Materials Physics and Mechanics 37 (2018) 198-204 Received: December 22, 2017

MICROSTRUCTURE MODELLING OF BOTTOM ASH REINFORCED ALUMINUM METAL MATRIX COMPOSITE WITH STRESS RELAXATION

M. Abdulrahim*, Herlina, V.E.S. Pratiwi

Department of Industrial Engineering, University of 17 Agustus 1945 Surabaya, Indonesia

*e-mail: muslimin@untag-sby.ac.id

Abstract. It is studied stress relaxation at microstructure modeling, in particular percentage of rolling reduction and relaxation time at forming microstructure. For the specimen ingot is given a stress in hot-rolling method at temperature of 250 °C. The variable parameter is 1, 2 and 3% bulk reduction during rolling; loading duration is 0.5 – 3.5 s. Tensile test is used to measure the tensile strength. Knowing the initial time of grain formation, we state the initial and final moments of precipitate during recrystallization. The microstructure analysis is performed by using Scanning Electron Microscopy (SEM). The research results show that in the case of 1% bulk reduction during rolling, there is a microstructure recovery in the first 0.5 s, then recrystallization begins via 1 sec, the beginning of precipitation takes place after 1.5 s, and grain growth begins after 2.5 s. Corresponding results for 2% bulk reduction during rolling: recrystallization begins via 0,5 s, the beginning of precipitation takes place after 1 sec, and grain growth begins after 2.5 s. The results for 3% bulk reduction during rolling: the beginning of precipitation takes place after 0.5 sec, and grain growth begins after 1.5 s.

Keywords: microstructure modeling; stress relaxation; Scanning Electron Microscopy (SEM).

1. Introduction

The mechanical properties and microstructure formation are strongly influenced by the process of precipitation and grain size in final material microstructure, for which control and prediction of precipitation and recrystallization are necessary. One of the techniques that is cheap and produces accurate predictions is the stress relaxation technique [1].

The advantage of this microstructure modeling/prediction process is that cost of final good can be calculated [2]. Based on the microstructure modeling, we define: the grain size, the precipitate formed, the stress relaxation curve, the precipitation time and the crystallization time.

Composite materials as alternative materials are developed very rapidly. Some their advantages include: light, low and stable at high temperatures coefficient of thermal expansion (CTE).

The performed simulation process was able to control and predict changes in microstructure during the manufacture and to estimate the mechanical properties of the final good. This is very advantageous in planning the process of making the composite "Al 6061 - coal ash" due to reducing the cost of the "trial – error" process.

By using the methods of metallurgical physics, rolling technology, prediction and control of microstructure changes can be carried out quickly and precisely. One of the

http://dx.doi.org/10.18720/MPM.3722018_13

developed microcontrol structure technology is so-called the Structure Property Prediction and Control (SPPC) technique, which accelerates production process, reduces manufacturing cost and improves quality of good. The developed mathematical modelling the formation process of "Al 6061 – coal ash" includes modelling microstructure changes, namely grain growth and precipitation process [2]. To estimate of microstructure changes during thermomechanical manufacture process, many test methods have been applied. One of these method for optimization of thermo-mechanical processes is so-called stress relaxation [3].

2. Methods

Figure 1 shows a flowchart of the developed experiment.

