

IN THE MIX

Massimiliano Di Febo and Pasquale Paganini, IPC, Italy,
suggest a method for analysing centrifugal compressor performance and evaluate the influence gas mixture composition has on this.

Centrifugal compressors are vital components within process plants. Often, ensuring their availability is one of the main tasks for maintenance teams. To understand if the compressor is working as expected, the capability to quantitatively evaluate the machine performance is vital. Today, software tools like CMap allow users to predict compressor performance and obtain quantitative indication about performance parameter deviations.

Compressor designers and users know that compressor performance depends on the gas mix composition and operative inlet conditions (inlet pressure and inlet temperature). Operative parameters are in fact affected by the inlet conditions. Therefore, every approach attempting to evaluate the machine conditions, based on the assessment of compressor performance, will require the capability to predict the compressor performance when working with actual inlet

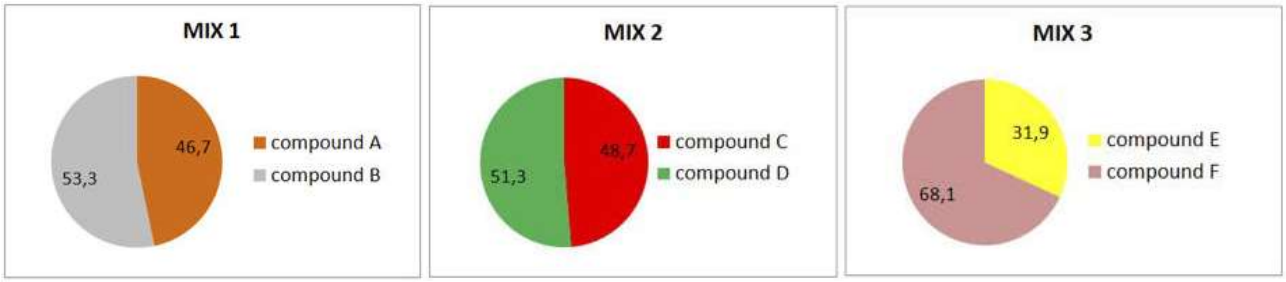


Figure 1. Three different variations of the gas mixture being considered.

