WARPAGE CONTROL DUE TO HEAT TREATMENT PROCESS ON CONVENTIONAL FURNACE

MUHAMMAD ASIF BIN MD YUSOF

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I declare that I have been done reading this report
and in my opinion, this report fulfill the condition in all
aspect that must be in project writing as need in partial fulfillment
for Bachelor of Mechanical Engineering (Thermal – Fluid)

Signature	:	……
Supervisor Name	:	En. Hamzah Bin Mohd Dom
Date	:	……

"I declare that this report had been done originally from me except some of them where I have been explain each one of them with its sources"

Signature : ……

Name : Muhammad Asif Bin Md Yusof

Date : …….

For my beloved parents:

Mr. Md Yusof Bin Jamil

Mrs. Noraishah Binti Hussin

For my supportive siblings:

Mohamad Arif Bin Md Yusof

Nurul Adila Binti Md Yusof

"Mi Amor"

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ABSTRAK

Tesis ini berkaitan tentang kajian terhadap masalah meleding yang terjadi semasa rawatan haba dijalankan dengan menggunakan relau. Kini, terdapat pelbagai jenis proses rawatan haba yang dijalankan seperti sepuh lindap, sepuh lazim, lindap kejut dan pembajaan. Sewaktu menggunakan relau apabila proses rawatan haba dilakukan, besi keluli mengalami perubahan isipadu sewaktu berlakunya perubahan struktur dalaman besi keluli. Apabila bahagian tersebut mengalami proses lindap kejut, perubahan kepada struktur dalaman berlaku sekali lagi dan perubahan isipadu kali ini tidak dapat mengimbangkan perubahan pada struktur besi keluli sewaktu proses pemanasan. Perkara ini telah menyebabkan perubahan bentuk ataupun meleding terutamanya kepada bahagian yang nipis sewaktu proses rawatan haba di dalam relau. Maka, projek ini bertujuan bagi mengoptimumkan parameter proses rawatan haba yang dapat menyebabkan meleding kepada bahagian yang nipis di struktur besi keluli. Projek ini juga difokuskan kepada relau konvensional dan material keluli lembut menggunakan Teknik Taguchi bagi menganalisis parameter tersebut.

ABSTRACT

This thesis is about analyzing warpage problem due to heat treatment process on conventional furnace. Nowdays, there are various types of heat treatment employed in heat treatment process such as annealing normalizing, hardening and tempering. By using furnace during heat treatment process, steel parts change volume as they change their inner structure. When these parts are quenched, their internal structure changes again, thus making the volume change is not sufficient to offset the change upon heating. This change of volume causes shape distortion especially on thin parts during heat treatment process in the furnace. So, this project is to optimize heat treatment parameter that can cause warpage on thin parts. It is focusing on conventional furnace and material of mild steel to be used with Taguchi Method is selected for parameter analysis.

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LIST OF SYMBOLS

ANOVA	=	Analysis of Variance
DOE	=	Design of Experiment
OA	=	Orthogonal Array
ECL	=	Electrical Communication Lab
QFD	=	Quality Function Deployment
S/N	=	Signal-to-Noise

CHAPTER 1

Introduction

1.1 Overview

Heat treatment is known to be a controlled heating and cooling of metals in changing their physical and mechanical properties. This process happened without altering the product shape. Heat treatment is sometimes done due to manufacturing processes that either heating or cooling the metal such as welding or forming.

Heat treatment is made to increase the strength of material and enables the manufacturing process in the steel industry. It also improve the material performance by increasing the strength or other desirable characteristics. Warpage or shape distortion is due to the process of heat treatment are different because it is usually a result of process and design issues thus affecting the phase changes of the material. While furnace is a tool which heat is discharged and transferred directly or indirectly for the purpose of effecting a physical or chemical change in the material.

1.2 Objective of the project

The objective of this project are as follows:

1) To conduct an experiment and analyze warpage problem due to heat treatment on conventional furnace using Taguchi Method.
2) To optimize the heat treatment parameter on controlling warpage by conventional furnace.

1.3 Scopes of the project

The scopes of this project are as follows:

1) To do a survey on warpage problems due to heat treatment process.
2) To conduct an experiment on studying heat treatment parameter of racking arrangement at controlling warpage by conventional furnace.
3) To find solution of improvement in reducing warpage using Taguchi Method during heat treatment.

1.4 Problem statements of the project

It is understand that furnace is an apparatus in which heat is used in order to change the physical and chemical substance of the treated material. There are various types of heat treatment used today such as annealing, normalizing, hardening, and tempering. Thus, by using furnace when heat treatment is made, upon heating, the steel parts changes volume as they change their inner structure. When these heated parts are quenched, their internal structure changes again, so the volume change is not sufficient to offset the change upon heating. This change of volume causes warpage especially on thin parts during the heat treatment in the furnace. So, this project is to make an analysis of warpage control due to heat treatment using Taguchi Method and it is focusing on conventional furnace. Then, it is to find a solution of improvement in reducing warpage during heat treatment.

CHAPTER II

LITERATURE REVIEW

This chapter will explain about the literature review that have been done to guide the research in the future. It will explain all about Warpage, Heat Treatment, Design of Experiment (DOE) and Taguchi Method in detail.

