ANDREW HARRISSON

AIR RAGE

Engineers who are lucky enough to have perfect conditions for their air-moving systems probably don't realise the frustrations that their less-fortunate colleagues must endure

There has been a great deal of investigation into, and design of, air-moving and oil-cooling systems to maximise efficiency and minimise noise. This has involved creating an optimised venturi inlet, controlling impeller speed, minimising tip clearances, creating low-noise blade profiles and adjusting impeller placements – all of which can considerably improve performance if it is possible to develop perfect conditions in which to run.

But what can be done if, for reasons of space or economics, it is not possible to create optimal operating conditions? Multi-Wing has in its arsenal of quality impellers a blade profile specifically designed to operate in very poor inlet conditions – an increasing-arc impeller.

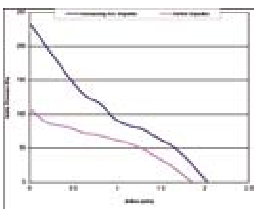

FIGURE 1: **Comparison of airfoil and increasing-arc impellers within optimum conditions (venturi inlet, 0.5% tip clearance)**

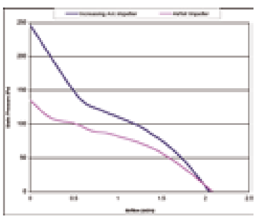

FIGURE 2: **Comparison of airfoil and increasing-arc impellers within orifice plate, 0.5% tip clearance**

An ideal installation

In general, the most quiet, efficient installation occurs when an impeller is mounted in its optimum position within a venturi, with tight tip clearances (i.e. there is very little gap between the blade and the housing). In these circumstances, sickle-bladed and airfoil impellers will outperform increasing-arc impellers, particularly in low noise and efficiency.

But when installation conditions are not ideal, an impeller's performance reduces dramatically. A venturi inlet can often require an axial depth of a third of the impeller's diameter, and the optimum mounting position requires an even greater depth. To maximise these benefits, it is necessary to ensure there is further space between the impeller and any obstructions to allow a stable flow to develop. Such space is all too often impractical – if not impossible – to create.

A venturi inlet also requires a large investment in tooling, and so in low-volume projects it may be impractical to design and build.

Tight-tip clearances may be possible in fixed and rigid systems, but oil coolers do not often fall within that category. The impeller can be mounted directly to a motor that is isolated from the chassis by rubber vibration mounts. The impeller housing, however, is typically mounted as part of the heat exchanger assembly, which is in turn mounted directly to the chassis. This results in the impeller being in a position where it is free to move within its housing, requiring a larger gap between the tip of the impeller and its housing.

All of these factors result in an installation where a simple hole is often cut within a steel plate and the impeller is mounted within it with a large gap between the blade tip and the steel housing. This mounting will be referred to here as an orifice plate.

Increasing-arc impellers have been developed to operate within these non-ideal installations with minimal reduction in performance at an economical price.

Comparison of airfoil and increasing arc

Examining the performance of two such impellers within ideal conditions with similar performance also enables the typical effects of poor inlet conditions to be investigated. It can be seen in Figures 1-4 that the airfoil section blade's performance is dramatically reduced by poor operating conditions, while the increasing arc is only minimally affected.

Following several system curves, it was found that an airfoil impeller experienced twice the effect on airflow than the increasing-arc impeller. In the typical conditions of 2% tip clearance in an orifice plate, an increasing-arc impeller experienced a 10% reduction in airflow compared with a 24% reduction of the airfoil profile impeller (see Figure 5).

These savings are consistent on all regions of the performance curve, with even less reduction in the traditionally unstable regions. Increasing-arc impellers were found to be far less susceptible to stall and surge than their counterparts within an orifice plate installation.

Optimising the application

A few methods have therefore been devised to ensure maximum performance is achieved in a less than ideal installation:

• Choose the appropriate blade profile. To maximise performance in poor inlet conditions, increasing-arc impellers are recommended. The optimum position is for the leading edge of the impeller to be level with the venturi inlet.

• Where will the impeller be mounted? Tests performed at ambient temperatures show a marginal improvement in performance if the impeller is mounted in a 'sucking' configuration, i.e. the air is drawn through the radiator and then through the impeller. In this way, the cooling of the radiator by the air would

FIGURE 5: **Reduction in performance from ideal conditions (venturi, 0.5% clearance)**

	0.5% clearance		2% clearance		4% clearance	
Profile	Airflow	Static pressure	Airflow	Static pressure	Airflow	Static pressure
Airfoil	14%	25%	24%	40%	28%	49%
Inc. arc	8%	15%	10%	18%	15%	28%

result in an increase of the air temperature at the impeller, which would also reduce the air density, resulting in less efficient performance and counteracting any of the advantages suggested by measurements taken at ambient temperatures.

• Ensure an even velocity profile is developed across the entire radiator. It is possible to create a very efficient installation that draws a large quantity of air through a portion of the oil cooler directly in front of the impeller blade tips. An alternate installation may be less efficient and draw less air overall, but due to turbulent flow there is a more even pressure difference across the entire oil cooler. This may result in a greater cooling capacity despite less airflow. Allowing a reasonable distance between the impeller and radiator will help create even pressure difference across the entire radiator.

• Select an appropriate blade material. It is important to avoid mounting impellers directly to engines and other high acceleration conditions. In these cases, try to use belt drives or viscous clutches to reduce the start-up and stopping forces of the impeller. If the impeller is likely to experience major accelerations, then consider using an appropriate material such as a vibration-stabilised nylon material (PAGST).

A fast-moving impeller can be greatly affected by impacts. If part of a blade breaks off it can cause complete failure of the rest of the blades. While plastic blades are more susceptible to failure, they do less damage to the surrounding parts than metal ones. It is better to ensure no foreign matter can enter the system: it could be argued that the two most common causes of impeller failure are due to service personnel having a rag sucked from a pocket when testing the machine, or using water to clean a moving impeller – both of which can cause massive damage to the blades.

In summary

If ideal conditions can be created, then use a sickle or airfoil-profile impeller for most applications. Otherwise, an increasing-arc impeller mounted appropriately will minimise performance reductions inherent in these systems and should be considered.

As highlighted, there are many factors to consider, so a local impeller supplier will be able to assist with specialised knowledge and tools. A local Multi-Wing distributor can advise regarding these factors and offer free tools such as the Multi-Wing Optimiser software to assist in any selections. ***iVT***

✎ **Andrew Harrisson was an applications engineer in the air-moving industry and now provides consultancy services to Multi-Wing International as a director of Cornerstone Solutions**

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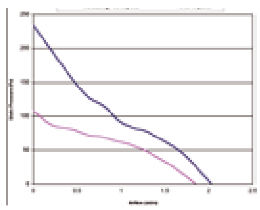

FIGURE 3: **Comparison of airfoil and increasing-arc impellers within orifice plate, 2.0% tip clearance**

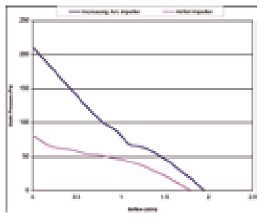

FIGURE 4: **Comparison of airfoil and increasing-arc impellers within orifice plate, 4.0% tip clearance**