01 May 1994

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ABSTRACT

The actions that solvents take on polymers was the focus of the summer 1993 research. There were two goals: one was to measure the distances between the cracks that formed in the plexiglass and two was to determine the time of arrival of the cracks. Two solvents, butyl acetate and acetone were used to generate data on polymethyl methacrylate (PMMA/Plexiglass).

The measurement of the time of arrival of a crack was another goal. This quantity is related to the growth of the fractures. This was difficult since only a localized portion of the plexiglass sample could be viewed.

INTRODUCTION

It has been observed that engineering apparatus such as distillation columns cannot be designed using polymeric materials as they are always in contact with organic liquids. In the presence of organic liquids they crack easily. This is called environmental stress cracking.

Researchers have suggested various mechanisms and theories which have been reviewed by E.H. Andrews in The Physics of Glassy Polymers [1]. These mechanisms are often conflicting and are not reliable. If a mechanism is to be used, it should be able to predict two things: 1) how cracks are distributed, i.e., the gap between adjacent cracks and 2) the rate at which the cracks appear.

When polymers are contacted with a solvent fractures form. The gap size, the distance between the cracks, is related to what is called the perturbation wavelength.

The distances between and the sizes of the cracks were among our interests in the research.

EXPERIMENTAL

The procedure used for research was essentially the same as that developed by Matt Griscom, an undergraduate student who had worked on the project earlier [2]. He studied the size of the cracks themselves. With a few alterations, the procedure was as follows:

1) A 1/2" (approximate) square of plexiglass was machined to create a 1/4"(approximate) groove in the plexiglass. This is shown in Figure 1. Myrlen Troutt, Supervisor of Technical Labs, did the machining.

2) A piece of wax was placed on the grooved surface covering it entirely. It was observed that the wax was easier to work with if softened between the fingertips first. The wax must cover the surface to prevent solvent from contacting horizontal surfaces.

3) The wax was trimmed away at an angle using a utility knife. This allows vertical contact and keeps the horizontal surfaces covered. This is shown in Figure 2.

4) A small drop of solvent, butyl acetate or acetone, was placed on the diagonal surface of the wax and allowed to sit approximately 45 minutes. The orientation of the wax allows the solvent to rest against the vertical surface of the polymer and it also protects the horizontal surfaces from exposure. Thus, viewed from the top, we have two halves: one half is dry PMMA and the other half is acetone. This is shown in Figure 3.

5) With the microscope set at 10X power the slides were observed. The microscope was equiped with a graduated eyepiece thus allowing easy measurement of the distances between the cracks.

6) Distances, in mm, between cracks were noted and the data collected. The form of the cracks and the arrangement in general are shown in Figure 4.

RESULTS

Two solvents were used: butyl acetate and acetone. The butyl acetate was used for most of the data because it showed better results than the acetone. The butyl acetate produced fewer cracks but they were longer in length. The acetone produced large quantities of small cracks. Also, if there was a long contact time large pockets would dissolve out of the plexiglass sample.

Table 1 shows the data that were collected. The first column shows the length of the distances between cracks, r mm. The second column shows the number of cracks less than r mm. Column three shows the smoothed data. The slope is calculated in column four using the smoothed data and attributed to an average value of r. The butyl acetate data is listed first then the acetone data.

In Figure 5, the distribution of gap sizes is shown for the butyl acetate solvent. Figure 5 shows the cumulative gap size distribution of gaps less than a certain dimension. All butyl acetate data was taken at approximately 45 minutes of reaction time. In Figure 6, the derivative was taken of the data to show

which gap size were most preferred. A maximum occurs at approximately 0.3 mm. This means that the most cracks are closer to one another by less than 0.5 mm. Another small maximum is located at about 2.75 mm.

Figures 7 and 8 show the acetone data that was collected. These samples were allowed to react for about 24 hours. Figure 7 again shows the cumulative distribution and Figure 8 the maxima. Once again the maximum occurs at an r less than 0.3 mm.

In conclusion, the data that was collected consistently showed that the majority of the gap sizes are of small r values.

ACKNOWLEDGMENTS

Dr. P. Neogi was the faculty advisor and offered several suggestions that were very helpful. Matt Griscom did previous research on a similar project and his results provided a procedure for the summer's research. Finally, Myrlen Troutt did the machining on the polymer as well as helping with equipment problems.