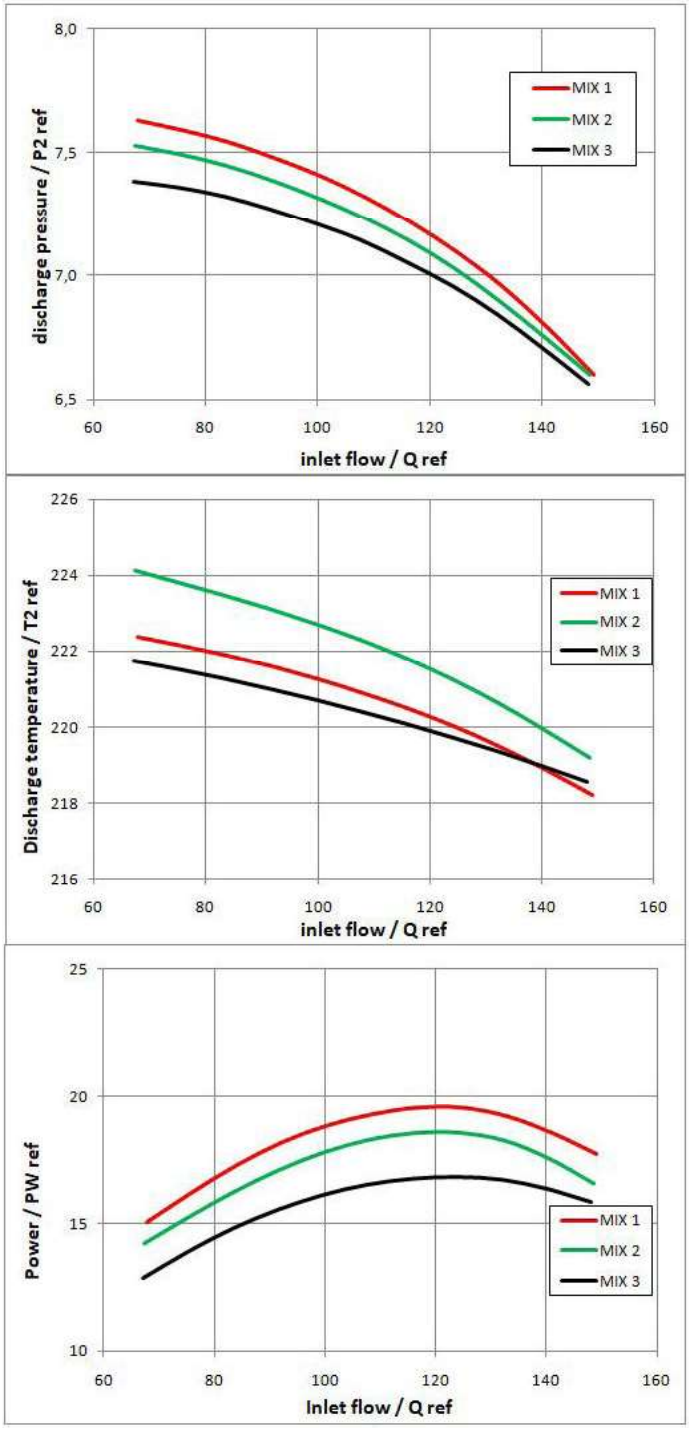


Figure 2. Performance map of gas mixtures.

conditions, i.e. actual pressure, temperature and gas mix composition.

In order to accomplish this specific task, CMap software uses an adequate computational model that embeds and couples both compressor aeromechanics and compressed gas thermodynamic models.

In general, it may happen that during operational time, the field inlet conditions are different from specification conditions (usually indicated in the machine data sheets). In these situations, an adjustment of the design performance maps to actual operative conditions is necessary to produce an accurate quantitative assessment of compressor performance.

The main purpose of this article is to provide a method description and present numerical analysis results showing the effect on compressor performance caused by variations in individual gas mixture components. Therefore, this article aims to demonstrate that variations in performance maps caused by changes in the gas mix composition can be calculated using the capabilities provided by CMap for compressor performance prediction.

All numerical evaluations executed with this software reported in this article have been developed using the most recent thermodynamic theories and machine aero-mechanical models. Also, they have been established according to ASME PTC10 (Performance Test Code on Compressors and Exhausters) standard.

The following section will describe the adopted method and discuss the results obtained.

The starting point of the method is the availability of a reference centrifugal compressor performance map. This reference map may be OEM datasheets or even 'as tested' maps. In general, any congruent set of performance maps may be used as a starting point for the method, provided that they give a valid description of the compressor behaviour in a known reference condition.

Starting from the reference gas mix composition and thermodynamic conditions (pressure and temperature), as well as the availability of reference performance maps, the IPC software performs complex calculations in a fully automated way and generates the predicted compressor performance

map for gas mix compositions different for design/reference ones.

These calculations are closely coupled with thermodynamic gas compression and thermodynamic real gas mixtures, so that a single variation in any one of the gas mixture components can have an effect. The main purpose of this study is to numerically investigate the consequence of the variation of each one of the gas mix components on the overall compressor performance. To develop the investigation, several cases with different gas mix composition have been considered and calculated. All considered cases have been set to the same overall mix molecular weight, to observe the effect on the machine performance of gas mixes with the same molecular weight but different gas mix composition.

For all cases the inlet conditions have been set constant.

With CMap it is possible to calculate compressor performance in three off-design conditions. These three conditions feature the same inlet pressure and temperature, and the same gas molecular weight but, importantly, a different gas mix composition (Figure 1).

Effect of single gas mix components of performance

As mentioned, the gas mix composition is changed in such a way that the molecular weight remains constant.

Figure 2 shows how performance changes when there is a variation in gas mix composition, but with constant molecular weight.

In these curves, the shift of the surge line, the shift of the stonewall and the change of the slope curve can be noted.

