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Strengthening of Copper by Using RCS Process and Optimization Through Taguchi Method

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ABSTRACT

Severe plastic deformation (SPD) Processes is to be determined as metal forming processes in which a very large plastic strain is imposed on a bulk process in which to make an ultra-fine-grained metal. Generating an ultrafine grained metal is to allow lightweight parts by using high strength metal for the safety and reliability of micro-parts and for eco-friendly, is the main intention of SPD Processes. In Severe plastic deformation processes (SPD), repetitive corrugation and straightening (RCS) are one of the new technical processes, in which the grain size is reduced to ultrafine grain size then the strength of copper is going to be increased by using this process in this project. The Taguchi optimization technique is utilized with conventional orthogonal array L9, in which to determine the process parameters are statistically significant on hardness. Finally, the verification test was carried out to investigate optimization enhancements.
Keywords : SPD Method, RCS Processes , Taguchi Optimization Technique.

I. INTRODUCTION

Bulk nanostructure alloys treated by severe plastic deformation (SPD) are of essential moment in the materials science similarity because they are porosity vacant and wide suitable for mechanical or physical property measurements they have more elevated mechanical properties including high strength, good extensibility, high formidability, and ultimate malleability at huge strain rates and low heats. In contradiction, the mechanical properties of coarse-grained corporeal ties accompany each general vitality and elasticity swap that is high strength is almost continuously followed at moderate ductility. The preferred properties of bulk nanostructure alloys obviously set them separate from coarse-grained materials and make them extremely attractive for organic applications. There are currently various SPD methods to integrate bulk nanostructure metals, including same channel angular pressing (ECAP) and high-pressure torsion (HPT) which are among the multiple developed and studied. In an ECAP process, a bulk specimen is hugged to go through a die with two channels, which are identical in cross-section and intersect at an angle, usually 90. The specimen is constrained to a shear strain as it flows within the crossway of the two channels, which creates it probable to repetitively press the same sample in which to introduce high accrued strains and down the grain size significantly. But, ECAP is currently an intermittent process; furthermore, it can treat individuals hardly for certain sizes. In HPT, only disk-shaped specimens can be concocted under stress and torsional deformation.

Suggesting the opportunity of using a new technique, repeated corrugation and strengthening (RCS), to concoct bulk nanostructure materials. I used a criterion intermittent RCS set up, i.e. a tool-steel die fixed with teeth, to prove the principle.

Copper is a chemical element with symbol Cu and atomic number 29. It is a soft, flexible including malleable alloy among extremely essential thermal and electrical conductivity. A freshly revealed surface of pure copper has a reddish-orange colour. It is used as a conductor of flame and electricity, as a building material, and as an ingredient of assorted metal alloys.

II. METHODS AND MATERIAL

Cereals size discrimination is an identity of the best-established strengthening methods in steels, as well essentially in other metals. The well-known Hall-Petch equation explains the relation between ferrite grain size and the yield strength.

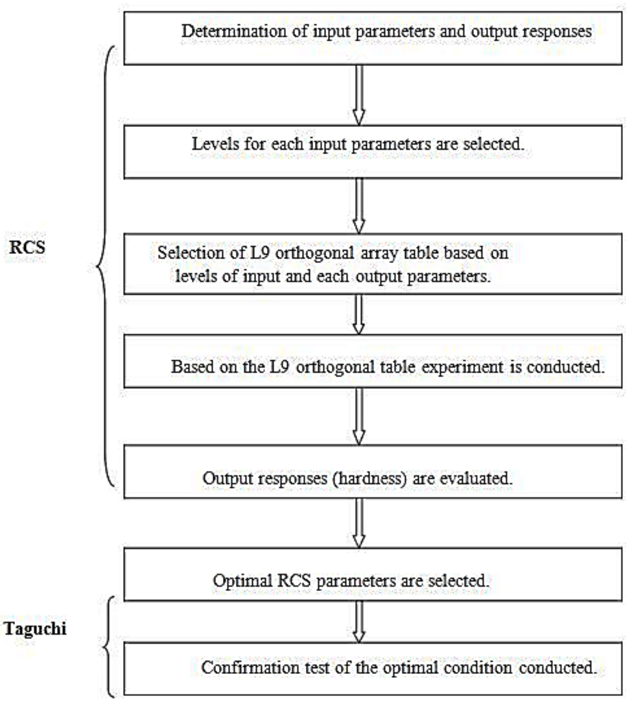

Figure 1.

