

PERFORMANCE IMPROVEMENTS OF A WESTINGHOUSE W-171 GAS TURBINE BY COATING AXIAL COMPRESSOR BLADING

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ABSTRACT

Gas turbine performance and efficiency is of increasing interest with the rising cost of energy. The axial compressor of a gas turbine requires 70% of its generated horsepower for operation, which makes the compressor an ideal place to develop efficiency improvements. By using an iron-aluminide intermetallic coating on the compressor blading of a gas turbine, it is possible to reduce blade surface friction; thus increasing efficiency, performance and reducing wear. This type of coating was used to increase the usable horsepower of a W-171 gas turbine in the Brownsville, Texas, Union Carbide Plant more than 10%.

INTRODUCTION

On June 8, 1981, a base loaded Westinghouse W-171 gas turbine, driving a Westinghouse 12,500 KW generator, was shut down for a major overhaul. Due to repeated vibration problems with the exhaust end of the turbine since 1978, it had been decided that a complete and extensive overhaul of the rotor was necessary. Initial examination of curvic clutch faces after the rotor disassembly revealed that clutch faces would have to be re-ground, and four weeks would be needed to complete the job. It was also found that eleven out of fourteen rows of compressor rotating blades were worn or damaged and needed replacement. Twelve of the fourteen rows of compressor rotating blades were original blades and had 130,029 fired hours. Also rows 6-14 of stationary compressor diaphragms were eroded and required replacement.

The two month outage required to rebuild the rotor and the need to replace the compressor blading made this overhaul an ideal time to test a compressor blade coating.

COMPRESSOR

The Westinghouse W-171 gas turbine uses a fourteen stage axial flow compressor to generate compressed air for cooling and ignition with natural gas. A 410 S.S. alloy is used in the construction of the blading, both stationary and rotating, for all 14 stages of blades as well as the inlet and outlet guide vanes.

Although extensive compressor blade erosion was found during the compressor examination it was not unexpected due to the loss of generator output since December, 1980.

The compressor performance information is available in Table I.

COATING

The blade coating selected for this compressor was S-SA12 which is an iron-aluminide intermetallic formed by the packed cementite process. This coating was developed and applied by Chromolloy's Turbine Support Group in San Antonio. The S-SA12 coating was selected because of higher surface hardness and a finish of less than 10 μ -IN.

Application of the coating is made by cleaning the blade and then packing in an aluminum powder before heating in a furnace. During the furnace heating period an iron-aluminide intermetallic is formed on the surface of all metallic surfaces. Then a series of conversion later applications and polishing steps are applied to achieve the final product. Although the S-SA12, at this time, had never been applied to an industrial gas turbine, the coating has performed well with no sign of failure.

PERFORMANCE DATA

It was important to have a set of base line data on the turbine to compare with the turbine's performance after coating. Due to the reoccurring vibration problems of this particular W-171, the Operation and Maintenance Departments had been recording operating conditions since May, 1980. A selection of this data can be found in Table I. The base line data selected was well before any significant losses in generator output appeared.

Immediately after start-up on the 29th of August, 1981, the generator was load tested for performance. The output on the generator was recorded at 16,000 KW, 87 psi compressor discharge pressure, 78°F compressor inlet temperature, no pressure on the exhaust duct, and a heat rate 14,531 BTU/KW-HR. This was not considered a true performance test because the waste heat boiler was not available to provide the normal 9" of water back pressure on the turbine exhaust. In Table I is the November 20, 1981, data showing the turbine output under normal conditions. All the recorded data since coating was compared to the September 24, 1980, and design data for improvement calculations.

Comparing the August, 1982, data with data taken before the coating reveals that heat rate improvements have been lost as well as some of the horsepower improvements. This was caused by an oil film on the blades which allowed dirt and volcanic ash to adhere. The oil film came from a vent off the reduction gear box. The fumes were inadvertently being drawn back into the inlet through the filters.

Although the oil vapors have been diverted, the compressor is still dirty. Pecan hull cleaning on line has been tried but it only provides a temporary return of full output. A water-

TABLE 1. GAS TURBINE PERFORMANCE DATA

	Design	8-24-80 (9:00 PM)	9-30-81 (1:00 PM)	11-20-81 (11:00 AM)	6-4-82 (9:00 AM)	6-4-82 (10:00 AM)	8-15-82 (11:00 AM)
KW	12,020	12,000	13,500	15,100	12,700	12,500	13,000
Comp. Inlet Temp. — °F	90	90	90	65	91	96	90
Turbine Inlet Temp. — °F		1490	1475	1490	1500	1500	1510
Exhaust Temp. — °F	802	800	797	797	795	795	797
Inlet Duct Static Press-in-H ₂ O	2	5.3	5.5	5.9	5.2	5.2	5.4
Inlet Duct. Diff. Press-in-H ₂ O		43.0	44.7	46.9	42.8	42.5	42.9
Comp. Disch. Press — psi		79	81	86	79	79	80
Exhaust Duct. Press-In-H ₂ O	10	8.7	8.9	8.8	8.8	8.9	9.1
Atmospheric Press — psi	14.69	14.70	14.64	14.81	14.58	14.58	14.74
Fuel Gas Flow — MM BTU/HR	180	196	203	223.6	207.0	206.7	212
Heat Rate BTU/KW — HR	14,980	16,334	15,037	15,104	16,299	16,480	16,300
Comp. Air Flow Cfm	164,500	214,387	218,583		213,888	213,137	214,094
Horsepower	16,118	16,092	18,104	20,249	17,031	16,766	17,433
Power Increase %			12.5	25.8	5.8	4.2	8.3
Fuel Consumption Inc. %			3.6	14.2	5.6	5.1	8.16
Heat Rate Decrease %			8.6	8.1			
Air Flow Increase %			1.9				
Hp Increase %			12.5	25.8	5.8	4.2	8.3

solvent wash will be necessary to return the machine to full capacity as recorded by the September 30, 1981, data.

EXPENDITURES & BENEFITS

The initial expenditure for coating all blading was \$36,000. Any other compressor blading cost were not deducted from the savings because the blade replacements were necessary to return generator output to design.

As of August, 1982, the savings has been \$200,000 from reduced consumption of higher cost power. Also a savings of

\$130,000 was realized due to the improvement in heat rate for six months after coating and before the blades became fouled.

CONCLUSIONS

There is no doubt a \$294,000 savings is significant. The rising costs of purchased power will increase the savings each year. If the coating lasts for a full two year interval, the savings will pay for the cost of the recommended biennial overhauls. Coating gas turbine compressor blading definitely has its benefits, to what extent can only be shown with service.