Weir Power & Industrial

Case Study

Natural gas compressor re-rate

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Natural gas compressor re-rate in South East Asia

1.0 Background

Three identical natural gas compression trains on a natural gas platform in South East Asia were commissioned in 2002.

The trains comprised of GE LM2500 driven 25MB4-3 Centrifugal Gas Compressors via Speed Increasing Gear-Box.

2.0 Problem definition

All three units experienced failures due to several reasons soon after commissioning.

The failures on the compressors were associated with fouling and resonance. Metallurgical analyses on failed impellers suggested that the broken impellers failed due to fatigue. Modal analyses clearly suggested that there was impeller natural frequency inside the speed range of the compressors. Traces of mercury were found inside the gas although no direct mercury-related failure was reported.

The resonance issue could not be resolved since it would require manufacture of a new impeller. Instead, the impellers were scalloped by the OEM (see Figure 1) and the maximum running speed (MCS) was reduced. The excessive scalloping and the reduced speed range reduced the compression capability of the compressors, while decreasing efficiency levels.

In addition to the operational and design related issues, the Operator introduced a new gas platform. The natural gas from the new platform would be directed to the existing platform and the combined gas would be compressed by the existing compressor trains. As a result, the aerodynamic design of the existing compressors was no longer capable of handling the combined gas.

Figure 1. Scalloped impeller on original rotor.

3.0 Solution

In order to resolve the design related issues and to account for the additional gas from the new platform, the Operator opened a bid for a re-rate to the existing compressors. The re-rate was required to:

- Resolve resonance issues
- Handle existing production
- Handle new production
- Handle combined existing & new production

with a maximum available power of 15.5 MW. A factory test (FAT) and later a site test (SAT) were required for verification of the design. The materials used on the re-rate would have to be NACE compliant as well as mercury resistant.

The solution to the re-rate offered by Weir Power & Industrial's Turbomachinery business was a 7 stage back-to-back design with 19 inch impellers. The existing driver, gear-box, couplings and ancillaries were to be retained as is. Existing dry-gas seals and seal system would also be retained. Existing journal bearings and thrust bearing were to be utilized upon confirmation by rotordynamic analyses and detailed design work.

To be able to fulfil all duty requirements, the compressor efficiency had to be high. To achieve the high efficiency levels, vane diffusers were introduced at each stage. See Table 1 for performance data. To prevent any resonance issues, modal analyses of all impellers would be performed during design and later verified by ring testing. To delay fouling, the rotor wetted surfaces would be coated with Teflon based coatings.

The design would be verified by an ASME PTC-10 Type II factory test and a site acceptance test (SAT) following commissioning.

All design, manufacture and commissioning work was to be carried out by Weir Power & Industrial's Turbomachinery business.

In addition, dimensions of existing equipment (e.g. casing, bundle, rotor, housings, etc.) were to be measured and amendments to operation and maintenance manuals were to be provided by Weir Power & Industrial.

Project management and regional support was to be provided by a third party.

	CASE 1		CASE 2 - RECYCLE		CASE 3	
	LP	HP	LP	HP	LP	HP
GAS HANDLED	Case 1	Case 1	Case 2	Case 2	Case 3	Case 3
STANDART FLOW, MMSCFD	175	175	116	132	255	255
WEIGHT FLOW, kg/h	197477	197477	146848	162688	314633	314633
INLET CONDITIONS						
PRESSURE (kPaA)	1800	5199	1500	4661	3000	6706
TEMPERATURE (°C)	26.69	42.95	42.61	42.92	42.61	42.92
MOLECULAR WEIGHT (%)	22.58	22.59	24.69	24.69	24.68	24.68
COMPRESSIBILITY (Z_1)	0.954	0.890	0.964	0.856	0.927	0.835
INLET VOLUME, (m³/h)	11543	3934	10029	3294	10333	4172
DISCHARGE CONDITIONS						
PRESSURE (kPaA)	5349	12500	4611	12500	6856	12500
TEMPERATURE (°C)	119.3	121.5	142.7	131.5	113.7	98.2
COMPRESSIBILITY (Z_1)	0.957	0.922	0.965	0.916	0.931	0.868
FRICTION POWER (KW)	50		49		30	
kW REQUIRED (ALL LOSSES INCLUDED)	15484		12699		15207	
SPEED (RPM)	10341		10211		8780	
POLYTROPIC HEAD (kJ/kg)	131.8	103.2	137.7	108.9	90.5	61.1
POLYTROPIC EFFICIENCY (%)	83.9	82.9	83.5	81.5	83.3	79.8
CERTIFIED POINT	YES		NO		NO	

Table 1. Re-rate performance data.

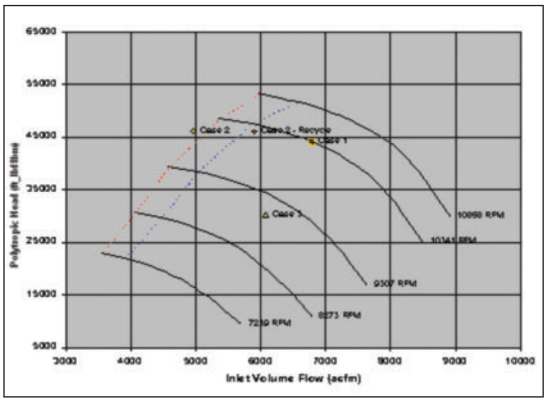


Figure 2. Low pressure (LP) section performance map.

