Composite fans and the efficiency advantage

MechCaL – a Technology Top 100 winner recognised for the design and manufacture of advanced fans – is a South African company that is currently making inroads into international OEM markets. *MechTech* visits the company's Pretoria premises and talks to Gavin Ratner, MD (left).

MechCaL's modern 45 kW energy efficient axial ventilation fans offer lower total cost of ownership and have become the company's 'commodity' product.

MechCaL was founded in 2005 as a calibration service company by a group ex-CSIR engineers, but quickly migrated towards combining its accumulated expertise in composite materials and structures, aerodynamics and computational fluid dynamics towards modernising fan technology. "Our design advantage is in the use of computational engineering methods and the use of fit-for purpose-materials, which allows us to easily tailor solutions to clients' needs," begins Ratner. "And this unique advantage has allowed us to develop technologically superior range of centrifugal, axial and jet fans, along with several custom designed axial flow and centrifugal fans for niche OEM applications," he adds.

"At the CSIR, I was involved in the experimental side and I was the facilities manager for the supersonic blow down wind tunnel. This company was formally registered by a group of senior CSIR designers, from defence, aeronautics and the structures division. We were involved with flutter prediction and analysis on aircraft wing components and complex composite development using CFD and finite element analysis," he adds.

For the impellers on the axial vane fans EN19 steel proved to have better impact resistance, but composite cone and stator vanes have been retained.

Initially, MechCaL's seven full time and two part time engineers, began offering customised fans for problem areas that few other companies were willing to tackle, such as compact centrifugal cooling fans for electrically driven mobile haul trucks. A typical ultra-heavy haul truck has a payload of up to 400 t and has a 2,0 MW diesel engine that drives an alternator. A frequency inverter is then used to control the speed of the vehicles electric traction motors.

"We began to make centrifugal fans to cool the alternators, inverters and electric motors on these units. And by using the significant load to mass ratio advantages offered by carbon fibre, we were able to optimise the size and weight of these units. In addition, because composites are much more easily formed than metal equivalents, we were able to optimise the aerodynamic design to significantly reduce noise, a critical issue at that time. And since noise and energy efficiency are so closely linked, the net effect is that our carbon fibre centrifugal fan designs are much more efficient than metal equivalents."

Citing a comparative study of a Haulpak 423 mm centrifugal cooling fan, Ratner says that the MechCaL composite fan for this application is 60% lighter, costs less, is 16% more aerodynamically efficient, has a much simpler hub mounting arrangement and has completely solved a bearing failure problem associated with the metal equivalent it replaced.

"We target niche OEM markets for custom designed systems at relatively low volumes, and OEMs such as Caterpillar, Siemens, Hitachi and CDC, whose products are used by mining companies across South and southern Africa – by Kumba, Exarro and Ashanti, for example," says Ratner.

"By switching to carbon fibre centrifugal fans, the mean time between failures (MTBF) of the cooling fans on haul trucks has increased substantially," he continues. "Metal equivalents had to be replaced after 5 000 hours of operation, which is, basically, every year. We have MechCaL centrifugal fans that are still running after 50 000 hours," he says.

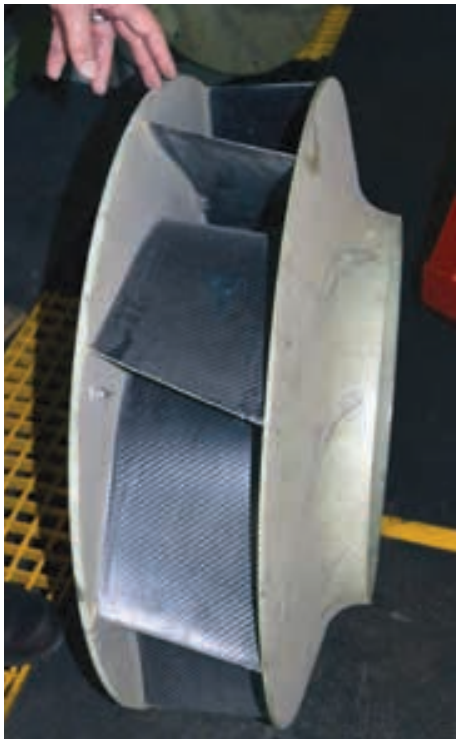
He cites a particular customisation that involved a fan sitting on the back axle of a haul truck to suck in clean air and blow it over the traction motors. "This unit sits on a hollow axle and is mounted on a gooseneck support frame. The combination of the bouncing and gyroscopic forces induced by the rotating metal fan were causing fatigue at the welds. Our carbon fibre versions are much lighter and virtually fatigueless. The total weight is less than half of that of the original design and almost all of that weight is sitting close to the shaft, so the fan and frame is subjected to significantly lower moments when the axle bounces," he explains.

