Fracture and Fatigue of Fe$_{78}$Si$_9$B$_{13}$ Metallic Glass Ribbon

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ABSTRACT

Vickers microhardness indentations, tension and notch toughness tests, as well as controlled static and cyclic strain experiments via bending over mandrels of different diameter have been performed on 30 µm thick Fe$_{78}$Si$_9$B$_{13}$ metallic glass ribbons. Vickers microhardnesses of 910 ± 100 kg/mm$^2$ and 1030 ± 35 kg/mm$^2$ were obtained for the air side and wheel side, respectively. Tensile strengths were 1640 MPa ± 35, somewhat less than the strength predicted from microhardness. The notch toughness values obtained were 34.5 ± 5.5 MPa$\sqrt{m}$. The static ‘bend over mandrel’ tests revealed that the ribbons simply deformed via shear banding for mandrel diameter as small as 0.225 mm. Fully reversed flex bending fatigue experiments revealed a fatigue limit of 2300 MPa via testing over mandrels with different radii under cyclic strain control. SEM examination was used to characterize all fracture surface details. These results are discussed in the light of recent work on metallic glasses.

INTRODUCTION

MATERIALS & METHODS

- Fe-based amorphous ribbon was produced via melt spinning.
  - The cooling rate of about 10$^5$ K/s was applied.
  - The resulting ribbon had 20 µm width and 30 µm thickness.
  - The chemistry of the ribbon was Fe$_{78}$Si$_9$B$_{13}$ at. %.
  - XRD analysis revealed the ribbon to be fully amorphous.
  - Surface roughness was measured using Confocal microscopy.

  - Mechanical Testing
    - BUEHLER micro-hardness tester with a load of 100 g.
    - Uniaxial Tensile Testing
      - Instron Model 1125 universal testing machine: initial strain rate 10$^{-4}$ s$^{-1}$
      - Hourglass shape Tension specimens with Kt = 1.25 were used.

RESULTS SUMMARY

<table>
<thead>
<tr>
<th>Mandrel Diam., (mm)</th>
<th>Strain, ε</th>
<th>Stress, σ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.05</td>
<td>0.00197</td>
<td>173</td>
</tr>
<tr>
<td>12.7</td>
<td>0.00236</td>
<td>263</td>
</tr>
<tr>
<td>9.92</td>
<td>0.00302</td>
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<td>7.92</td>
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<td>5.95</td>
<td>0.00504</td>
<td>565</td>
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<tr>
<td>3.96</td>
<td>0.00738</td>
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<tr>
<td>1.98</td>
<td>0.01515</td>
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</tr>
<tr>
<td>1.19</td>
<td>0.0321</td>
<td>273</td>
</tr>
<tr>
<td>0.50</td>
<td>0.06 (+)</td>
<td>6600 (+)</td>
</tr>
<tr>
<td>0.225</td>
<td>0.13 (+)</td>
<td>14667 (+)</td>
</tr>
</tbody>
</table>

Notch Toughness Testing

- The notch was placed using a slow speed diamond impregnated wire saw with a root radius of 110 µm.
- Instron Model 1125 universal testing machine with pneumatic friction grips was used.

Surface Roughness Analysis via Confocal Microscopy

- Mechanical Properties
  - Microhardness (Hv): 910 ± 100
  - Microhardness, (GPa): 8.9 ± 0.1
  - Average Compressive Strength, (GPa): 2976 ± 3368
  - Tensile Strength, (GPa): 1640 ± 35
  - Notch Toughness, (MPa m$^{1/2}$): 94.5 ± 5.5
  - Bending over Mandrel Stress, $\sigma_b$ (MPa): 2775, $\sigma_b$ = 4600

CONCLUSIONS

- Bend over mandrel tests show permanent deformation at strain > 2.5 %.
- The cyclic fatigue tests revealed fatigue limit ≥ 260 MPa.
- The ribbons show significant plasticity via extensive shear banding.
- Shear bands & fatigue stration spacing is $\delta$ (mandrel diameter).

FUTURE WORK

- Evaluate the Mechanical Properties of Ribbons at low Temperatures.
- Study the Cyclic Fatigue Properties at different R Ratio.

REFERENCES


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