RESPONSE SURFACE OPTIMIZATION OF A FLUID REGULATING CONTROL VALVE

GILBERT MARANGWANDA: RAKESH MISHRA
University of Huddersfield, Queensgate, Huddersfield HD1 3DH, UK

ABSTRACT

A control valve is a flow control device typically used to regulate different types of fluid flow. Currently the design of control valves is primarily carried out using traditional methods that have been well developed over the years. Typically traditional valve design methodologies are based on existing' specific valve type' design data with the assumptions of geometric and flow similarity. These assumptions are the major limitations in traditional design methods. The advancement and development of Computational Fluid Dynamics tools (CFD) has provided a new insight into how control valves can be designed and optimized for a variety of applications.

In the past few years computational fluid dynamics (CFD) has been successfully used in the design and optimization of control valves. This paper proposes a CFD based multi-disciplinary and multi objective inverse design optimization tool for control valves. Multi objective and multi-disciplinary optimization has been used in a number of fields including automobile design, electronics, and fluid mechanism. The proposed tool in this paper is a multidisciplinary and multi objective design optimization methodology which utilises the response surface technique, where the problem function values are used to construct global approximations of the flow response. The optimal or the target output objective as in this case is then found from the response approximations at low cost.

Optimum design problems require the merit or performance of designs to be measured explicitly in terms of an objective function. At the same time it may be required that one or more constraint functions should be satisfied. To describe allowable variations in the design, shape parameterization has been prescribed in a cad tool (solid works) in the form of straight lines and arcs. The proposed design tool has been implemented in the computational fluid dynamics (CFD) environment of Ansys, which has been directly interfaced with the cad tool (Solid Works).
With the known complications associated with tools for derivative based optimization with reference to robustness and efficiency in methods of computing sensitivies of the flow field, the currently well-developed Ansys direct differentiation of the discrete equations of fluid flow in the form of the Reynolds averaged Navier stokes equations has therefore been implemented in this tool.

Control valves are typically designed for a particular service requirement. The valve capacity CV is an important design factor that determines the suitability of a valve to handle the flow conditions of a given application. In determining the CV, many important factors are considered such as range ability which describes the pressure drop allowable before the valve experiences choked/ critical flow conditions. If the valve is operated in choked flow conditions, cavitation occurs resulting in noise, severe vibrations and valve wear due to the vapour bubble implosion phenomena. In this model a target valve CV and the minimization of the vena-contracta pressure have been prescribed as the output design objectives, while tailoring the multi input variables in the form of the valve geometry. The inlet pressure into the valve has been taken as an input variable from the flow simulation. Consideration of structural loads imposed by the fluid flow has been included in design methodology. With reference to the constraints specified on the valve stem minimum diameter, a target maximum stress range has been prescribed.

The proposed tool developed to meet the desired need in the valve design follows the following process. First, the design points are determined through the central Composite Design DOE technique. Second, the response surface technique is used, with continuous refinement of the design points being carried out by the kriging response surface type which facilitates the auto refinement of design points. The auto refinement process continues until the Response surface is accurate enough for direct output parameters based on the relative error for convergence. Third, the optimization process is carried out from the resulting response surface approximations.
Finally a validation simulation is carried out based on the resulting combination of global response approximations providing the optimum or target objective output.

Keywords:
Control valve; CV; Design of experiments central composite design; Response surface optimization; Kriging response surface auto refinement; Multi-disciplinary optimization; Multi-objective optimization