Chapter 3

Static Test Results

Both the lumped capacitance and the distributed capacitance technique were used to calculate the total resistance between the hot and cold blocks used in the experiments. If the Biot number of the blocks was less than 0.05, then the lumped capacitance method was used. A Biot number of less than 0.05 occurred for all of the embossed polyethylene and the polyester used in the experiments. In general the Biot number was greater than 0.05 for the polypropylene tests, and therefore the distributed capacitance data reduction method was used. The pressure was varied from 0.35 kpa to 6 kpa for all of the plastics, representing a pressure range commonly encountered in unnipped heating cases. Eight tests were run at each pressure, and the results averaged and used to find the standard deviation of each set.

A low pressure dependence on the contact resistance was found for all of the plastics. This may be due in part to the small range of pressures investigated in this study. Generally contact resistance studies on pliable materials have been done on up to approximately 300 kpa and beyond by Seyed-Yagoobi et al (1992a) and others. However with paper studies, contact resistance is generally more of a function of basis weight than interface pressure, and comparing plastics with a paper of similar basis weight is not appropriate. In addition the contact resistance of a paper interface becomes negligible when the ratio of the actual contact

area to the nominal contact area of the paper approaches the average void density of the paper.

3.1 Smooth Films (Polyester & Polypropylene)

The polyester and polypropylene tested in this study have a smooth finish, and were produced by drawing a relatively thick web of plastic through nips and successively stretching the plastic to its final thickness. As the contact resistance is based primarily on the finish properties of the surfaces, the internal molecular structure of the plastics has only a small effect on the joint resistance. The plastic molecular structure will effect the thermal conduction resistance in the plastic however.

The contact resistance data measured for the polyester and polypropylene to aluminum surface is statistically identical. Under the range of pressures used in the study, the pressure had only a small effect on the contact resistance, with slightly higher measured contact resistance at the lowest interface pressures. For the smooth plastics, the standard deviation of the 8 tests run at each pressure decreased with increasing pressure. This is probably due to a better ‘fit’ of the sample in the test apparatus, reducing the random effect of how the plastic sample was placed between the two blocks.

The results for the polyester-aluminum interface are shown in figure 3.1.1 below.

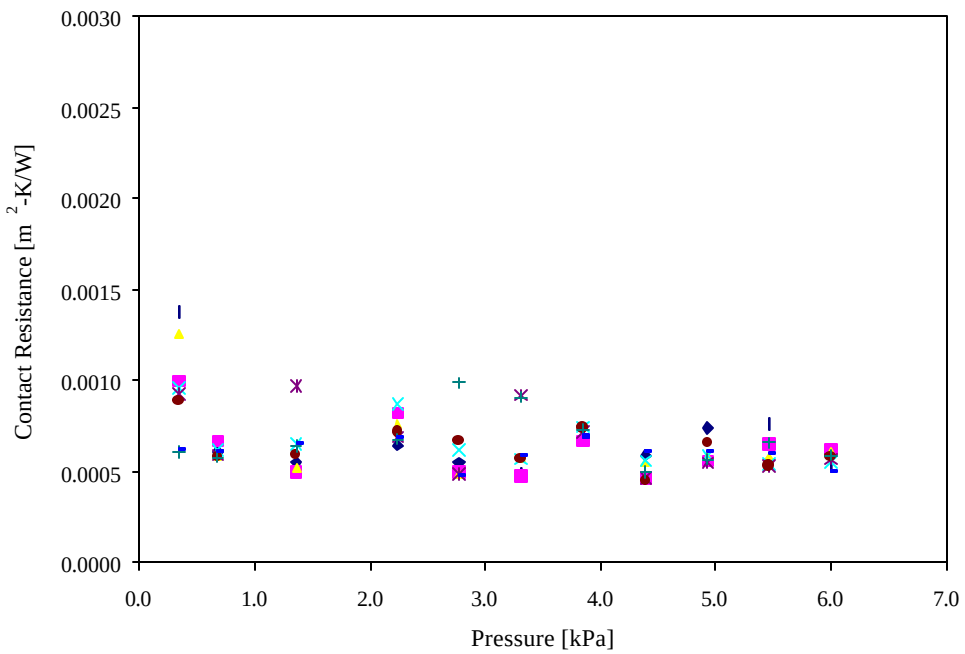

Figure 3.1.1: Aluminum – Polyester Contact Resistance Measurements.

The contact resistance for the polyester –aluminum interface varied from a maximum of 0.0015 m^2-K/W to a minimum of 0.0005 m^2-K/W. The average for all of the polyester runs was 0.0007 m^2-K/W.

The results for each polypropylene run are shown in figure 3.1.2 below.

