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Optimization of Shear Strength of 420 Stainless Steel Brazing Joints Using BNi-2 by Response Surface Methodology

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Abstract

In this research, the parameters of brazing temperature, brazing time, and joint seam have been optimized in brazing joints of AISI 420 stainless steel with BNi-2 filler metal on the shear strength of lap joint samples using response surface methodology. The parameters of brazing temperature, brazing time, and joint seam were determined by the design of the experiment. The thickness of BNi-2 filler metal was considered to be 0.04, 0.07, and 0.1 mm in this research. After preparing the samples, they were placed in a vacuum furnace at temperatures of 1000°C, 1070°C, and 1140°C for 10, 30, and 50 minutes. The mechanical tensile test was performed to determine the shear strength. It was observed that increasing the joint seam from 0.04 to 0.1 mm caused a 14% decrease in shear strength. Also, increasing the brazing temperature from 1000°C to 1140°C has increased the shear strength by 21%, and increasing the brazing time from 10 to 50 minutes has increased the shear strength by 27%. In the end, it was optimized that the maximum shear strength is 164.429 MPa in the joint seam of 0.04 mm, the temperature is 1109.84 °C and the time is 46.58 minutes.

Keywords: Optimization, Brazing, Shear Strength, BNi-2, Response Surface Methodology

1. Introduction

Brazing is a process in which the connection is made by heating the workpiece to a suitable temperature (above 427 °C) by filler metal with a melting point higher than 427 °C and lower than the melting point of the base metal [1]. Variables that affect brazing can be mentioned the characteristics of the base metal, the characteristics of the filler metal, brazing time, brazing temperature, joint seam, overlap of the brazed area, and surface preparation [2 and 3].

Due to the wide use of bells, extensive research has been done on them. Sheng et al [4] investigated the microstructure and mechanical properties of CB2 steels hardened by brazing nickel base alloy BNi-2. They considered the thickness of the nickel-based filler metal to be 30 micrometers and constant, which has a melting temperature between 970 °C and 1020 °C. They investigated the brazing temperature parameter on the samples and concluded that keeping the time constant, increasing the temperature from 1050 to 1150°C increased the tensile strength by 32%. Also, they investigated the brazing time parameter on the samples and concluded that, keeping the temperature constant, increasing the time from 1800 to 7200 seconds caused a 12% decrease in tensile strength. Also, they obtained the highest tensile strength of 934 MPa at a temperature of 1150 °C and a time of 1800 seconds, which increases the elongation to failure by 5.3%.

Yaning et al [5] investigated the connection between stainless steel pipes using a vacuum furnace. They used two types of stainless steel 316L and PSS, which were in the form of tubes, as the base metal and BNi-7 alloy as the filler metal. They placed the samples in the furnace at a temperature of 930 °C to 1000 °C and a time of 3 to 5 minutes. They considered the joint seam in all samples to be constant and 60 microns. They subjected the samples to tensile loading and reported that the highest tensile strength was in the sample brazed at 980°C for 15 minutes with a tensile strength of 245 MPa.

Dong et al [6] investigated the strength of TiAl/Ni brazed joints by Zr-Al-Ni-Co filler metal at two room temperatures and above They brazed the samples at temperatures of 980, 1000, and 1020 °C and at times of 5, 15, and 30 minutes. They conducted shear tests at two temperatures of 30 °C and 600°C and concluded that the highest shear strength was at a brazing temperature of 1000 °C and a brazing time of 15 minutes.

This research aims to achieve the maximum shear strength in these brazed joints. The design of the experiment was done by the response surface methodology. The geometry of the joints in this research was butt-to-butt, and the parameters of the joint seam, brazing temperature, and brazing time were investigated. The joint seam (thickness of BNi-2 nickel base alloy) was considered 0.04, 0.07, and 0.1 mm in this research. After preparing the samples, they were placed in the vacuum furnace at temperatures of 1000°C, 1070°C, and 1140°C for 10, 30, and 50 minutes.

2. Methodology

In this research, AISI420-type martensitic stainless steel produced by Bavo Steel Company and prepared by Techno Steel Company was used as the base metal. BNi-2 alloy has also been used as a filler material. To prepare the samples, AISI 420 stainless steel was cut according to the AWS C3.2 standard in the desired dimensions [7]. The schematic of the samples is shown in Figure 1.

