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LDRD 18A12-088 , Thermomechanical Processing of Titanium Alloys for Improved Ballistic Performance

Thomas M Lillo, Jeffrey A Anderson, Kenneth R Bratton, Henry S Chu, Jason K Walleser

August 2019

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LDRD **18A12-088** , **Thermomechanical Processing of Titanium Alloys for Improved Ballistic Performance**

T.Lillo, J.Anderson, K.R. Bratton, H. Chu, J. Wallesser

National Objective:

Accelerate the development and deployment of advanced/emerging armor materials

- Reduced weight
- Increased ballistic protection

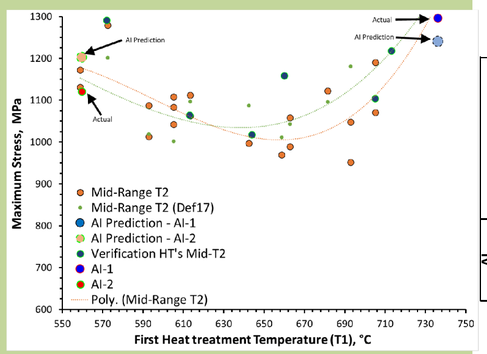
Approach

- Develop novel experimental methods and systems for rapid evaluation of advanced materials properties of new/emerging alloys
- Develop advanced computing methods for rapidly predicting material performance and optimizing material processing
- Demonstrate approach on Ti-10V-2Fe-3Al alloy

Methods

- Gleeble 3800 Universal Testing machine to
  - Obtain elevated temperature flow stress from small samples (10 mm dia x 12 mm)
  - Simulate rolling schedules (10 mm x15 mm x 20 mm)
- Heat treatment and mechanical testing
  - Sub-sized tensile bars
  - Test matrix via Latin HyperCube
    - Good for multiple variables
    - Reduced sample count from 81 to <40
- AI methods yield relationship between
  - Processing and ultimate tensile strength
  - Processing and ductility
  - Processing and energy-absorbing capability
- In remaining FY20 -Process large plate using AI results
  - Obtain plates with different tensile, ductility and energy-absorbing characteristics
  - Correlate processing/mechanical properties with ballistic performance

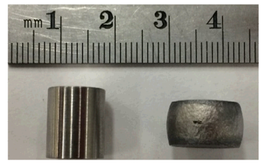
Artificial intelligence (AI) methods rapidly yields application-specific, optimized materials processing parameters from a small amount of material.



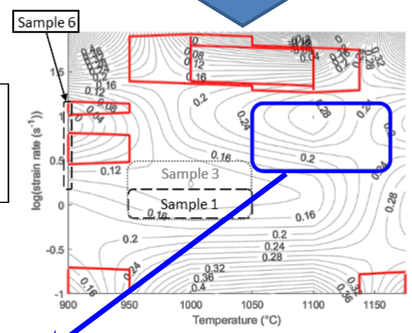
Optimization Flow Diagram

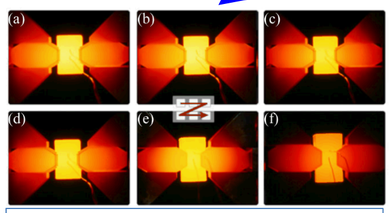
Gleeble 3800

Compression tests

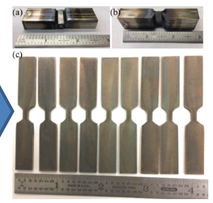


Deformation Processing Diagrams





Simulated Rolling



Heat Treat & Mechanical Testing

	Sample ID	1st Heat Treatment Temperature, °C	1st Heat Treatment Duration, hrs	2nd Heat Treatment Temperature, °C	2nd Heat Treatment Duration, hrs	Mechanical Properties Failure Strain, %	Mechanical Properties Ultimate Stress, MPa	Mechanical Properties Deformation Energy Parameter
Experimental Data	Ti-700-580	700	4	580	8	17.2	893.3	120.2
	Ti-700-500	700	4	500	8	18	991.5	125.6
	Ti-700-400	700	4	400	8	13.9	1151.9	108.7
	Ti-700-350	700	4	350	8	13.7	1089.4	100.1
	Ti-650-580	650	4	580	8	17	989.4	120.7
	Ti-650-500	650	4	500	8	22.1	1033.1	182.7
	Ti-650-400	650	4	400	8	20.9	1070.2	170.4
	Ti-650-350	650	4	350	8	18.4	1033.4	44.9
AI Prediction, Ultimate Stress	State 1	736.3	8.5	429.4	10.6	-	1239.8	-
	State 2	559.7	2	404	15.1	-	1201.7	-

AI Analysis and Optimized Processing Parameters

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