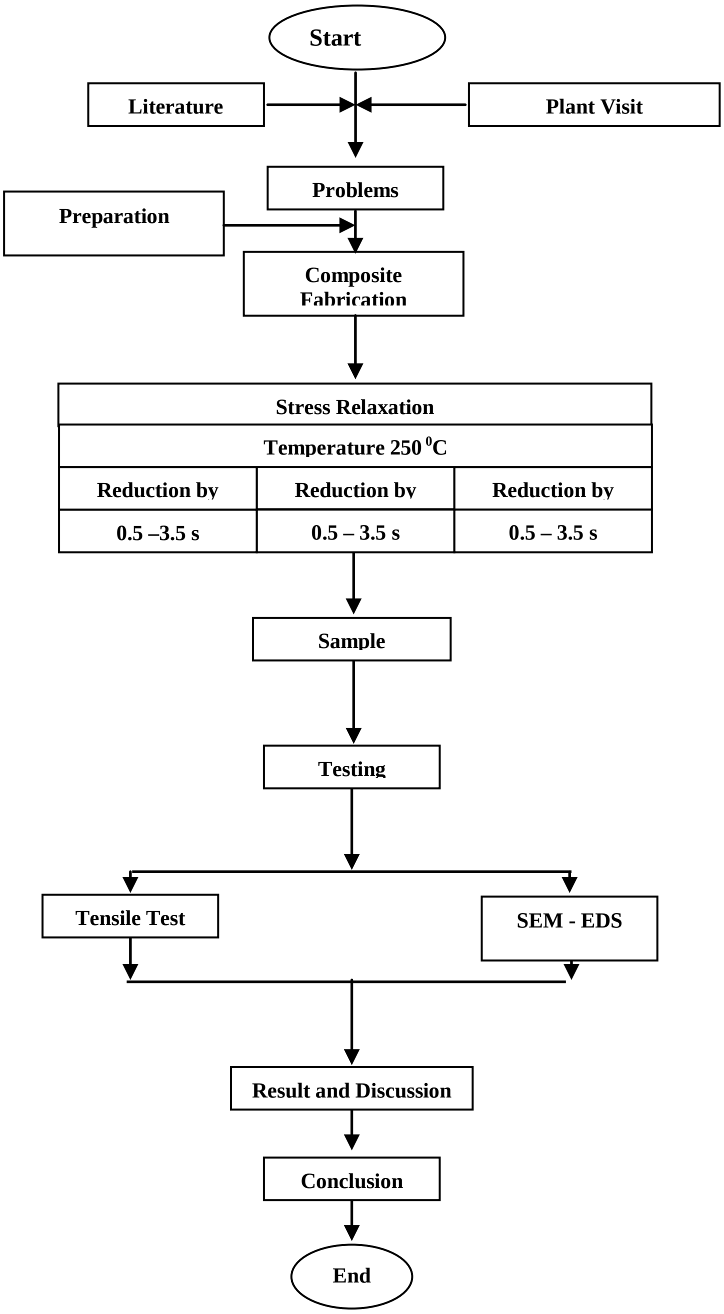

Fig. 1. Flowchart diagram of experiment.

3. Results and Analysis

The obtained results of tests on bulk reduction, stress relaxation at different stage of hot rolling are present in Tables 1 – 3 and Figs. 2 – 5.

Table 1. Tensile test results after hot rolling for 1% bulk reduction and stress relaxation time 0.5 – 3.5 s.

Relaxation (s)	Diameter (mm)	Square (mm^2)	Load (kgF)	Tensile Stress (kgF/mm^2)
0.5	4.9	18.848	163	8.648
0.7	5.0	19.625	168	8.561
1.0	4.6	16.611	145	8.701
1.2	4.9	18.848	135	7.163
1.5	5.0	19.625	131	6.675
1.7	5.2	21.226	168	7.915
2.0	4.8	18.086	167	9.233
2.2	5.3	22.051	199	9.025
2.5	4.9	18.848	186	9.868
2.7	4.6	16.611	148	8.910
3.0	5.2	21.226	144	6.784
3.2	4.7	17.341	112	6.459
3.5	5.0	19.625	114	5.809

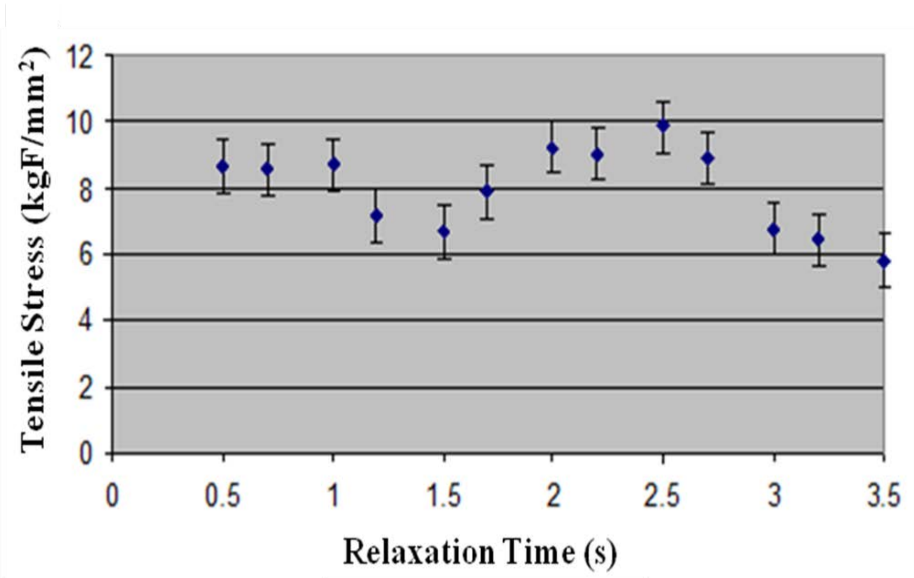

Fig. 2. Tensile stress *vs* relaxation time in 1% bulk reduction.