In 2008, off the back of the successful development of a silent scrubber – a reduced noise fan system developed to control the dust generated by continuous miners in an underground bord-

and-pillar coal mining operation – MechCaL was awarded an IDC loan to develop energy-saving fan products. "The energy crisis had just hit and we had developed a colliery dust control system for a continuous miner. As a result of the noise reduction, we had also achieved substantial energy savings, and since secondary ventilation accounts for significant percentages of the base-load draw of underground mines, we were awarded some research funding to improve the performance of the vane axial ventilation fans in widespread use underground," Ratner tells *MechTech*.

Using its composite, CFD and finite element analysis experience, MechCaL redesigned the forced exhaust and forced draft fans typically used in their hundreds in underground mining operations. The rotor blades were originally designed using composites, as were the stator vanes, which are optimised to straighten the flow and minimise losses. A uniquely shaped composite nose cone was also developed, all of which recover static pressure and improve overall efficiency. "Our first contract was for Sibanye, which was still Goldfields at that time, at Driefontein, Kloof and Beatrix, where we won a contract to retrofit the whole 45 kW fleet," recalls Ratner. "We originally supplied 10 units on trial, which were placed in the older areas of the mine – some of these are still running today after three years. The traditional cambered metal units are generally refurbished once or twice a year, so this solution was seen as ideal for clean forced draft air.

"But the design proved unsuitable for forced exhaust air with significant particulate. We found that the impellers had to have better impact resistance, so we replaced the rotating blades with EN19 steel blades, instead. The composite



MechCaL's carbon fibre centrifugal fans for mobile haul trucks are 60% lighter, costs less, and have proved to be 16% more aerodynamically efficient than traditional equivalents.

MechCaL fans are statically and dynamically balanced. The individual blades are first weighed and a proprietary software programme sequences the placement of blades to achieve best possible static balance. An automatic dynamic balancing system is then used to identify where additional weights need to be added.

cone and the stator vanes, however, were retained. Since the switch to steel rotor blades, we haven't had a failure of any kind on any of the installed fans on the mechanical side and, to date we have installed more than 1 300 units over the past 23 months," says Ratner adding that Sibanye has now converted its whole 45 kW fleet and standardised on the MechCaL product, while Harmony and Lonmin are also overhauling their fleet with the new technology.

As well as aerodynamic analysis and optimisation, the new MechCaL fan was also extensively analysed from a vibration perspective. Vibration levels on our original design, while much better than traditional designs, were still about twice as high in the axial direction as compared to the radial direction. And although we were still outperforming traditional designs by significant percentages, we decided that this was unacceptable," Ratner informs *MechTech*.

By increasing the rigidity using a patent-pending web mounting design, MechCaL has been able to lower axial vibration levels to below 1,0 mm/s. "This, we believe, is the critical life extension factor for fan bearings, which on our modified design, has gone up from six months to more than 24 months," he reveals.