The numerical analysis presented in this article illustrates how it is possible, using advanced computational tools, to determine the centrifugal compressor performance accurately under varying inlet conditions.

The investigation shows the effect on performance caused by the modification of the gas mix composition while maintaining the same overall molecular weight, and highlights how the impact on the performance can be considerable even when this molecular weight remains constant.

The experiences with real machinery showed that compressor performance predictions obtained with CMap software are in alignment with field measurement and OEM predictions for machines in good condition.

Conclusion

In summary the methods proposed and described in this article make it possible to:

- Predict the performance map of a centrifugal compressor in off-design conditions. The prediction of compressor performances is accurate even at high pressures, where the ideal gas theory commonly used introduces considerable errors.
- Predict the modification of surge points in actual operative conditions, with different inlet pressure and temperatures, and different operative gas. It is also possible to implement advanced protection from surge.
- Detect deviation from expected performance and therefore identify possible machinery trouble before other indicators, such as vibrations.
- Detect trends in parameter deviation which may provide valuable support for planning machinery outage and set up effective and money-saving maintenance plans.

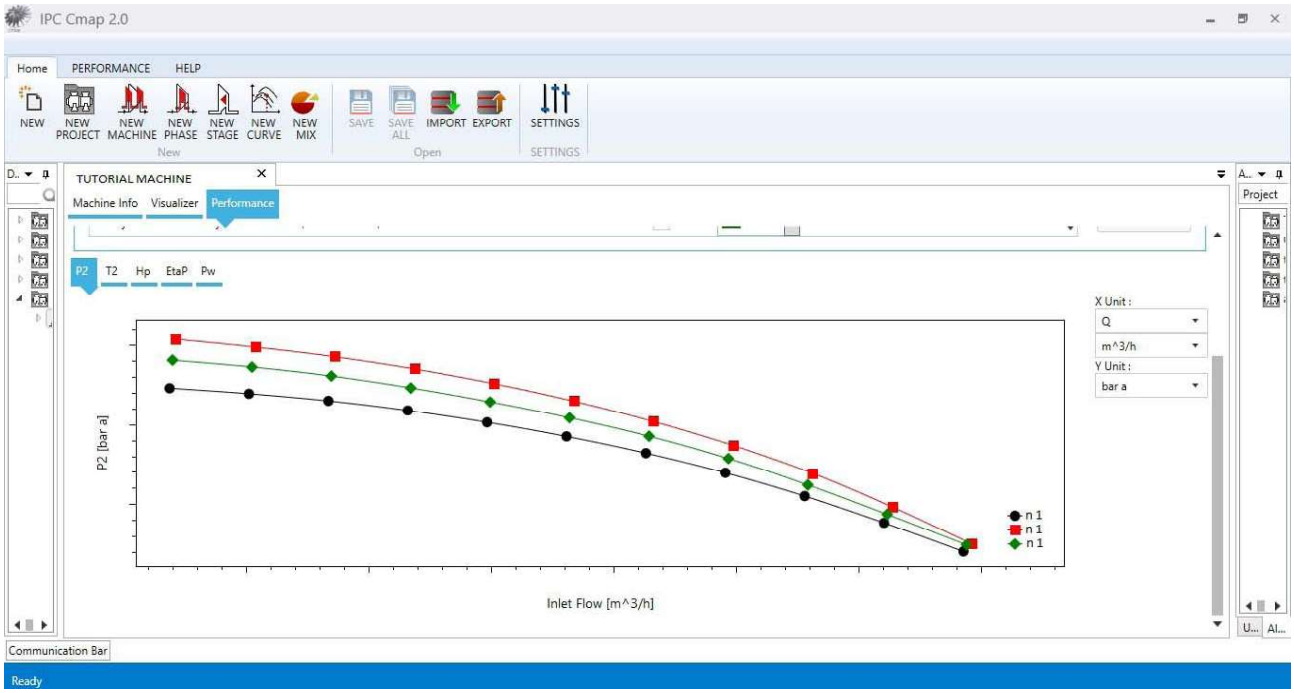


Figure 3. Screenshot from CMap 2.0.