The Effects of Annealing on Dezincification on H02 Temper Brass C26000

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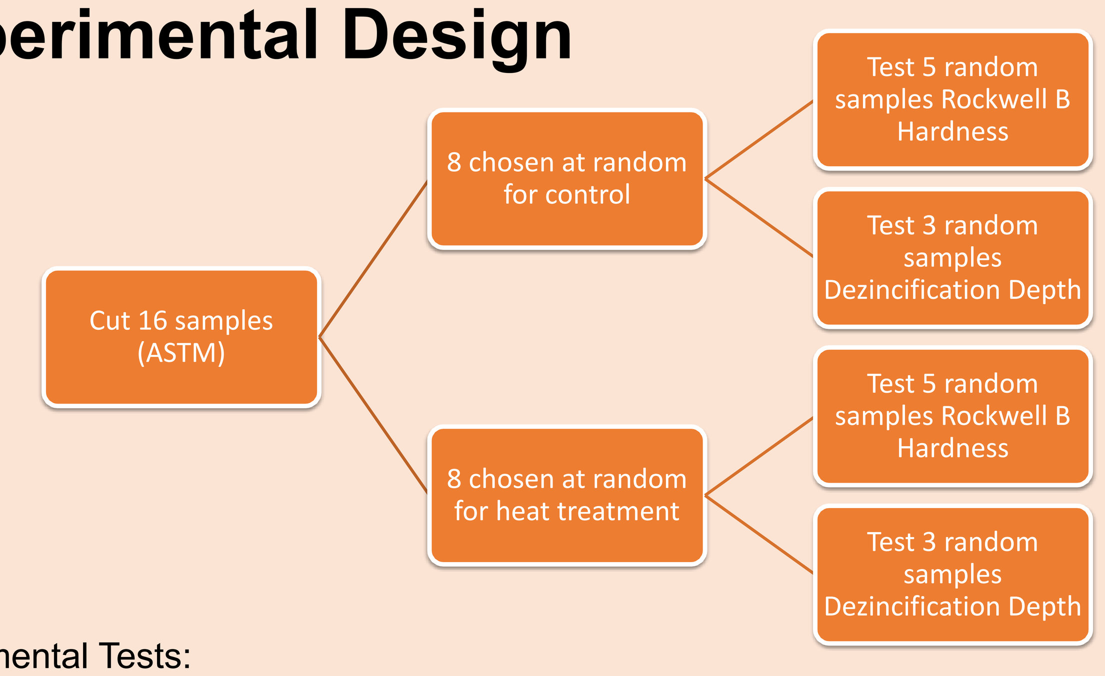
Abstract

Brass pipes have been used as a safer alternative to lead piping, especially for safe water transport. However, in certain brass alloys with higher zinc concentrations, a corrosion phenomenon called dezincification can take place. When in contact with water or other saline solutions, zinc will diffuse out of the alloy and into the solution it is in, leaving a porous structure behind, which is now more susceptible to other forms of corrosion [1]. To improve on this issue, we investigate how annealing brass at 538ºC for 30 minutes and then furnace cooled will increase the resistance to dezincification and therefore corrosion. When annealing at this temperature, there is expected to be a reduction in the zinc (beta) phase in the alloy, leaving a higher copper-saturated (alpha) phase behind [2]. The reduction in the amount of zinc in the alloy, decreases the ability for zinc to diffuse out and cause dezincification corrosion. The resistance to dezincification is measured using a dezincification depth test, and the hardness is measured with a Rockwell Hardness B test. This process showed that there was a significant, yet acceptable for the application, reduction in hardness by 32%. The resistance to dezincification was optically determined to be effective as the decrease in the area of pitting was statistically significant.

Introduction

Copper pipes are commonly used but have problems with corrosion while in the plumbing system, requiring many repairs and replacements [3]. To prevent against this, Brass pipes with can be used. Brass pipes can withstand the necessary water pressures, are very durable, and are corrosion-resistant [4,5]. A pipe used for plumbing needs a minimum Rockwell B scale hardness of 40, which our Brass sample averages to after annealing for use [6,7]. Cartridge Brass pipes contains a large percentage of Zinc. To prevent corrosion issues, our sample was annealed at a temperature based on previous literature [2,8,9]. Ensuring that the hardness of the Brass sample is equal to or greater than 40 RB will enable it to be used for pipe applications. The increased resistance to dezincification will improve the functionality and longevity of the pipes.

