Fluidic circuits as a kinetic system for modulation of multiple hot spots as a thermally functional reactor

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ABSTRACT

The challenge in material science is our ability to evaluate heat flow within a material and monitor temperature with time. This research studies fluidic geometry aligned to elevated temperatures for enhanced cooling to specific multiple hot spot regions. To manage thermal stresses within a metal by modulating volumetric flows using structured channel networks. To regulate conductance point load characterised through fluxes in studying the effects of heat transport within 5754 grade aluminium, Using a kinetic mixing strategy of unified heat dissipation within channel structures for real time response to conduct heat as a function of Re regime scales. The characteristic aspect of the approach is to induce the mixing reaction rate as a turbulent kinetic system to fold the flow, re-direct the flow, stretch the flow and combine streams to disperse and dissipate thermal energy. The temperature dependence is determined by; circuit channel geometry, fluidic thermal capture and precise hydrodynamic control for increased cooling power in monitoring temperature heat loss to time through flow generation.

Keywords: thermal stress,Re scales, kinetic mixing, cooling power

1. INTRODUCTION

This technical work is to develop a thermally functional metal to conduct heat away from a source under hot spot temperature regimes where miniaturisation of fluidic flows are required. For deployment in aircraft design, for an exterior metal surface which will be hot. In this scenario, as the laminar air flow transitions to turbulent flows, the metal surface mix the boundary layer air to create mixing drag (1,2), forming a high risk of overheating a structure (3). This research studies a fluidic approach to direct energy capture using tailored flows by precise hydrodynamic control for heat seeking targeting.

Currently, the main technologies utilised for thermal management include coolant in high volumetric flows rates within solid metal plates acting as a heat sink for thermal conductivity management in turbines, hydrogen fuel cells and battery cooling for electric vehicles. This connects to heat exchangers with temperature monitoring to reduce overheating. These operational systems of fluidic distributions are contained within large channels and associated increase in weight by fluidic volume. However, these solutions cannot reach necessary requirements of lightweighing through; increased fluidic mass, requirement of increased material scale and depth for layer configurations that are significant. This restricts the integration into extreme operational environments for lightweight dependent applications in vehicles.

This research uses limited depth fluidics in hierarchical structures for heat transport embedded within a solid to develop a multifunctional conduction approach. By thermal conductance selection using variation of conductance states to specific thermal conductance targets, acting as a thermal switch (4). To manipulate lateral heat transfer to a minimum fluidic volume in avoidance of low Reynold numbers $Re < 10^2$ for higher develop turbulent flows $Re > 10^3$ for new mission conditions (5,6). Where uniform mixing combined with unified heat flow are optimised within channel geometries configurations. To control elevated temperature for thermal stability, opening up new opportunities in aerospace applications. Our investigation developed a device with testing undertaken using 2D chaotic mixing at high Reynold numbers. That induced turbulent flows streams with twisting and folding capillaries, for high dispersion of heat within a thin aluminium plate (3mm). Aluminium was selected for high thermal transfer and cost. For examining and measuring thermal conductance effects of heat transport flow across solid to fluid interface to modulate multiple heat spot locations to pane regions.

2. RESULTS

Studies evaluated flow generation of a turbulence approach determined through variation in resistance to form flow geometry structures by unequal distribution for convective circulation. For design of spatial channels in spilling streams, recombining mixing streams in chaotic flow regimes at high Reynold numbers for high thermal absorption aims. To create developed channel structures by hierarchical sequence patterns using uniform flow and avoidance of short cut circuits path ways within the network channel structures. Combining with porous flow pattern (lower resistance) effects to circuit regions for inbalanced flow to hot spot locations. By mixing streams to fluidic chambers to create uniform resistance that is moderated to sync to material regions of multiple hot spot loading. These fluidic chambers act as high absorption zones to capture increased energy for transport. With limitation of fluidic volume to reduce hydrostatic pressure differences inside the capillary interpane space with increased thermal transfer of energy. Feed in manifold input and extract channels configured to be balanced, by symmetry in geometry for recirculation of fluid return into the inlet manifold, as a closed loop cycle.

Analysis of network circuit's resistance determines channel geometry to variation in cross sectional area given by three resistances;

$$\dot{R}_i = R1_{+i} + R1{,}2 + R3_{+i} \tag{1}$$

R1 hydraulic resistance R of cross slot rectangular channel with constant cross sectional area given by;

$$R1_{+i} = \frac{\rho_\infty \bar{u_\infty} D_h}{\mu_\infty} \tag{2}$$

R1,2 resistance due to conduction through the channel wall and manifold flow rates pressures from inlet and outlet longitudinal manifold denoted by Qm

$$R2_{+i} = \frac{\Delta p_n}{Qm_n} = \frac{p_{inlet} - p_{oulet}}{Qm_n} \tag{3}$$

