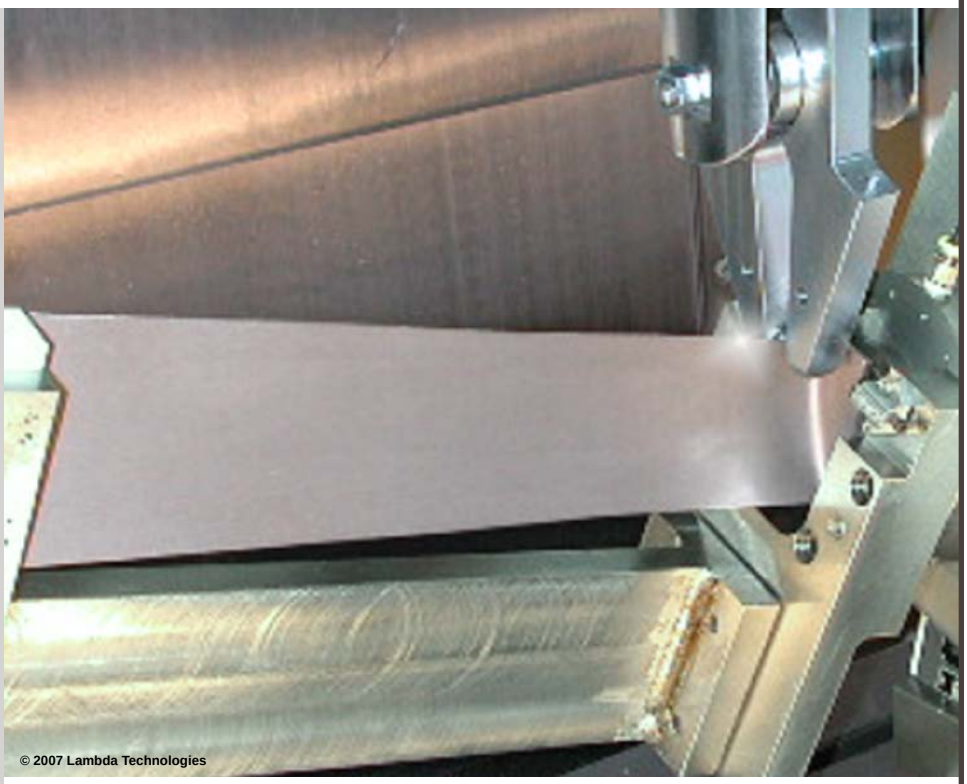
LAMBDA TECHNOLOGIES

Military Aviation

LPB APPLICATION NOTE

ENGINE COMPONENTS



AV-8B Harrier II

Low Plasticity Burnishing (LPB) improves foreign object damage (FOD) tolerance and high cycle fatigue endurance limits while completely mitigating cracking along the trailing edge of the Ti-6Al-4V Alloy F402 First Stage Low Pressure Compressor (LPC1) Vane used in the U.S. Marine Corps V/STOL tactical strike aircraft.

www.lambdatechs.com

Lambda Technologies ■ 3929 Virginia Avenue, Cincinnati, OH 45227
Tel (513) 561-0883 ■ Toll Free/U.S. (800) 883-0851 ■ Fax (513) 322-7186

AV-8B Harrier II

Ti-6Al-4V F402 First Stage Low Pressure Compressor (LPC1) Vane

LPB APPLICATION NOTE

ENGINE COMPONENTS

LPB can increase "time on wing" by improving the service life of the engine vane in the Marine Corps fighter-bomber.

Photo 1: The "Harrier" features the world's only operational V/STOL engine.

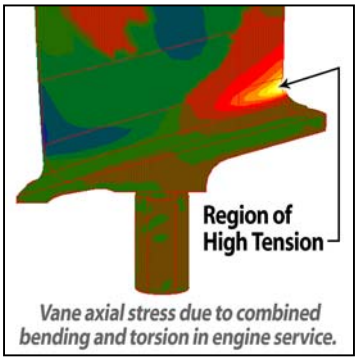


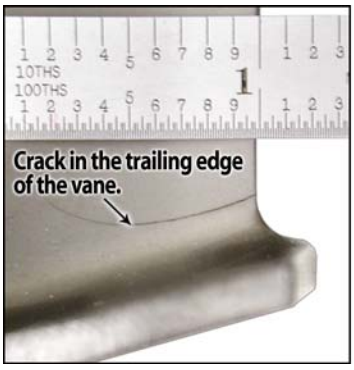
Figure 1: FEA modeling indicating the region of high tension occurring at the site of observed fatigue cracking.

Background information on the engine vane. Since the 1950's, the U.S. Marine Corps has sought a V/STOL (Vertical/Short Take-Off and Landing) tactical strike aircraft that provides close, offensive air support for U.S.M.C. operations. Powered by a single Rolls-Royce Pegasus F402-RR-408 turbofan engine, the AV-8B Harrier II can operate from various basing postures by diverting its engine thrust downward for vertical takeoff and landing using rotating engine exhaust ports thereby eliminating the need for conventional runways.

The F402-RR-408 engine employs Ti-6Al-4V 1st stage low pressure compressor (LPC1) vanes which are subject to both high stresses (Figure 1.) and FOD generated by airborne debris during takeoff. Inspection and maintenance costs adversely impact flight readiness and significantly increase the total cost of ownership and operation of the F402 engine.

