Department of the Navy SBIR/STTR Transition Program

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NAVAIR JSF16-1131

Topic # N13A-T002
Modeling of Integrally Bladed Rotor (IBR) Blends
Optimal Solutions Software, LLC

WHO

SYSCOM: NAVAIR

Sponsoring Program: JSF-Prop

Transition Target: IBRs are prevalent in the fan and compressor sections of the current and emerging fleet of DoD gas turbine engines such as the F119 and F135.

TPOC:
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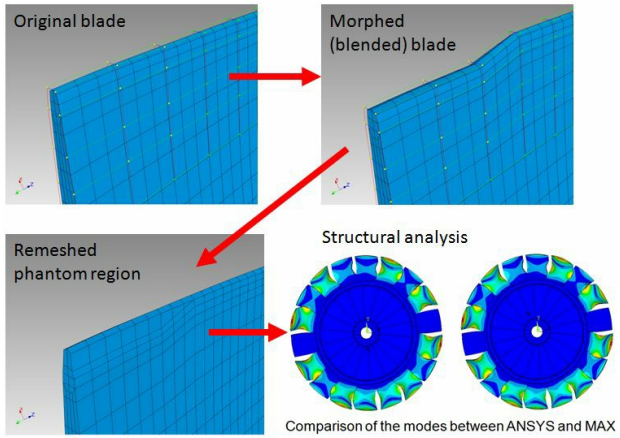
Other transition opportunities: This technology will expand the use of Sculptor to solve more design issues for our current customers such as Gulfstream, Lockheed, Cessna, Pratt & Whitney, United Technologies, Harley Davidson, Honda, Toyota, Formula One Racing, NASCAR, to name a few, and helps us to attract new ones.



Notes: Our latest success has been the application of Sculptor's morphing and optimization to create a Shape Matching capability that allows the as-designed geometry (FEA/CFD mesh and/or CAD model) to be morphed to match the actual scanned (laser scan) shape so that the actual shape of the part may be analyzed for its performance rather than just look at geometry tolerances.

WHAT

Operational Need and Improvement: Blending, currently the only method to repair IBRs, uses specialized tooling to remove adjacent material from the damaged location to alleviate critical stress; however, blending changes the following: modal characteristics of the blade, tuning of the IBRs and (if not balanced) may induce vibration to the IBR. While blends alter IBR mechanics, there can also be aerodynamic effects that adversely affect engine performance (e.g. compressor efficiency) and operability (e.g. stall). Tools currently exist to calculate each of these aspects individually, but no method exists for quickly and easily analyzing the effect of each blend and all blends as a whole.

Specifications Required: The tool must be able to model different "types" of blends with varying aspect ratios, specifically to quickly and iteratively minimize stress concentration ratios at the damaged location as well as percent resonant frequency shifts for different sized blends and blend shapes across multiple mode shapes. The effect these blends have on rotor balance, tuning/mistuning, performance and operability also needs to be modeled, which allows the analysis necessary to determine the optimum blending to repair the IBR, without removing it from wing. It also provides the ability to predict the effect of multiple, larger, and more aggressive IBR airfoil blends on modal characteristics, engine performance and operability. The new tool should leverage commercially available computer aided design and finite element analytical models and processes where available.

Technology Developed: Integrated design and analysis tool for assessing large damage and blends for compressor IBRs on gas turbine engines and other blade systems. This tool will have at its core the automated analytical modeling of as-measured or as-expected airfoil blends for the structural and aero response to the shape change due to blends using the University of Michigan's MAX method and Optimal Solutions Software's Sculptor; expanding the existing library.

Warfighter Value: An expansion of the blend limits on IBRs increases the size, shape, and number of blends/repairs that can be executed on a given IBR thus lowering the cost of engine removal from the aircraft to make repairs and extending the current life cycle of the of the engine.

WHEN

Contract Number: N68335-15-C-0373 **Ending on:** March 1, 2017

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Sculptor applied specifically to turbine blade design shape optimization and shape matching for analysis of as-built blades	Low	Import and morph turbine blade FEA and CFD and CAD models. Optimize performance or shape match to actual manufactured blade shapes	5	August 2015
Use Sculptor to create (morph) blend shapes for analysis and design of blended blades/fans/blisks for repair of foreign object damage (FOD)	Low	Create FEA mesh of blended blade shapes automatically for the analysis of structural and aerodynamic responses due to blended shapes	5	March 2017

HOW

Projected Business Model: For the foreseeable future, we will continue to use our current method of licensing our Sculptor annually or perpetual licenses. This is a license key controlled method where the software is installed on the customers computers, either nodelocked or server based. We do and will offer consulting services, bid on a case by case basis. These can be firm fixed price or cost-plus agreements. We can price by the job or by the hour as desired.We also offer our services to develop special applications that expand Sculptor's current capabilities for a particular solution.

Company Objectives: We are open to any opportunities that would help us expand our customer base in all areas; we have customers around the world in aerospace, motorsports, automobiles, medical, oil/gas, manufacturing, etc. Investment into our company to increase marketing and sales activities, improve and add to Sculptor's features and capabilities, etc. We would be open to being acquired by larger engineering software companies if the terms are attractive and only if our current employees are treated well. Acquisition offers by investors would also be considered.

Potential Commercial Applications: Emerging commercial fleets have also committed to the use of integrally bladed rotors in their compression systems. The analytical methodology developed under this proposed activity is directly applicable to commercial turbine engines. This current work is a specialized application of Sculptor to any turbine blade, fan, propeller, etc. This same methodology can be applied to other non blade damage repair also. Sculptor has many currently available features and capabilities for the general shape optimization of aerodynamic and structural designs. There have been many other problems solved with Sculptor's morphing and optimization tools such as Shape Matching where a given shape can be morphed into a target shape. This is useful in many areas of design such as being able to analyze the actual shape of a part when it is manufacture not to perfect as-designed geometry shape. This results in substantial savings by accepting many parts that would otherwise be scrapped.

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