Ti-5Al-5V-5Mo-3Cr
Forgeability and Mechanical Properties

Lauren Moody

5,000 ton Verson Press
Agenda

• Overview of Ti-5Al-5V-5Mo-3Cr
• Explanation of Experiments
• Processing and Heat Treatment
• Testing Results
• Conclusions
Ti-5Al-5V-5Mo-3Cr
Overview

• Developed in Russia – derivative of VT22 & VT22-1
• Excellent Hardenability
• Fast cooling not required
  • Few distortion problems in machining
• Compared favorably to Ti-6Al-4V in both tensile and fatigue properties
Three Forging/Heat Treat Models

I. $\alpha$-$\beta$ forged with BASCA-160 heat treat

II. $\beta$ forged with BASCA-160 heat treat

III. $\alpha$-$\beta$ forged with STA-180 heat treat

**BASCA-160 models were heat treated in vacuum.**
Material

• 12” diameter billet from Allvac

• Beta Transus Temperature range – 1540-1580 °F

• Hydrogen Range – 0.0036-0.0058 ppm

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Si</th>
<th>Mo</th>
<th>Al</th>
<th>V</th>
<th>Fe</th>
<th>Zr</th>
<th>O</th>
<th>N</th>
<th>Cr</th>
<th>H</th>
<th>Al Eq</th>
<th>Mo Eq</th>
<th>Tot Eq</th>
<th>BT range</th>
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</thead>
<tbody>
<tr>
<td>Heat 1</td>
<td>0.006</td>
<td>0.05</td>
<td>4.69</td>
<td>4.81</td>
<td>4.70</td>
<td>0.39</td>
<td>0.16</td>
<td>0.143</td>
<td>0.004</td>
<td>2.59</td>
<td>0.0036</td>
<td>6.367</td>
<td>12.036</td>
<td>18.403</td>
<td>1560-1580</td>
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<td>Heat 2</td>
<td>0.008</td>
<td>0.03</td>
<td>4.99</td>
<td>5.06</td>
<td>4.92</td>
<td>0.40</td>
<td>0.08</td>
<td>0.121</td>
<td>0.01</td>
<td>2.94</td>
<td>0.0058</td>
<td>6.464</td>
<td>12.945</td>
<td>19.409</td>
<td>1540</td>
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<tr>
<td>Heat 3</td>
<td>0.010</td>
<td>0.02</td>
<td>4.69</td>
<td>5.48</td>
<td>4.67</td>
<td>0.42</td>
<td>0.11</td>
<td>0.126</td>
<td>0.002</td>
<td>3.48</td>
<td>0.0036</td>
<td>6.879</td>
<td>13.203</td>
<td>20.082</td>
<td>1545-1560</td>
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<tr>
<td>Heat 4</td>
<td>0.012</td>
<td>0.03</td>
<td>4.89</td>
<td>5.21</td>
<td>4.87</td>
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<td>0.12</td>
<td>0.129</td>
<td>0.002</td>
<td>3.02</td>
<td>0.0053</td>
<td>6.660</td>
<td>12.987</td>
<td>19.647</td>
<td>1555-1565</td>
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</tbody>
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I. α-β forged w/ BASCA-160 | II. β forged w/ BASCA-160 | III. α-β forged w/ STA-180
Forging Configurations

Die No. 40002
Yoke Fitting, Fwd Engine Mount.
Input Wt – 82 lbs
Original Mat'l – 6Al-6V-2Sn
Approx 2.5” thick and 34” long

Die No. 40009
Slat Track
Input Weight – 86 lbs
Original Mat'l – 6Al-6V-2Sn
Approx. 2” thick x 50” long

Both configurations used in all three models of this experiment

I. α-β forged w/ BASCA-160 | II. β forged w/ BASCA-160 | III. α-β forged w/ STA-180
Forging Configurations

Die No. 40043
Latch Support – Cargo Door
Input Wt – 78 lbs
Approx. 1” to 4” thick and 18” long
Used in Model I
Original Mat’l – 6Al-4V

Die No. 40090
Diagonal Brace
Input Wt – 219 lbs
Approx. 1” to 4” thick and 18” long
Used in Models II and III
Original Mat’l – 6Al-4V

I. α-β forged w/ BASCA-160  |  II. β forged w/ BASCA-160  |  III. α-β forged w/ STA-180
Heat Treat Requirements

BASCA-160  Beta Anneal Slow Cool and Age
Beta Anneal
Controlled cool to age temperature
Low temperature age

STA-180  Solution Treat and Age
Alpha Beta solution treat
Air Cool
Low temperature age