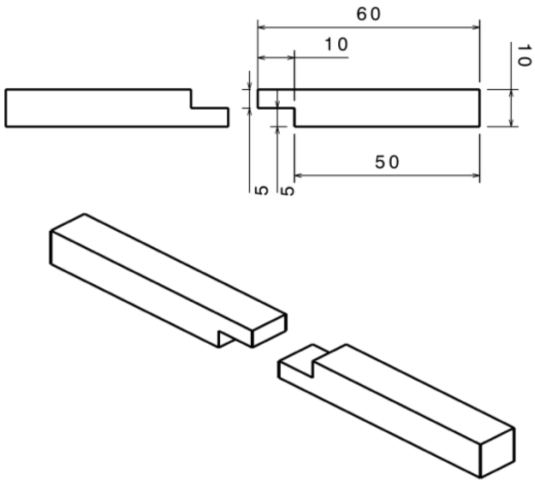

Figure 1. Schematic of samples

In this research, to achieve a quantitative relationship between mechanical properties and variables to create modeling capabilities for the examined properties and reduce the number of experiments, the design of experiments using the response surface methodology has been used. To determine the shear strength of the brazed samples, the tensile test was performed using the Z100 Universal Tensile Testing Machine manufactured by Zwick Roell Company with a jaw speed of 10 mm/min.

3. Discussion and Results

In this part, the effect of joint seam, brazing temperature, and brazing time on the shear strength of joints has been investigated. After the samples were subjected to the tensile test, the average shear strength results for the 15 tested samples are shown in Table 1. The tensile test was repeated three times for each sample.

Table 1. Results of the shear strength

Number of Sample	Joint Seam (mm)	Brazing Temperature (°C)	Brazing Time (min)	shear strength (MPa)
1	0.04	1000	30	132±1.17
2	0.10	1000	30	114±0.94
3	0.04	1140	30	158±1.34
4	0.10	1140	30	137±0.86
5	0.04	1070	10	125±1.42
6	0.10	1070	10	108±0.63
7	0.04	1070	50	159±0.83
8	0.10	1070	50	135±1.07
9	0.07	1000	10	100±0.55
10	0.07	1140	10	125±0.57
11	0.07	1000	50	133±1.12
12	0.07	1140	50	157±1.51
13	0.07	1070	30	136±1.39
14	0.07	1070	30	135±1.81
15	0.07	1070	30	134±1.76

The results of the effect of joint seam, brazing temperature, and brazing time on the shear strength of joints are shown in Figure 2. As can be seen, the increase in the joint seam has decreased the shear strength. Increasing the joint seam from 0.04 to 0.1 mm has reduced the shear strength by 14%.In brazing with nickel-based filler metals, the joint seam plays an important role in controlling the amount of brittle phases formed during the brazing process [8].

It can also be seen that the increase in the brazing temperature has increased the shear strength. Increasing the temperature from 1000°C to 1140°C has increased the shear strength by 21%. At the temperatures tested in this research, some of the brittle phases remain in the joint. For this reason, the increase in strength observed in the poured samples in this research is less than the results related to the increase in time [9].

It was observed that increasing the brazing time increased the shear strength. Increasing the time from 10 to 50 minutes has increased the shear strength by 27%. The increase in time has led to the penetration of elements forming brittle phases (silicon and especially boron) towards the base metal. This increase in shear strength is because by increasing the brazing time, the amount of these phases in small seams can be controlled and reduced.

