

Innovative on-line wash nozzle for large gas turbines



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Experience of more than a decade of on-line compressor washing has shown a loss of its effectiveness in the largest gas turbines, with higher mass flow preventing uniform wetting of compressor blades. To overcome this problem, Turbotect have developed an air-assisted nozzle system, specifically for the largest gas turbines which has been successfully demonstrated at Peterborough power station and will be the basis of their future offerings.

Fifteen years ago Turbotect introduced an on-line compressor washing system and embarked on a comprehensive series of field trials at a district heating plant in the Netherlands. Since then, gas turbines have become bigger and the need for regular on-line compressor washing is maintained in the competitive merchant plant environment.

The extent to which gas turbine output is degraded with time depends on where it is located and the quality of and maintenance of the intake filters. In a typical urban situation beside a busy road junction leading to an industrial estate, the same conditions as in a test program back in 1990, a combined heat and power plant serving it could see a complex cocktail of traffic fumes and process emissions which could cause rapid loss of output in two or three days. At a rural site, an ostensibly clean environment could carry pollen and fine dust particles at different times of year, and on coastal sites there is the problem of salt spray.

Operators, as a matter of principle, perform an off-line wash every time the gas turbine is shut down. This will recover the lost output from a dirty compressor, but degradation will begin again as soon as the gas turbine restarts at the end of the outage.

Manufacturers now supply on- and off-line compressor washing systems for their gas turbines. This comprises an array of nozzles placed in the air inlet plenum which direct a spray of fine water droplets into the intake. A wash skid, as shown overleaf on the cover at Senoko, Singapore, which

adds detergent and distributes the solution to the nozzles completes the installation.

Peterborough power station, about 150 km north of London, is a 360 MW combined cycle with two GE MS9001E gas turbines and one steam turbine. Completed in 1993, for the first seven years of its life it ran as a base load station but with the introduction of the New Electricity Trading Arrangement (NETA) in April 2001 it has moved over to a 2-shift operation as one of now five gas turbine stations owned by British Gas Power Group.

Under NETA the power generators make contracts with energy traders who sell power to the consumer. While the object of the change was to create a more competitive market which would reduce the price of electricity to consumers it has created a situation which has highlighted a strong overcapacity and brought several generators to the fringe of bankruptcy.

The people who have fared best under the new arrangements are those with a large customer base of their own. British Gas Power are a division of Centrica the company which supplies gas to the domestic market. Thus with a nationwide customer base and five gas-fired power stations they were able to build up a market through an attractive tariff package for gas and electricity to domestic consumers. Not only that, but with the take over of Kings Lynn and Peterborough they also acquired the customer base of the former Eastern Electricity, who were the largest of the original Regional Electricity Companies at privatisation.

Peterborough therefore supplies

the domestic market which on weekdays builds up at the end of the afternoon as people return home from work. Demand for electricity is at its highest until in the late evening it starts to fall. The station therefore comes on at about 5.00 pm and shuts down at midnight. The plant is situated on the eastern edge of the city of Peterborough with farmland on two sides and a main feeder road to a motorway passing in front of it.

When the plant was built, GE (then as European Gas Turbines) supplied their own compressor washing system for which the station bought detergents from Turbotect.

In the early years of base load operation, the plant was being shut down periodically for an off-line wash. However, as word of the Turbotect system got around owners became interested in on-line washing, since it could retard output degradation and increase the intervals between outages for off-line washing.

This is best illustrated by an example. Suppose that the unwashed gas turbine loses 100 kW of output per day, and that when output is down by 3 MW the unit is shut down for an off-line wash. This will recover the 3 MW lost and twelve washes, each probably involving a weekend outage, will have to be performed each year.

However, if a daily on-line wash is performed, it won't recover all the loss, but it might recover 80%, so that the station loses only 20 kW/day. Since the off-line wash is triggered when 3 MW has been lost this condition will not now have been reached until after 150 days, thus nine outages will have

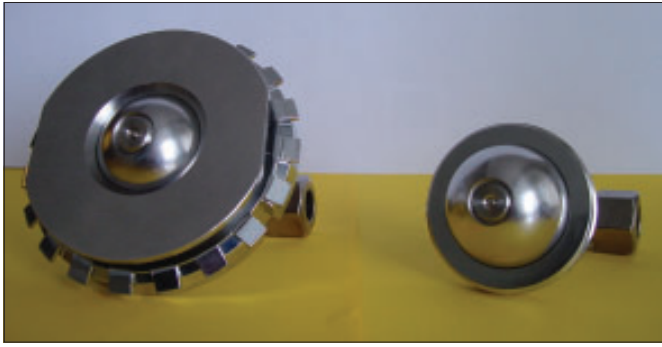


Fig.1: The PSA Mark 1 nozzle in current use has a steerable spherical nozzle which projects into the intake air stream.



