Fan revamping

Fan revamping can be a cost-effective and efficient way of increasing production. The modification or replacement of other plant components can also require fans to be upgraded to meet new operating conditions. This article looks at how fans can be optimised to provide a 40 per cent increase in fan performance and the options available when considering a revamp.

■ by **Paolo Saccenti and Vincenzo Avolio,** *Boldrocchi, Italy*

When plant operators want to increase production, the perennial question is: do we have to buy new components to make it happen, or can we reuse what we have? Budget always being a factor, the latter is a popular option. Indeed, in many instances, production can be increased significantly by modifying existing components, such as filters and fans – with an increase of 40 per cent in fan performance achievable.

Moreover, the modification and/or substitution of some plant components, such as filters or mills, require fans to be upgraded as well to meet the new operating conditions. In many cases, it is possible to increase fan capacity and pressure, while minimising layout and ductwork changes, rendering the decision of whether to buy new or revamp existing fans easier. Therefore, there are a number of options to be considered when analysing the possibility of a fan revamp.

What is fan revamping?

Fan revamping means modifying the fan to increase performance. This is calculated in terms of capacity and pressure: the parameters related to increasing the output of the process or meeting the operating conditions of a new plant arrangement. It is understood that with a fan revamp the layout cannot be changed – ie, the following components must remain the same: foundations, inlet/outlet ducts and fan casing (only minor modifications).

Fan components that can be involved in revamping are:

- impeller blades
- inlet bell
- shaft
- bearings
- coupling
- e-motor
- rotor
- casing (eventual modifications).

Newly-manufactured impellers for Cementos Moctezuma by Boldrocchi

This article focusses on fan revamping to increase performance and will not discuss fan modifications to improve mechanical reliability (which includes changing the bearings), the operational life of the fan (which includes changing the rotor material alone) or the erosion/corrosion resistance performance (which includes changing the impeller wear plates alone).

Revamping solutions

Revamping a fan to increase performance may include:

- increasing the fan speed
- tipping the impeller blades
- changing the rotor.

The qualitative results of all three methods may be seen in Figure 1a and 1b.

- Curve 'A' represents the fan pre-modification
- Curve 'B' is the fan post-modification (Note that the system resistance, indicated by the two parabolas, may or may not change. This is because the system resistance only changes when additional components are also modified.)
- Curve 'C' is the increase of capacity and pressure without system modifications, representing ΔQ and ΔP
- Curve 'D' – ΔQ_1 and ΔP_1 are relevant to a system modification
- W_{1r} represents the new absorbed power without a system modification;
- W_{2r} represents the new absorbed power in the case of a system modification.

Figure 1a: flow rate – static pressure

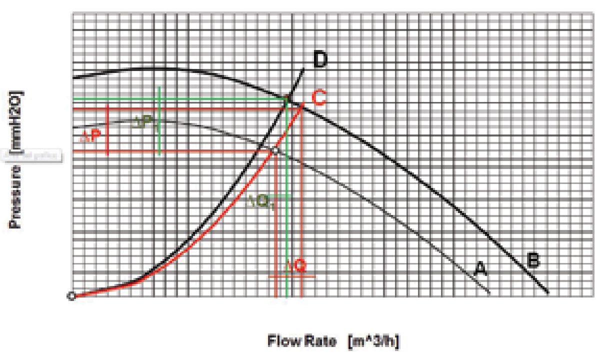
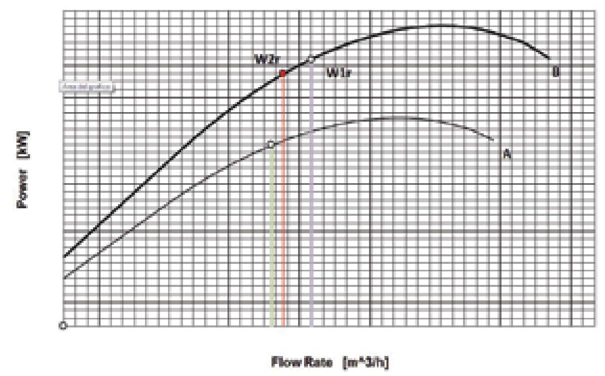


Figure 1b: flow rate – shaft power



Increasing the fan speed

Increasing the fan speed is the easiest but least common way to improve the performance of big fans. Table 1 shows how their performance in relation to a change in speed is calculated, where the suffix 'r' refers to the modified fan. The effect on performance curves is shown in Figures 2a and 2b.

Increasing the speed is not a commonly-used solution to upgrade fan performance mainly due to mechanical issues related to the fixed polarity and installed power of asynchronous E-motors. If a variable-frequency drive (VFD) is installed, this solution can be reliable.

Tipping the impeller blades

Tipping the impeller blades is an easy mechanical solution, but it provides a limited performance increase.