Experimental Design



Experimental Tests:
Rockwell Hardness B
Dezincification Depth Test (ISO6509) [10] [13] where the average area of pitting of the beta phase will be measured on ImageJ

Statistical Analysis:
The sample number for a 2^3 factorial experiment was determined using JMPro [12] to be 8 samples for each blocking group (control and test) to obtain a 95% confidence interval.
For the hardness data, the best way to determine the percent difference in the means of the control and test samples is to conduct a simple percent error calculation.
However, the hypothesis for the dezincification experiment requires that a t-test be run to determine if there is a significant difference between the means of the control and test samples. The type of t-test chosen was a pooled t-test due to the small sample size and not knowing the variance of the populations.

Results

Hardness Testing Data

Sample	Control (±0.01)	Experimental (±0.01)
1	54.76	38.32
2	63.53	38.07
3	60.06	39.81
4	59.14	41.89
5	59.33	43.78
Average	59.36	40.37

Fig. 1: Rockwell Hardness test for both control and heat-treated samples

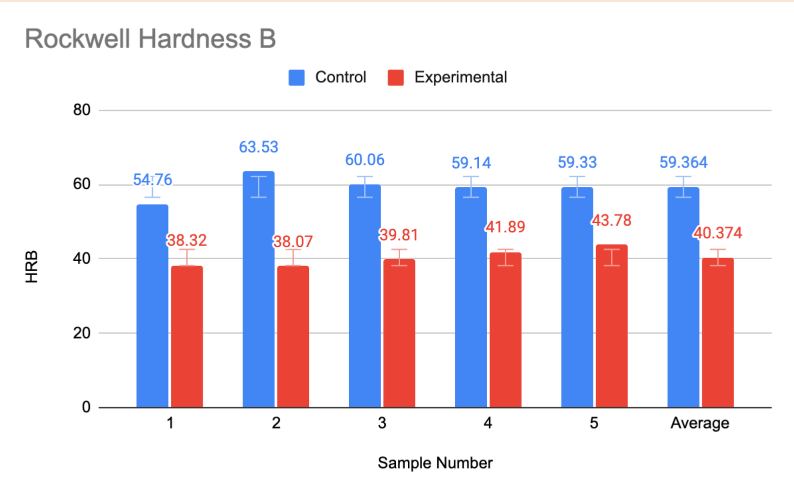


Fig. 2: Bar Chart comparing the Rockwell Hardness B data between the control and test samples, as well as the averages

Dezincification Testing Data

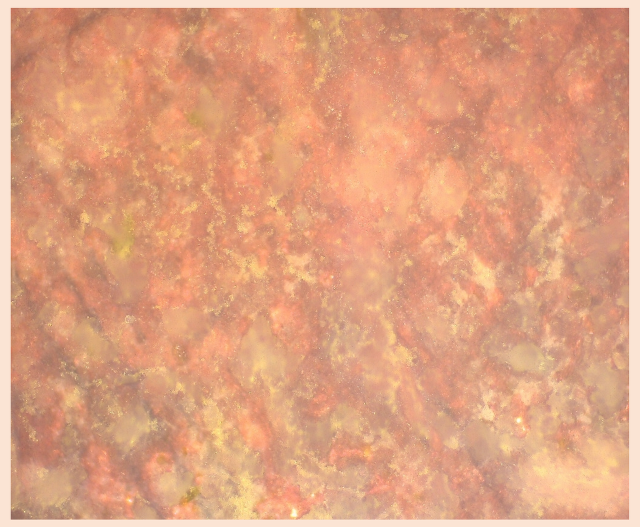
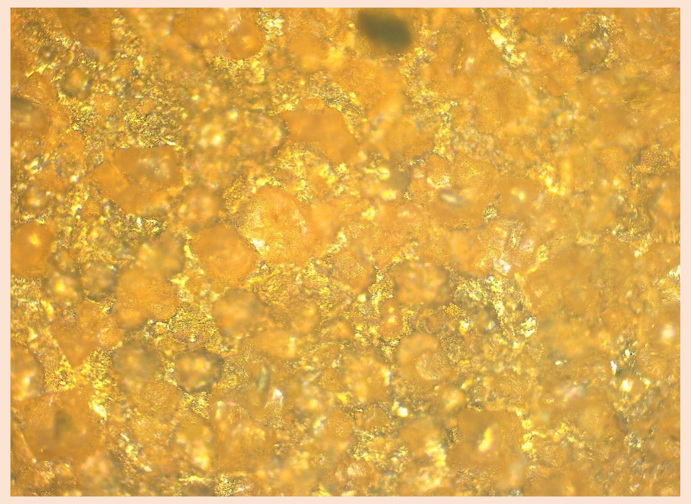


Fig. 3: A control sample after 42.83 hours in the $CuCl_2$ solution at 20x magnification

Fig. 4: A heat-treated sample after 42.83 hours in the $CuCl_2$ solution at 20x magnification



Data Analysis

Hypothesis 1:
If a brass sample is annealed to 537.8 ºC and cooled to room temperature, then the hardness of the brass will decrease by at least 20% from its original hardness.
Hypothesis 2:
If a brass sample is annealed to 537.8 ºC and cooled to room temperature, then the area of the pitted "islands" which represent the dezincification of the sample will decrease.

