RVLT TC1.1: Variable Speed Power Turbine Tech Demo

Brief Summary of Completion / Accomplishment:
Technical Challenge: Variable Speed Power Turbine (VSPT) Demonstration
Tech Challenge Exit Criteria: Demonstrate variable speed power turbine with 50% improvement in efficient operational capability

Cascade testing defines the loss buckets for incident tolerant blade designs required for VSPT. Completed VSPT cascade testing at high and low inlet turbulence levels over a large range of Mach number, Reynolds number, and incidence to provide a benchmark data base to validate the ability of CFD analysis codes to predict the VSPT losses over the entire flight operating envelope.

VSPT Design to meet the TC objectives and full scale VSPT test Rig Design completed. Joint US Army AATD / NASA VSPT component contracts awarded to Pratt & Whitney (P&W) and General Electric Aviation (GE). The P&W 4 stage VSPT design met the VSPT efficiency goals at 100% speed or maximum rated power (MRP) for vertical lift and a 55% speed or maximum continuous power (MCP) for cruise. The VSPT design efficiency exceeded 90% over the entire operating range.

*Successful completion of VSPT rig test achieves goals and demonstrated the potential of the VSPT concept as a viable approach to improve engine efficiency over a wide range of operating conditions***.** The full-scale VSPT 3 stage component rig was installed in the P&W Canada Continuous Flow Turbine Rig facility and tested over a wide range of operation. The facility emulated the engine inlet flow conditions to the VSPT compete with swirl and turbine main frame struts.

Design and computational analysis tools validated experimental results. CFD was integrally used in the VSPT design process. Post-test analysis of the detailed rig data indicated the CFD had accurately predicted (pre-test predictions) radial distribution of the key flow field parameters, the vane pressure distributions, and the overall performance over the wide operating range.

Beginning TRL 2, Final TRL 5 after VSPT demonstration

TC Related Publications

Publications
Hearn, T., Hendricks, E., Chin, J., Gray, J., and Moore, K., "Optimization of Turbine Engine Cycle Analysis with Analytic Derivatives," AIAA Aviation 2016, Washington, D. C., June 13-17, 2016
Thurman, D., Flegel, A., and Giel, P., "Inlet Turbulence and Length Scale Measurements in a Large Scale Transonic Turbine Cascade," Paper AIAA-2014-3934,50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Cleveland, OH, July 2014.
Snyder, C. A., "Exploring advanced technology gas turbine engine design and performance for the Large Civil Tiltrotor (LCTR)", 50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Cleveland, OH, July 28-30, 2014
Flegel-McVetta, A. B., Giel, P. W., Welch, G. E., Ames, Forrest, A. and Long, Jonathon, A., "Complimentary Aerodynamic Datasets for Variable-Speed Power-Turbine Blade Section from Two Independent Transonic Turbine Cascades," Paper ISABE 2015-20163, International Society of Air-Breathing Engines (ISABE) Conference, Phoenix, AZ, July 2015.
Flegel-McVetta, A. B., Giel, P. W., and Welch, G. E., "Aerodynamic Effects of High Turbulence Intensity on a Variable-Speed Power-Turbine Blade with Large Incidence and Reynolds Number Variations," Paper AIAA-2014-3933, 50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Cleveland, OH, July 2014
Ameri, A., Giel, P., and Flegel, A., "Simulation of VSPT Experimental Cascade under High and Low Free-Stream Turbulence Conditions," Paper AIAA-2014-3935, AIAA Propulsion and Energy Forum and Exposition 2014, Cleveland, OH, July 2014