Fig.2: The PSA Mark 3 nozzle, designed for large gas turbines, has low pressure air jets at either side of the water nozzle.

been avoided and as a result the availability and power output of the plant will have increased significantly.

This then is the underlying philosophy at Peterborough. Although they are shutting down every day they do not have enough time for an off-line wash. It is also in their interest to have higher availability in case a big nuclear or coal-fired unit should trip. In this event National Grid can call up Peterborough for frequency control even though it may be shut down at the time. So while the station responds mainly to domestic demand, they must also be available at any time. By performing an on-line water wash every day they slow down the rate of degradation of the available, saleable output and reduce the number of outages needed to correct it.

The original Turbotect PSA Mark 1 on line nozzle uses a low-pressure injection system working at 4 bars and producing very small droplets which can easily penetrate the boundary layer and enables good wetting and cleaning of the first row vanes.

However, as gas turbine output has grown, mass flow has increased along with the machine diameters and it has been found that droplets cannot so easily penetrate the air inlet stream. What in fact happens is that they are deflected in their mid course trajectory which reduces the efficiency of blade wetting and reduces the effectiveness of on-line washing. With some competing systems, the droplets are concentrated along the inlet cone so that as they enter the compressor they impact the blade root and do not spread over the blade surface, and in time this can lead to serious erosion. Many operators of the larger gas turbines have told *Turbomachinery International* that although they have on-line and off-line capability, they only do off-line washes.

The challenge then was to develop a nozzle which would allow the same size droplets to penetrate much further

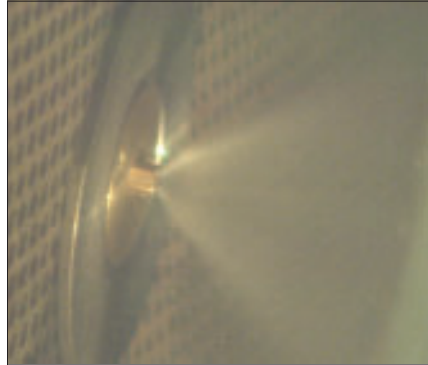


Fig.3: PSA Mark 3 nozzle during on-line wash at Peterborough shows how air jets push out the droplet spray, and that there is no early deflection or dribbling from the nozzle outlet.

across the inlet air flow and thereby provide more effective wetting of the blade surfaces.

Initial tests were made in Thailand at EGCO's Rayong plant. Variations in nozzle positioning and tip geometry were explored using existing and various other nozzle designs in tests carried out during 2000. However data collected was not conclusive and further tests were made the following year at Peterborough, including comparison with some commercially available air-assisted nozzles. Parallel studies were made on a wind tunnel at a Swiss university, as a result of which the PSA Mark 3 nozzle, for which a patent is pending, has been introduced and which is now being applied to GT2 at Peterborough, while GT1 remains with the GE designed OLWW nozzle system as originally supplied.

Like the PSA Mark 1 nozzle, the PSA Mark 3 nozzle is also a low pressure system operating at 4 bars with a droplet size in the range 50 to 250 microns. This flush mounting design is an air-assisted type with a flat water spray that is shielded and sandwiched between two high velocity flat-profile air sprays. These dual air sprays protect the water spray and punch it through the boundary layer into the main air stream. The water

droplets are protected from premature deflection, and a longer penetration trajectory is obtained. In practice this means that for a larger gas turbine the Turbotect Mark 3 on-line nozzle can deliver a more controlled and stable water spray pattern into the air inlet stream which will improve wetting and cleaning performance.

In a comparison test under normal atmospheric conditions a Mark 3 nozzle mounted 1.2 metres above a surface, and directed horizontally, produced a wetting distance from 0.8 to 2.0 metres without air assistance. With air assistance the range of wetting increases to 4.5 metres.

There is also a greater volume of water with air assistance: 0.8 litres/min, compared with 0.38 litres/min for the unassisted Mark 1 nozzle. However a fewer number of Mark 3 nozzles is required for the same gas turbine air inlet, so that the total water mass flow is the same as required for Turbotect's Mark 1 design.

The Mark 1 nozzle continues to be used for the smaller gas turbines but for the larger gas turbines, the Mark 3 nozzle is designed with the same fitting assembly so as to provide an easy retrofit for the Mark 1 unit.

For the GE Frame 9 E engine, given the improved spray characteristics and droplet penetration of the air flow, only sixteen nozzles will be fitted in selected positions and blanking plates fitted in place of the other Mark 1 nozzles. Water requirement will only be 12.8 litres/min at 4 bars. This is still an extremely low volume system compared with some others on the market without air assistance. The risk of compressor blade erosion is greatly reduced due to the very low total mass flow, small droplet size range, and optimised positioning of nozzles around the intake bell mouth.

At Peterborough comparative tests continue for twelve months with the new nozzles installed on GT2 and the original GE system on GT1.



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