TAGUCHI METHOD

Aggressive change in manufacturing during the 1970‟s and 1980‟s that provided inflation to the renovated quality movement, leading to the enlightenment of the Taguchi method to the U.S. in the 1980‟s. Taguchi's approach is a method of design installations to increase quality. Taguchi Methods regards to a collection of principles which make up the core work of a constantly evolving approach to the essence. Taguchi Methods from Quality Engineering design is built around three aggregate elements, signal-to-noise ratio, significant loss function and orthogonal arrays.

Taguchi method concentrates on Robust Design through use of

- Orthogonal arrays.
- Signal-To-Noise ratio.

A Taguchi design or orthogonal attire the method is intending the experimental procedure using different types of design like two, three, four, five, and mixed level. In the study, a three-factor combined level setup is taken with a total of eighteen numbers of experiments to be performed and hence the orthogonal apparel L9 was determined. This configuration would facilitate the two-factor synergies to be appraised. As a few more factors are to be added for further study with the same type of material, it was decided to utilize the L9 setup, which in turn would reduce the number of trials at the later stage. In addition, the comparison of the results would be simpler.

The levels of experiment parameters thickness, number of passes and strain rate are shown in table.

Table : Processing parameters and their level

Symbol	Processing Parameters	Units	Level 1	Level 2	Level 3
A	Thickness	Mm	0.5	0.8	1
B	Number of passes		1	2	3
C	Strain rate	mm/min	1.0	1.5	2.0

III. EXPERIMENTAL WORK

a) Specimen Preparation:

The commercial copper sheet of 1mm, 0.8 and 0.5 thickness was cut into samples of 100mm width and 200mm length with the mechanical properties as follows.

Properties	Values
Density	8.96g/cm^3
Shear modulus	48Gpa
Poisson's Ratio	0.34
Young"s modulus	110-128
Thermal conductivity	401w/m-k
Melting point	1357.77k
Hardness (Brinell)	235-878

Table shows mechanical properties of copper

Figure 2. Copper Specimen

b) RCS Process

The method consists of bending a straight Billet with corrugated tools and then restoring the straight shape of the billet with flat tools. By repeating these processes in a cyclic manner, high strains can be introduced in the work piece.

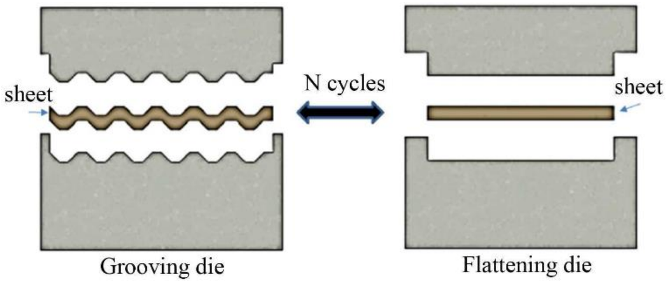

Figure 3. Working principle

Figure 4. Corrugated specimen

Figure 5. Straighten specimen

C) Hardness Test

Figure 4. Hardness test machine

Suggested by Swedish engineer Johan August Brinell in 1900, it was the first extensively used and graded hardness test in engineering and metallurgy. The large size of indention and desirable damage to test-piece limits its utility. The indention is measured and hardness calculated as:

$$\mathrm{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where,

P = load applied (kgf)
D = diameter of indenter (mm)
d = diameter of indentation (mm)
In this, we have used the diamond indenter with the diameter 1.5mm and load 100kgf for the heat treated mild steel

D) Optical Microscope

The picture from an optical microscope can be captured by normal light-sensitive cameras to generate a micrograph. Originally portraits were arrested by a photographic film but modern improvements in CMOS and charge-coupled device (CCD) cameras support the capture of digital images. Essentially digital microscopes are now available which use a CCD camera to examine a sample, showing the resulting vision directly on a computer screen without the need for eyepieces.

