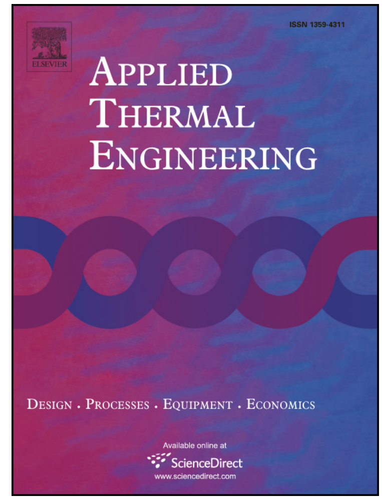

The continuous adjoint method for shape optimization in conjugate heat transfer problems with turbulent incompressible flows

K.T. Gkaragkounis, E.M. Papoutsis-Kiachagias, K.C. Giannakoglou

PII: S1359-4311(18)31174-8
DOI: https://doi.org/10.1016/j.applthermaleng.2018.05.054
Reference: ATE 12193

To appear in: *Applied Thermal Engineering*

Received Date: 21 February 2018
Accepted Date: 13 May 2018

The continuous adjoint method for shape optimization in conjugate heat transfer problems with turbulent incompressible flows

K.T. Gkaragkounis[a,1], E.M. Papoutsis-Kiachagias[a,2], K.C. Giannakoglou[a,3]

[a] *Lab. of Thermal Turbomachines, Parallel CFD & Optimization Unit*
National Technical University of Athens
9, Iroon Polytechniou, NTUA Zografou Campus, 15780, Athens, Greece

Abstract

In this paper, the development of the continuous adjoint method for shape optimization in Conjugate Heat Transfer (CHT) problems with incompressible flows is presented. The main focus of this study is to develop a continuous adjoint method which computes accurate sensitivity derivatives by (a) extending the adjoint to the Spalart-Allmaras turbulence model, by taking into consideration additional contributions arising from the differentiation of the heat transfer equation valid in the flow domain and (b) extending the Enhanced-Surface Integral adjoint formulation, recently introduced by the authors' group for single-disciplinary problems, to CHT ones. The so-computed sensitivities are compared to the outcome of finite differences and alternative adjoint formulations in 2D turbulent flows. The proposed method is firstly validated in two simple cases and, then, used to perform the CHT optimization of a 2D internally cooled turbine blade and a 3D car piston-engine cylinder head.

Keywords: Continuous Adjoint Method, Conjugate Heat Transfer, Shape Optimization, Grid Sensitivities, Adjoint Turbulence Models

1. Introduction

The simulation of heat transfer between fluids and solids, known as Conjugate Heat Transfer (CHT) analysis, appears in a variety of applications, such as in turbine cooling systems that make use of internal and film cooling [1–4], cooling of electronics [5], heat sinks [6, 7] etc.

Beyond just solving the CHT problem (analysis problem), there is a great interest in the shape or topology optimization of relevant devices. In shape optimization, evolutionary algorithms [8, 9] and gradient-based methods [10, 11] have been utilized. For the latter, an adjoint method can be used to compute the gradient of the objective function, since its computational cost does not scale with the number of design variables. So far, adjoint methods are widely used in single-disciplinary fluid flow problems for shape [12–15] or topology [16–18] optimization.

The continuous adjoint method for topology optimization in CHT problems, used to design fluid passages inside solid bodies for a given objective function and possible constraints, was presented in recent publications [19–21]. In porosity-based topology optimization, due to the changing FSI boundary, the heat conductivity of fluids and solids is usually interpolated in the design domain in terms of the porosity field. In [19], optimizations under geometrical and thermal constraints were performed in a 2D square domain with various inlets and outlets and immersed heat sources. In [20], a U-bend and a straight duct with a backward-facing

Email addresses: kogkar@hotmail.com (K.T. Gkaragkounis), vaggelisp@gmail.com (E.M. Papoutsis-Kiachagias), kgianna@central.ntua.gr, web page: http://velos0.ltt.mech.ntua.gr/research/ (K.C. Giannakoglou)

[1] PhD Candidate
[2] Postdoctoral Researcher
[3] Professor