2.1. Distortion

Prabhudev (2004) states that distortion is defined as a permanent and an unpredictable change in shape or size of component during processing. It is probably the biggest problem in heat treatment operation. Then, Sinha (2003) states that distortion is an irreversible and unpredictable dimensional change in the component while doing the processing from heat treatment and from temperature variations and loading in service. The usage of term dimensional change is used in denoting the changes in both shape and size. Thus, distortion is known to be a general term often use by engineers in describing the irreversible dimensional changes in a heated part during heat treatment operations in steel during hardening and tempering. Sinha (2003) also states it is known as one of the most difficult and troublesome problem that is encountered by the heat treater and heat-treatment industries on a daily basis. Distortion occurred due to combined effect of thermal and transformation stresses. This refers at the dimensional changes after

hardening process that takes place as a result of volume change during phase transformation.

Distortion can be classified into two categories that is size distortion that is the changes in volume and shape distortion that is warpage which is due to changes in geometrical form of the steel component.

2.1.1 Size Distortion

Sinha (2003) states that size distortion is the net change in specific volume between the parent and transformation product produced by phase transformation without a change in geometrical form. Size distortion occurs due to the expansion or contraction in steel component. This type of distortion is less problematic than size distortion

2.1.2 Warpage (Shape Distortion)

Warpage is a physical distortion where there is a change in geometrical form or shape of the workpiece and is revealed by changes of curvature (angular relations) or curving, bending, twisting and nonsymmetrical dimensional change without any volume change (Sinha, A. K. 2003). Warpage is also known to be an irreversible change in shape of the component that occurs during heat treat processing. The change in shape can be resulted due to nonuniform heating or cooling (quenching), metallurgical structure or prior residual stresses (Dossett *e. al.* 2006).

For designers and heat treaters, this type of distortion poses greater problem than size distortion. Upon heat treatment, part movement could occur immediately and sometimes later in a subsequent processing operation. Parts that is machined, cast or formed to achieve the accurate dimensions due to heat treatment, often came out from the heat treatment process with apparent changes in their dimensional structure. There are a lot of cases which the distortion that occurs is shown by warpage such as bowing or twisting of sheet metal, canning of machined pocket areas, and other forms of part movement.

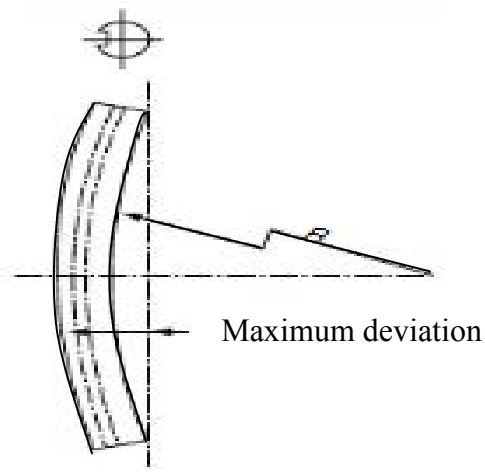

Figure 2.1 : Warpage of Thin Plate Specimen
(Sources :Rajan et all. (2011))

2.1.2.1 Causes of Warpage

Based from the latest research (Croucher 2008), warpage of heated parts during and after the heat treating process is due to many factors. Some parts will warp for reasons the heat treater can control, but others will distort for causes that occurred before the heat treater received the parts and are beyond control. Thus, by understanding and

controlling these factors, this allows the heat treater to minimize the occurrence of heat treating warpage. The factors are:

a. Relief of pre-heat treat residual stresses

b. Expansion and contraction of parts during processing of heat treatment

c. Inadequate racking procedures in the furnace

d. The process of quenching is too fast

e. Improper quenchant selection

f. Uneven quenching due to inadequate agitation or spacing

g. Improper quench immersion rates

h. Furnace air flow design in relation to part orientation

2.1.2.2 Minimizing Warpage

According to Rajan et. all. (2011), in minimizing warpage or known as shape distortion during heat treatment, a number of factors must be taken into consideration such as:

a. Stress Relieving

The presence of residual stress due to the previous machining or forging operation will enhance the tendency of warpage. Thus, fabrication stresses caused by these operations must be relieved by subcritical annealing or normalizing operation.

b. Heating Rate

The components heating rate must not be too fast or the components may crack or warp as sections are having different heat up at different rates. So, the difference in temperature can be controlled by preheating the components to a temperature below the lower transformation of steel.

c. Preheating

Preheating can reduce shape distortion in steels by reducing the thermal stresses that is made. This is due to the gradient temperature prevailing between the surface and interior part of component. Then, for large cross-section, complicated parts and high alloy steels that has poor thermal conductivity, it is preferable to carry out two-stage preheating.

d. Quenching Media

The basic aim of hardening of steels is to get martensitic structure and avoiding the formation of pearlite and bainite. So, the rate of cooling of heated component must be fast enough in producing a fully martensitic structure but faster cooling rate will increases the severity of quench. Thus, it is essential to use the least quenching medium that made martensite happened. Shape distortion can be further reduced while quenching if the cooling conditions are made uniform as possible. Usually, basic quenching media used are water, brine and conventional oils. Even salt baths, hot quenching oils and polymer quenchants is still considered as quenching media as they gave good results.

e. Press Quenching

Press quenching or die quenching of steel is not common to most of commercial heat treating industries. So, during press quenching, warpage can be minimized by physical restraint of part during its rapid cooling from austenitic condition. So, quenching jigs are used for this purpose.

The part is clamped in a jig and then placed in a hydraulically operated press after heating. Then, the jig should be preheated in avoiding rapid cooling of the surface of component which comes in contact with the jigs. Along with the closing of the press, oil is flown over the component. This will resulted in maintaining the plane shape during the quenching operation.

f. Trays, Fixtures and Supports.

It is achieved that odd shaped components and unsymmetrical sizes needed to use the holding trays and fixtures. This will maintain the shape of the components during heating and rapid cooling from austenitizing temperature. The parts should lie on a flat surface.