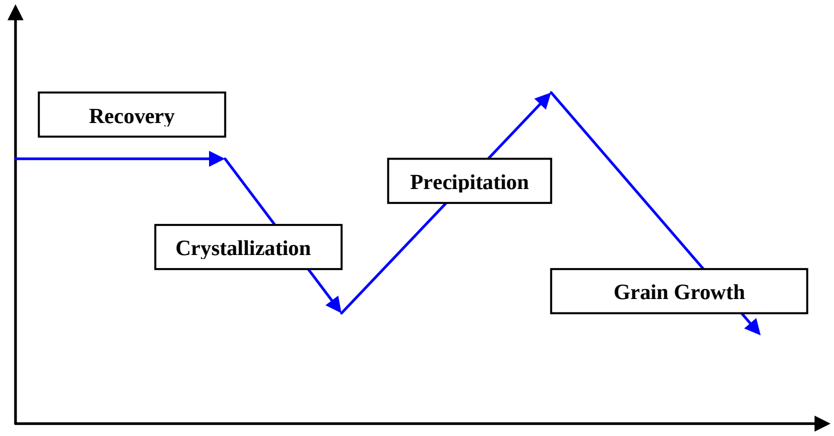

Fig. 3. Scheme of Stress Relaxation.

Table 2. Tensile test results after hot rolling for 2% bulk reduction, stress relaxation time 0.5 – 3.5 s.

Relaxation time (s)	Diameter (mm)	Square (mm^2)	Loads (kgF)	Tensile Stress (kgF/mm^2)
0.5	4.8	18.086	122	6.745
0.7	4.9	18.848	120	6.367
1.0	5.1	20.418	112	5.485
1.2	4.8	18.086	135	7.464
1,5	5.0	19.625	164	8.357
1.7	4.7	17.341	175	10.092
2.0	4.9	18.848	181	9.603
2.2	5.2	21.226	220	10.364
2.5	5.2	21.226	237	11.165
2.7	5.0	19.625	196	9.987
3.0	4.7	17.341	174	10.034
3.2	5.1	20.418	160	7.836
3.5	5.0	19.625	158	8.051

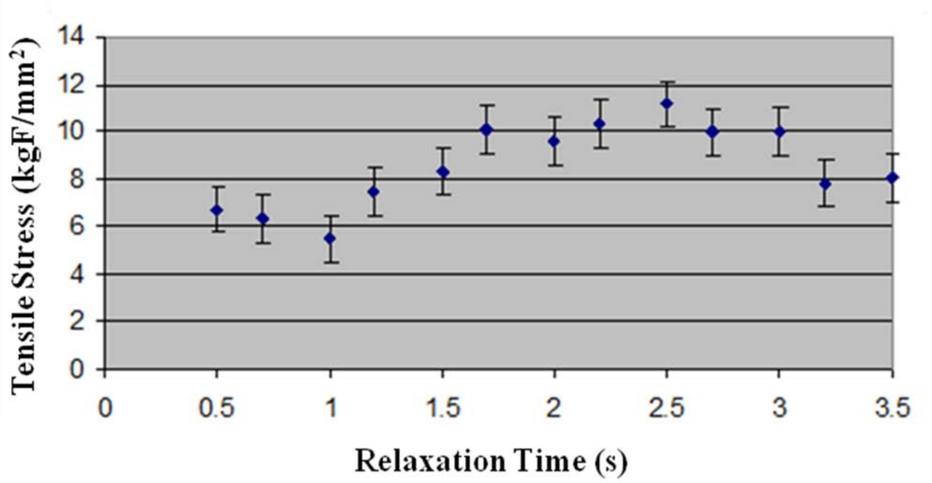

Fig. 4. Tensile stress *vs* relaxation time in 2% bulk reduction.