The idea with this modification is to increase the diameter of the impeller by adding "extensions" to the trailing edge of each fan blade. The blade tips protrude outside the back plate (centreplate for double suction wheels) and side cones of the impeller. The tip may follow the blade angle, as shown in the second focus circle of Figure 3a, or increase the blade angle as shown in the first focus circle of the same figure.

The performance curve of the fan varies like a virtual increase of the rotational speed but with a correction factor.

- $Q_r = Q * D_r/D * K$
- $P_{sr} = Ps * (D_r/D*K)^2$
- $W_r = W * (Dr/D*K)^3 * K_1$

where: D = impeller diameter

K, K_1 = coefficients > 1

The coefficients K and K_1 depend on the diameter increase and the tip angle.

The effect on the fan performance curves is qualitatively the same as the two pressure-capacity lines shown in Figure 1.

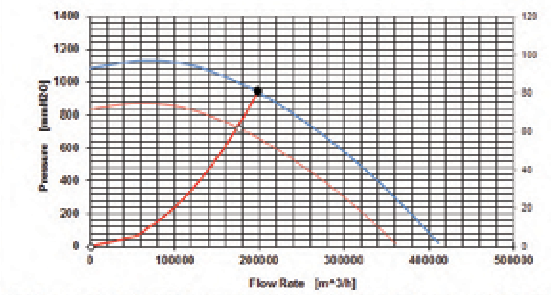
Manufacturing solutions

There are a few manufacturing solutions to tip the impeller blades, shown in Figure 3a-c. As shown in Figure 3, the tip blades are welded on the blades and the cones/centre plate/back plate. In the case of a clean gas fan (Figure 3a), the tip is simply fillet-welded onto the blade. This solution is not wise for wheels with wear plates because a fillet weld would likely be discontinuous due to (severe) blade erosion. In such a case a butt weld is mandatory (Figure 3b) and the tip must be reinforced with the half-discs welded to the side cone and back plate. For airfoil blades, in which a dust load is usually not present, the tips may be fillet-welded or screwed as shown in Figure 3c. The distance between the scroll cut-off and the outside diameter of the impeller is important as well. Usually the minimum distance is around five per cent of the impeller's new diameter. This solution does have a limited end-performance result: the performance increase will never be more than 5-8 per cent of the original capacity.

Table 1: performance of big fans relating to change in speed

Performance	Calculation
Capacity	$Q_r = Q * RPM_r/RPM$
Pressure	$P_{sr} = P_s * (RPM_r/ RPM)^2$
Shaft power	$W_r = W * (RPM_r/ RPM)^3$
Efficiency	$Eff._r$ - Eff.

Figure 2a: effect on performance curves (flow rate – static pressure)



the blue curve is the fan at higher speed, while the red is the actual. The two operating points vs. the system resistance curve are marked.

Figure 2b: effect on performance curves (flow rate – shaft power)

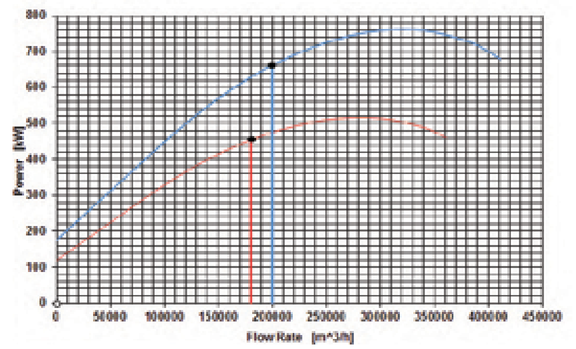


Figure 3a-c: effect on performance curves (flow rate – static pressure)

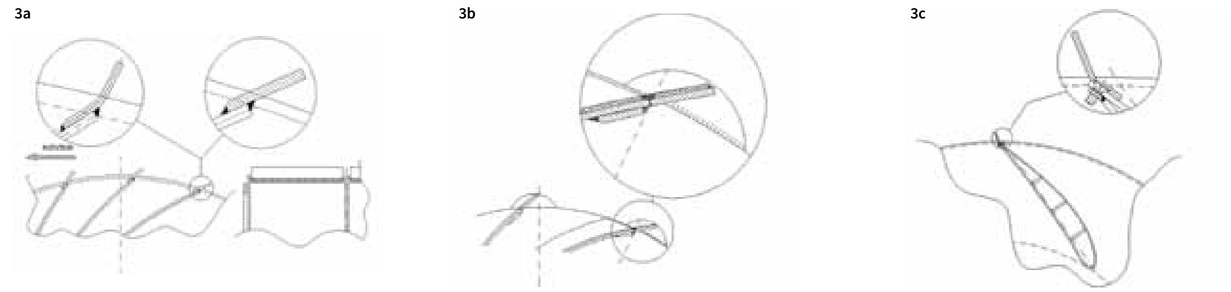
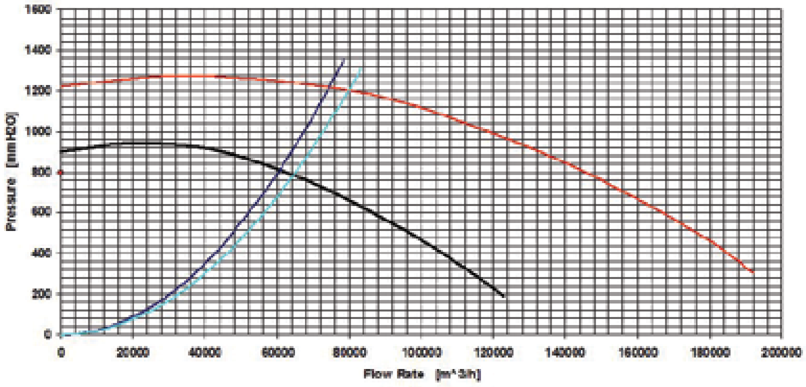