Conventional surface treatments offer mediocre results. Shot peening of Ti-6Al-4V has been widely used to introduce a shallow (<125 μm) beneficial compressive layer, at the expense of roughening and heavily cold working the surface. The shot peening does not introduce the through-thickness compression along the trailing edge required to sufficiently improve damage tolerance.

Low Plasticity Burnishing (LPB) provides a superior solution. Applying the LPB process to the F402 LPC1 vane improves FOD tolerance of damage of up to 0.100 in. deep and increases fatigue strength by a factor of 5 with complete mitigation of fatigue failure when tested at the design stresses. See page 2 for further details.



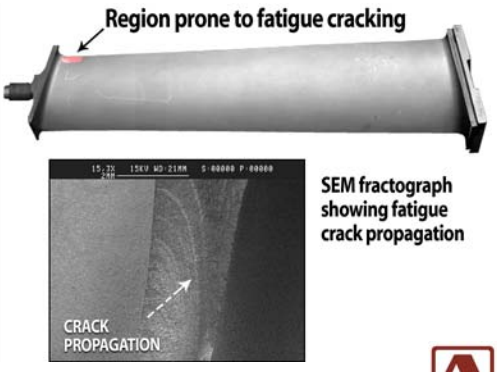


Figure 2: View of the F402 LPC1 vane with fatigue cracking in the region of the trailing edge fillet; the region prone to cracking; and a fractograph showing crack propagation. Testing of LPB processed vanes from fielded engines has shown that LPB improves FOD tolerance, increases HCF endurance limits, and completely mitigates fatigue cracking.

Lambda Technologies ▪ 3929 Virginia Avenue, Cincinnati, OH 45227 **www.lambdatechs.com**
Tel: (513) 561-0883 ▪ Toll Free: (800) 883-0851 ▪ Fax: (513) 322-7186

AV-8B Harrier II

Ti-6Al-4V F402 First Stage Low Pressure Compressor (LPC1) Vane

LPB APPLICATION NOTE

ENGINE COMPONENTS

LPB offers cost effective means of increasing vane's service life.

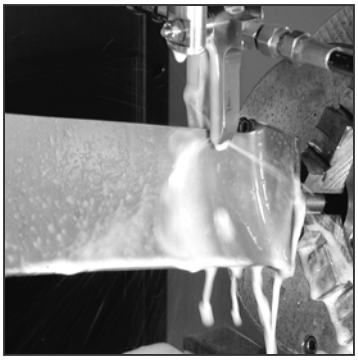


Photo 2: F402 LPC1 vane being processed by LPB caliper tool.

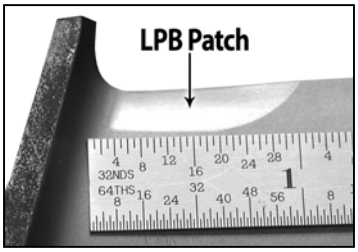


Figure 3: Processed F402 LPC1 vane illustrating the LPB zone.

Navy endorses program to improve engine vane. Lambda Technologies' development of the LPB procedure for the Ti-6Al-4V F402 1st stage low pressure compressor (LPC1) vane was initiated through a Phase II SBIR Contract with NAVAIR, the Naval Air Systems Command. The purpose of this program was to substantially extend the life of the F402 LPC1 engine vane as a result of improving FOD tolerance and increasing fatigue strength by imparting through-thickness residual compression along the vane's trailing edge.

LPB improves FOD tolerance, HCF endurance and mitigates fatigue cracking. Fatigue testing of LPB processed, in-service F402 LPC1 vanes and vane-edge feature specimens manufactured from Ti-6Al-4V material were conducted and the results are shown in Figures 4 and 5, respectively. LPB processing of fielded vanes, with a current trailing edge damage tolerance of 0.002 in., resulted in a ten-fold increase in damage tolerance to at least 0.020 in. FOD. LPB applied in the critical high stress area on the trailing edge doubled the fatigue strength from nominally 55 to 110 ksi. FOD up to 0.060 in. was tolerated in the vane-edge feature specimens with a fatigue strength of 60 ksi at R=0.1. The test results were corroborated with linear elastic fracture mechanics modeling for the residual stress level and FOD sizes investigated.

LPB improves the service life of the F402 LPC1 vane by imparting through-thickness residual compression to counter the applied tensile stresses in the component thus increasing the vane's damage tolerance and eliminating fatigue cracking. LPB offers a significant reduction in the cost of aircraft ownership and improved fleet readiness.

Figure 4: Fatigue strength at 10^7 cycles for as-received and LPB vanes with and without 0.020 in. deep damage.

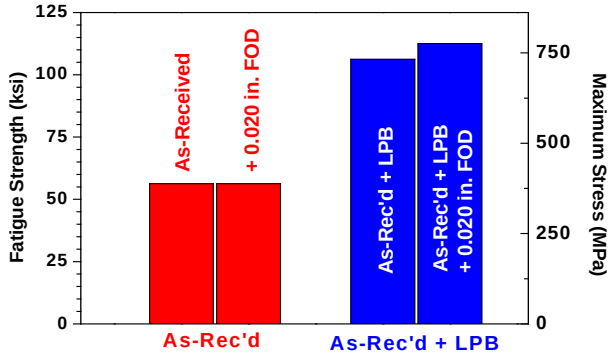


Figure 5: Fatigue strength at 10^7 cycles for baseline and LPB vane edge simulation specimens. Note the deeper FOD for LPB test.