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THE MATERIAL PHYSICS OF DEFORMATION OF AA5182 UNDER HOT ROLLING CONDITIONS

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ABSTRACT—The forming process of hot rolling not only has obvious commercial importance but also is scientifically challenging to understand. Accurate characterization is difficult as material physics affecting plastic deformation change on the same time scale as that of the process itself. Recovery and recrystallization provide examples: the development of an annealed state may occur between rolling passes, with subsequent impact on upcoming rolling passes. We have used the constitutive response of the metal in interrupted loading experiments to ascertain whether recrystallization or recovery is an active mechanism as a function of deformation history, complimenting a study of Wells et al.[1998].

INTRODUCTION: We found that loading a AA5182 compression specimen to a given state, pausing for a particular time, and reloading the specimen gave not only constitutive information, but it allowed us to ascertain whether or not the specimen had recrystallized during the pause. The key to this understanding was plotting the materials constitutive response as hardening (Θ), that is dσ/dε, versus stress (σ). Common to all tests, Θ versus σ plots show an initial transient followed by a linear decrease in hardening rate with stress (Voce behavior). The stress level at which individual curves join the common curve gives indication of the restorative mechanism: recrystallized samples join at stresses less than or equal to, and recovered samples stresses greater than that observed for the initial curve. By varying the lengths of the pause in the loading history we were able to determine the time required for recrystallization as a function of strain rate and temperature. This procedure was inspired by the technique of “metallography by Instron” used by McQueen and Jonas[1975].

PROCEDURES, RESULTS AND DISCUSSION: The deformation of the AA5182 at a strain rate of 3.0s⁻¹ to 0.25 compressive strain at 475°C provides a specific example of this technique. These results are shown in Fig. 1. One can see the close match between the initial hardening response and that from reloading after hold times of 20 and 25s. The reload hardening after a 10s hold is similar to these data, perhaps just a bit higher. The hardening curves after holds of 4, 2, and 1s are distinctly higher than the loading data.

We have taken x-ray inverse pole figures of two compression specimens that were quenched after deformation to 0.25 strain at 475°C and ˙ε=3s⁻¹. In the first case the specimen was immediately quenched and secondly the sample was held for 3s at 475°C
before quenching. A thermocouple was mounted in each of these samples to record their time-temperature profile. We know that it took 7.4 and 10.9s respectively for these samples to drop below 300°C, in the quenching process. Temperatures above 300°C are sufficient to cause recrystallization. The classical compression texture is (101), while that for recrystallization is (001). We found that 7.4s was sufficient to begin the recrystallization process, Fig.2. The (101) deformation texture is dramatically diminished. However, the process was not completed as there was not a distinct (001) component. In the second case, 10.9s, the (001) component is present and dominate. The recrystallization was completed or nearly completed. This inverse pole figure is shown in Figure 3.

Based on the $\Theta$ versus $\sigma$ data together with the inverse pole figures from specimens deformed under identical circumstances and quenched we have been able to draw conclusions concerning the timing of recrystallization for compression samples deformed identically at $\dot{\varepsilon} = 3s^{-1}$ to 0.25 strain, for temperatures of 400, 425, 450, 475, and 500°C. Table I is a summary of these experiments. The extent of recrystallization, or simple recovery without recrystallization is indicated for each time/temperature condition we investigated, by words and shading. We have added the letters IPF (inverse pole figure) to particular time/temperature blocks where texture measurements verified our conclusions.

![AA 5182, 475°C, Strain Rate of 3.0s⁻¹, Reload Behavior](image)

Figure 1. Constitutive response, hardening, of the AA5182. The material was loaded to a strain of 0.25 at 475°C and a strain rate of $3s^{-1}$; deformation was paused for different time increments and the sample reloaded. The reloading hardening response provides evidence for recrystallization or only thermally activated dynamic recovery during the pause.
based on constitutive response. One should note that we could not obtain quench times shorter than 6.2 seconds for temperatures at and above 450°C.

Figure 2. The beginning of recrystallization. The sample was quenched to 300°C from 475°C in 7.4s.

Figure 3. Nearly complete recrystallization. The sample was quenched to 300°C from 475°C in 10.9s.

Table 1: Measurements Of Recrystallization Based On Constitutive Response.

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Duration of Loading Pause (Seconds) Before Reload, ̇e = 3s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
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<tr>
<td>400</td>
<td>Partial</td>
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<td>425</td>
<td>Final</td>
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<td>450</td>
<td>Final</td>
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<tr>
<td>475</td>
<td>Final</td>
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<tr>
<td>500</td>
<td>Final</td>
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CONCLUSIONS: We have demonstrated a technique that will allow us to measure the kinetics of recrystallization for the strain rates and temperatures associated with hot rolling, which cannot be done with a quenching technique alone. This provides information required to develop constitutive models.

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