University of Huddersfield Repository

Marangwanda, Gilbert and Mishra, Rakesh

Response surface optimization of a fluid regulating control valve

Original Citation


This version is available at http://eprints.hud.ac.uk/19405/

The University Repository is a digital collection of the research output of the University, available on Open Access. Copyright and Moral Rights for the items on this site are retained by the individual author and/or other copyright owners. Users may access full items free of charge; copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational or not-for-profit purposes without prior permission or charge, provided:

- The authors, title and full bibliographic details is credited in any copy;
- A hyperlink and/or URL is included for the original metadata page; and
- The content is not changed in any way.

For more information, including our policy and submission procedure, please contact the Repository Team at: E.mailbox@hud.ac.uk.

http://eprints.hud.ac.uk/
Multi-Physics and Multi-Objective Response Surface Based Design Optimization of a Control Valve

Gilbert Marangwanda u0865788@hud.ac.uk; Professor Rakesh Mishra
The University of Huddersfield: Energy, Emissions and the Environment Research Group

Introduction

A control valve is a flow control device typically used to regulate different types of flow. Currently, the design of control valves is primarily carried out using traditional methods which have been well developed over the years. Typical traditional valve design methodologies are based on existing specific valve design data with the assumption of geometry and flow characteristics similarities. These assumptions are the major limitations of traditional valve design methods; such that existing data cannot be accurately referenced in the case of different geometry profile trim being introduced into the valve.

Traditional approach of building few prototypes and measuring performance only assists in understanding a small fraction of the design space. One factor at a time (OFAT) experiments and simulations systematically vary one design variable at a time while holding the others constant and recording the impact on performance. The time required makes it practical only to cover a small fraction of the design space. This approach fails to account for the multiple factor interactions. These challenges have been addressed in this tool.

Hypothesis & Objectives

We hypothesize that the response surface artificial neural networks (ANN) paradigm model can be successfully implemented in the control valve design tool, and can accurately predict the multi-physics and multi-objective target function output values at low cost.

Objectives:
- Develop a robust universal and automated control valve design tool,
- Determine the accuracy of the response surface neural network model in predicting the non-linear and discontinuous flow field, and resulting fluid structure interaction (FSI) stress and deformation response.

Methodology

The response surface optimization of the control valve is implemented in the computational fluid dynamics (CFD) platform of ANSYS, the fluid simulation tool is coupled with a finite element analysis tool (FEA) from which direct fluid structure interaction response is determined.

Valve baseline design concept (CFD) (FEA) simplified.

- Top cage flow holes Diameter
- Top cage flow holes Diameter
- Pressure outlet
- Stem Outside diameter
- Vena contracta region
- Bottom cage flow holes

Control valve design tool update process strategy

Methodology

Design of Experiments (DOE)

The Latin Hypercube Sampling Design DOE type has been implemented in this tool. The DOE is generated by the LHS algorithm, an advanced form of the Monte Carlo sampling method that avoids clustering samples. The user-defined sampling type has been used in this tool with an initial 30 sample design points.

Response Surface : Artificial Neural Networks (ANN)

This mathematical technique is based on the natural neural network in the human brain. In order to interpolate a function, we build a network with three levels (Input, Hidden, Out) where the connections between them are weighted, like this:

![ANN Diagram]

Table of (ANN) response surface design target predictions and verified results with % error

<table>
<thead>
<tr>
<th>Name</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>Vp1</th>
<th>Vp2</th>
<th>Vp3</th>
<th>% FS Error</th>
<th>% FS Error</th>
<th>% FS Error</th>
<th>% FS Error</th>
<th>% FS Error</th>
<th>% FS Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Point 1</td>
<td>30</td>
<td>25</td>
<td>15</td>
<td>13</td>
<td>9.3</td>
<td>21.3</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>Control Point 2</td>
<td>30</td>
<td>25</td>
<td>15</td>
<td>13</td>
<td>9.3</td>
<td>21.3</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>Control Point 3</td>
<td>30</td>
<td>25</td>
<td>15</td>
<td>13</td>
<td>9.3</td>
<td>21.3</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Results

Detailed response surface plots at low cost giving insight into multiple factor interaction.

Conclusion:

A multi-physics and multi-objective control valve design tool has been proposed. The artificial neural networks response model has accurately predicted the multiple objective and multi-physics target design outputs within a small % error with validation results. The proposed tool can be successfully used in the design and optimization of control valves at very low cost of computational analysis and time to results.