

The M-Series: A New Generation of Highly Efficient Centrifugal Fans

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Summary

The market is showing an increasing demand for highly efficient industrial centrifugal fans with impellers optimised for efficiency. Increased efficiency reduces energy consumption and thus operating costs, and also reduces environmental pollution. Furthermore, many countries impose mandatory energy efficiency guidelines. As a result of intensive research, Venti Oelde has recently been able to present a state-of-the-art generation of impellers known as the M-Series.

At the heart of Venti Oelde's M-Series are new impeller blades, entirely designed using computer modelling, that enable total fan efficiencies of more than 90%. The computer modelling method makes it possible to calculate impeller blade designs for any blade profile. This greatly extends the scope of possibilities for impeller blade design compared with conventional methods. Due to the enormous number of possible blade variants, the newly designed impeller blades, on completion of their preliminary design, are simulated, using computational fluid dynamics.

Since the outside impeller dimensions of the optimized impellers remain unchanged, it is possible to retain the casing, shaft and bearings when replacing the impeller. This leads to higher total efficiency with associated energy savings of 3 - 5%. In addition to increased efficiency, the optimized impellers from Venti Oelde offer substantially lower noise emissions and improved running smoothness due to significant reductions in turbulence. Turbulence in the impeller can cause flow-induced vibrations that can reduce the service life of the fan. Therefore, in addition to enhanced efficiency, these modifications also increase the service life of the optimized impellers. Last but not least, the new design, which offers huge reductions in turbulence, also noticeably reduces caking in the event that the airflow is contaminated with particles. This extends maintenance intervals. The amount of cleaning needed for the impellers decreases.

All Venti Oelde fan series are currently being updated to include the new impeller types. At the present time, several series have been optimized and are ready for deployment.

Abstract:

The demands of users for large centrifugal fans which provide ever better efficiency and thus lower energy consumption are constantly increasing. In order to reduce the environmental impact and in particular operating costs, computer-assisted development and optimization processes are currently being employed, which until recently were still considered too complex and expensive for the construction of large fans. As a result of comprehensive basic research, which could be effectively implemented in a new design process for large centrifugal fans, Venti Oelde is now ready to present users with a significantly improved generation of impellers, the M-Series.

Introduction:

Improvements in efficiency, which lead to reduced power consumption, are particularly noticeable in the case of large fans, whose impellers with diameters of up to 5 meters usually have a power consumption in the megawatt range. The intention is that lower power consumption will help protect the environment. It can be assumed that legal regulations will be tightened worldwide in the future. Last but not least, operating costs should be reduced in order to counteract rising energy costs. Furthermore, the behaviour of the impeller in an airstream with a high particulate content, e. g. in a cement works, is an important scenario and one which was considered when designing the new M-Series impeller. A conscious decision was taken to ensure users could replace just the impeller in existing Venti Oelde fans with an optimized impeller, while retaining all other original fan components, such as casing, shaft, inlet box, bearings, etc.

Chapter 1: Design & Optimization Process

In order to be able to exploit fully the performance potential of the impeller, Venti Oelde developed the most advanced design process based on current state of the art for fully computer-assisted modelling of an impeller blade. The computer-modelled impeller blade makes it possible to calculate the impeller blade in advance, in complete detail, with any blade profile. In particular, the possibility of being able to freely select the contours of the blade, i. e. the curvature at any point along the blade, offers the developer much more freedom to optimize the impeller than with classic methods. Previously, the blade profile was specified as a line, radius or logarithmic function, the design options of which are far less flexible than the newly developed design method.

As the required specifications cannot be explicitly determined in advance, an iterative process is employed in which the impeller is simulated after the preliminary design with the help of computational fluid dynamics. The results thus obtained can be displayed both as a numerical value, such as pressure increase or efficiency, as well as graphically in the form of flow visualizations such as flow lines, vectors or pressure gradients. By comparing the results with each other and with the actual state during an optimization case, it is possible to obtain data about the progress of the development. The main goal of impeller configuration is to develop an impeller through which air flows with minimum turbulence, together with low-impact flow onto the blade leading edge and a uniform outflow at the impeller outlet. In addition to reduced power consumption due to high efficiency, this serves in particular to keep the deposits that are unavoidable in dust-laden flows as low as possible and to increase operational smoothness.

Today, flow simulations can model dust-laden flows. By comparing a flow simulation with particles with impellers in real operation in dusty airstreams, Venti Oelde was able to localize areas where deposits occur and to optimize the design selectively. Massive deposits occur particularly in areas of the impeller where the flow is subject to strong turbulence, and thus to drop of pressure and velocity, due to suboptimal flow control. Strong turbulence can induce localized backflows in the impeller; it has been proven that these are the areas most affected by deposits. During impeller development particular attention is given to achieving the lowest possible turbulence as well as a deposit-free flow through the impeller, especially in the particularly critical zones below the impeller blade, the so-called blade underside. The innovative design process of the M-Series offers a substantially wider range of options than previous processes.

Optimization is considered complete as soon as the conditions relating to pressure increase, efficiency and flow behaviour are achieved and no further improvements can be made.

