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An Experimental investigation of thermal contact conductance between Interfaces of Two Contacted Solid Materials

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Abstract: - *An experiment was performed to investigate the effects of thermal contact conductance (TCC) at different pressure and temperature and the results show that thermal contact conductance increases with the increase of interfacial pressure and temperature. An experimental investigation of thermal contact conductance was conducted with pair Stainless steel 304, over the temperature range from 30 °C to 70°C, with contact pressure from 60KPa to 700KPa. An experimental setup to measure the thermal contact conductance across solid/solid interface is described in this paper and experimental investigation is done at vacuum environment.*

Keywords: *Experimental investigation, Thermal contact conductance, Interfacial pressure, Interfacial temperature*

1. INTRODUCTION

When heat flows across the interface of two contacting bodies, a temperature discontinuity occurs at the interface of contacting solids. Thermal contact conductance (TCC) is ability to conduct heat from one body two another bodies. An understanding, and measurement, of TCC is necessary in a variety of engineering fields such as the automotive, microelectronics, metalworking, gas turbine industries and space application [1, 2].

When two surfaces are in contact with each other, the presence of surface roughness and hardness produces imperfect contact at their interface. Due to the microscopically rough nature of any engineering surface, the actual contact area between two conforming surfaces is a small fraction of the nominal contact area, usually only 1-2% [1]. The actual area of contact is much smaller than the apparent area of contact. In many applications involving rough and hard surface contact, it is important to know the thermal contact conductance through the real contact areas. This area of actual contact occurs where the asperities of one surface are in contact with the asperities of the other surface. The number of these contact spots is further reduced when surface waviness and errors in form are taken onto account. Typically, there is some material or fluid filled in the interstitial spaces between the contacting surfaces, and heat is transferred through this interstitial material.

Thermal contact conductance is increases by decreasing contact resistance and to reduce this resistance pressure is applied on the contacting surface to reduce contact gap. When contact gap is reduces then contact area is rise and due to that contact conductance is rises. Other method to increase thermal contact conductance between solid contacts is filling conductive material between gaps of solid then thermal contact conductance is increases [3].

II METHOD OF APPROACH

2.1 Test principle

Thermal contact conductance (TCC) is an additional heat transfer conductance as to the complete contact across the interface, whose inverse is defined as thermal contact resistance and in the flowing equation:

$$\boldsymbol{R_{th}} = \frac{\boldsymbol{\Delta T}}{\boldsymbol{q}}$$

Where $\boldsymbol{R_{th}}$ is thermal contact resistance, ΔT interface temperature drop, and q heat flux per unit area.

$$\boldsymbol{h_c} = \frac{\boldsymbol{q}}{\boldsymbol{\Delta T}}\left(\frac{\boldsymbol{w}}{\boldsymbol{m^2}\,°\mathrm{C}}\right)$$

The steady state method is used in this paper, ΔT between the interfaces can be calculated by extrapolating the temperature profiles of each test jobs to the interface. And q is calculated by multiplying the temperature gradient with the heat-flow meter's thermal conductivity.

2.2 Experimental Setup

The experimental setup is illustrated by Figure 1 shows the cylinder test jobs. The interface force is applied at the top of test jobs (see Figure 1). RTD sensors are used to measure temperature of test jobs there are 8 ports of temperature sensors. The heat is dissipated by electrical heat generation with heaters. Thermal insulation is used to control heat leakage of test jobs. And to reduce convection and radiation losses test was conducted in vacuum environment and setup was covered by multi layer insulation.

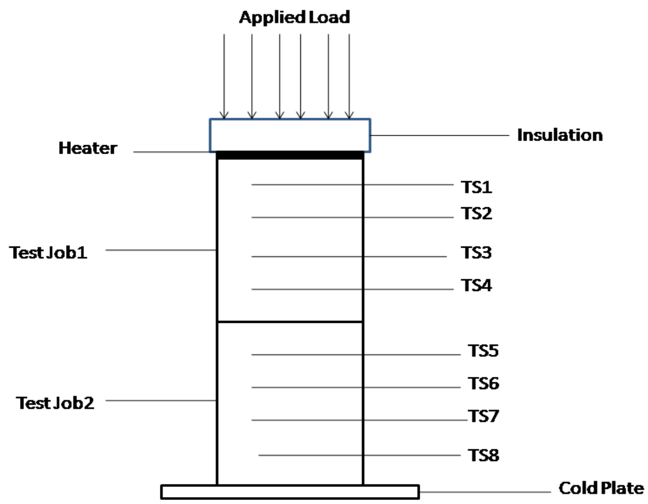

Figure 1 schematic diagram of setup

2.3 Test Jobs

The test jobs used in this study were made up of stainless steel- 304 block and they are bare in contact. The cross section of test jobs is circular in shape. To measure temperature of test jobs RTD sensors were used and the sensors are placed 50mm deep of test jobs