Figure 4: effect on fan performance



Changing the rotor

Changing the rotor will offer the largest performance increase – 35-40 per cent at the same rotational speed. Although it remains much less costly than changing the entire fan, it is a more expensive solution than the previous revamping options and is therefore, in most cases, only carried out when the requested performance increase exceeds the maximum capacities of the previous solutions. The effect on the fan performance curves is shown in Figure 4.

The performance curve in red reflects the fan flow rate and pressure with a new impeller while the black is the original. The increase in capacity is Q2 – Q1, in the presence of a system resistance modification, from the original pale blue curve to the dark blue.

The system resistance will increase if some modifications to the ducting have been carried out. This condition happens frequently during revamping. The increase of velocities inside the casing of the fan leads to higher pressure losses, but the effect on fan efficiency is negligible from a design standpoint.

Manufacturing solutions and examples

The arrangement of the new rotor in the existing casing must be carefully studied. The inner dimensions of the casing, ie the width and the cut-off distance to the rotational axis, must offer enough room for the new rotor to function properly. Figure 5 shows the dimensions that are important to verify. When the diameter of the new wheel is too close to the actual cut-off, a modification of that part of the casing must be made. Figure 6 shows the cut-off modification.

Installation time

Relatively little installation time is

Table 2: fan design operation point before and after revamp

Performance objectives	Fan design point before revamp	Future operation point after revamp
Capacity (m^3/h) (cfm)	475,000 279,412	660,000 388,235
Static pressure (mbar) (wg)	67 26.4”	83 32.67”
Specific weight (kg/m^3) (lb/ft^3)	0.507 0.0317	0.475 0.0297
Velocity (rpm)	890	940
Temperature (˚C) (˚F)	430 806	380 716
Absorbed power (kW) (bhp)	1121 1505	1980 2655
Dust (g/m^3) (lb/ft^3)	30 0.0019	30 0.0019

Figure 5: important dimensions to verify

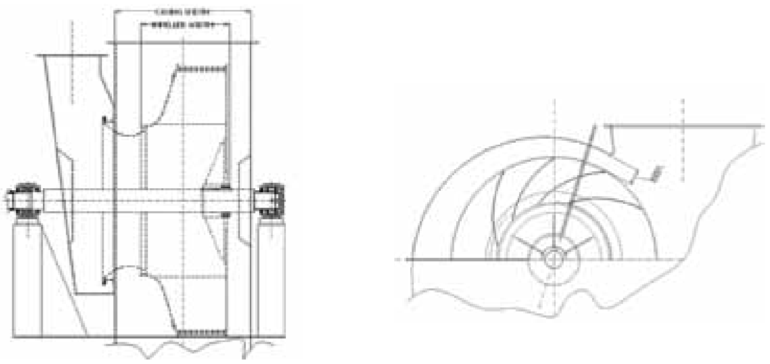
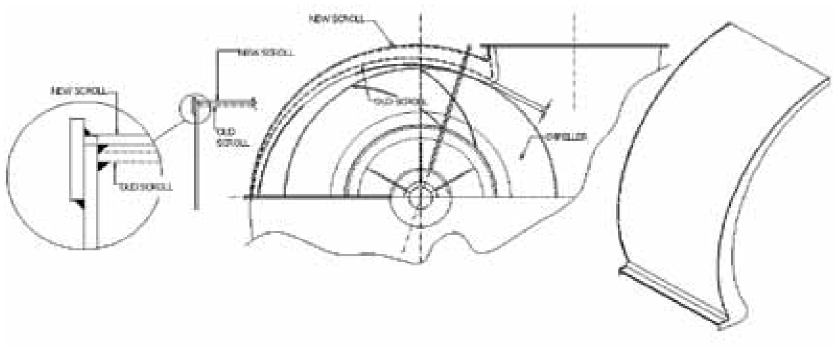


Figure 6: a study of the cut-off modification



necessary for a fan revamp once the components are on-site. Any blade extensions for a blade tipping – and the template to properly position them – are manufactured in a workshop and delivered to the site prior to installation. Once on-site, blade tipping can be carried out without dismantling the fan in three days and requires a short fan shutdown to complete. Changing the rotor takes longer. Once the components are on-site, it takes roughly two to three weeks and is nearly always performed during the plant's next scheduled shutdown.

