Experimental investigation of two centrifugal fans in a serial arrangement

Martin Nudischer, Institute for Engineering Design and Industrial Design, University of Stuttgart, Germany.
Hansgeorg Binz, Institute for Engineering Design and Industrial Design, University of Stuttgart, Germany.

Long Abstract

Introduction

Centrifugal fans are widely used for gas compression in a variety of industrial areas, especially for ventilation or as components in industrial processes. The single centrifugal fan is object of many scientific publications which have been released for decades [1],[2],[3],[4]. The demand for higher pressures requires wider operating ranges of the fans. One way to increase the performance is to accelerate the fan impeller leading to an increase in pressure and volume flow rate. Due to the feasible strength of the used materials (often steel or aluminum), the peripheral speed is limited for welded or riveted sheet metal impellers [5]. Thus with a single centrifugal fan the available pressure and volume flow rate are limited.
To increase the pressure even further two centrifugal fans can be combined to a serial arrangement. Aside from the advantage of higher pressure, there is also the potential to significantly save energy at part load conditions. Furthermore, the modularity of the system provides the possibility to generate a wide range of different characteristic curves through combining two or more centrifugal fans. Therefore, the potential of multi-staged arrangements is enormous considering the achievable performances in pressure and volume flow rate. Only two or more centrifugal fans and connecting pipes are necessary to set up such an arrangement in general.
However, the changes accompanying this connection are still unknown and there is no scientifically based approach for dimensioning serially arranged fans or the generation and constitution of the characteristic curve. The paper presents investigations on the derivation of the characteristic curve and changes in the bearing loads of a two-staged serial arrangement of centrifugal fans. The focus is on the behavior of each fan in the serial arrangement in comparison to one standalone device regarding the performance and resulting loads.

Experimental setup and first results

Figure 1 represents a serial arrangement of two fans. The installed fans are geometrically identical and the final performance of the arrangement is measured on a test rig in accordance with the international standard EN ISO 5801:2009 [6].

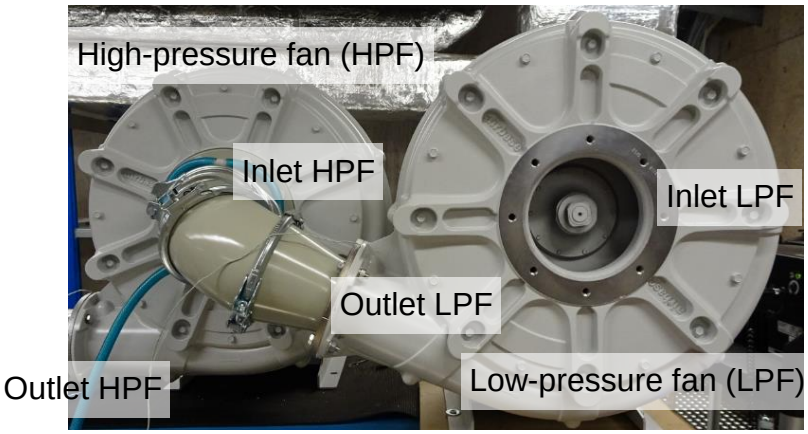

Figure 1. Serial arrangement of two centrifugal fans

The Low-pressure fan (LPF) is directly connected to the High-pressure fan (HPF). By measuring the pressures and temperatures at the inlet of the LPF, at the outlet of the LPF respectively inlet of the HPF and finally at the outlet of the HPF the performance of each fan is examined.
Figure 2 shows the relative pressure increase over the mass flow rate. The relative pressure increase is the quotient of the pressure at the outlet to the pressure at the inlet of a fan. In Figure 2 the relative pressure increase of the single fan, the LPF and the HPF is shown.

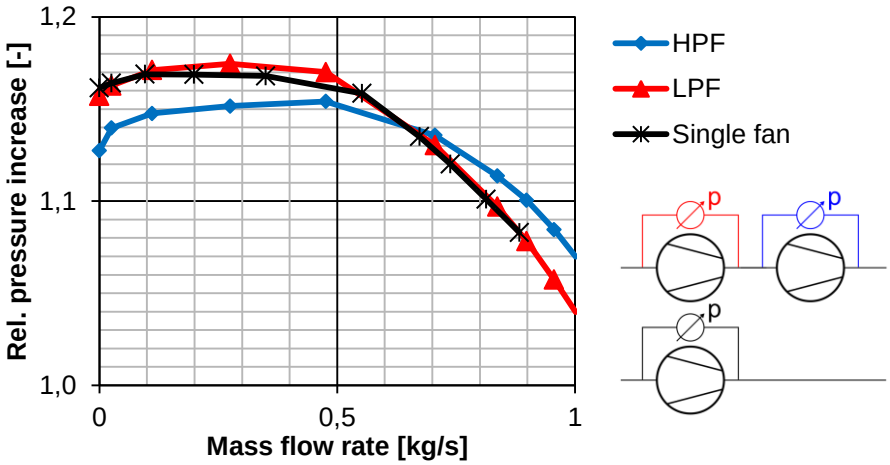

Figure 2. Relative pressure increase over volume flow rate

It is obvious that the black line of the single fan and the red line of the low pressure fan are almost identical. This leads to the conclusion, that the LPF in the serial arrangement has a behavior comparable to a single fan. It stands to reason that in any serial arrangement the first stage will not be affected by the downstream stages. Therefore, the state of the art of single fans can be transferred to the low pressure stage of a multi-stage arrangement. The shape of the curve for the HPF (blue line) differs from the LPF and also the single fan. Especially at low volume flow rates the increase in pressure is lower compared to the single fan. This leads to the conclusion that the pressure increase is unequally composed. Only at one operating point the pressure increase is equally distributed on both fans. For lower mass flow rates the main section of the pressure increase is delivered by the LPF. With increasing mass flow rates there is a reversal of the runs. At higher mass flow rates the ratio of the pressure increase is higher at the HPF. So despite the geometrically equal structure of both fans, their behavior differs. A different pressure distribution also leads to a change in the loads of the bearings. In the paper the influences on the characteristic line and the resulting effects on the bearing forces will be described in detail.

References

[1] L. Bommes. Ventilatoren. Vulkan, 1994.
[2] W. Bohl. Ventilatoren: Berechnung, Konstruktion, Versuch, Betrieb. Vogel,1983.
[3] T. Carolus. Ventilatoren. Springer, 2013.
[4] B. Eck. Ventilatoren: Entwurf und Betrieb der Radial-, Axial- und Querstromventilatoren. Springer, 2003.
[5] T. Carolus. Theoretische und experimentelle Untersuchung des Pumpens von lufttechnischen Anlagen mit Radialventilatoren. University of Karlsruhe, 1984.
[6] EN ISO 5801:2009, Industrial Fans - Performance Testing Using Standardized Airways, Beuth, 2010.