Figure 6. Optical microscope

The cover of a metallographic specimen is equipped with several methods of grinding, polishing, and etching. After preparation, it is often analyzed using optical. For the mild steel transferring reagent, we used is Natal. By utilizing an optical microscope we have seen the microstructure of the corrugated and straightened specimens.

IV.RESULTS AND DISCUSSIONS

A) Design of Experiments

Design of Experiments (DOE) is a structured, organized method for determining the relationship between factors influencing a input process and the output of that process. Design of experiment techniques like, Factorial design, Response surface methodology, Mixture design, Taguchi design, Among those, I had selected Taguchi Design for optimizing the tensile strength, flexural strength, and hardness.

$$D.O.E=(F-1)*L+1$$

Factors	Level 1	Level 2	Level 3
Thickness	0.5	0.8	1
Strain rate	1	1.5	2
No. of passes	1	2	3

$$DOE = (3-1)*3+1$$
$$=7$$

Using L9 orthogonal array nine experiments are taken into consideration and performed operations

S No.	Thickness Mm	Strain rate mm/min	No. of passes
1	0.5	1	1
2	0.5	1.5	2
3	0.5	2	3
4	0.8	1	2
5	0.8	1.5	3
6	0.8	2	1
7	1	1	3
8	1	1.5	1
9	1	2	2

DOE using L9 orthogonal array

B) HARDNESS TEST RESULT

S no.	Thickness Mm	Strain rate mm/min	No. of passes	Hardness (BHN)
1	0.5	1	1	429.71
2	0.5	1.5	2	609.37
3	0.5	2	3	742.09
4	0.8	1	2	742.09
5	0.8	1.5	3	1172.25
6	0.8	2	1	474.62
7	1	1	3	1373.52
8	1	1.5	1	508.37
9	1	2	2	921.41

C) ANALYSIS OF TAGUCHI BY USING THE SIGNAL TO NOISE RATIO

S no.	Thickness	Strain rate	No. of	Hardness	SNR A1
			passes	(BHN)	
1	0.5	1	1	429.71	52.6635
2	0.5	1.5	2	609.37	55.6976
3	0.5	2	3	742.09	57.4091
4	0.8	1	2	742.09	57.4091
5	0.8	1.5	3	1172.25	61.3789
6	0.8	2	1	474.62	53.5269
7	1	1	3	1373.52	62.7567
8	1	1.5	1	508.37	54.1236
9	1	2	2	921.41	59.2891

D) S/N RATIO PLOT FOR HARDNESS TEST

S/N Ratios is calculated by using below formulae.

Higher the better: 20 logs Y1

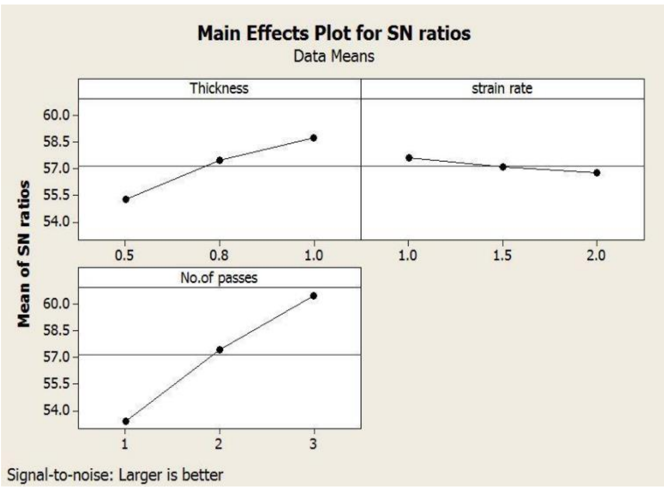

Figure 7.

S/N Ratio plots for HARDNESS TEST

From the graphs, it is clear that the optimum hardness can be achieved at 1mm thickness, 1mm strain rate, and 3rd pass.

