Harmonic Analysis of Diffuser Inlet Static Pressure Distortion for Centrifugal Stages

David Japikse, Chairman/CEO, Concepts NREC, LLC, White River Junction, VT
Sharon E. Wight, Senior Engineer, Concepts NREC, LLC, White River Junction, VT

Long Abstract

Abstract

Preliminary studies of the impeller exit / diffuser inlet static pressure field distortion at the discharge of a centrifugal impeller have been reported by Japikse and Krivitzky (2016). The present work extends the study to a set of nine different impellers with a wide variety of diffusers from three different test rigs and a three-stage industrial compressor. Pertinent work of similar cases from others is reviewed. In all cases where a high number of pressure taps (p_2) were used to measure the time-averaged local pressure, a clear set of harmonics in a Fourier representation of the diffuser inlet pressure field was evident, which effectively establishes the signature or fingerprint of the specific stage.

In all such cases, the strongest harmonic amplitude for the resulting pressure trace analysis was the diffuser vane count which exhibits small phase shifting with change in flow rate for a given speed operation. The next largest harmonic amplitude was for the first, second, or third spatial harmonic and can never be neglected for pressure trace representation. Significant phase angle shifts and amplitude shifts occur for these lowest spatial frequencies, representing part of the static pressure field when moving from flow point to flow point along an operating speed line. In certain cases, for example with a 14-vane diffuser, spatial subharmonics of 6, 8, and 12 may also play a role in fully representing the circumferential inlet static pressure field.

When conducting a compressor test with low pressure p_2 tap count, suitable averaging of the measurements to get a true mean value is very difficult. Mathematical studies of select subsets leads to a preferred methodology.

The cause of this unexpected pressure field distortion, which incidentally can be just as big for a vaneless diffuser as for a vaned diffuser, is not completely understood at this point. Hypotheses are suggested, and the next steps for research are outlined. The historical hypothesis of equal flow per diffuser passage is carefully reviewed and rejected.

The role that CFD can play in understanding this phenomenon is discussed including various tests conducted to test invariance to rig and environmental factors. Early CFD team study observations are shared.