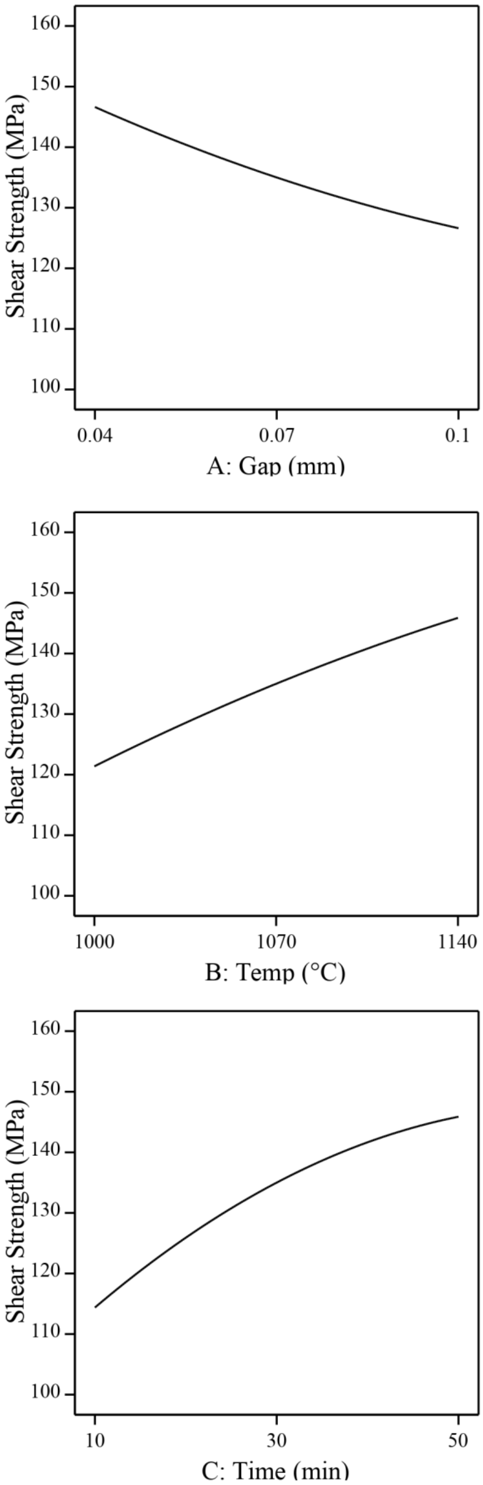

Figure 2. Effect of joint seam, temperature and time on shear strength of joints

The optimization results using the response surface methodology are shown in Figure 3. According to this figure, it is concluded that the sample with 0.04 mm joint, temperature 1109.84°C, and time 46.58 minutes has the highest shear strength of 164.429 MPa.

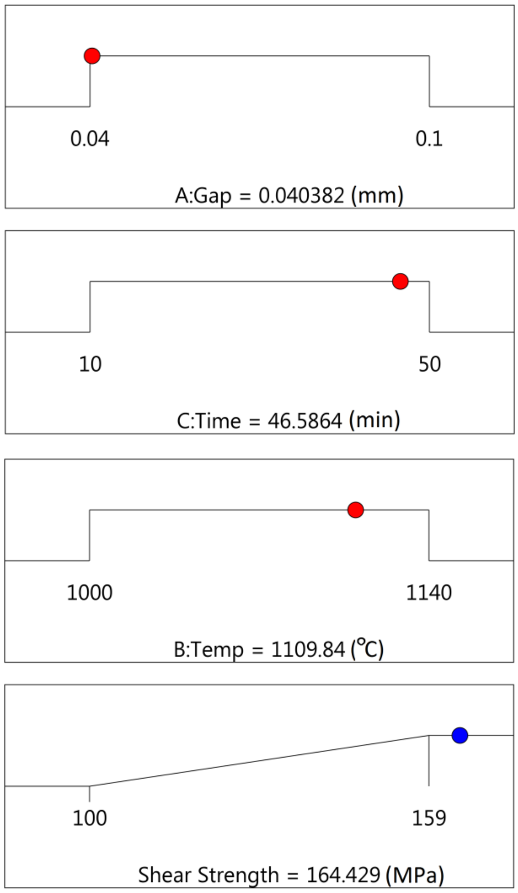

Figure 3. The optimization results using the response surface methodology

4. Conclusions

In this research, the optimal conditions on the effect of temperature, time, and seam parameters in brazing joints of AISI 420 stainless steel with BNi-2 filler material on shear strength were investigated using response surface methodology. The results showed:

1. The increase of the joint seam decreased the shear strength so the increase of the joint seam from 0.04 to 0.1 mm caused a 14% decrease in the shear strength.
2. Increasing the brazing temperature has increased the shear strength, so that the temperature increase from 1000°C to 1140°C has increased the shear strength by 21%.
3. Increasing the brazing time has increased the shear strength. Increasing the time from 10 to 50 minutes has increased the shear strength by 27%.
4. By optimization, it was concluded that a sample with a joint seam of 0.04 mm, temperature of 1109.84°C, and time of 46.58 minutes has the highest shear strength of 164.429 MPa.

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