R3 resistance to porous flow pattern (lower resistance) effects to individual flow resistance chambers that form multiple chambers ,i that can be calculated using the cross sectional area at the mid point;

$$R3_{+i} = \frac{\mu Po 2 L_m}{A_i D_{hi}^2} for\ i = 1,2,3,4 \tag{4}$$

Where Ai and Dhi is the area and hydraulic diameter at the mid-point of the chamber, i.e.

$$A_i = \bar{w}_i h\ and\ D_{hi} = \frac{4A_i}{2(\bar{w}_i + h)} for\ i = 1,2,3,4 \tag{5}$$

This resistance network utilising flow generation of bifurcated streams twisting and folding capillaries in high dispersion to creates resistance sequencing. Patterns of higher resistance areas, manipulated and adjusted to value of channel configuration geometries by specification to a known material depth. The structure and forms are a turbulent dominant system to create active convective circulation for cooling increase effects controlled by tailored flow rates. Figure 2 illustrates the schematic of the geometry network to hot spot defined regions with fabrication drawing indicating the fluidic chambers for faster reaction kinetics in heat transfer. Testing studies undertaken to assess flow behavior paths using a hydrophobic solution to reduce friction forces illustrated. A pmma cover with 'o' ring formed the seal to the aluminium plate to study flow reactions of transitioning fluid flow was observed. From this study the pmma (1mm) plate was replaced with a aluminium cover plate and 'o' ring seal for heat transfer loading studies.

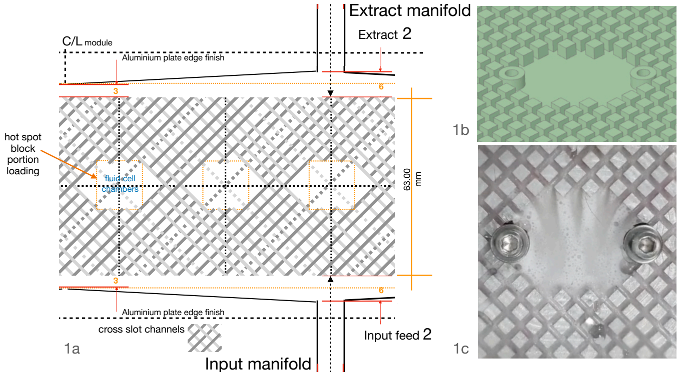

Figure 1 (1a) schematic identifying cross slot channel geometries of unified flow to the relationship of identified hot spot load positions to fluidic chamber geometry patterns, (1b) fabrication diagram of a fluidic cell chamber, (1c) Hydrophobic solvent testing of flow through a chamber cell.

3. HEAT TRANSFER

Thermal point loading was determined using three block locations held in position by mechanical fixing and resin conductive bonding. That are aligned to the fluidic network to ensure direct heat transfer to quantify thermal flows. Characterized by heat transfer qn(x), where n is the number of interface material layers, and x is heat transport across a layer thickness and surface temperatures at each layer interface determined by Tn(x).The fluid (distilled water) is continuously flowing to capture heat fluxes entering the channel wall that is related to wall temperature and fluid temperature. The energy balance is determined by thermal conductivity of the fluid characterized by fluid density, flow rate and specific heat. This energy dependency relates to heat fluxes entering the channel walls to leaving the channel layer. Where heat is conducted in the solid surrounding for heat flow transfer to channel surface spatial volume.

Experimental studies monitored; input and extract fluid temperature, interface boundary temperature of the plate to each block load path, temperature within the block and underside plate temperature to monitor temperature decay to time. Volumetric flow rate 8.281 cc/s with buoyance effects are reduced due to scale area of channels for increased heat transfer absorption rates. Initial testing studies through two hot spot positions by maximum separation in positioning to the fluidic network was undertaken with the results of this study identified in figure 2.

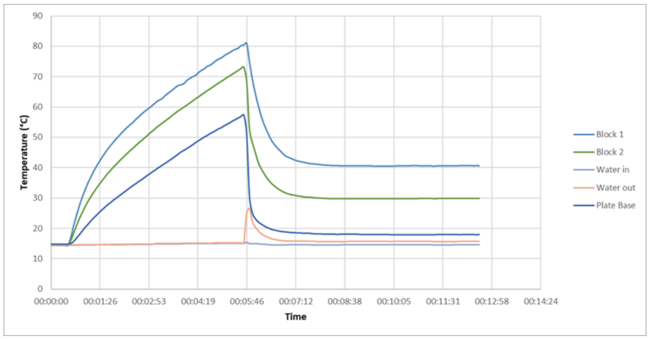

Figure 2: indicates an applied hot spot load (block 1 + 2) that is allowed to increase in temperature to 00:05:46 when fluid flow commenced. Monitoring temperature using; fluid input and output, interface temperature transfer of the block to plate surface (block 1 and block 2) and underside of plate base temperature directly below heating block positions. Flow rate 8.281 cc/s

Studies highlighted effects of flow kinetics to a tailored flow rate combined for greater cooling power in moderation of hot spot temperature through rapid heat transfer. By commencement of a delayed volumetric flow rates in the device. From this study heat loading was increased to plate pane regions to assess differing thermal properties in transferring energy by changing multiple hot spots heat flow paths. Thermal load variation enveloped differing hot spot impact to surface regions through switching conduction sources (block, 1, 2 and 3) was undertaken. To observe differing effects of heat transport for targeted hot spot cooling. Figure 3 identified heat transfer reaction time to peaks (heat flow, W) measured as a function of volumetric flow rate.