E) GRAIN STRUCTURES

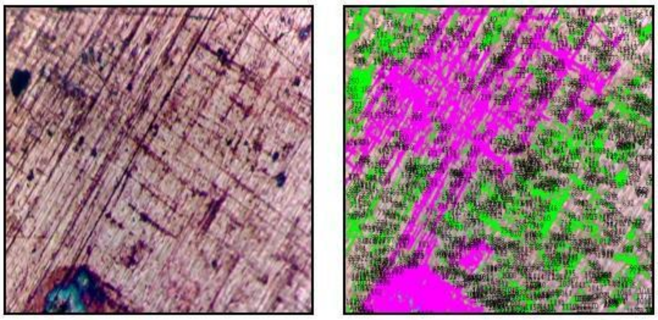

Figure 8. 0.5mm thickness base metal and No. of grains 1140

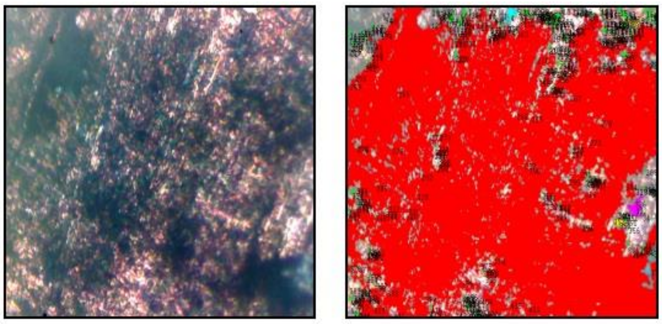

Figure 9. 0.5 mm thickness 3rd pass and No. Of grains 1420

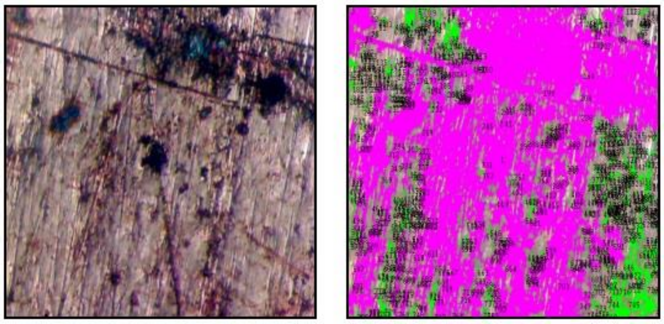

Figure 10. 0.8 mm thickness 3rd pass and No. Of grains 1730

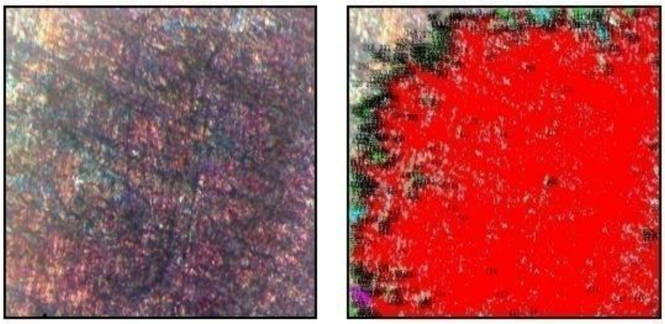

Figure 11. 1mm thickness 3rd pass and No. Of grains 2080

Grain size is decreased and no. of grains is increased so the thermal conductivity can be decreased.

V. CONCLUSION

The RCS process is successfully performed on copper. Hardness number has increased from 367.52 to 1373.52. Grain size has decreased. By using Taguchi Best sequence is found that thickness 1mm, strain rate 1mm/min, no. of passes 3 and hardness is 1373.52 BHN. As grain size decreases thermal conductivity of copper can be decreased. Finally, the total strength of the copper plate is improved by using the RCS process. The optimum number of passes required to improve the strength of copper to a maximum level in the RCS method is 3 passes.

VI.FUTURE SCOPE

As a future scope work can be done on a characterization of the grain in the workpiece by using a Scanning Electronic Microscope, Transmission Microscope, and Differential Scanning Calorimeter. The groove angle can be varied for 300 and 600 for the specimen. By using analysis software, the stress-strain distribution can be predicted. The process of RCS can be implemented for other materials also.

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