Filter and Housing Performance Improved Fast Using Optimisation Workflows

Summary

Using the dezineforce integrated design analysis and optimisation workflows, the flow performance of an inline hydraulic filter was improved by more than 40%, meeting the performance targets within the project timescales.

Gambit and Fluent computational fluid dynamics (CFD) software from Ansys was used to simulate and assess a selection of design options. These were used, via dezineforce workflow technology, in conjunction with design search and optimisation (DSO) tools that identified the combination of design parameter values to achieve the required design targets.

Introduction

Aircraft hydraulic systems are protected using inline filters. These filters consist of pleated cylindrical filter elements. Space constraints limit the maximum length and maximum diameter of the housings for such filters. The challenge is to design a filter and housing assembly which is acceptable for manufacture and has the least impact on total system pressure and resulting pump and power requirements.

A typical and widely validated approach for this type of product uses axis-symmetric simulations. The pleated filter element was modelled as a homogenous annular cylindrical region, representing the viscous loss as a momentum sink. The porous values were calculated from the filter dimensions. Filter element life was not considered in this study.

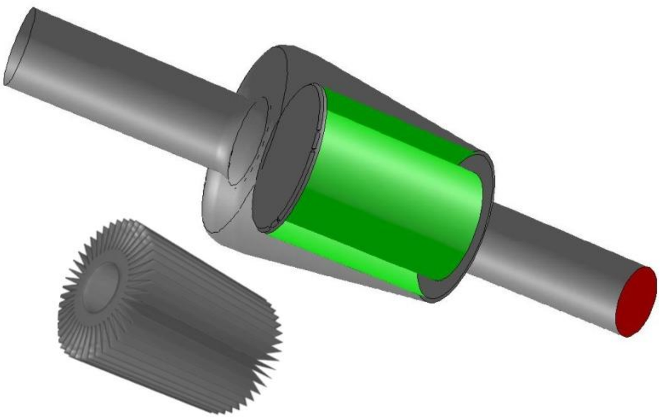

Figure 1: Filter assembly with simplified filter element and pictorial view of pleated filter element

Design Challenge

The initial design, based on a typical product, is shown in Figure 1 with the simplified filter element shown in green. Flow enters the assembly via the pipe on the left, passes round the outside of the 'endcap' at the left hand end of the element, then radially inwards, through the filter media, before passing axially out of the filter centre into the pipe on the right. The total pressure drop in the initial design from the start (left hand side) to end of the domain was calculated as 830 Pa.

An initial parameterisation was selected based on a combination of product and flow knowledge and needed careful consideration to maximise the range of possible designs for consideration while minimising infeasible designs, for example, due to self intersecting geometry, and ensuring that overall design space constraints were not exceeded.

The following geometric features were controlled using seven geometric input parameters:

- External housing shape including expansion from the inlet pipe
- Angle on front of the filter element 'endcap'
- Filter element length
- Minimum and maximum filter element diameter, which implicitly includes filter pleat height

There were also three dependent geometric parameters and the dependent value for the porous media zone.

Design Solution

Design of Experiments (DoE) techniques combined with response surface modelling, also known as surrogate modelling, were used to drive the design process and identify the combinations of design parameters to evaluate to quickly identify a design to meet the performance criteria.

Figure 2: Design progression for initial study

Figure 2 illustrates the progress of the design search and optimisation process. Points are shown for the fifty best design options with their predicted pressure drop values. The optimisation search and update loops rapidly improve upon the best of the DoE. At the end of the process the rate of improvement, shown by the red line, is still significant. This indicates that there may be benefit in further search and update cycles.

A total of six search and update cycles were completed. This resulted in a minimum pressure drop in the final generation, of 759 Pa, an 8% improvement on the initial design.

Insight into the design space was gained using the online visualisation tools to view the multi-parametric relationships of the complete data set.

The geometry for the best design was checked for manufacturability and the auto-created flow images studied to determine potential further parameterisations. Figure 3 shows velocity vectors indicating flow re-circulating in the filter and around the outside of the expansion into the unit. There is also a significant acceleration into the outlet pipe.

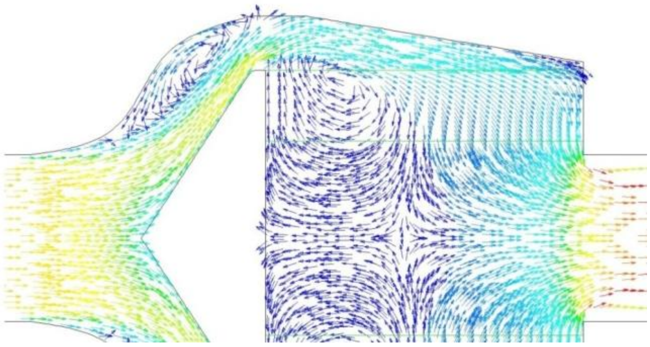

Figure 3: Velocity vectors for the best design from the initial parameterisation

Attention is drawn to the recirculation zone towards the top left of Figure 3. Whilst recirculation zones of this type may improve performance, they should be treated with caution as the exact location of separation and reattachment may not be accurately predicted by turbulence models. This highlights the importance of engineering input to ensure changes to the flow physics are captured adequately by the simulations.

In this case the variables selected limited the possible designs, such that the recirculation zone in this area could not be completely eliminated. This indicated that the design parameters required further consideration.

Reviewing the CFD output from the initial study indicates three areas where improvement would be advisable: two recirculation zones and the acceleration into the outlet pipe. To address the recirculation zones, the ‘endcap’ shape and housing profile inputs were re-defined. A chamfer was included at the start of the outlet pipe to reduce the acceleration.

Based on the results from the first stage, six new independent parameters were defined. A further design search and optimisation run was carried out.

A series of six search and update cycles were performed with a maximum of five update points per loop. As previously the best solution was achieved in the final search and update cycle with a total pressure drop reduction to 486 Pa. Again the geometry for this design, Figure 4, was checked for manufacturability.

In the two optimisation stages the pressure drop for the initial design (830 Pa) was reduced down to 486 Pa, a reduction of more than 40%.

Analysis of the results from the final design indicate that further reductions could be obtained with additional optimisation stages and further refinement in the parameterisation, however, in this case the design target of a maximum pressure drop less than 500 Pa had already been reached.

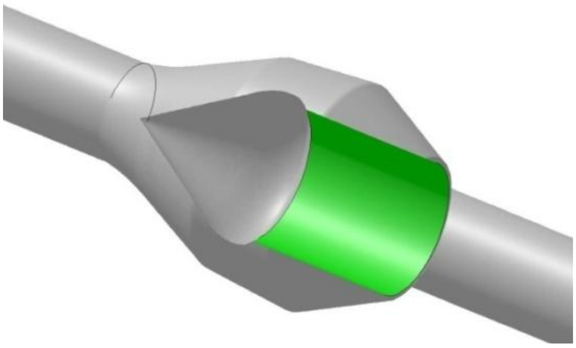

Figure 4: 3D CAD model of final design for manufacturability assessment

Benefits

Design search and optimisation has been used to improve the performance of the design, with a reduction in pressure drop of more than 40% relative to the initial design. This achieved the design target for pressure drop and thereby reduced both the system installation and operating costs, relating to pump requirements.

Design improvement was made possible through the integration of commercial computational fluid dynamics and meshing applications, a rich suite of optimisation tools and the supporting computational and data infrastructure.

This case study was completed using the dezineforce service that provides customers access over the web to engineering analysis and optimisation workflows in a high productivity computing environment.