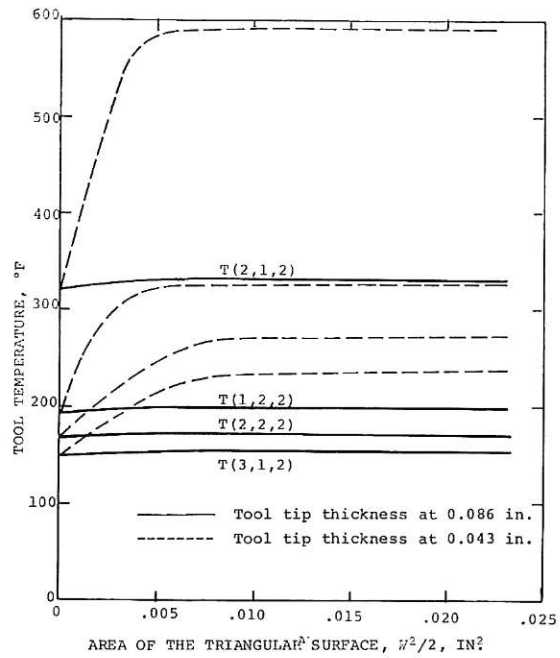

Fig. 17 Effect of width of removed material on temperature responses in Method B

0.086 in. and larger. The measured temperature, however, could have involved considerable error when the tool tip became too thin.

Conclusions

1 An experimental simulation for the face-milling process studying the tool temperature response was performed. The experimental results reflect similar temperature responses to those obtained in cutting experiments. A more coherent and intensive heat source seems to be required in order to produce better simulated temperature responses.

2 A digital computer simulation of the face-milling process provides information for plotting transient temperature responses at any location in the tool for a desired time period. The temperature distribution curve obtained as a result of the computer simulation shows good agreement with that obtained from the cutting experiments.

3 The effects on the tool temperature of removed material from the carbide inserts to accommodate the attachment of a thermocouple were evaluated by the numerical method. No significant effects can be detected for a tool tip thickness of 0.085 in., which was the dimension used in the previous investigation.

Acknowledgments

This project was supported by the Ingersoll Milling Machine Company, Rockford, Ill. Use of the University of Wisconsin Computing Center was made possible, in part, by the National Science Foundation, other United States Government agencies, and the Wisconsin Alumni Research Foundation through the University of Wisconsin Research Committee.

APPENDIX

Summary of Data and Statistics for Simulation Experiments

Tools used in Method A

Depth from rake face, in.	Temperature responses, deg F Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	N	$\bar{y}$ deg F	$\hat{\sigma}$ deg F
0.010	513	522	529	535	519	5	523.6	6.2
0.016	487	477	519	490	503	5	495.2	16.2
0.020	380	388	409	406	428	5	402.2	18.9
0.028	431	425	457	451	...	4	441.0	15.4
0.038	341	360	347	357	380	5	357.0	14.9
0.055	271	270	302	302	308	5	290.8	18.2
0.082	318	318	341	318	334	5	325.8	10.9
0.088	286	295	318	312	308	5	303.8	13.1
0.187	236	253	236	282	249	5	251.2	18.8

Estimated pooled variance, $s_p^2 = 219.07$
Estimated pooled standard error, $s_p = 14.8$ deg F

Tools used in Method B

Depth from rake face, in.	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	N	$\bar{y}$ deg F	$\hat{\sigma}$ deg F
0.010	573	604	601	627	...	4	602.5	20.0
0.015	513	503	490	513	519	5	507.6	11.4
0.020	425	457	438	443	...	4	440.8	13.3
0.030	367	367	357	399	399	5	377.8	19.8
0.050	331	364	338	389	386	5	361.6	26.5
0.070	282	318	292	318	321	5	306.2	17.8
0.094	253	272	249	282	276	5	266.4	14.6
0.187	243	263	236	256	249	5	249.4	10.6

Estimated pooled variance, $s_p^2 = 308.07$
Estimated pooled standard error, $s = 17.55$ deg F

DISCUSSION

Paul M. Braiden[4]

I would like to compliment the authors on this paper which follows work which I performed at the University of Sheffield, where I presented a method for calculating the thermal stresses which occur in tools used in intermittent cutting.[5] One of the difficulties in this type of work is the absence of any data on the heat transfer coefficients for the tungsten carbides, and I would be interested to hear how these authors overcome this difficulty. Obviously, a change in the values of the heat transfer coefficients will affect the isotherms shown in Figs. 11 and 12.

I would also be interested to know if the authors found thermal cracks in the tools tested with this technique.

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[5] Braiden, P. M., "The Performance of Tungsten Carbide Tools in Intermittent Cutting," Ph.D. Thesis, The University of Sheffield, England, July, 1968.

Authors' Closure

The authors wish to thank Dr. Braiden for the interesting questions raised in his discussion. The heat transfer coefficients on carbide tools seldom appear in literature. The thermal conductivity values of Kennametal Grade K-21 carbide, which were used in the experiment, were supplied by the manufacturer. A comparative method was used in the measurement of thermal conductivity K according to the Bureau of Standards specification. Two K values provided are 25.6 Btu/hr-ft-deg F at 212 deg F and 25.4 Btu/hr-ft-deg F at 842 deg F. The values at other temperatures were linearly interpolated or extrapolated to 1200 deg F in the calculations.

The thermal resistance between two metal surfaces in contact depends essentially on the smoothness of the matching surfaces and the applied force. In this study, an average K value of the carbide and carbon steel was chosen as an equivalent thermal conductivity at the contact surfaces. In view of the small temperature gradient in those areas, the effect of this assumption is not expected to be significant.

The convection heat flow at the heat source, i.e., the tool-chip interface, was assumed adiabatic. Heat transfer coefficients at other surface nodal points were estimated based on boundary layer thickness of a rotating cylinder.

Possible thermal cracks at the tool tip area were not investigated in this study.