Proceedings of the 18th UK Heat Transfer Conference
9-11 September 2024, Birmingham
UKHTC2024-098

FASTT - AN ALTERNATIVE TO HEATPIPE AND MICROCHANNEL HEAT TRANSFER TECHNOLOGIES

W.D. Alexander[1*]

[1]ACPI Ltd. Hopton, Stafford ST18 0TG, United Kingdom

1. ABSTRACT

Foil And Slot Thermal Transfer (FASTT) uses precision, solid foils operating within tight tolerance slots to transport heat from high flux sources to low flux sinks such as ambient air. Earlier research utilised simple lumped parameter models to determine system performance. This paper describes recent three dimensional time transient finite element analyses, which have been used to examine system behaviour in more detail. The results support the earlier findings that FASTT can provide high thermal flux throughput, but over much wider temperature ranges than existing technologies, such as those based upon microchannels or heatpipes.

2. INTRODUCTION

Heatpipes and microchannel heat exchangers provide outstanding performance in the temperature range from 20°C to over 100°C, however, there are many applications which require high flux heat transfer at temperatures both below zero Celsius to well above 100°C. The operating principles of FASTT have been outlined in earlier papers (Ref 1, 2, 3, 4), but in essence the cooling fluids utilised in heatpipes and single phase systems, are replaced by solid foils which provide both the high flux capability at source as well as the low heat flux sink to ambient air. The velocity dependent boundary layer inherent in fluid systems, is replaced by an engineered "air gap", which for systems below 1000 W throughput is typically 20 to 40 microns. Figure 1 gives schematic views of a rotary form of FASTT which can be applied to semiconductor chip cooling.

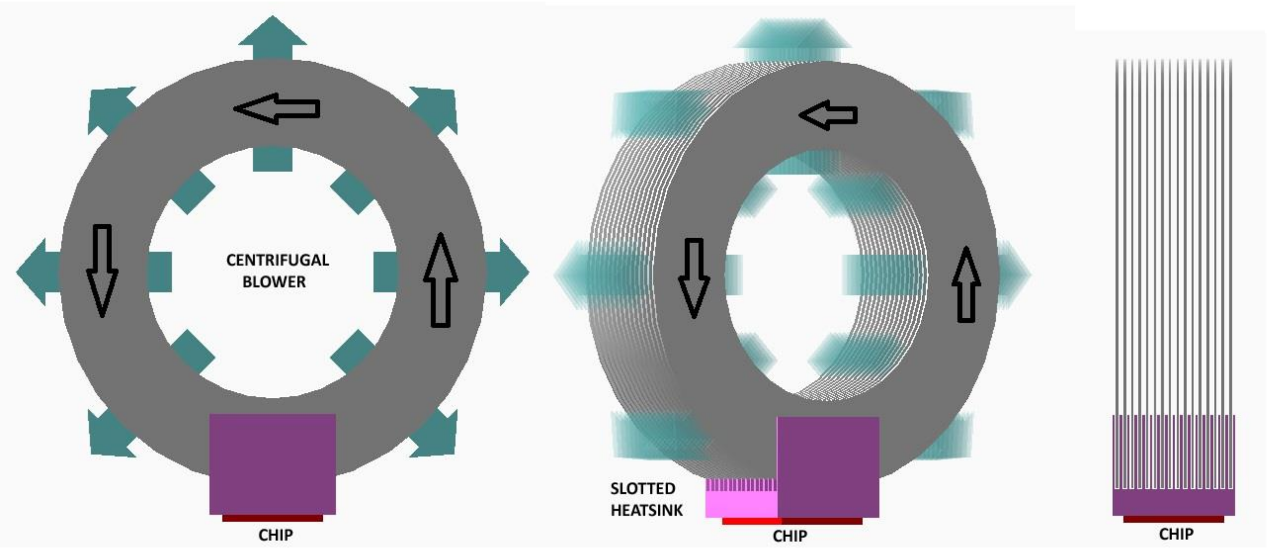


Fig. 1 Three views of Rotary FASTT – multiple foils engage with slotted heatsink on top surface of chip