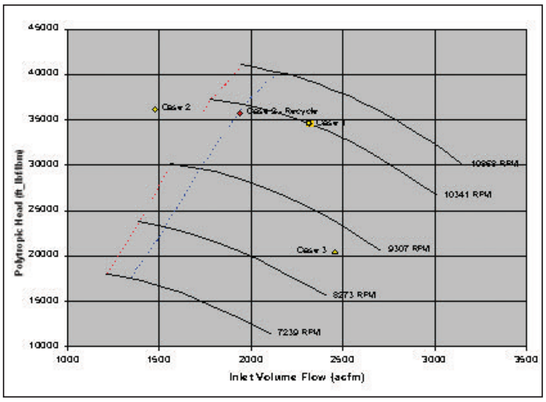


Figure 3. High Pressure (HP) section performance map.

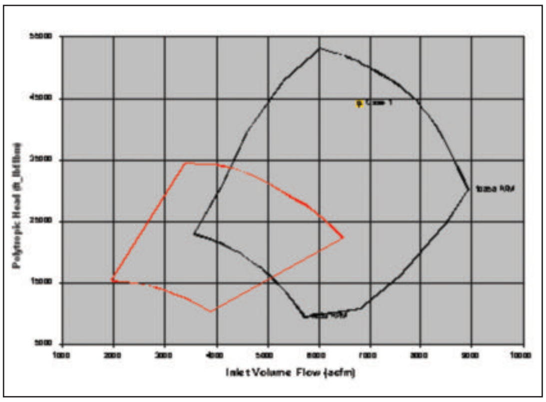


Figure 4. Existing vs re-rate LP performance map.

4.0 Project execution

4.1 Design

A joint project team was formed by Weir Power & Industrial's Turbomachinery business and the third party. All design work was carried out by Weir personnel. An initial design was carried out using approximated dimensions of the existing equipment from user-supplied drawings. This design provided approximate rough stock dimensions for critical components.

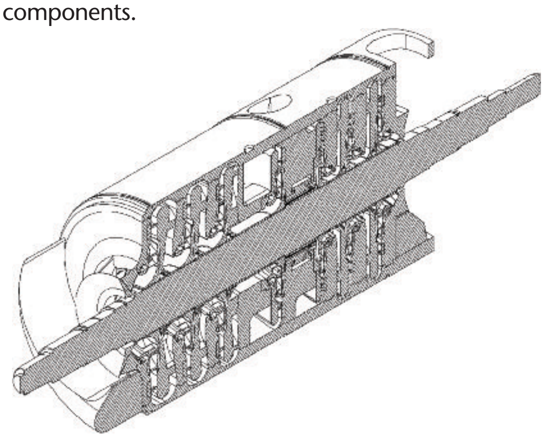


Figure 5. Re-rate design

Later, the Design Engineer and the Drafter visited the site, where a spare rotor and bundle of the existing compressor was made available.

The impeller modal analysis was carried out after all aerodynamic and stress analyses were completed. The modal analysis assured that there were no impeller structural modal frequencies inside the running speed range of the compressor. The calculated frequencies were later verified by ring testing.

Inlet scoops were added to each section inlet to better guide the flow into the first stage. Low solidity vane diffusers were designed for each diffuser to improve efficiency levels.

The labyrinth seals were designed with swirl-breaks to reduce destabilizing effects. The labyrinth material was chosen as Arlon to protect against mercury damage, as agreed with the customer.

The rotordynamic analysis was carried out with the new rotor and stability analysis was also carried out. The train torsional analysis was performed and results suggested that the existing coupling could be re-used.

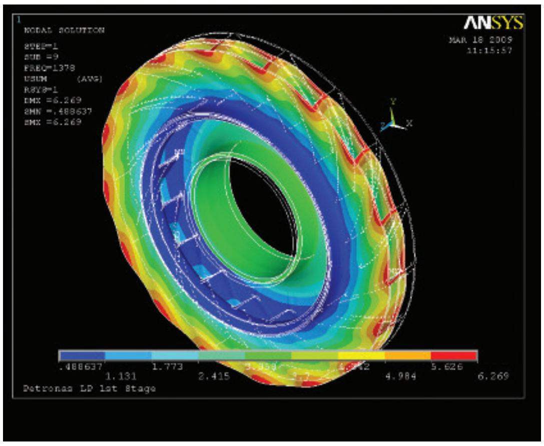


Figure 6. LP 1st stage modal analysis – 9th mode.