Table 3. Tensile test results after hot rolling for 2% bulk reduction, stress relaxation time 0.5 – 3.5 s.

Relaxation time (s)	Diameter (mm)	Square (mm^2)	Loads (kgF)	Tensile Stress (kgF/mm^2)
0.5	5.0	19.625	124	6.318
0.7	4.7	17.341	118	6.805
1.0	4.8	18.086	130	7.188
1.2	5.0	19.625	158	8.051
1.5	5.2	21.226	184	8.668
1.7	5.0	19.625	165	8.408
2.0	4.9	18.848	146	7.746
2.2	4.8	18.086	135	7.464
2.5	5.0	19.625	136	6.930
2.7	5.0	19.625	122	6.217
3.0	5.0	19.625	124	6.318
3.2	5.2	21.226	119	5.606
3.5	5.0	19.625	104	5.299

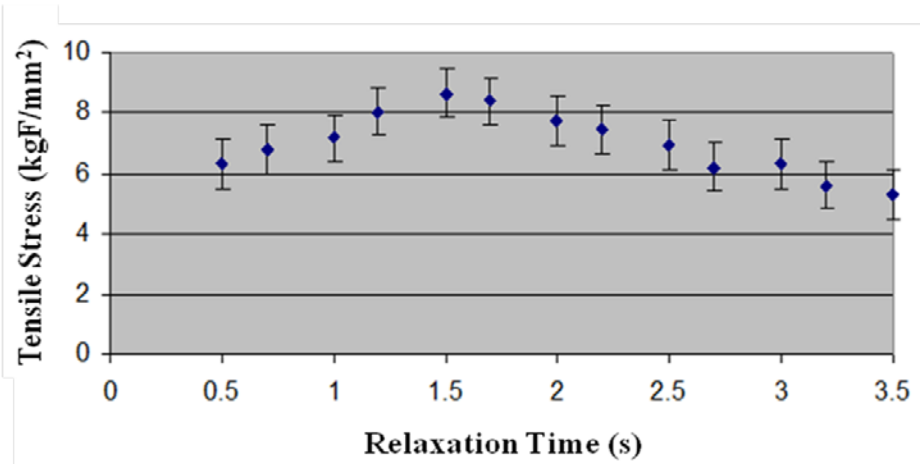

Fig. 5. Tensile stress *vs* relaxation time in 3% bulk reduction.

From the above tensile stress and relaxation data it can be concluded that in the range from 0.5 to 1 s, microstructure recovery takes place and recrystallization occurs from 1 to 1.5 s, and during 1.5 to 2.5 s occurs precipitation, but grain growth takes place from 2.5 to 3.5 s. The stress relaxation occurs after heating the specimen to a temperature of 250 °C (0.4 – 0.5T_m, where T_m is the melting point), then the relaxation process continues during from 0.5 to 3.5 s in following quenching.

The improvement of relaxation process could be caused by the hardening due to the formation of precipitates into matrix. The strength of the aging hardening alloy is determined by the interaction between moving dislocations and precipitates [2]. Barriers to precipitation in hardening alloys that block the movement of dislocations may be caused by: (i) strain around the precipitation zone and (ii) itself the zone or precipitate or both factors.

Clearly, that if the zone plays the main role, then the moving dislocations must cut it or move around it. Therefore, there are at least three causes of hardening, namely:

1. coherent hardening due to strain coherency;
2. chemical hardening, when dislocations cut precipitates;
3. dispersion hardening, when the dislocations move around or over the precipitates.

Figure 6 compares microstructure morphologies of various specimens.

Effect of bulk reduction during rolling could be estimated at morphology comparisons of samples. Fig. 6 presents example of morphology changes at 1% rolling reduction during 0.5 – 3.5 s. Effect of rolling reduction on recrystallization time can be estimated from the results for tensile stresses, presented in Figs. 2, 4 and 5. We can conclude that the percentage of rolling reduction, experienced by a material, greatly affects recrystallization time. The greater the rolling reduction leads to the acceleration of material recrystallization.

By knowing the time of recrystallization we can define the spacing between rollers at absence of material changes due to the precipitate formation during recrystallization. So we can adjust the distance between first and second rollers, taking into account that this distance should be overcome by the rollers for time no exceeding 1 s for 1% reduction, 0.5 s for 2% reduction, and from 0 to 0.5 s for 3% reduction.

