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CFturbo – Modern turbomachinery design software

Designing new compressors from scratch and compressor redesign

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Compressor design is complex and time consuming. Therefore modern high-quality software tools are required to enable the engineer to create and analyze several geometry variations and find quickly an optimal solution. This article describes the application of the software CFturbo for designing new compressors from scratch or for using existing geometries for redesign and optimization.

Introduction

CFturbo is an interactive design software for turbomachinery components: impellers, vaned and unvaned stators and volutes. It enables the user to either start from scratch or redesign existing geometries. The main advantage of the software is the combination of fundamental conceptual design equations, proven empirical correlations and extraordinary geometrical capabilities. The modern user interface enables a comfortable and highly productive designing.

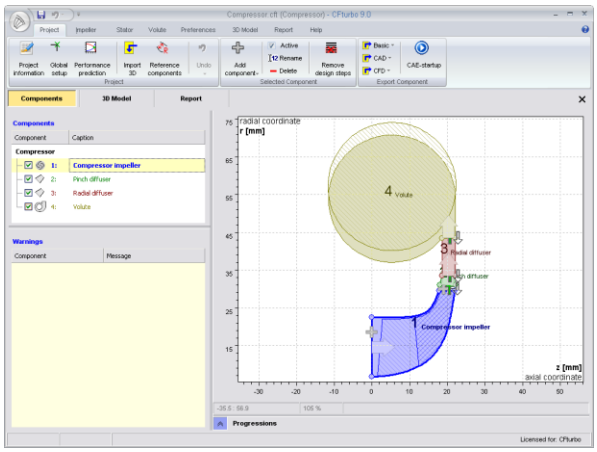

Figure 1: Machine topology

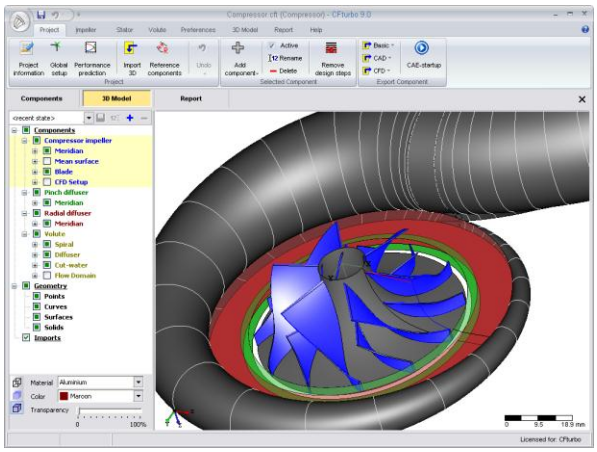

Figure 2: 3D model

The CFturbo model is fully parametric - as a result of each geometrical modification all dependent parts of the model are updated automatically. Neighboring components have a shared interface to ensure a correct alignment.

The design process

Turbomachinery design is complex and cannot be handled straight forward by a closed mathematical model. As a result new designs are useless without trustworthy checking either by measurement or high quality simulation. Therefore CFturbo has various interfaces to all state-of-the-art CAD/FEM/CFD systems. CFturbo has not its own CFD/FEM solver intentionally, but focuses on interfaces to the best simulation systems available on the software market in order to create smooth workflows. Automated workflows are a pre-condition for iterative design loops, which can't be avoided during the design process. This can be done manually in CFturbo based on the CFD/FEM results or automatically using optimization software.