TC Related Publications

Publications
McVetta, A. B., Giel, P. W., and Welch, G. E., “Aerodynamic Measurements of A Variable-Speed Power-Turbine Blade Section in a Transonic Turbine Cascade At Low Inlet Turbulence,” GT2013-94695 for IGTI 2013 Turbo Expo Conference, San Antonio, TX, June 2013
Howard, S. A., “Rotordynamic Feasibility of a Conceptual Variable-Speed Power Turbine Propulsion system for Large Civil Tilt-Rotor Applications,” NASA/TM-2012-217134, Jul 2012
Welch, G. E., McVetta, A. B, Stevens, M. A., Howard, S. A.; Giel, P. W.; Ameri, A. A., To, W., Skoch, G. J.; Thurman, D. R., “Variable-Speed Power-Turbine Research at Glenn Research Center, ” AHS International, 68th Annual Forum and Technology Display, Fort Worth, Texas, May 2012, NASA TM-2012-217605, July 2012.
Welch, G. E., “Advanced CFD and Instrumentation for Turbomachinery Research,” Turbomachinery Technical Working Group workshop, Sept 5-6, 2012, Ohio Aerospace Institute.
McVetta, A. B., Giel, P. W., Welch, G. E., Aerodynamic Investigation of Incidence Angle Effects in a Large Scale Transonic Turbine Cascade,” AIAA-2012-3879, Proc. 48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, Atlanta, GA, Jul-Aug. 2012.
Snyder, C. A., and Acree, C. W., “Preliminary Assessment of Variable Speed Power Turbine Technology on Civil Tiltrotor Size and Performance,” AHS 68th Annual Forum, Fort Worth, TX, May 2012.
Ford, A., Turner, E., Bloxham, M., Gegg. S., King, B., Harris, C., Bell, M., Eames, D., “Variable-Speed Power-Turbine Component Research Plan,” NASA/CR-2012-217423, Feb. 2012 (Export Controlled, unlimited rights)

TC Related Publications

Publications
Suchezky, M., Cruzen, C. S., Variable-Speed Power Turbine for the Large Civil Tilt Rotor," NASA/CR-2012-217424, Feb. 2012 (Unlimited rights)
Delgado, I., Dempsey, P., Simon, D., "A Survey of Current Rotorcraft Propulsion Health Monitoring Technologies," NASA/TM—2012-217420 January 2012
Boyle, R., Miller, I., Halibag, M., DiCarlo, J., Bhatt, R., Jaskowiak, J., "Design Concepts for Cooled Ceramic Matrix Composite Turbine Vanes," 36th International Conference and Exposition on Advanced Ceramics and Composites January 22-27, 2012, Daytona Beach, FL
Halbig, M., "Ceramic Matrix Composites for Rotorcraft Engines," 36th International Conference and Exposition on Advanced Ceramics and Composites January 22-27, 2012, Daytona Beach, FL
Welch, G.E., "Computational Assessment of the Aerodynamic Performance of a Variable- Speed Power Turbine for Large Civil Tilt-Rotor Applications," NASA/TM-2011-217124, Nov 2011, presented at AHS 67, May 2011.
Welch, G. E., "Computational Study of the Impact of Unsteadiness on the Aerodynamic Performance of a Variable-Speed Power Turbine," 50th AIAA Aerospace Sciences Meeting, Nashville, TN, Jan 2012. AIAA-2012-937
Acree, C. W. and Snyder, C. A., "Influence of Alternative Engine Concepts on LCTR2 Sizing and Mission Profile," AHS Future Vertical Lift Aircraft Design Conference, San Francisco, CA, January 2012.
Snyder, C. A., "Defining Gas Turbine Engine Performance Requirements for the Large Civil Tiltrotor (LCTR)," 67th Annual Forum of the American Helicopter Society, Virginia Beach, VA, May 3-5, 2011.

TC Related Publications

Publications
Snyder, C. A., Robuck, M., Wilkerson, J., Nordstrom, C., “Summary of the Large Civil TiltRotor (LCTR2) Engine Gearbox Study,” AHS International Powered Lift Conference, Philadelphia, PA , Oct. 5-7, 2010.
Welch, G. E. and Boyle, R. J., “Assessment of aerodynamic challenges of a variable-speed power turbine for Large Civil Tilt-Rotor application,” 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Snyder, C. A., Thurman, D. R., “Effects of gas turbine component performance on engine and rotary wing vehicle size and performance,” 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Chen, S., “Preliminary Axial Flow Turbine Design and Off-Design Performance Analysis Methods for Rotary Wing Aircraft Engines; I-Validation,” NASA/TM—2009-215651/PART1 and Part 2.
Snyder, C. A., and Thurman, D. R., “Gas Turbine Characteristics for a Large Civil Tilt-Rotor,” 65th AHS Forum, Grapevine, TX, May 27-29, 2009.
Editors: Yamauchi, G. K. and Young, L. A., “A Status of NASA Rotorcraft Research,” NASA/TP-2009-215369, September 2009
Simon, D., and Litt, J., “Automated Power Assessment for Helicopter Turboshaft Engines,” 64th American Helicopter Society (AHS) Annual Forum, Montreal, Canada, April 29-May 1, 2008

