KÖTTER CONSULTING ENGINEERS

FLUID MECHANICS

Vibration problem at a 4.3 MW flue gas fan successfully solved

To modernise a Northern European coal-fired power plant, the existing three units of a flue gas cleaning plant were expanded. To produce a flue gas quantity of up to 1,850,000 Nm³/h, a double-barrelled radial fan (booster fan) was installed for each unit with a driving power of 4.3 MW each (see fig. 1). The flue gas quantity of the axially supplied flow from the outside was varied by adjustable guide vanes at a fixed rotation speed of 745 RPM. Due to the complex guidance of the duct, several flow simulations and model experiments (plexiglas at a scale of 1:35) were carried out in advance by different institutes. In these investigations baffle plates and mixing plates at the discharge side of the duct upstream of the fan were recommended and then implemented, as high and locally very different flow velocities were detected. During the commissioning of the first unit, significantly exceeded vibrations at the rectangular flue gas duct were detected. These vibrations occurred in bypass operation, when the flue gas circulated within the plant, as well as during the production of flue gas over the chimney in normal operation. At the same time, these vibrations increased up to 165 mm/s RMS at the housing of the fan depending on the operating conditions. Therefore, a safe operation of the plant could not be granted. First metrological investigations by the operator and manufacturer indicated a resonance excitation of the duct walls. On the basis of these results the duct walls were stiffened and the flow deflectors were modified. The vibrations at the flue gas duct were reduced but the duct vibrations were still significantly too high.

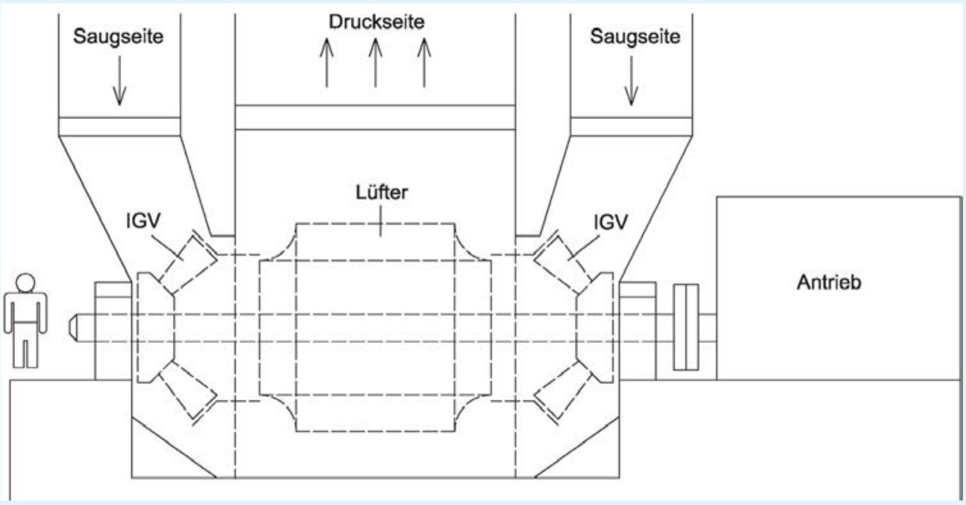
To analyse the cause, KÖTTER Consulting Engineers was charged at short notice with an investigation at the new flue gas cleaning plant. The static and dynamic pressure situation in the duct system as well as the vibration situation at the fan, at the fan fundament and at the duct walls was analysed with 52 channels at the same time. Moreover, further parameters – like e. g. the position of the adjustable guide vanes, the flue gas quantity, the pressure difference over the fan, the damper position and temperatures – were registered. The measurements were carried out in bypass operation as well as in normal operation for different volume flows.

The first analysis of the measurement results showed that the vibrations occurred independently of the operating conditions. A supposed acoustic resonance (standing wave) was not detected. The vibration excitation of the duct walls arose from the pressure difference in the flue gas, whereas the duct walls (cross section: around 7 m x 7 m) were excited at a different level depending on the position of their natural frequency and damping. A comparison between the measured and the calculated characteristics of the fan manufacturer showed significant deviations. Due to the detected pressure deviations at the discharge side of the duct course and the detected deviations in characteristics, the fan was put into the focus as possible cause.