*Corresponding Author: bill_alexander@btinternet.com

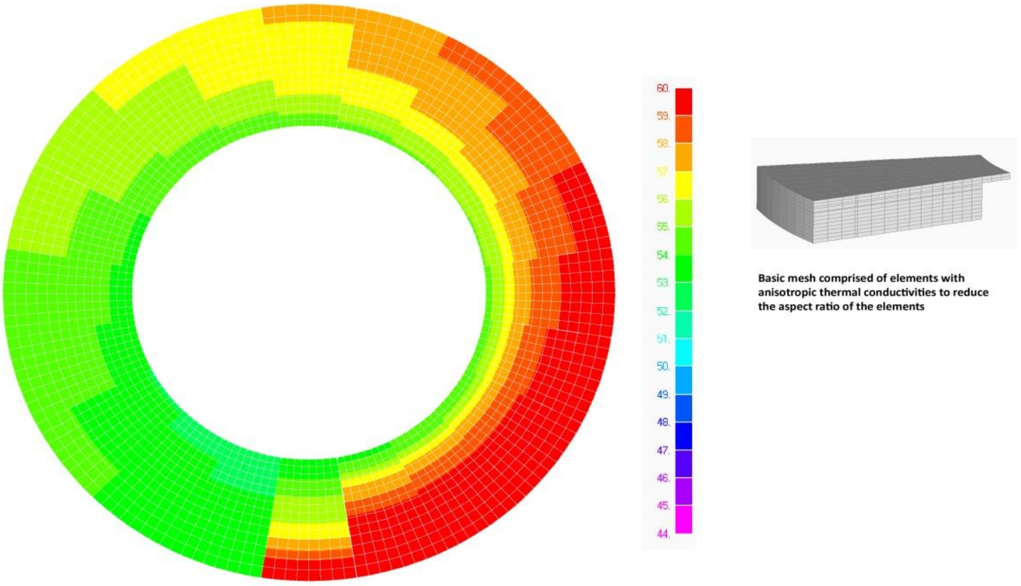
The solid foil materials used are readily available to cover temperature ranges from below liquid nitrogen, to above 800°C. These materials are generally recyclable and non-toxic. The high thermal conductivity coupled with potentially large (density*specific heat) product, give solids very high thermal transport capability. Earlier modelling of FASTT systems involved lumped parameters which although providing a good basis for design have been augmented by the recent work using finite element techniques. These more advanced modelling techniques allow higher levels of confidence in the use of the new technology, particularly for those applications where existing heat transfer technologies are struggling to achieve the desired design objectives. Experimental work has already been reported which indicates cooling flux levels above 3.0 x 10^5 [Wm^{-2}] are readily achievable (Ref.4). This paper will concentrate on recent finite element modelling applied to the rotary form of FASTT.

3. METHODOLOGY

The finite element analysis of foil and slot devices presents three basic challenges. The first of these is the high aspect ratio of the foil and slot. The second is the transient nature of the thermal problem coupled with sections of the model in which there is relative motion during the cycle period. The third is the determination of the settled condition, which can take tens of cycles to reach good convergence. A solution to each of these issues has been found, using appropriate assumptions. Three dimensional time transient thermal analyses have been carried out using FEMAP v6.01 (pre- and post-processing) together with CAEFEM v5.0 (solver) software. Composite graphics of finite element output files has been carried out using Adobe Photoshop.

4. RESULTS

The current model has been designed to simulate a cooling device for a computer chip with dimensions 40mm x 40mm, and with an expected maximum dissipation of 480 W. Figure 2 shows the results from a series of transient analyses which combine to show the temperature variation around the foil disc. The thermal input section occupies the three major segments at the lower edge, the remaining segments, anticlockwise, are subject to convective loss alone h.t.c = 30 [$Wm^{-2}K^{-1}$]. Core and foil both set as Aluminium (k = 180 [$Wm^{-1}K^{-1}$]



Basic mesh comprised of elements with anisotropic thermal conductivities to reduce the aspect ratio of the elements

Fig. 2 Settled Temperature field around foil disc (44°C-60°C, 1°C step). Anticlockwise rotation.