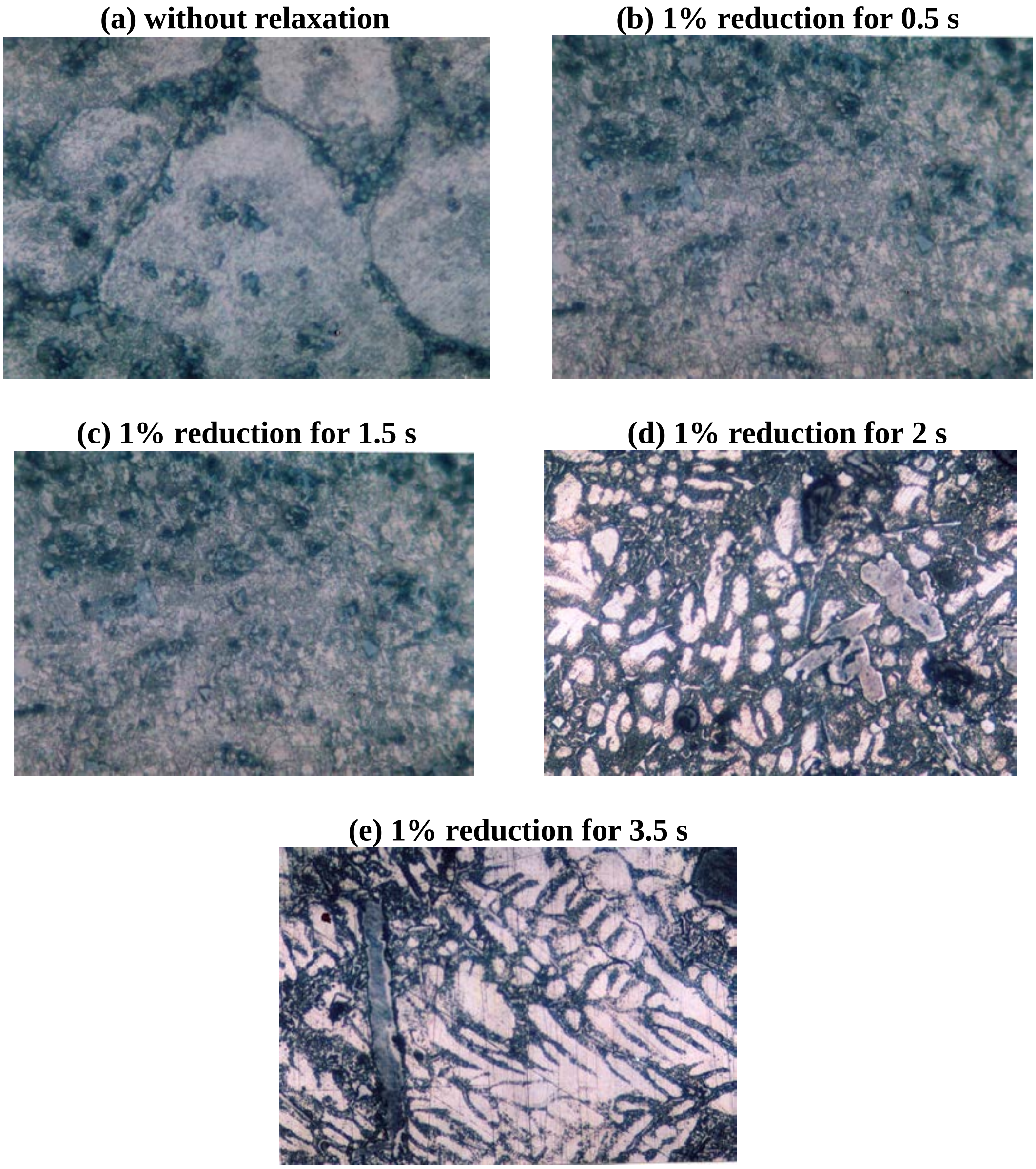

Fig. 6. Morphology comparison of samples.

4. Conclusion

1. The higher the bulk reduction by rolling, the faster recrystallization will take place.
2. From the morphology of microstructure, we can see the precipitate, formed by carbon, aluminum, and silicon.
3. By knowing recrystallization time, we can adjust the distance between rollers and determine the optimal value of the bulk reduction.

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