The further results of the measurements showed that the vibration excitation was caused by an interaction between the guide vanes (IGV) and the fan rotor. The vibration frequency was thereby inverse proportional to the IGV position. This phenomenon is called in literature "inlet vortex" and is a special form of a flow instability. It differs generally from other known fluid machine instabilities like "rotating stall" or "surge". The "inlet vortex" develops out of a vortex shedding after a corresponding angle of attack at the IGV-shovel and changes in dependency of the volume flow and the fan rotary frequency. The so-called "dorsal fins" as a fixed flow guidance downstream the IGV or adjustments of the IGV-shovel geometry have been proven as a remedial measure.

Because of the local conditions, the installation of expanded flow plates ("tabs") at the IGV guide vanes was proposed as alternative reduction measure. This led to a flow deflection so that the vortex shedding at the IGV could be avoided. For a quick realisation they were directly welded onto the IGV in agreement with the fan manufacturer (fig. 3).

During the following unit start-up it became clear - due to the significantly decreased acoustic radiation - that the problem was tackled correctly. This was confirmed by the measured values during the start-up. The pressure pulsations and the occurring duct vibrations could be reduced significantly on an admissible level. The vibrations at the fan housing were minimised by a factor of almost 10 up to 17 mm/s. The successful measure was quickly implemented at all three units so that the new plants could be handed over "vibration-free" to the operator.



Principal draft of the double-barrelled radial fan with suction and pressure ducts.

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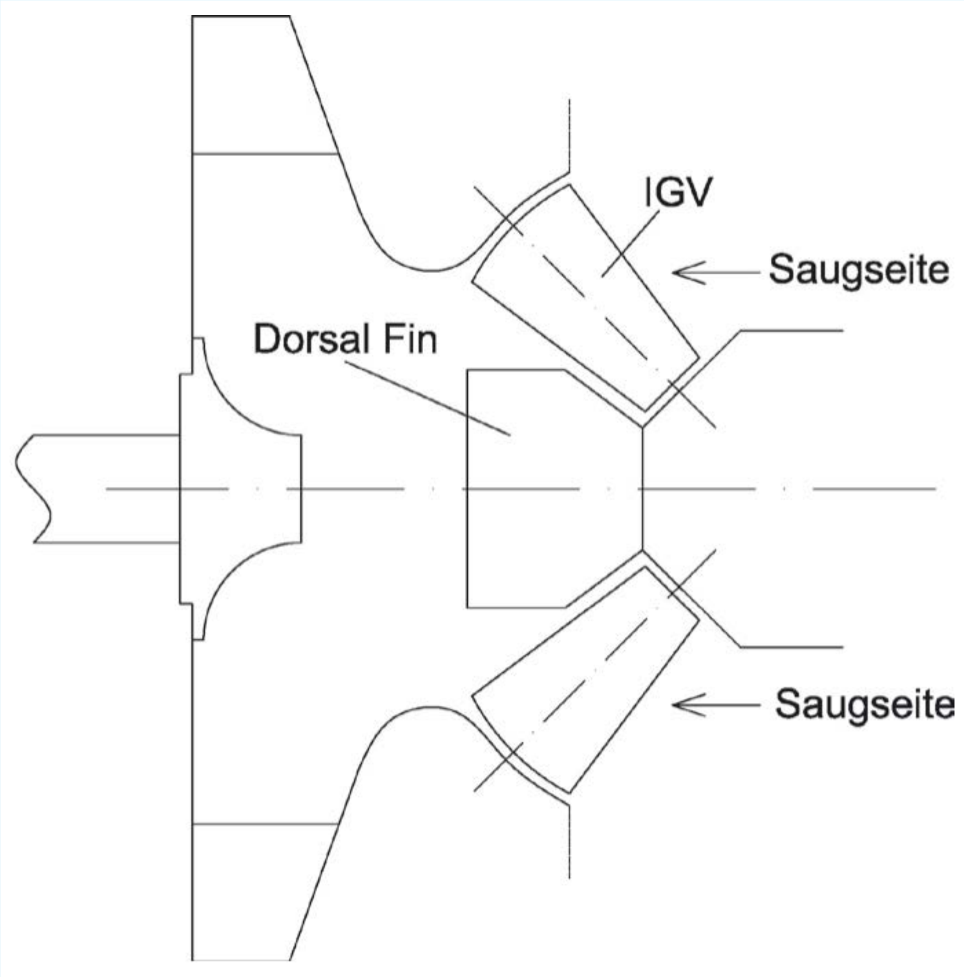

Reduction measure “dorsal fin” during installation behind the IGV.

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Picture of the realised reduction measure at the IGV.

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