Results indicated modulation of heat transfer regulated by fluidics to applied surface hot spot thermal areas. Through uniform stream mixing with unified thermal flow to capture variation in heat transfer load patterns combined for higher cooling power effects. Unified heat flow across hot spot regions in the thermal test was identified in figure 3 by transfer in watts. That reflected in water comparisons to hot spot block loading surface positions. Increasing the conductive states of the fluid could have enhanced cooling power of the device. A nanofluid of high thermal properties for conductivity transport of the fluid, water with carbon black in 1-5%wt dispersion to maintain viscosity close to water, would have been beneficial in the test. This conductive solution will have increased heat transport by thermal mass with surface to volume capture in channel streams at differing Reynold number regimes. Thermal testing of the device undertaken gave active management to reduce the impacts of hot spots that grow and conglomerate to create unsteady generated temperatures that are significant. Through an active response that is addressed by this research. Using fluidic flows in 2D spatial geometries in mixing streams to advance mechanical properties for thermal stability.

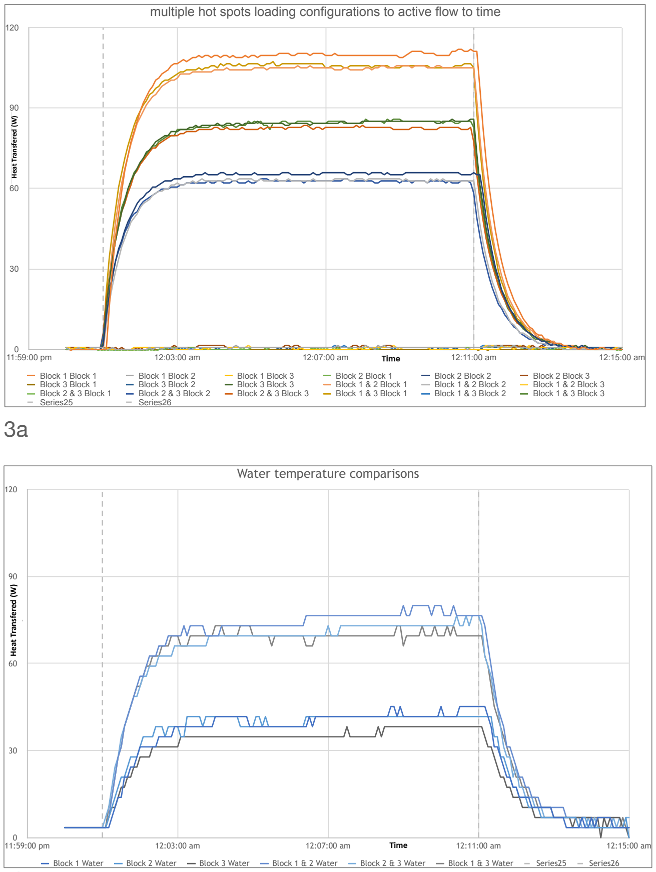

Figure 3: (3a) testing studies of multiple configurations of hot spot switchable loading positions using blocks; 1,2 and 3. To change the thermal transfer path to observe temperature modulation to time. To assess heat seeking targeting of fluidic circuits at scaling relationship through resistance hierarchy in response to interface surface cooling geometries requirement. (3b) water temperature to individual hot spot location by applied loading blocks.

4. CONCLUSION

The characterisation of the device is determined through resistance hierarchy using fluidic structural networks configured by geometry synced to multiple hot spot loading. Using chaotic flow regimes at high Reynold numbers gives an approach to high thermal absorption in meeting new challenging areas. For unified mixing of streams for uniform heat transport as a turbulent kinetic system to fold the flow, re-direct the flow, stretch the flow and combine streams to disperse and dissipate thermal scale heat flow at Re regimes. To modulate and reduce propagation of thermal spots passing over a hot metal surfaces by precise hydrodynamics to capture.

By variation of conductive states in channel geometries network through convective circulation for increased cooling to specific thermal conductance targets. Key learning to generate chaotic flow by varying channel geometry configurations to fluidic volume, utilizing fluidic absorption for increased dispersion depth. Through hierarchical configured circuits defined by a resistance strategy aligned to multiple changing hot spot regions. Aluminium was selected to attain high conductance for transfer to the fluid where channels networks are characterized to Re scaling to critical geometry temperature regions.

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