The ultimate advantages of using this modern 45 kW axial ventilation fan are energy efficiency and total cost of ownership. Revealing the results of an early drop-out study comparing a traditional design with MechCaL's optimised design, Ratner says that the original fan was delivering 9,5 m^3/sec while drawing very close to 45 kW. "We replaced the fan and connected it to the identical infrastructure. Our fan, while drawing around 8,4 kW less power delivered 12,5 m^3/s into the same resistance curve. Because of the 25% higher volume flow, this translates into a 27 kW power savings on a 45 kW fan," he calculates.

"To do a like for like comparison, we would have to use a VSD on our system and adjust it until we were getting the same flow rate as the traditional fan," he continues. "Which we can now do. We have recently developed a new control system that allows us to achieve all of the benefits associated with ventilation-on-demand solutions: using timers to switch the systems off when ventilation is not required, ramping up the fan to clear the blast area faster, and down again between blasts," he reveals.

Describing a wider case study at Sibanye Gold, Ratner reveals that MechCal fans were drawing below 30 kW of power at an relative density of 1,2. "A typical steel fan's power draw is between 40 and 45 kW, so we are achieving a 12,5 kW saving, at least. Using the old electricity price of 55 cents per kWh that applied when this study was conducted, this amounts to a R60 225 saving per fan per year, and this saving is already up to at least R71 175 per fan per year at today's electricity prices. In terms of a return on investment, the payback period for installing one of our new fans is less than a year based on energy costs alone, not to mention the longer maintenance cycles and losses due to the downtime when the old fans fail," Ratner points out.

Building on these successes, MechCaL is now in position to design and build customised fans that realise these benefits. "From 2008 to 2013,

***Above**: MechCaL's 6,0 bar autoclave for curing composite components.*
***Left**: A composite stator for a MechCaL high-efficiency axial vane fan. Composite and carbon fibre fan designs are much more efficient than metal equivalents.*

our analysis processes were not fully validated. We use CFD followed by numerical analysis to optimise a design, but unless these techniques are validated, it is still necessary to build and test prototypes to verify the analysis results. Several prototypes and iterations, with feedback back into the CFD models and the objective functions of the numerical analysis are necessary to continually confirm that the models and functions relate accurately to the real world," he explains.

"Once the models are validated, one can then go directly from CFD and numerical optimisation to production – and we have been able to do this with our new 75 kW design. We effectively went directly from the optimised design into production tooling and the accuracy is within 2-3% of predictions. This gives us absolute confidence in our ability to produce low-volume customised solutions for niche OEM applications," Ratner reveals, a process that significantly reduces development time and costs.

Also being rolled out is a range of commodity ventilation fans in different sizes. As well as the larger 75 kW sizes, a 22 kW (760), 15 kW (570) and 4,0 kW (406) fans are now also available. "These will become our 'commodity' product range, suitable not only for mining applications, but for a host of industrial ventilation systems," Ratner believes.

Another award winning design is the company's patented jet fan. "These fans increase the throw of air, enabling better forced ventilation. They are commonly used during bord-and-pillar mining before the ventilation system is fully established. When cutting a new roadway, for example, there is no air circulation and the workface cannot be easily ventilated. So a jet fan is used to project a plume of clean air as far into the roadway as possible. Our jet fan design achieves a 50% increase in throw compared to currently used conventional forced draft fans," he notes.

At a recent workshop held earlier this year involving mining and engineering delegates from across South Africa, included Impala Platinum, Anglo Ashanti, De Beers, Glencore, Golfields, Sibanye, Worley Parsons and Rawlins Mining Engineers, Ratner pointed out the additional benefits of switching to MechCaL fans as a result of the new 12L tax incentive: "In the first year of implementation, taxpayers can claim deductions of 45 c/kWh or kilowatt hour equivalent on any energy efficiency savings made against a baseline measured at the start of each year of assessment," he explains.

The use of composites for the stator exit vanes allows for more complex and smoother surfaces, reducing losses and improving efficiency.

"On top of the direct energy efficiency benefits of MechCal fans, substantially reduced operating and maintenance costs and the noise reduction advantages, this makes the new designs an even more attractive proposition," he concludes. ❑