ACCURATE BRAZING
And Thermal Processing
CASE STUDY 1.02

2020 INDEPENDENT HIP STUDY

HIP Rejuvenation to Extend the Life of FR7FA.02, Stage 1 Buckets.

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In this case study, specimens were removed from the root and airfoil, and 2 heat treatments were evaluated, i.e. a 2050°F/2hrs + 1550°F/24hrs versus a HIP Rejuvenation that exposed the material to 2200°F for 4 hours at 15ksi. In addition, tensile and stress rupture tests were conducted as shown in Table 1. Tensile tests were undertaken at room temperature, 800°F and 1200°F. Stress rupture tests were undertaken at 1400°F/95ksi and 1800°F/27ksi to ensure both a low temperature/high stress level and high temperature/low stress level condition would be evaluated.

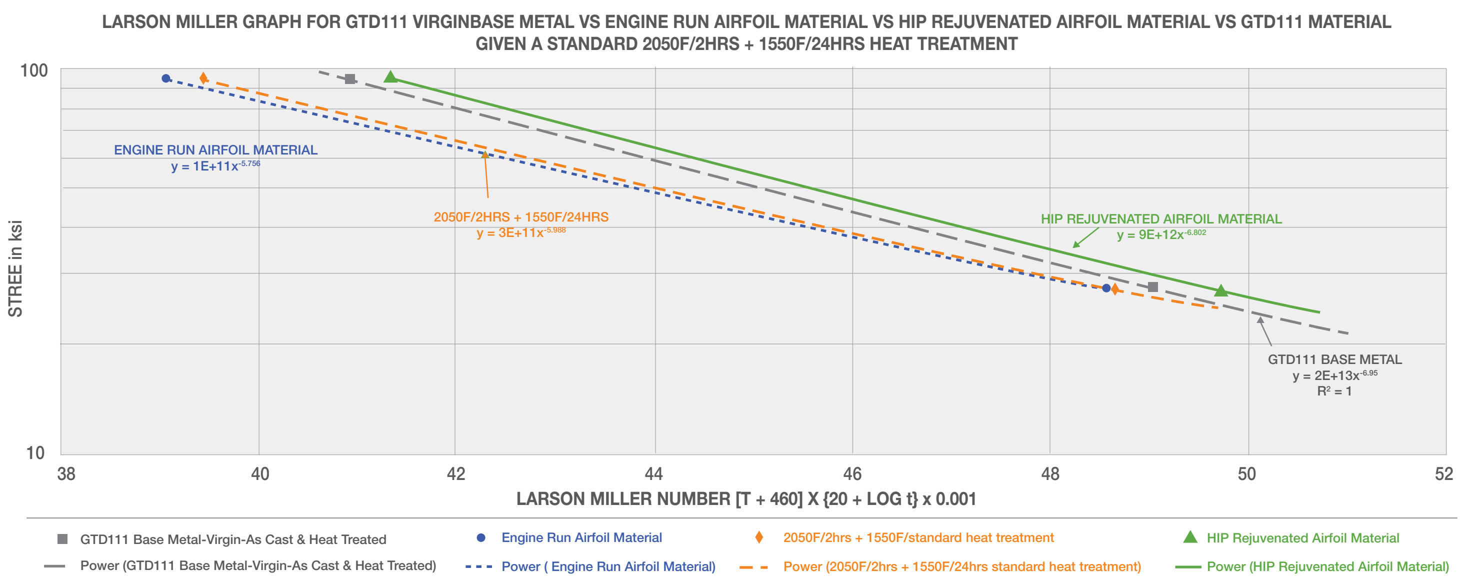
FIGURE 1: A Fr7FA.02, stage 1 bucket after 2 service intervals

TABLE 1: Tensile and Stress Rupture comparison between certain repair heat treatments undertaken on engine run airfoil and root material excised from Fr7FA.02, stage 1 buckets

CONDITION OF MATERIAL	LOCATION OF SPECIMEN	TEST TEMP °F	STRESS Ksi	UTS Ksi	0.2% YS	ELONG %	RoA %	HOURS TO FAILURE
Engine run 2 HGP intervals	Root	70	N/A	172.4	135.8	7	11	N/A
2050F/2hrs + 1550F/24hrs	Root	70	N/A	144.5	123.6	9	14	N/A
HIP Rejuvenated	Root	70	N/A	148.2	126.5	9	10	N/A
Engine run 2 HGP intervals	Root	800	N/A	142.8	124.8	8	12	N/A
2050F/2hrs + 1550F/24hrs	Root	800	N/A	157.8	121.2	7	11	N/A
HIP Rejuvenated	Root	800	N/A	139.9	110.4	9	14	N/A
Engine run 2 HGP intervals	Airfoil	1200	N/A	161.6	124.2	6	8	N/A
2050F/2hrs + 1550F/24hrs	Airfoil	1200	N/A	180.5	116.3	9	15	N/A
HIP Rejuvenated	Airfoil	1200	N/A	181.2	118.6	7	12	N/A
Engine run 2 HGP intervals	Airfoil	1400	95	N/A	N/A	23	31	10
2050F/2hrs + 1550F/24hrs	Airfoil	1400	95	N/A	N/A	24	33	16
HIP Rejuvenated	Airfoil	1400	95	N/A	N/A	19	24	165
Engine run 2 HGP intervals	Airfoil	1800	27	N/A	N/A	31	35	32
2050F/2hrs + 1550F/24hrs	Airfoil	1800	27	N/A	N/A	28	49	32
HIP Rejuvenated	Airfoil	1800	27	N/A	N/A	27	35	100

