Applied Thermal Engineering 45-46 (2012) 64–78

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

An inverse method to estimate the moving heat source in machining process

Vanda M. Luchesi [a,*], Reginaldo T. Coelho [b]

[a] Department of Mechanical Engineering, School of Engineering of Sao Carlos, University of Sao Paulo, Trabalhador Sao-Carlense 400, CEP 13566-590 Sao Paulo, Brazil
[b] Department of Production Engineering, School of Engineering of Sao Carlos, University of Sao Paulo, Sao Carlos, Sao Paulo, Brazil

ARTICLE INFO

Article history:
Received 6 December 2011
Accepted 5 April 2012
Available online 20 April 2012

Keywords:
Milling
Heat conduction
Integral transform
Heat source
Inverse problem

ABSTRACT

The present work propounds an inverse method to estimate the heat sources in the transient two-dimensional heat conduction problem in a rectangular domain with convective bounders. The non homogeneous partial differential equation (PDE) is solved using the Integral Transform Method. The test function for the heat generation term is obtained by the chip geometry and thermomechanical cutting. Then the heat generation term is estimated by the conjugated gradient method (CGM) with adjoint problem for parameter estimation. The experimental trials were organized to perform six different conditions to provide heat sources of different intensities. This method was compared with others in the literature and advantages are discussed.

1. Introduction

Modern manufacturing industries require the optimization of every aspect involved in the whole process of transforming simple material forms into useful pieces of equipment. When dealing with metal cutting, for example, the economical use of cutting tools is fundamentally based on their wear rate. Tool wear depends, to a big extent, on the heat produced by the interaction between the tool cutting edge and the workpiece material. Fig. 1 depicts how this interaction occurs in metal cutting operations and the main heat sources zones.

There are three heat source zones in the cutting process as shown in cross-sectional view of orthogonal cutting (see Fig. 1). As the edge of the tool penetrates into the workpiece, the material ahead of the tool is sheared over the primary heat zone to form a chip. The sheared material, the chip, partially deforms and moves along the rake face of tool, which is called the secondary heat zone. The friction area, where the flank of the tool rubs the newly machined surface, is called tertiary heat zone.

In a typical metal cutting operation almost 100% of the total energy spent is converted into heat, which has to be dissipated by the tool cutting edge, workpiece, chip and also by the cutting fluid normally used. The percentual of heat flow to the tool cutting edge, workpiece, chip is under study and little is known about this topic. Vernaza-Pena, Mason and Li [2] report that 17% of the heat generated in the primary zone of the orthogonal cutting of an aluminum alloy flows into the part. However, for low metal removal this amount is usually around 50%. Moriwaki, Sugimura and Luan [3] assumed that in orthogonal cutting of copper pieces, half the heat generated due to friction-piece tool is transmitted to the part and the other half as a tool to heat flow. There are many analytical models for determining the use of heat energy partition of Blok [4]. Table 1 shows a summary of equations used by many researchers to calculate the heat partition B flowing to workpiece or (B-1) flowing to chip in a typical machining process.

Literature on temperatures models when partitioning the heat generation among the tool, chip and workpiece assume steady state conditions. Consequently, the predicted heat fluxes into these three components are constant [10]. This implies that the amount of heat going into the workpiece for example is underestimated during the transient time. Moreover for interrupted cutting process, where heating (i.e., when the tool engages) and cooling (i.e., when the tool disengages) periods alternate, these models can severely under-predict the workpiece steady state temperature and transient times.

In machining process with cooling fluids the heat transfer coefficient is an important topic in the field of heat transfer technology. The heat transfer coefficient, regulates the heat transmission between the surface of a solid body and a neighboring fluid. In addition, the Biot number, the dimensionless form of the convective coefficient, may physically be interpreted as the ratio of the internal and external conductances of a heat problem with convective boundary.

* Corresponding author. Tel.: +55 16 33739438.
E-mail addresses: vmluc@sc.usp.br, vmluchesi@gmail.com (V.M. Luchesi).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.04.014