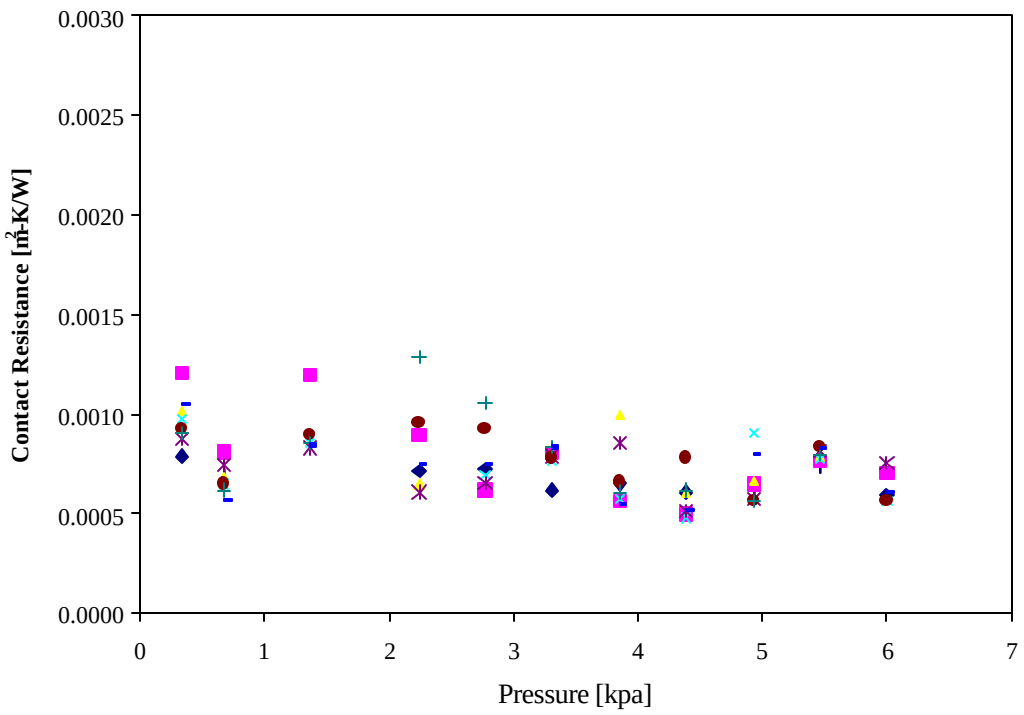

Figure 3.1.2: Aluminum – Polypropylene Contact Resistance Measurements.

The maximum of the runs was 0.0013 m^2-K/W with a minimum of 0.0005 m^2-K/W. The average for the series of runs was 0.0008 m^2-K/W. These are very similar to the values encountered in the polyester runs.

3.2 Rough Films (Embossed Polyethylene)

Tests were run on a previously embossed sample to measure the effect of a ridged surface on the contact resistance between the plastic and the roller. The results for the embossed polyethylene runs are shown in figure 3.2.1 below.

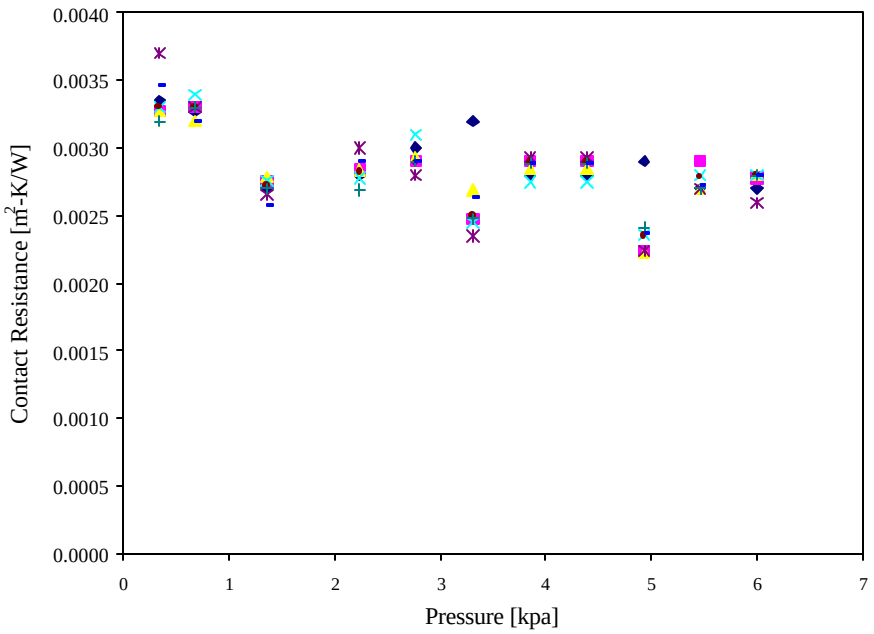

Figure 3.2.1: Aluminum – Embossed Polyethylene Contact Resistance Measurements.

