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USE OF EVOLUTIONARY ALGORITHMS TO DETERMINE TOOL HEAT FLUXES IN A MACHINING OPERATION

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EXTENDED ABSTRACT

This research demonstrates the solution of a three dimensional inverse heat conduction problem using an Evolutionary Algorithm. Specifically, the heat flux from a work piece into a tool during a turning process is determined using evolutionary operations and measurements of the surface temperature on the tool.

Figure 1 is a photograph of the turning operation studied in this research. The inset showw the triangular tungsten carbide cutting tool, which is in operation in the center of the photograph. A single thermocouple sensor is attached to a point on the surface of this cutting tool. Based on the temperature history measured at this point, the heat flow into the tool is to be determined.

Experiments to measure these temperature histories were obtained by one of us in a prior investigation [1].

The strategy adopted in this research to solve the inverse heat conduction problem associated with this process is to model the tool and tool holder using a commercial finite volume CFD code (FLUENT®, Fluent, Inc.). This code accepts as input a sequend of numbers describing the heat flux, and computes the temperature response at the point corresponding to the temperature measurement location. These temperatures are used in the Evolutionary Algorithm to find the best combination of surface heat fluxes to match the measured data. In order to expedite the process the EA code was run on a parallel computer in a cluster environment.

The results indicate the EA is able to render reasonable estimates for the heating of the tool.

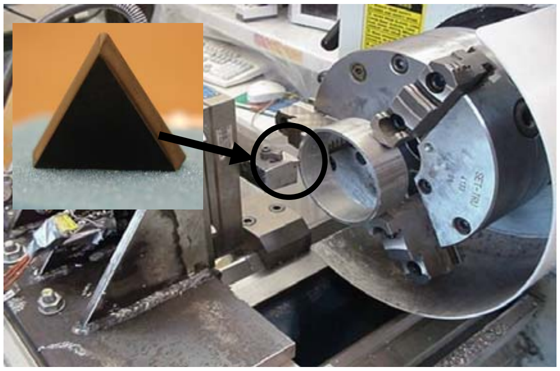

Fig 1. Turning operation. Inset shows tool located in center of photo.

Experimental Methods

The turning process is seen in Fig. 1. A small thermocouple (Type K, xx mm) is affixed to the surface of the cutting tool behind the cutting edge with adhesive. The location of the sensor is seen in Fig. 2.

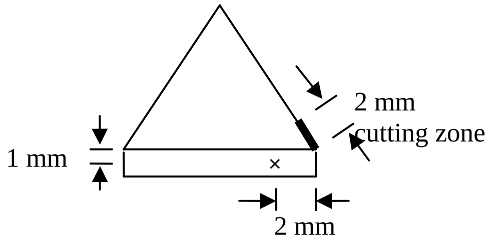

Fig 2. Location of the temperature sensor (‘x’) relative to the cutting zone on the tool

The temperature of the sensor was recorded at a frequency of 10 Hz during a cutting process which lasted about 10 seconds. Data were recorded using a Labview® based digital data acquisition system. The data collected are seen in Fig. 3.

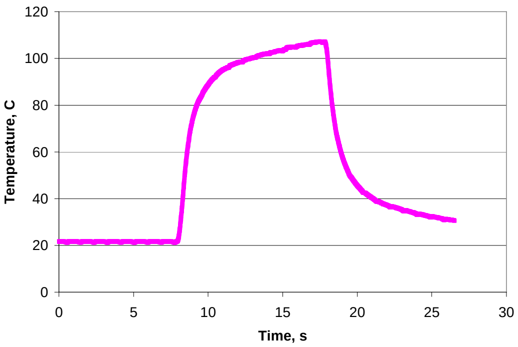

Figure 3. Data collected on the tool

Computational Methods

A detailed three-dimensional computational model of the tool and tool holder was created using the pre-processor GAMBIT®. The mesh contained approximately 625,000 hexagonal/wedge type elements generated in a Cooper meshing scheme with an interval size of 0.25 mm.

The unknown heat flux was parameterized as a piecewise linear function. From the data (Fig. 3), the start and stop times of this flux input are clearly discernable, and six values of heat flux were uniformly spaced over that interval. These heat fluxes were determined using an evolutionary algorithm (EA).

The temperature response of the tool was determined by simulation using the software FLUENT® for assumed values of heat flux generated by the EA. Each simulation required about five to six minutes on a 3.0 GHz Xeon CPU.

The EA uses vectors of real numbers as unknowns. The evolutionary processes of selection, reproduction, and mutation are used to produce new generations of solutions from an existing one. The techniques used have been described by Woodbury [2]. A population size of 24 heat flux histories were propogated for 50 generations.

The objective function for the EA is based on the sum-of-squares error between the measured temperatures (Fig. 3) and those produced by the FLUENT® simulations. Since the EA was designed to maximize a function, the objective function used was taken as

$$f = \frac{1}{1+S} \qquad (1)$$

where S is the sum-squared error.

In order to speed computations, simulations and the EA were tailored to run on a parallel computing platform. The simulations were assigned to individual nodes in the computing cluster. The physical architecture of the computing platform facilitated processing of up to 16 simulations simultaneously.

Results

Equations should be numbered consecutively beginning with (1). The number should be enclosed in parentheses and set flush right in the column. It is this number that should be used when referring to equations within the text.

Table 1. Margins and column width

Settings	Size	
	cm	**inch**
Top Margin	2.95	1.16
Bottom Margin	2.03	0.8
Left Margin	2.03	0.8
Right Margin	2.03	0.8
Column Spacing	0.7	0.28
Column Width	7.12	2.80

$$\beta = \frac{d_{k+1}}{d_k} = n^{-\frac{1}{D+1}} \qquad (1)$$

Formulas and equations should be created to clearly distinguish capital letters from lowercase letters. Care should be taken to avoid confusion between the lowercase "l" (el) and the numeral “one”, or between “zero” and the lowercase "o." All subscripts, superscripts, Greek letters, and other symbols should be clearly indicated. All formulas and equations should be typed starting from the left margin.

There should be a minimum of one line of space between equations and text.

SI units must be used.

REFERENCES

1. J. Liu, *Investigation of Heat Fluxes in Machining*, PhD dissertation, University of Alabama, 2005

2. Woodbury, K. A.. “Application of Genetic Algorithms and Neural Networks to the Solution of Inverse Heat Conduction Problems: A Tutorial”. In H. R. B. Orlande (Ed.), *Inverse Problems in Engineering: Theory and Practice* pp. 73-88, 2002.