Core to Convective region ratio 12:1, radial cooling air from centrally mounted centrifugal fan 30°C to 40°C

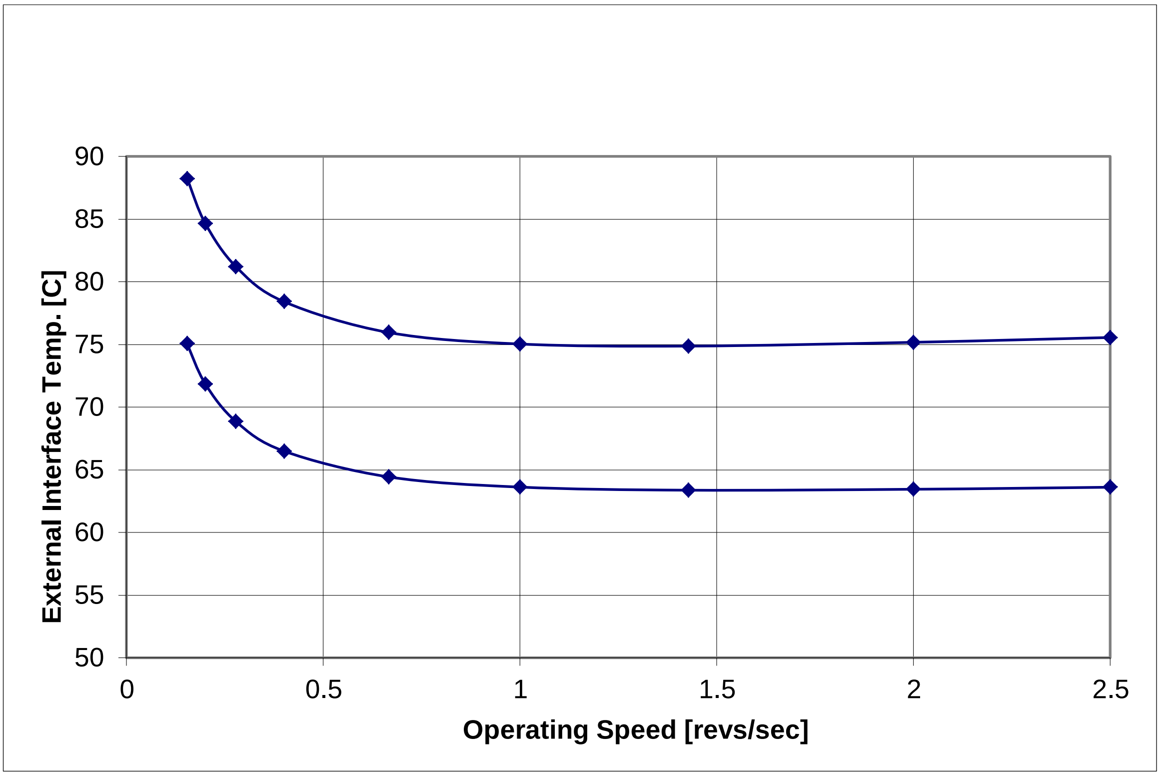


Fig. 3 Chip Interface Temperature vs Device Speed (Al core ,upper and Cu core, lower curves)

5. CONCLUSIONS

The detailed finite element modelling of rotary FASTT devices reinforces the earlier lumped parameter modelling results and indicate that the technology can offer high flux throughput over very wide operating temperature ranges, and offers to extend the operating envelopes of both cooling and heating systems. FASTT does require power input to move the foils around the system circuit, however, single phase fluid cooling systems generally require a pump, and although heatpipes may be considered as "passive" devices, the use of fans is usually required on the SINK side of systems with ambient air. FASTT may offer an alternative to existing technologies where extended operating temperature range is required.

REFERENCES

[1] W. Alexander, Novel Heat Transfer Using Solid Phase Transport Medium, *14th UKHTC Edinburgh 2015*, Edinburgh University, 7-8 Sept. 2015

[2] W.D. Alexander, FASTT Technology and some observations relating to other Cooling Technologies, *15th UKHTC Brunel 2017*, Brunel University London, 4-5 Sept. 2017

[3] W. Alexander and R. Alexander, Solid Phase, High Flux Cooling of Electronic Equipment, *SEMITHERM2017*, San Jose, California U.S.A. , March 2017

[4] W. Alexander, Progress with Development of Foil And Slot Thermal Transfer Technology, *Thermal Science and Engineering Progress*, Elsevier Pub., March 2020

[5] W.D. Alexander, Performance of a Linear, High Flux, Foil And Slot Thermal Transfer (FASTT) Device, 17th UK Heat Transfer Conference, UKHTC2021, Manchester, 5-7 Sept 2021