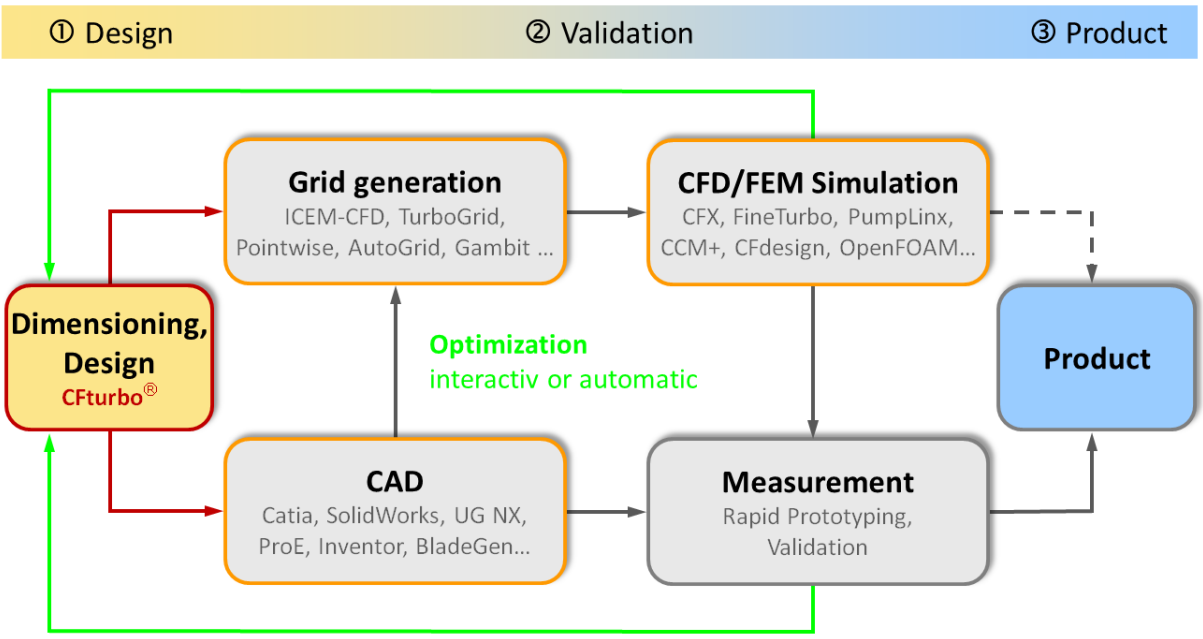

Figure 3: Turbomachinery design process

CFturbo can be used for both - designing new machines from scratch or using redesigned machines as a starting point for adaption or optimization.

New impeller design

Starting point is the definition of the design point data (flow rate, pressure ratio or difference and rotational speed) as well as the fluid properties. Impeller main dimensions are calculated using estimated efficiency values and empirical parameters whereas alternative calculation methods can be selected. Meridional contour design is made by Bezier splines for hub, shroud and blade leading edge, whereas a variety of optional features can be used. Leading edge blade angles are calculated for shockless inflow considering blade blockade, whereas incidence definition is possible. Trailing edge blade angles are calculated using the Euler equation and a slip model.

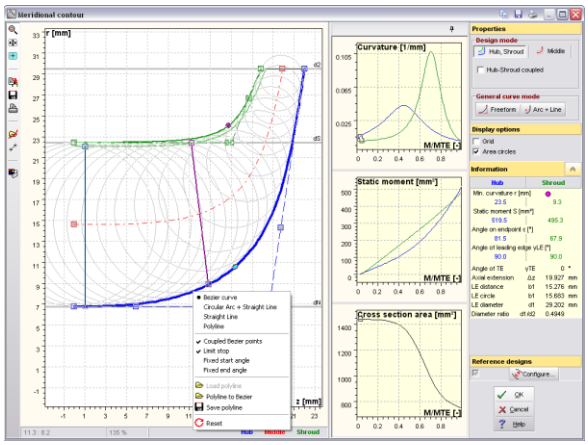

Figure 4: Impeller meridional contour

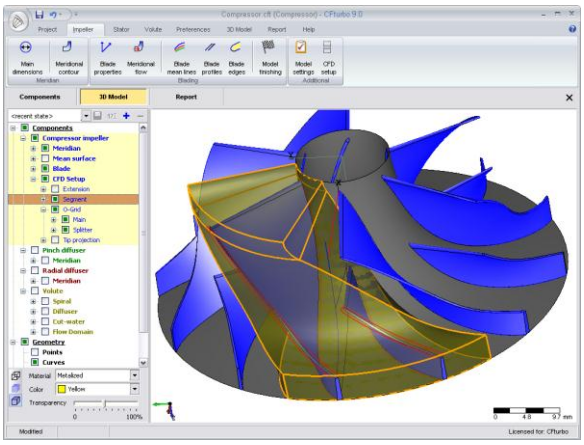

Figure 5: Impeller 3D model

New stator design

Rotationally symmetric stators can be designed very flexible. There are no limitations in the stator direction - radial, mixed-flow as well as axial directions are possible, for both vaned and unvaned stators. Some special 2D blade shapes as a combination of logarithmic curve/ circular arc and straight line/ Bezier curve are available for vaned radial diffuser design.