I. α-β forged w/ BASCA-160  |  II. β forged w/ BASCA-160  |  III. α-β forged w/ STA-180
Experiment – Model I

α-β Forged with BASCA-160 heat treat

<table>
<thead>
<tr>
<th>Die No. 40009</th>
<th>Die No. 40043</th>
<th>Die No. 40002</th>
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<tbody>
<tr>
<td>17 Tensiles</td>
<td>11 Tensiles</td>
<td>14 Tensiles</td>
</tr>
<tr>
<td>3 (K_{1c})</td>
<td>2 (K_{1c})</td>
<td>4 (K_{1c})</td>
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<table>
<thead>
<tr>
<th>Die</th>
<th>Heat</th>
<th>UTS (ksi)</th>
<th>YS (ksi)</th>
<th>Elong (%)</th>
<th>RofA (%)</th>
<th>(K_{1c}) (ksi (\sqrt{\text{in}}))</th>
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<td>#3</td>
<td>167.24</td>
<td>151.76</td>
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<td>28.29</td>
<td>91.23</td>
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<td>#4</td>
<td>165.00</td>
<td>151.27</td>
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<td>#1</td>
<td>166.86</td>
<td>152.07</td>
<td>11.93</td>
<td>22.86</td>
<td>94.10</td>
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I. α-β forged w/ BASCA-160 | II. β forged w/ BASCA-160 | III. α-β forged w/ STA-180
Experiment – Model I

Model I Load-Displacement Comparison
Die No. 40002

- I. α-β forged w/ BASCA-160
- II. β forged w/ BASCA-160
- III. α-β forged w/ STA-180
Experiment – Model II

β Forged with BASCA-160 heat treat

<table>
<thead>
<tr>
<th>Die No.</th>
<th>Tensiles</th>
<th>Heat</th>
<th>UTS (ksi)</th>
<th>YS (ksi)</th>
<th>Elong (%)</th>
<th>RofA (%)</th>
<th>$K_{1C}$ (ksi √in)</th>
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</thead>
<tbody>
<tr>
<td>40009</td>
<td>17</td>
<td>#4</td>
<td>166.68</td>
<td>152.22</td>
<td>9.29</td>
<td>17.66</td>
<td>85.37</td>
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<tr>
<td>40090</td>
<td>20</td>
<td>#1</td>
<td>163.13</td>
<td>147.55</td>
<td>10.75</td>
<td>19.13</td>
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<td>40002</td>
<td>14</td>
<td>#2</td>
<td>162.82</td>
<td>147.88</td>
<td>10.57</td>
<td>19.62</td>
<td>86.75</td>
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</table>

I. α-β forged w/ BASCA-160  | II. β forged w/ BASCA-160  | III. α-β forged w/ STA-180
Experiment – Model II

Model II Load-Displacement Comparison
Die No. 40090

I. α-β forged w/ BASCA-160  |  II. β forged w/ BASCA-160  |  III. α-β forged w/ STA-180
Experiment – Model III

α-β Forged with STA-180 heat treat

<table>
<thead>
<tr>
<th>Die No.</th>
<th>Heat</th>
<th>UTS (ksi)</th>
<th>YS (ksi)</th>
<th>Elong (%)</th>
<th>RofA (%)</th>
<th>K_{1C} (ksi √in)</th>
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</thead>
<tbody>
<tr>
<td>40009</td>
<td>#4</td>
<td>191.53</td>
<td>188.00</td>
<td>11.32</td>
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<td>#1</td>
<td>190.50</td>
<td>185.60</td>
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<td>#2</td>
<td>185.59</td>
<td>177.59</td>
<td>6.35</td>
<td>8.69</td>
<td>38.20</td>
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I. α-β forged w/ BASCA-160  | II. β forged w/ BASCA-160  | III. α-β forged w/ STA-180
Conclusions

• Ti-5Al-5V-5Mo-3Cr has exhibited higher overall properties than standard 6Al-4V material

• Potential for increased yield in forging and machining with slower cooling rates.

• All models examined are workable in production
  • Standardized forging and heat treat temperatures need to be determined.

• Ti-5Al-5V-5Mo-3Cr has shown superior forgeability to Ti-6Al-4V in α-β ranges
• Additional forging trials to create a streamlined process for future production use.

• Further investigation into both BASCA-160 and STA-180 to optimize heat treat cycles and to move toward the best possible mechanical properties.

• Machining trials to determine if yield savings is possible, and if so, how much

• Moving forward in qualifications of Weber Metals for production of this material in future applications.