Hardness:

The expected hardness value for Cartridge Brass C26000 H02 Temper is Rockwell B 70 [11]. Figure 1 shows the control average Rockwell hardness was 59.36, while the experimental hardness was 40.37. This means the samples began with lower hardness than expected, but the experimental samples still met the minimum Rockwell B value of 40 required for pipes.

The percent error between the means was calculated to be 31.989%, indicating that the heat-treated samples had decreased in hardness around 32% from the control samples. This number is nearly double the percent decrease we had anticipated from the literature, so the hypothesis for a 20% decrease between the control and test samples is rejected.

Dezincification:

Microscopic imaging was used to determine the treatment's impact on dezincification. The control sample, as seen in Figure 3 demonstrates significantly more pitting on the surface. In Figure 4 the sample has smaller pores and retained the brass color. We were unable to calculate the depth of dezincification, but we could compare the area of the pitting and subsequent "islands". Using ImageJ, the area of the pitted islands was found through using a circle as an approximation to find the area of the beta phase attacked during dezincification. The 10 values were then averaged and are shown in Figure 5. A t-test was run on the data to compare the means of the control samples to the test samples with a 95% confidence. The result of the t-test demonstrated in Figure 6 was a t statistic of 5.746 and a critical t value of 2.1009, and because the t statistic is greater than the critical value, the null hypothesis is rejected.

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Sample	Control ((±0.01)	Test(±0.01)
1	29819.43	15240.43
2	41491.57	6369.00
3	33785.00	7994.00
Average	35032.00	9867.81

Fig. 5: Area of pitting for dezincification test.

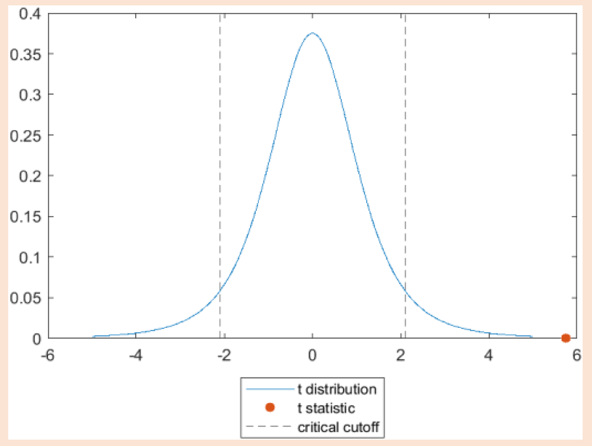

Fig. 6: T-test for dezincification

Conclusion

After testing, we found a significant, but acceptable, decrease in hardness of the heat-treated samples versus the controlled samples. While this may weaken the integrity of the brass pipes, the hardness values of the annealed samples remain within the realm of the safety specifications, allowing the brass pipes to continue carrying out their structural requirements. Although we were unable to observe the depth of dezincification in both sample groups quantitatively, we were able to compare them visually. After submersion in the $CuCl_2$ solution for 42.83 hours, the controlled samples resulted in far more pitting and returned to a copper color, indicating a substantial amount of Zinc diffusion out of the sample. On the contrary, the heat-treated samples retained its brass color and resulted in far fewer and considerably smaller pores on the surface. Thus, we are able to conclude that heat-treating brass would result in brass piping being more corrosion resistant, while remaining ductile enough to shape, and strong enough to withstand forces from the water pressure.

Future Experiments

In future experiments, having samples with a higher initial hardness would enable our samples to be above the minimum hardness for pipe applications. Further, knowing the initial hardness before the design proposal would be beneficial.
While preparing our sample for the dezincification test, we recommend setting the mounted sample in the solution with the perpendicular surface (thin side) down and to not submerge the entire sample. This would enable the visual analysis of the solution penetration into the sample, as the sample is too thin with the large surface submerged to visually calculate a penetration depth.
Also, during preparation, it would be beneficial to polish the sample's large surface, as well as the surface perpendicular to the large surface area, or the thin side. This will allow a visual observation, as well as calculation, of the amount of penetration from the $CuCl_2$ solution into the Brass sample.

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Acknowledgments

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