Multi-objective adjoint optimisation of intake port geometry

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Meeting the stringent efficiency demands of next generation direct injection engines requires not only optimisation of the injection system and combustion chamber, but also an optimal in-cylinder swirling charge flow. This charge motion is largely determined by the shape of the intake port arm geometry and the valve position.

In this presentation, we outline an extensible methodology implemented in OPENFOAM for multi-objective geometry optimisation based on the continuous adjoint. The adjoint method has a large advantage over traditional optimisation approaches in that its cost is not dependent upon the number of parameters being optimised. This characteristic can be used to treat every cell in the computational domain as a tuneable parameter – effectively switching cells “on” or “off” depending on whether this action will help improve the objectives. Unlike CAD based parameter optimization, the adjoint approach starts from a supplied design space and then systematically removes all elements counter-productive to the design objectives. The final “design” is then the fluid volume left over after all the counter-productive elements have been blocked.

The adjoint system is implemented as an adjunct to a compressible steady state flow solver with the ability to maximise the swirl in a target volume while minimising the pressure loss of the system. The tool is used to optimise the shape of the intake port arms of a combustion chamber in a static flow test configuration. A range of results were produced at different weightings of the pressure loss and swirl objectives and the ability to generate a trade-off curve between the objectives is demonstrated. At the high end, an increase in swirl of up to 250% was observed for modest increases in pressure loss, unequivocally proving the effectiveness of the new methodology.