Case study: revamping the kiln fan at Cementos Moctezuma

Last year Cementos Moctezuma awarded Boldrocchi a contract to revamp its kiln fan at its Tepetzingo plant, Mexico. With plant officials looking for a major performance increase, Boldrocchi's engineering team analysed the options at the plant and concluded that maintaining the existing fan would be possible, saving significant amounts of money.

However, to achieve the performance increase requested, the rotor would have


Figure 7: custom-designed partial casing replacement for the Cementos Moctezuma fan

to be completely changed, in turn requiring the replacement of the bearings and prime movers as well. Modifying the casing was also necessary.

Existing fan data

- No of unit: 1
- Fan type: HF 4S TD 315 3TD8A
- Arrangement: 17 (double inlet with boxes – impeller between bearings)
- Speed: 890rpm
- Drive: electric motor
- Drive rating: 1400kW
- Control type: variable speed

Augmenting the installed power

To feed the new capacity and absorbed power requirements, installed power had to be increased as well. This was achieved by adding an identical motor already available at site to the other end of the fan shaft. Therefore, the new fan arrangement is a double-driven fan with a new double end shaft. Boldrocchi supplied a completely new metallic base frame and anchor bolts to support and fix the new motor in place. The customer engineered and manufactured a new foundation plinth.

Changing the impeller

Boldrocchi supplied a new impeller, type 45L-355/1800M DWDI, selecting it because of its special backward curved blades (single thickness) with a diameter of about 3600mm (11ft 10in). To protect the blades and part of the centre plate from the abrasive dust, wear plates were added to 50 per cent of the area of the blades as well as on the corners.

Due to the fan's high working temperature of 400 °C (752 °F), the impeller material chosen was ASTM A387 (a chromium-molybdenum (Cr-Mo) alloy plate steel for elevated temperatures). Since the new impeller is a different width from the outgoing one, the inlet bells were included in the scope of supply.

Replacing the shaft

The new impeller, because it is bigger and wider, is heavier than the existing one, meaning a new shaft had to be fabricated. Not dissimilar to the existing one, this new shaft had an increased diameter under the impeller's hub and in the bearing area. The new design meant replacing all bearings. Roller-type, oil-lubricated bearings were chosen.

The new shaft was sized to have a first critical lateral speed equal to 1.35 times the nominal speed, which is a good margin for this operation.

Modifying the fan casing

The increased diameter of the new impeller meant modifying the existing casing to have the required clearance between the new wheel and the outlet cut-off. Boldrocchi engineers came up with a solution to avoid having to completely replace the existing casing. They designed a partial casing replacement. They had a shaped portion of the casing manufactured in Boldrocchi's Milan workshop.

The team on-site was given detailed instructions as to how to remove part of the actual casing scroll and replace it with this newly-fabricated portion of shaped casing.

Technically speaking, an arch length about 3600mm (11ft 10in) was cut from the discharge cut-off while ensuring the division flange of the casing was not damaged. The idea was to dismantle the casing in two pieces to remove the rotor. The new shaped piece was delivered in two pieces to facilitate welding on-site.

E-motor and couplings

The higher absorbed power of the fan and the installation of the second motor meant a new transmission coupling with elastic elements was necessary (due to the presence of the inverter) suitable to absorb an axial displacement at nominal conditions of about 21mm (4/5in).

Conclusions

Revamping a fan – modifying some of its parts but without affecting its layout in the plant – is a cost-effective way to increase performance. The advantages are clear:

- the cost is somewhere around 30 per cent less than buying a new fan (depending of course on which revamp option is chosen)
- fan capacity is increased by between five to 40 per cent, depending on the solution chosen
- pressure and power will increase accordingly
- modifications have a minor impact on fan efficiency
- fan reliability is ensured
- on-site installation varies from a short-term shutdown of the fan to waiting for the next scheduled plant shutdown, necessary for a complete rotor change with casing modification.
- all three revamping methods may be combined, although a combination is usually useful when the performance increase desired is under 40 per cent.

Boldrocchi offers a 360° experience, from feasibility studies through engineering, manufacturing, testing, installation and commissioning of its solutions to performance testing on-site. In the past 25 years, the company has performed nearly 200 revamps on centrifugal fans alone, most of them aimed at boosting capacity and finding customers cost-effective ways of significantly increasing fan – and therefore plant – performance. ■