The measured contact resistances for the embossed sample were drastically higher than measured for either of the smooth plastics. The largest, minimum and average measured resistance was 0.0037 m^2-K/W, 0.0023 m^2-K/W and 0.0029 m^2-K/W respectively. As with the smooth plastics, pressure did not have a strong effect on the measured joint resistances.

The difference between the smooth samples and the embossed samples is shown in figure 3.2.2 below.

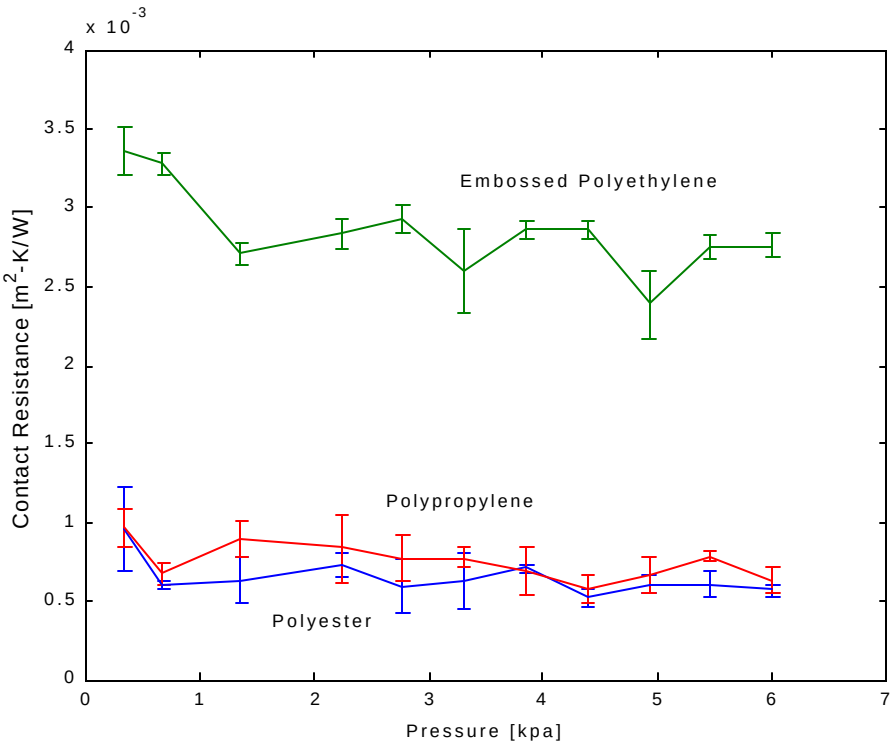

Figure 3.2.2: Summary of Contact Resistance Measurements.

The error bars shown in the figure are based on plus and minus one standard deviation. The embossed samples had a contact resistance 3-4 times larger than the smooth samples. For the embossed pattern on the sample, the area ratio between raised and shallow areas was about 5.

3.3 Comparison with Published Data

Any comparison with published data is hard to make due to the lack of appropriate plastic data for the pressure ranges encountered in this study. A comparison between calendered paper and the plastics can be made. Calendered paper has been densified and has a smooth surface finish similar to the smooth plastics in this study. Calendered paper was reported to have a contact resistance of 0.0006 m^2-K/W by Kerekes (1980), in an unnipped roller case. Similar results to Kerekes were reported by Burnside & Crotogino, (1984), again for calendered paper.

3.4 Error Analysis

As the total thermal resistance between the two blocks includes the conduction resistance in the plastic, any uncertainty in the plastic properties of thickness or thermal conductivity affect the measured contact resistance in a linear fashion. While the thickness of the plastics can be accurately measured, the thermal conductivity was not constant, or accurately known, over the range of temperatures experienced in the study. The conductivity of the embossed polyethylene varied the most in this study. The conductivity varied from 0.38 to 0.25 W/m-K under the temperature ranges found in the experiments. As the conduction resistance was 20% of the total resistance measured in the system, the maximum error due to property variation for the embossed polyethylene samples was 7%. For the polypropylene and the polyester the error was less than 2 %.

The largest source of random error was due to the flatness of the blocks. When the blocks were brought together for each test they were brought together in different orientations around the vertical axis. The flatness error of the blocks would have varying effect on the measurements of the joint resistance, but it is difficult to quantify. The surface characteristics of the blocks were machined to match as closely as possible the surface finish of the Thermalon® rolls. Due to the vastly different technique between polishing a flat surface and grinding a cylindrical roll, there were different macroscopic surface finish characteristics. The surface roughness parameter, a measure of the microscopic irregularities, can be matched, but the flatness of the blocks has no counterpart on a roller nor does the runout on the roller have a counterpart on the flat blocks.

After the static model had been used to measure the contact resistance for a plastic to metal interface, a finite difference model was written to simulate the effect of the contact resistance of a web passing over a hot roller. Chapter 4 discusses the work.