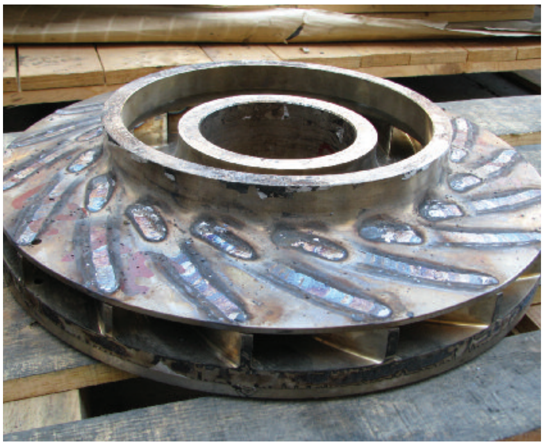
Thrust analysis suggested that the existing thrust bearing could be re-used. In addition, the existing dry-gas seals and the high-speed coupling were re-used.

4.2 Manufacturing and assembly

Manufacturing was undertaken at Weir facilities or Weir-approved vendors.

The impellers were milled as two pieces; the blades were milled into the hub and a shroud with weld slots was manufactured. The blade leading edges were welded with stellite weld rods to protect against erosion in the field. After heat treatment, the impeller was finish-machined, NDT inspected, balanced and spun to 115% of the Maximum Continuous Speed.

Hub and shroud weld prep.



Post weld.

Figure 7. Impeller manufacturing steps.

Following assembly and sequential low-speed balance, the rotor was coated by a Teflon coating to protect against corrosion. The rotor was then high-speed balanced.

Figure 8. Teflon coated rotor.

The inner casing and the diaphragms were also manufactured and assembled.

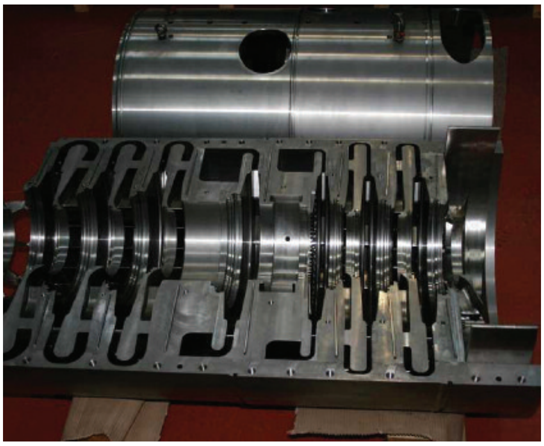


Figure 9. Manufactured bundle

4.3 Factory testing

ASME PTC-10 Type II aerodynamic performance and API617 mechanical testing was performed at Weir Power & Industrial's Turbomachinery facility in Barton-on-Humber in UK. This was carried out by assembling two purpose-built loops, one for the LP and one for the HP section. Each loop contained a flow control valve, cooler and flow meter together with the instrumentation to record the suction and discharge pressures and temperatures. The compressor was driven by a variable speed DC motor driving through two gearboxes to achieve the required rotational speed. The performance testing was carried out using Nitrogen at equivalent conditions and the field performance calculated in accordance with the procedures in PTC10.

Both aerodynamic and mechanical tests were successfully completed for both the machines that were tested.

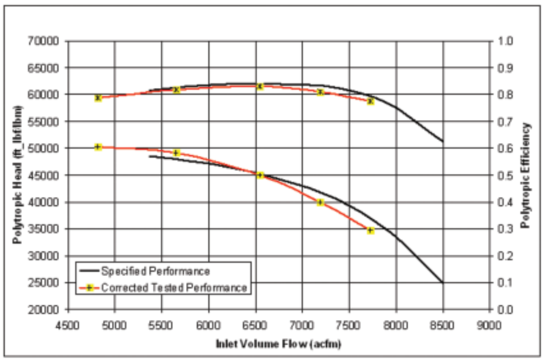


Figure 10. LP section FAT performance.

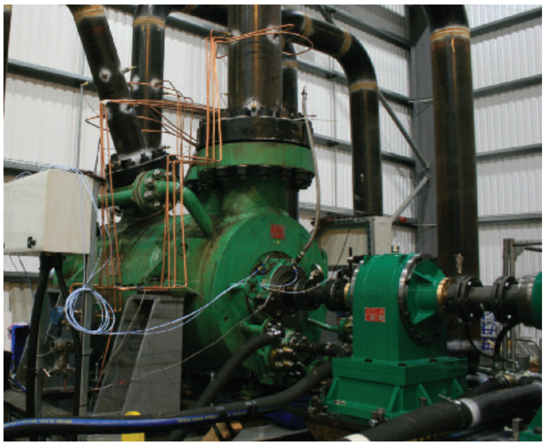


Figure 11. Test setup – compressor.

4.4 Commissioning and site testing

The first unit was shipped to site and was commissioned on the platform in mid-2011. The unit was immediately out on-line, offering significant power savings compared to the existing units.

Figure 12. First unit commissioned at site.

Turbomachinery Engineering

Humber Road
Barton on Humber
North Lincolnshire
DN18 5BN
UK

Telephone: +44 (0)1652 632 702
Facsimile: +44 (0)1652 633 401
E-mail: turbomachinery@weirgroup.com
Web: www.weirpowerindustrial.com

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Power & Industrial
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