HGP = Hot Gas Path, UTS = Ultimate Tensile Strength, YS = Yield Strength, Elong = Elongation, Temp = Temperature, RoA = Reduction of Area, N/A = Not Applicable to that test (Tensile or Stress Rupture)

As evident from Table 1, the airfoil material subjected to the HIP Rejuvenation heat treatment had 3X the life compared to the standard 2050°F/2hrs + 1550°F/24hrs heat treatment when tested at 1800°F/27ksi. In addition, the airfoil material subjected to the HIP Rejuvenation heat treatment had 10X the life compared to the standard 2050°F/2hrs + 1550°F/24hrs heat treatment when tested at 1400°F/95ksi. This shows the importance of heat treatment in the repair process of hot section turbine buckets. The tensile test data evident in Table 1 shows that at 1200°F, there is no statistical difference between the HIP Rejuvenation heat treated airfoil material when compared to the standard 2050°F/2hrs + 1550°F/24hrs heat treatment. Tensile properties are more important for the root attachment area, and the data in Table 1 indicated that at room temperature, the tensile properties of both the HIP Rejuvenated and the standard 2050°F/2hrs + 1550°F/24hrs heat treatment are statistically the same; whereas, at 800°F, the standard 2050°F/2hrs + 1550°F/24hrs



heat treatment gave better tensile strength values when compared to the HIP Rejuvenated material. However, stress rupture properties as seen in figure 2 are of more importance compared to tensile properties on rotating hot section gas turbine buckets, and therefore the end user preferred that the buckets be given a HIP Rejuvenation heat treatment versus the standard 2050°F/2hrs + 1550°F/24hrs heat treatment in the repair process of these buckets. It should be pointed out that the HIP heat treatment is not the only heat treatment performed in the repair process, so all specimens tested in this Case Study had 3 heat treatments following the HIP cycle, namely:

1. A full solution heat treatment above the gamma prime solvus temperature
2. A coating diffusion cycle
3. An age heat treatment cycle

FIGURE 2: (above) Shows that HIP Rejuvenated material had the best stress rupture properties and is better than virgin like base metal. The standard heat treatment of 2050°F/2hrs and 1550°F/24hrs does not rejuvenate the base metal at all. Obviously, the engine run material has the worse stress rupture properties as the exposure to high temperatures and stresses had degraded the material.

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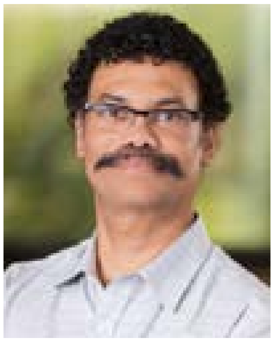

Dr. Miglietti is currently the President and Principal Metallurgical Consultant of Miglietti and Associates, LLC, a consultancy company based in Kansas City, Missouri. Prior to this he was Director of Repair Technology at ProEnergy and worked for 7 years at PSM-An Alstom Company. In addition he worked for 5 years at GE’s Repair Development Center and 5 years for Sermatech International as a process repair engineer and as a component repair engineer respectively. His principal responsibility was the development of novel repair techniques and processes for components, operating in advanced land-based gas turbine engines, such as the Frame 7FA.03, GT24/26 and W501F/M501F engines. He has over 30 years of experience and expertise in the Welding (GTAW and Laser), Brazing (Narrow and Wide Gap Diffusion), FIC, Acid Stripping and Heat Treatment of Ni and Co-base superalloys. Dr. Miglietti is the outgoing chairman of the Commission XVII – “Brazing and Diffusion Bonding” of the International Institute of Welding (IIW) and was past chairman of the Manufacturing, Materials and Metallurgy Committee of IGTI, an affiliate of ASME. He has authored or co-authored 47 technical papers and has 13 repair technology patents. Today, he has a strong focus on assisting clients with materials characterization and mechanical property evaluation of Additive Manufactured/3D printed components, as well as providing heat treatment information for these components.

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