2.4 Interfacial Contact pressure measurement

The interfacial contact pressure between contacting surface of test jobs were measured by load cell which was mounted on the top of the test job and uniform pressure distribution was considered. And digital process indicator was connected with load cell which was placed outside of vacuum chamber

2.5 Data logging and analysis

In this experiment the heater temperature were set at between 20°C to 100°C which corresponded to the heat flux ranged. Experimental data were taken when the temperature profile of test assumed to have been reached when none of the measured temperatures in test specimens varied. To determine the temperature difference (ΔT) across the interface, the upper and lower temperature profiles were extrapolated to the upper and lower junction surfaces of the specimens. Based on Fourier's law, temperature gradients and thermal conductivity of test the test jobs were used to calculate the heat flux through the temperature sensor and these data were collected in data logger.

III EXPERIMENTAL PROCEDURE

The test specimens were loaded to a maximum nominal pressure of 700KPa when two surfaces are in contact, only certain discrete asperities from each surface will contact the other surface. As the load is increased the initially contacting asperities will deform and so the mean distance between the two surfaces decreases. This will introduce newly contacting asperities and as a result the contacting area of test jobs will increase. Some of the asperities deform only elastically while some of them will deform plastically after some initial elastic deformation. This process is ongoing as the pressure is increased. Once the maximum load is reached and the interface is unloaded, the asperities that deformed plastically do not regain their original shape.

This increases the actual contact area at lower loads during unloading compared to the contact area at the same loads on loading. As a result the TCC is higher during unloading compared to loading at the same contact loads, leading to hysteresis effects [1, 4, and 5]. Assuming that the surfaces are not separated and they are loaded again, only the asperities that were in contact at the end of the first unloading will be in contact for the following new cycle. As the asperities that were in contact after the first unloading have already plastically deformed, for the same contact loads they will12 not deform any further than it already has after the first unloading. This is expected to hold true as long as the contact loads at any given loading history do not exceed the maximum load of the first cycle. This argument suggests that thermal contact conductance (TCC) for a given load should remain constant after the first loading unloading cycle, as observed from the results presented[1].

In this experimental work the pressure of test jobs were maintained constant and at this constant pressure temperature of test jobs were varied. The data were logged in system .and with the help of temperature sensors reading of contact conductance were calculated.

In this study the lower plate of setup was maintained at 20°C as a heat sink and because of this heat sink temperature were flow uniformly in test setup.

While heating test job1 the temperature of test job1 is also transmitted to test job2 and at low temperature and pressure there was contact resistance take place and at high temperature and pressure these resistance reduces and thermal contact conductance increases.

IV RESULT AND DISCUSSION

4.1 Interfacial temperature difference:

Temperature distribution of two stainless steel-304 test job was measured by RTD sensor. This was placed radial in the test jobs. There were temperatures differences between test job1 and test jobs.

The temperature of test jobs were controlled by foil heater, resistance of foil heater was 20ohm.and by varying voltage of foil heater temperature of test jobs were varies.

