Dear Sir,

Please find attached manuscript of the article *‘***A thermal cycling route for processing nano-grains in AISI 316L stainless steel for improved tensile deformation behaviour’**for consideration of publication in your journal.

The present work significantly improved the mechanical strength of AISI 316L stainless steel by producing nano-sized grains in it. The stable austenitic stainless steel was subjected to cold rolling followed by repetitive thermal cycling to produce ultra-fine/ nano-sized grains. In the present work, the optimum processing parameters including extent of cold deformation, annealing temperature for thermal cycling, soaking period during each thermal cycle, and number of thermal cycles required were determined through a systematic step-by-step procedure. After conducting thermal cycling under the optimum conditions, a significant amount of grain size reduction was achieved in the steel. The effect of nano-sized grains on the tensile deformation behaviour of the steel was also analysed. High cold deformation resulted in increased dislocation density and high amount of stored strain energy. The stored strain energy accelerated the re-crystallization kinetics during the thermal cycling process. Every thermal cycle given to the cold rolled specimen resulted in irregular dispersal of stored energy. This irregular dispersal of stored energy favoured recrystallization rather than grain growth and led to refinement of grains to nano-size in the absence of strain induced martensite. The repetitive thermal cycling process promoted grain refinement and resulted in very significant grain size reduction with the resultant average grain size in the range of 800–1200 nm as compared to the initial size of 90–120 µm. The resultant microstructure improved the tensile strength by 106.8 %, from 590 MPa to 1220 MPa.

Hope to hear a positive response from your end.

Thanks and regards,

Sincerely,

Dr. Tarun Nanda

Assistant Professor,

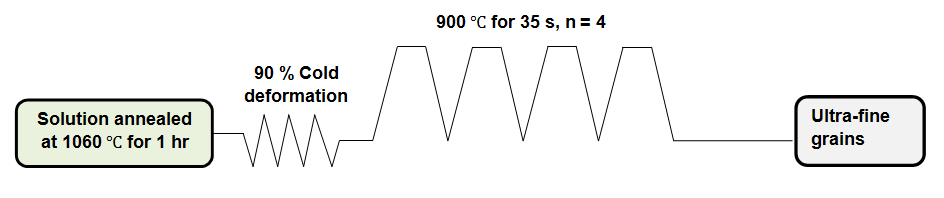
Mechanical Engineering Department,

Thapar University, Patiala, India

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**FIGURES**



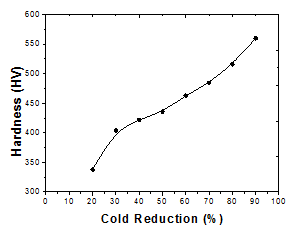
**Figure 1. Graphical representation of the thermal cycling process. n = number of thermal cycles.**



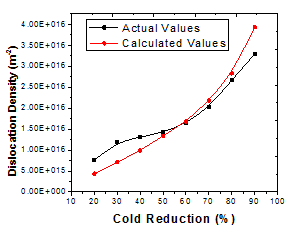
**Annealing Twins**

**Polygonal Grains**

**Figure 2. Optical micrograph of the solution treated 316L austenitic stainless steel**

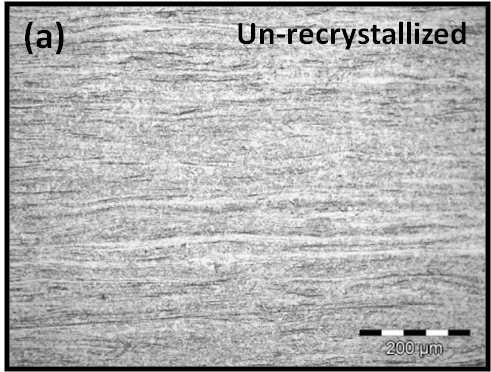


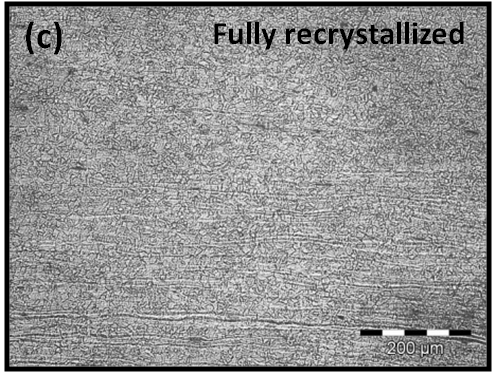
**(a)**



**(b)**

**Figure 3. Effect of cold deformation on (a) hardness, and (b) dislocation density**



**Figure 4. Optical image of 316L austenitic stainless steel after isothermal annealing at (a) 700 (b) 800 and (c) 900**



**Figure 5. Recrystallization fraction at 900 for different soaking periods**

|  |  |  |
| --- | --- | --- |
| C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\steel\925-10x.jpg | C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\90% steel sample\950-10x.jpg | C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\exp-1-steel\exp-1-10x.jpg |
| a) 875 , 30 s, n = 4 | b) 875 , 35 s, n = 4 | c) 875 , 40 s, n = 4 |
| C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\23-05-11-steel\900-50x.jpg | C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\12-05-11-steel\35-4-100x-2.jpg | C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\90% steel sample\950-100x.jpg |
| d) 900 , 30 s, n = 4 | e) 900 , 35 s, n = 4 | f) 900 , 40 s, n = 4 |
| C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\23-05-11-steel\925-50x.jpg | C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\12-05-11-steel\35-4-50x-2.jpg | C:\Users\pankaj sharma\Desktop\IMAGES & GRAIN SIZE\for steel only\90% steel sample\950-50x.jpg |
| g) 925 , 30 s, n = 4 | h) 925 , 35 s, n = 4 | i) 925 , 40 s, n = 4 |

**Figure 6. Microstructure of 316L austenitic stainless steel thermal cycled at different conditions**



**Figure 7. TEM images of AISI 316L stainless steel after thermal cycling under the optimum conditions**



**Figure 8. Tensile curves of solution annealed and thermal cycled specimen of AISI 316L stainless steel**

**Table File**

**Table 1. Chemistry of the starting AISI 316L steel**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Element** | **C** | **Si** | **Mn** | **P** | **Cr** | **Ni** | **Mo** | **Fe** |
| **% wt.** | 0.025 | 0.30 | 1.20 | 0.030 | 16.90 | 10.60 | 2.06 | **Balance** |

**Figures Captions**

**Figure 1. Graphical representation of the thermal cycling process. n = number of thermal cycles**

**Figure 2. Optical micrograph of the solution treated 316L austenitic stainless steel**

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