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Objective

Demonstrate 50% improvement in efficient operational capability using a Variable Speed Power Turbine (VSPT) concept

Technical Areas and Approaches

✓ Completed cascade testing at NASA and partners' facilities to validate design tools for incidence-tolerant blade designs and large swings in Re corresponding to the operating envelope.

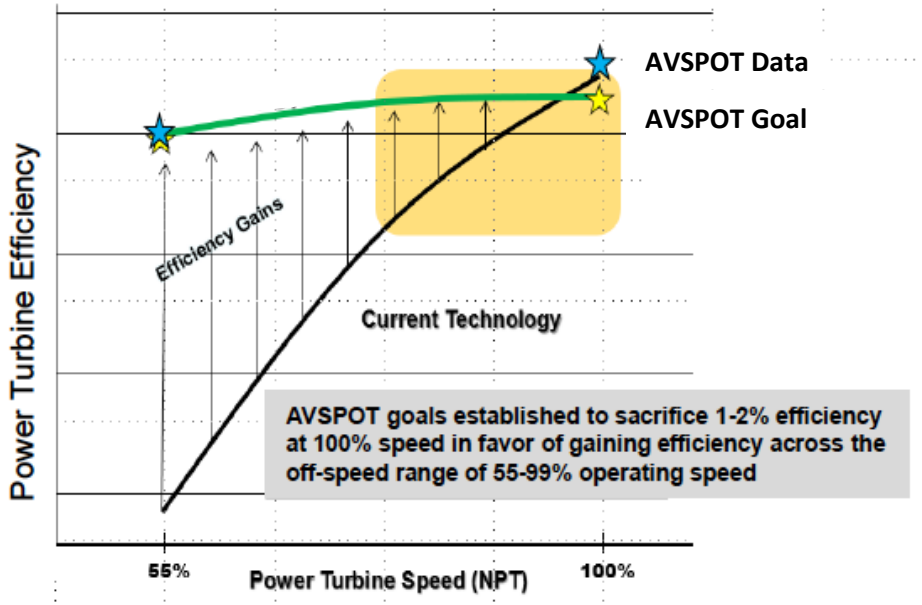
✓ Documented cascade test results & advanced in-house URANS simulation capability for multistage turbines

✓ Completed the design, fabrication, and testing of a VSPT power turbine (AVSPOT) which exceeded the design goals over the speed range. Test completed Jan 2016.

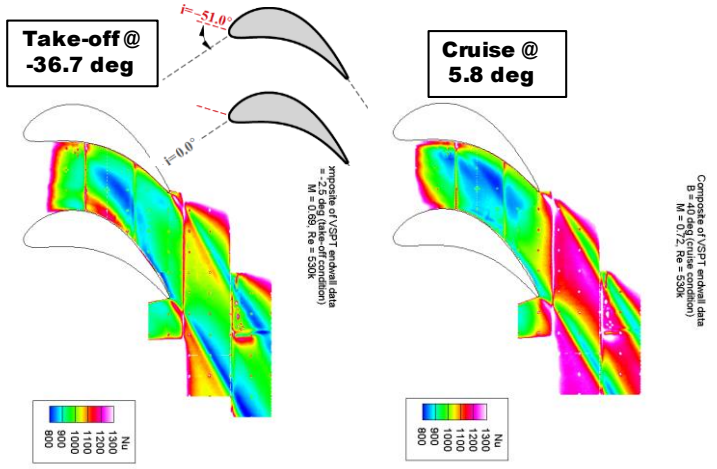
✓ Successful completion of VSPT rig test achieves goals and advances Variable Speed Power Turbine to TRL 5

✓ Final report summarizing test results and excellent comparison to analysis completed.

✓ Research disseminated via conferences, publications, and NASA datasets.



VSPT Rig Performance Testing



Infrared thermography image of endwall in CW-22 in support of wide incidence-tolerant blade testing.