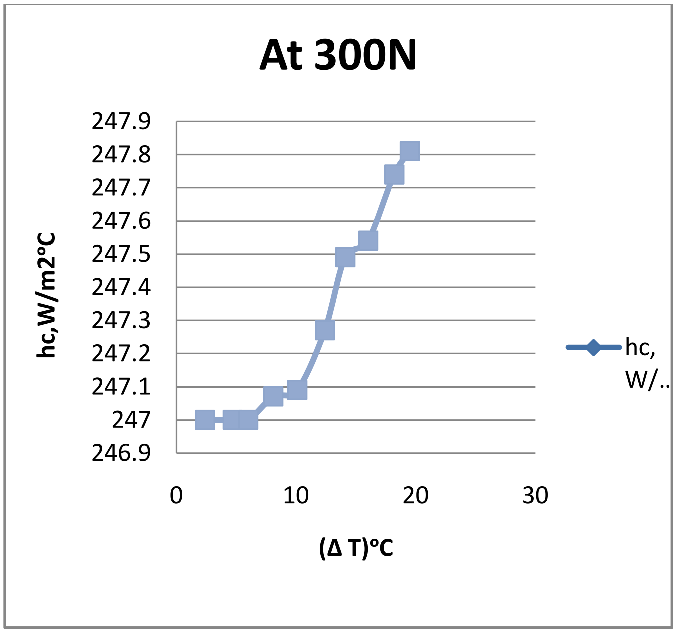

Figure 2. TCC at 300N

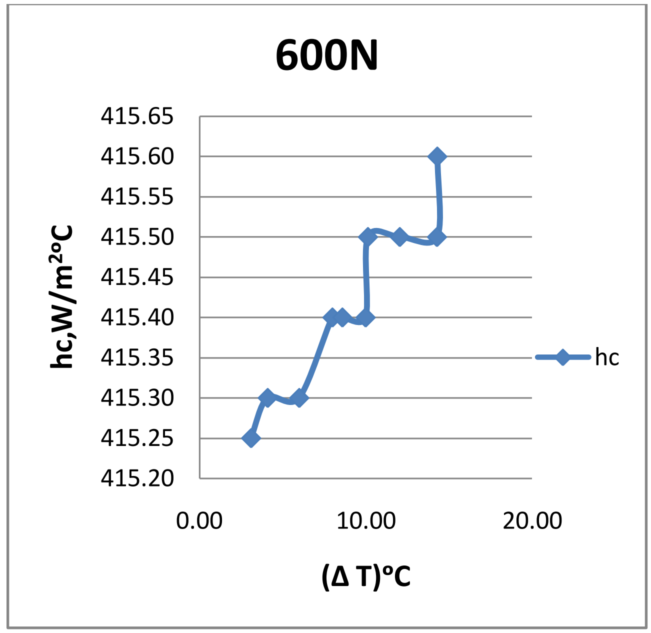

Figure 3.TCC at 600N

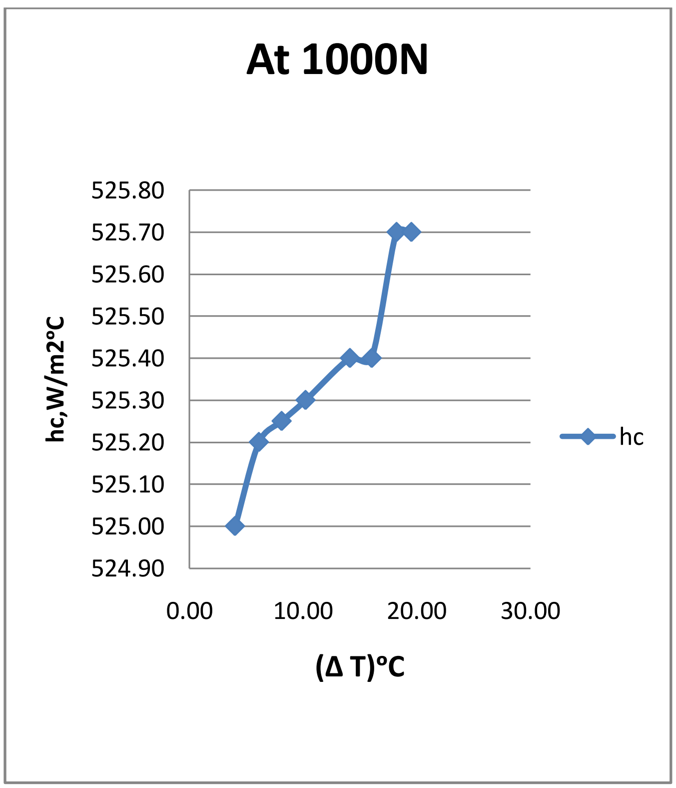

Figure 4.TCC at 1000N

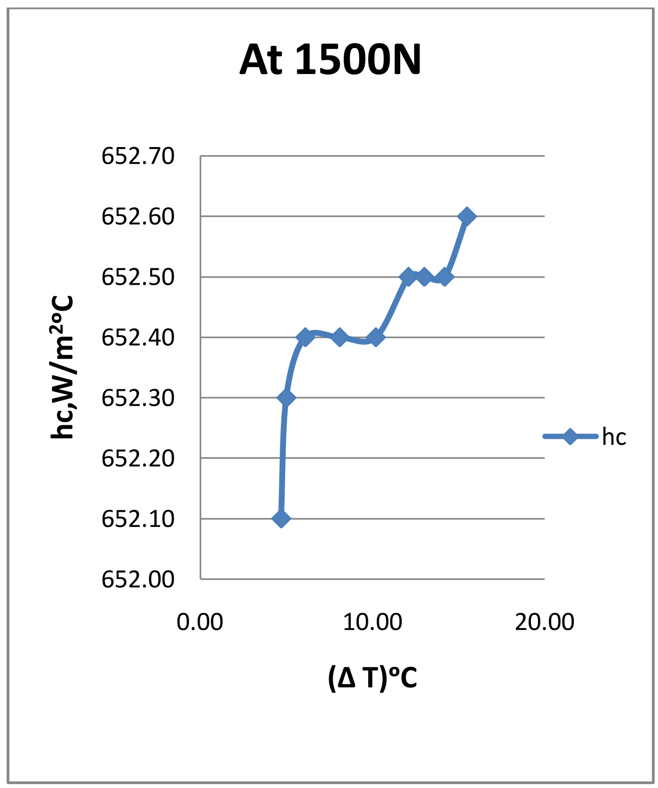

Figure 5.TCC at 1500N

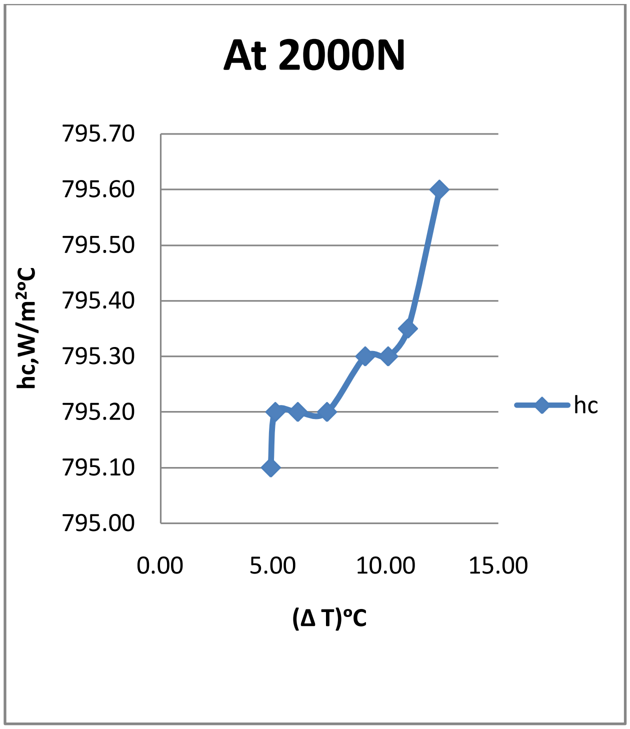

Figure 6.TCC at 2000N

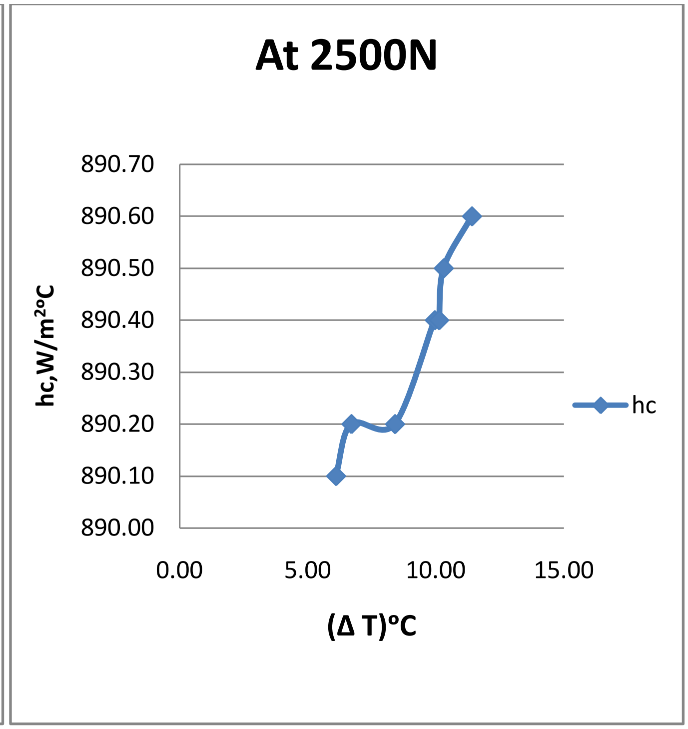

Figure 7 .TCC at 2500N

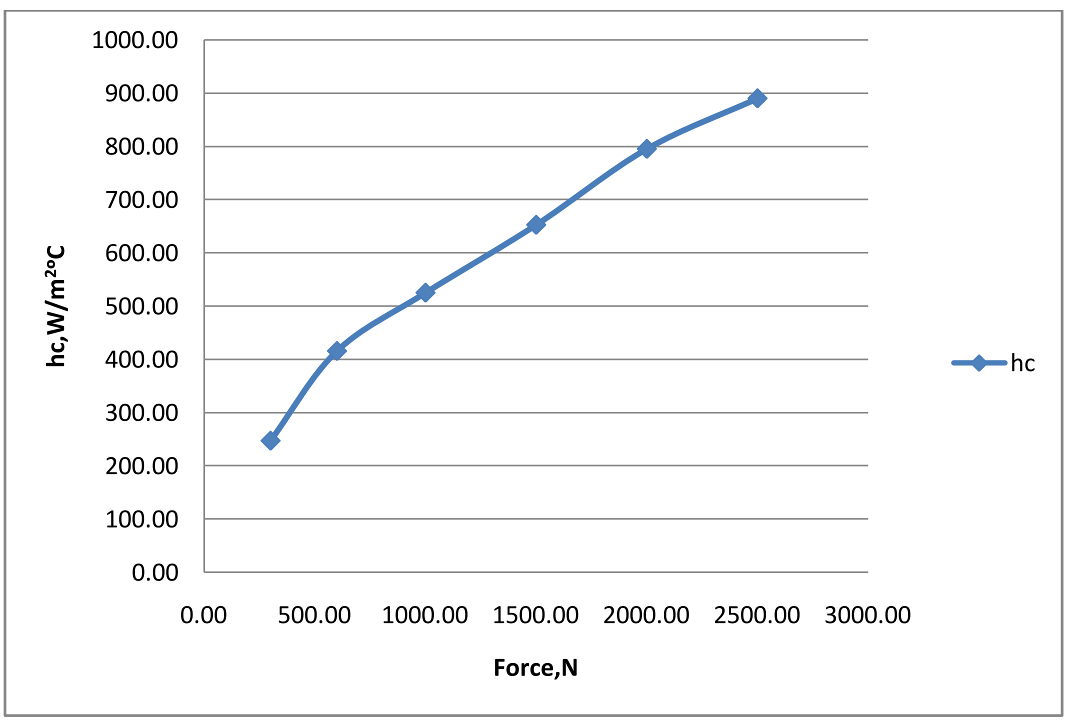

Figure 8. TCC at different contact force

In this study results shows that thermal contact conductance increases with increases pressure.

V CONCLUSION

In this study, an experimental setup was designed, which is placed in vacuum environment. This setup is simple structure, ease in operation, low cost and accurate. The comparison between experimental result and theoretical prediction proves that the present measurement equipment can be used for application. Some experiments have also been done in different conditions and the effect of the interfacial pressure, by the voltage of heater, the temperature compensation and the thermal conductive adhesive on the thermal contact resistance were examined by experimental method., The results show that the thermal contact conductance increases with increase of interfacial pressure,

With the help of experimental investigation results show that thermal contact conductance was increases with the increasing contact pressure. The contact pressure is the factor of most influence on contact conductance. As contact pressure grows, contact conductance grows (And consequentially, contact resistance becomes smaller). This is attributed to the fact that the contact surface between the bodies grows as the contact pressure grows. As pressure increase a greater asperity deformation happens and the thermal contact conductance increases. Thermo physical properties of contacting materials like's high values of thermal conductivity and thermal expansion coefficients have favorable effect on the conductance. As thermal conductivity and thermal coefficient vary with the temperature, the thermal contact conductance depends on the interfacial temperature and interfacial pressure.

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