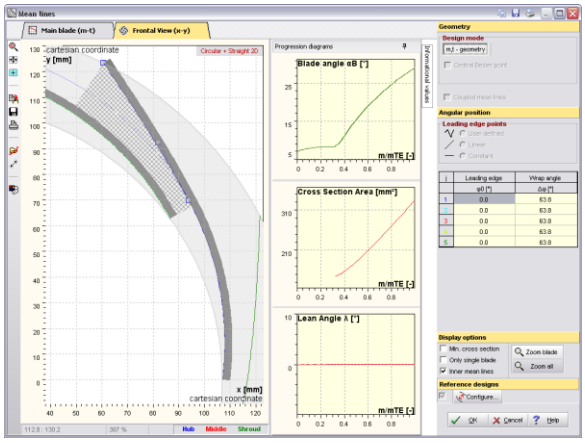

Figure 6: Radial diffuser blades

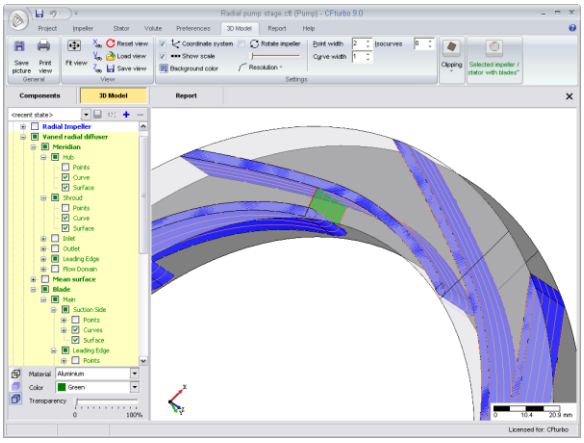

Figure 7: Stator 3D model

New volute design

Volute cross section can be variously shaped. The spiral development areas are calculated by the theory of Pfleiderer or Stepanoff alternatively. Different outlet diffuser shapes are available. The cut-water can be designed in two alternative modes in general – simplified as a three-sided surface with rounded edges or as a fillet on the intersection of spiral and outlet diffuser surface.

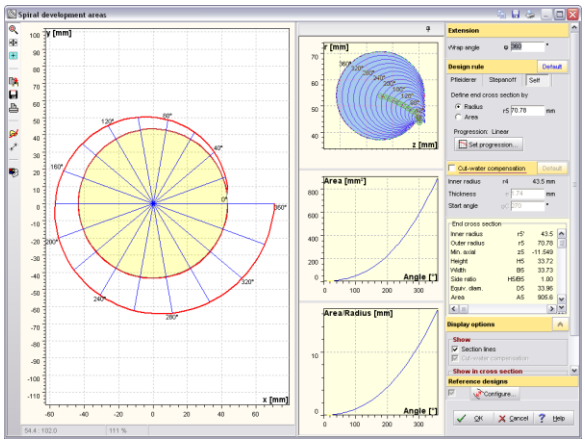

Figure 8: Volute spiral development

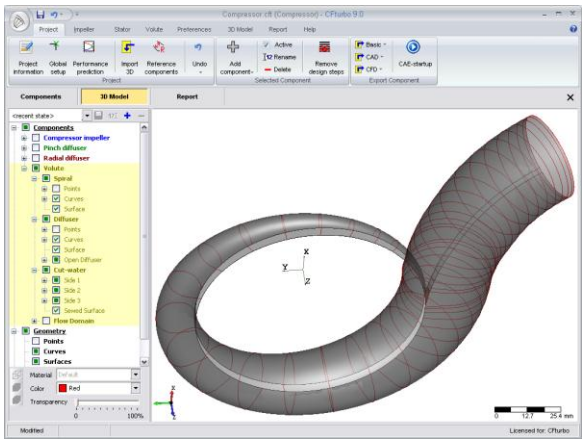

Figure 9: Volute 3D model

Redesign

Existing CAD models can be imported into CFturbo in neutral formats like IGES, STEP and STL for 3D visualization and comparison. The 2D CFturbo sketches are not generated automatically but require some manual adaption. The redesign of impellers with CFturbo works best in case 2D-data are available, that can be loaded directly into the respective design step diagrams where they can be used as a basis for Bezier curve fitting. Currently these 2D-data must be generated outside CFturbo.

Main dimension of the impeller can be specified easily in the main dimension panel. Meridional curves for hub and shroud can be imported as z, r-curves. This data can be extracted from the CAD model by intersecting hub and shroud surfaces with a co-axial plane. The imported meridional curves can be fixed absolutely or approximated by a 4th degree Bezier spline to enable later modifications.

After determined the blade angles at leading and trailing edge the mean lines can be redesigned by comparing with the existing conformal mapping of the mean lines geometry or with the blade angle distribution alternatively. Thickness distribution can be redesigned manually using Bezier curves of flexible order or imported directly as a thickness distribution along the blade.

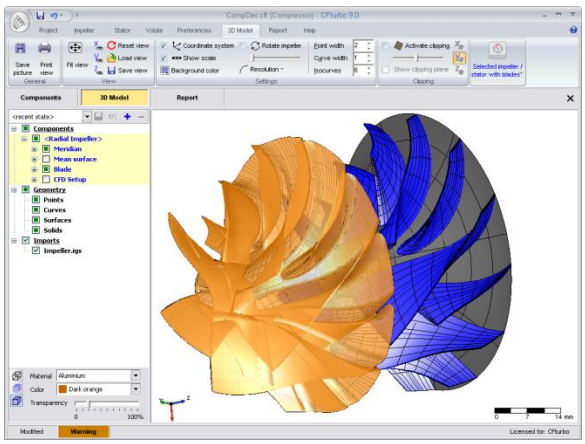

Figure 10: Original and redesigned impeller

Conclusion

This overview illustrates the capabilities of the software CFturbo to create new conceptual turbomachinery designs. Furthermore the redesign features for using existing geometries as a starting point for optimization is described. Using CFturbo in combination with modern CFD and FEM solvers gives the user the possibility of designing turbomachinery components very quickly on a high-quality level.