CHAPTER 1

Introduction

1.1 General

Boronizing is a thermochemical treatment process that was utilized as a surface hardening technique for steels. It transforms the surface of work-piece into a metallic boronized layer and enriches the surface of engineering components. In the presence of a boron rich medium around the work-piece, boron atoms diffuse into the components' surface at elevated temperature and form a boronized layer on the surface. The normal surface hardening technique conducts diffusion whether under solid, liquid or gas medium. This process offers a superior combination of mechanical properties. Boronized layers are usually extremely hard, have a good wear, corrosion and oxidation resistance. Boronizing is suitable for a wide range of material including all ferrous and non-ferrous material such as titanium, nickel-based alloys, nitriding steels, cobalt base alloys, tool steels, and cemented caches.

Superplasticity is the capability of alloy to exhibit ultra high plasticity without localized necking at a certain strain rate, temperature and microstructure. Superplastic materials show exceptional ductility where a maximum elongation of about 5000% can be achieved. Superplastic material should possess stable, equiaxed and ultra fine grains less than 10 µm. The forming temperature should be higher than half of the melting temperature of the metals and strain rate should be in the range of 10^{-5} s^{-1} to 10^{-2} s^{-1} (Carrino et al., 2003). Applications of superplasticity are well known in superplastic deformation and superplastic diffusion bonding process (SPDBP).

SPB is a new processing technology that combines boronizing with superplastic deformation. This process was proven not only to have a much faster boronizing rate than the conventional boronizing method, but also produces a boronized layer with improved mechanical properties (Xu et al., 1997). The principle is to conduct boronizing while the specimen is undergoing superplastic deformation to produce optimum surface properties with minimized processing time and cost. Many mechanics of superplasticity of metals and alloys have been studied by means of a tensile test in which a true constant strain or a constant displacement rate is imposed, and the steady-state flow stress is recorded. However, in practical application, there are few cases similar to the simple tension test but mainly involve compressively formed product. This research is proposed to study compression SPB process in application of surface engineering. DSS is used as the boronized substrate. Experiments were conducted by bulk compression at different temperatures and at same strain rate. Boronized layer thickness, layer morphology and surface hardness before and after boronizing were measured. Then, the kinetics of boronizing process were studied and evaluated.

DSSs are those with a mixed microstructure of about equal proportions of austenite and ferrite. Diphasic stainless steel enables serial superplastic forming as its fine grain microstructure has the ability to show superplastic behavior at certain high temperature and strain rate condition (Han and Hong, 1999). DSSs are known to have superior strength, toughness, and weldability, as well as corrosion resistance. DSS exhibits a yield strength that is more than double that of conventional austenitic stainless steel. This DSS is often used in the form of welded pipe or tubular components, as well as a formed and welded sheet product in environments where resistance to general corrosion and chloride stress corrosion cracking is important.

Increased surface hardness and increased wear resistance are the characteristics of boronized steels. When ferrous-based materials are boronized at temperatures of 800-1000°C for 1 h to 8 h, (Fe_2B + FeB) or Fe_2B iron-boride phases are formed at the material surface and a boronized layer of up to 2000 Hv hardness is produced. Therefore, development of SPB surface engineering is beneficial and it expands the industrial application of DSS alloys.

1.2 Research Objectives

Below are the objectives of this study:

(a) To study the effect and phenomenon of superplastically boronized DSS.

(b) To study the influence of compression strain and temperature on the surface properties in superplastically boronized DSS.

(c) To study the kinetic of superplastically boronized fine grained DSS under compression approach.

(d) To compare the SPB properties of DSS with the CB method.

1.3 Outline of Research

The outlines of the research are as follows:

1. Understanding of concept and fact
    - The procedure of compression method
    - The boronizing process as a surface hardening technique
    - The concept of superplasticity

- The properties of DSS

2. Literature review

   - Literatures were mainly based on researches of the boronizing process using compression method, the developments in the superplasticity area and also the applications of DSS.
   - Source of the literatures were journals, proceeding, books, magazines, previous theses and World Wide Web (www).

3. Experimental procedure

   - In the first part, the thermo-mechanically treated DSS with fine microstructure was used as the substrate. Special design of jig and die were developed for compression method. The experiment was done in Instrons machine with various temperatures and boronizing time.
   - In the second part, the experiment was focused and studied with effects by compression method of superplastic processes. Effects of strain condition and temperature were evaluated and studied.
   - The results obtained from the studies in terms of boronized layer morphology, boronized layer thickness and surface hardness were evaluated and compared. The kinetics for SPB processes by compression method was also determined.
   - The Vickers microhardness tester was used to measure the hardness of the specimens' surface before and after boronizing process. The morphology and boronized layer thickness was observed by using the

optical microscope. The X-ray Diffraction was used to detect the phases formed on the boronized specimens.

4. Result analysis

    - All the data obtained from the processes were compiled and analyzed accordingly. The results obtained are documented in Chapter 4.

5. Discussions

    - Overall results obtained from the study are discussed in Chapter 4. Chapter 5 concludes the present study and some future recommendations are presented.