low-carbon steels are predominantly used. Hence, the present study is attempting to investigate a plain low-carbon steel.

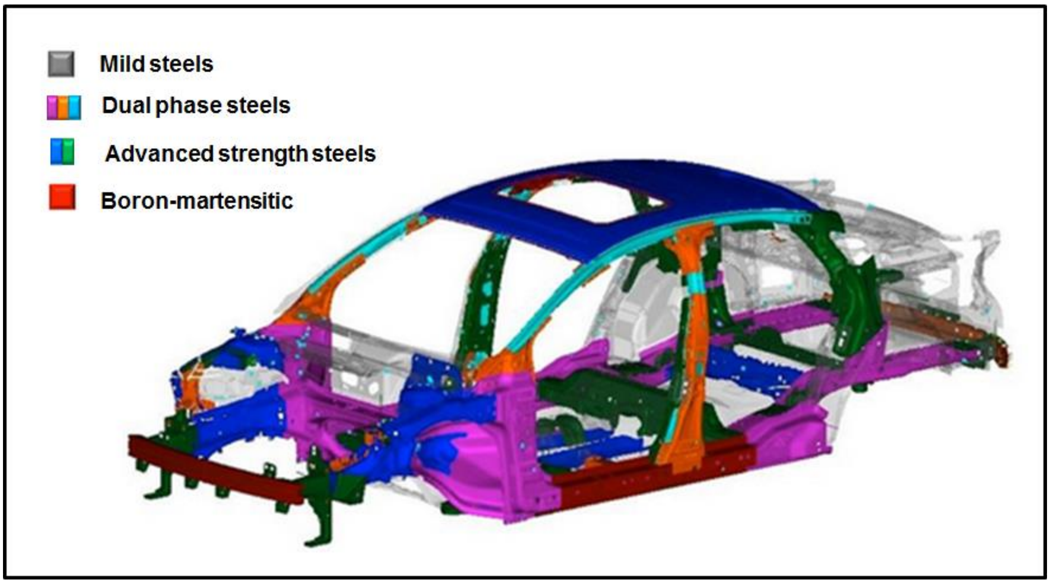

Figure 1.1 Schematic of Ford Car-2014 model, displaying the dissimilar types of materials for designing the body of the car (Mike, 2016).

1.2 Problem statement

Low-carbon steel is known as low mechanical properties and they have very limited applications compare to other higher mechanical properties steels. Many research groups have investigated various innovative methods to improve the strength of low-carbon steel. The methods include Severe Plastic Deformation (SPD) processes such as Equal Channel Angular Pressing (ECAP) (Nejnoto et al., 1998; Horita et al., 2000; Valiev et al., 2006), Accumulative Roll-Bonding (ARB) (Saito et al., 1998; Tsuji et al., 2002b), and High Pressure Torsion (HPT) (Valiev, 1997; Huang et al., 2003). By using these methods, ultrafine grains steel (grains size smaller than 1 μm) with superior mechanical properties (Tsuji et al., 2002b; Valiev et al., 2006) can be achieved.

Besides the SPD processes have been reported by other researchers as well. Fu et al., (2007) had improved the strength of low-carbon (0.10-0.25% C) steels by adding elements such as Titanium (Ti) and Cerium rare earth (Ce) into steels. They had found that tensile strength improved up to about 36% compared with the sample without addition of Ti and Ce. In addition, Li et al., (2014a) lately enhanced mechanical properties of low-carbon (0.091% C) steel by adding Manganese (Mn) and Titanium (Ti) alloy elements. The results showed a yield strength of 920 MPa with elongation about 10%.

Although all these methods have played a big role in improving mechanical properties of low-carbon steels, but they also show drawbacks as following:

(i) SPD processes are difficult for bulk production, particularly in producing large dimension of UFG steel with appropriate strength