According to the current state of the art, the resulting blade shape is, out of all possible large centrifugal fan blade shapes, closest to the ideal shape that is most favourable in terms of flow and operation. In the usual, cost-effective design with curvilinear blades with a linear leading edge, a total fan efficiency of over 90% is possible, using the new type of impeller blades!

Chapter 2: Presentation of the New Fan Blades

Venti Oelde's range of fans is currently being completely revised. This process will soon be completed. At the present time, several series have already been optimized. During our research, volute casings were analysed in addition to impellers. It was established that the existing Venti Oelde casings, which were designed based on an extensive series of measurements in cooperation with accredited university research institutions, do not offer any significant potential for improvement.

Since the outside dimensions of the optimized impellers are unchanged, it is possible to retain the casing, shaft and bearings when replacing the impeller, thereby achieving a significantly higher total efficiency with associated energy savings of 3 - 5%.

This can be clearly illustrated through the example of the HRV 63M Series, which is often operated as a cement mill fan with a throughput of up to 1,700,000 m³/h. The HRV 63M was one of the first models to be optimized and has been available since mid-2021. The use of the optimized impeller enables an increase in total efficiency of 4% compared to the previous model the HRV 63S. With a power consumption of 4,300 kW, this means a reduction in power consumption of around 170 kW.

Redesigning the impeller blade has significantly reduced flow turbulence through the optimized impeller. This is demonstrated by the shape of the simulated flow lines and vectors. Ideally, the relative component of velocity runs parallel to the blades, without causing flow separation. Flow separation partially blocks the channel, thus causing high-loss velocity peaks and an uneven flow onto the volute casing. In addition, separation increases deposits in a particle-laden airstream. The redesigning goal is therefore to create a low-turbulence impeller that offers both increased efficiency and fewer problems with deposits and abrasive wear. Of all the design methods, the computer modelled blade is most suitable for this purpose. The flow line and vector representation of the optimized impeller illustrates this impressively (Figures 1 and 2). There are no flow separations within the impeller channel. The flow is blade-congruent, the impeller outflow is almost completely uniform. The drop in speed visible in the vector representation in Figure 2, located directly behind the blade trailing edge, is technically unavoidable and is referred to in the jargon as trailing vortices.

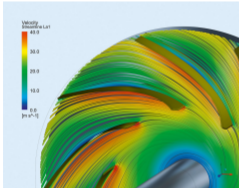


Figure 1: Flow line representation

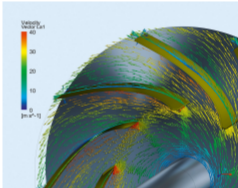


Figure 2: Vector representation

Since flow simulations are extremely time-consuming and the existing Venti Oelde casings are already operating in the optimal range, research is initially conducted using only one impeller sector containing one blade. Once impeller optimization is complete, the new impeller is simulated in the volute casing (Figure 3) to assess impeller casing interactions. If no unexpected events occur that lead to further optimization steps, development is considered to be complete. The prototype impeller is ready than for manufacturing and measuring in the test facility.

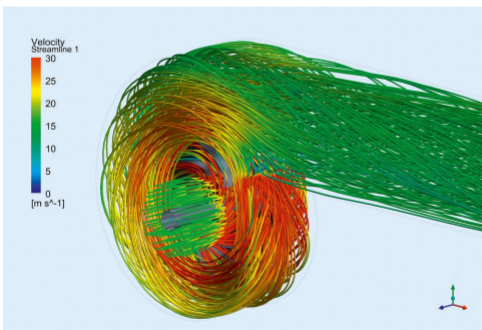


Figure 3: Flow line representation in the impeller casing assembly

Standardization takes place after the impeller has been measured in the testing facility in all practice-relevant configurations, including one-sided bearing arrangement (overhung) or impeller between bearings and with or without a suction box. Afterwards, the fan can be designed and manufactured in all required sizes up to around 5 meters impeller outer diameter.

The HRV 71M-1600/K was one of the first fans featuring the new fully computer-modelled impeller blades to be measured in Venti Oelde's large-scale testing facility (Figs. 4 and 5). At its best point, this fan achieved a measured total efficiency of 90%, which is very close to the theoretically possible maximum for large fans with a broad bandwidth. According to current state of the art, noticeable improvements are only possible with considerably more complex impeller designs. For example, using 3D impellers with spatially twisted blades that are brought forward into the impeller inlet, which would massively increase costs. In addition, further problems with spatially twisted blades could occur, for example in partial-load operation, since they react more sensitively to turbulence.

Due to this and other influencing factors, emphasis was placed on design simplicity when developing the new impeller series. Due to the high degree of robustness achieved, mechanical problems, e.g. due to vibrations caused by caking arising from impeller use in dusty flows, can be minimized.

The testing facility measurements required for standardization of the new impeller series have also proven that the impellers designed according to the newly developed process create significantly lower noise emissions and offer improved running smoothness due to lower flow-induced vibrations. This increases both efficiency and the maintenance interval.



Figure 4 and 5: M-Series fan in large-scale testing facility

The first series incorporating the newly designed impellers have already been standardized. Others are currently being measured. This means that flow-optimized impellers from Venti Oelde's M-Series are immediately available to fan operators.

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