REFERENCES

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Griscom, Matt. The Effects of Acetone and Butyl Acetate on Plexiglass. 1993

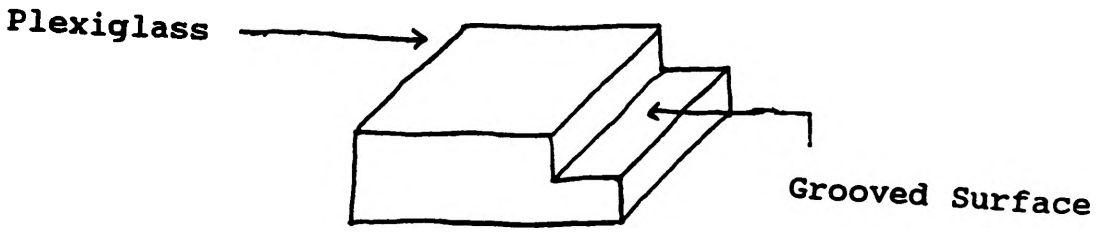

Figure 1. Schematic of machined polymer

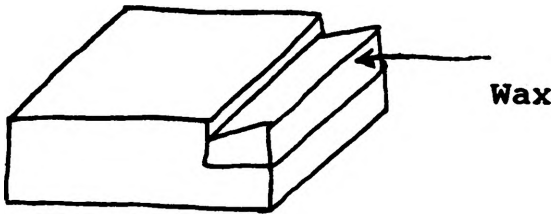

Figure 2. Placement of wax

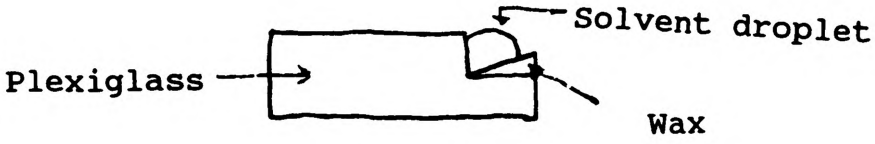

Figure 3. Orientation of solvent droplet on polymer and wax

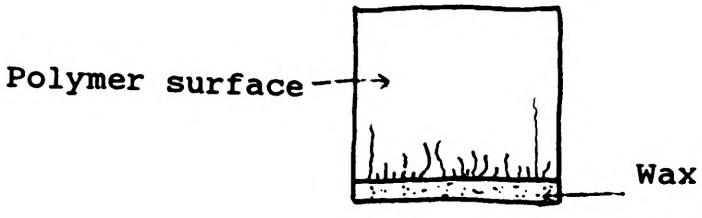

Figure 4. Form of the cracks and general arrangement

Table 1

Butyl Acetate Data

x r mm	y number	y' number	slope	r mm corrected
0	0	0	0	0
0.3	24	23	98.6	0.267
0.5	45	49.3	94	0.533
0.8	79	70	85.4	0.767
1	86	92	66.6	1.033
1.3	111	104.3	49.4	1.267
1.5	116	116.7	38.8	1.533
1.8	123	123.7	30	1.767
2	132	131.7	26.6	2.033
2.3	140	138	21.2	2.267
2.5	142	142.3	18.6	2.533
2.8	145	147.3	20	2.767
3	155	152.3	18	3.033
3.3	157	156.3	11.4	3.267
3.5	157	158	6	3.533
3.8	160	159.3	6.6	3.767
4	161	161.3	7.4	4.033
4.3	164	163	6	4.267
4.5	164	164.3	3.4	4.533
4.8	165	164.7	2.8	4.767
5	165	165	0	5.033

Acetone Data

x r mm	y number	y' number	slope	r mm corrected
0	0	0	0	0
0.3	11	10	93.2	0.267
0.5	19	23.3	43.64	0.533
0.8	40	34	28.53	0.767
1	43	44.7	15.24	1.033
1.3	51	50	10.4	1.267
1.5	56	57.7	9.03	1.533
1.8	66	64	7.43	1.767
2	70	70.7	5.37	2.033
2.3	76	75	4.27	2.267
2.5	81	80.3	3.65	2.533
2.8	84	84.3	2.91	2.767
3	88	88.3	2.52	3.033
3.3	93	92	1.97	3.267
3.5	95	94.7	1.32	3.533
3.8	98	98.7	1.23	3.767
4	99	99.3	1.36	4.033
4.3	103	102.3	1.41	4.267
4.5	105	105.3	1.1	4.533
4.8	108	107.3	0.842	4.767
5	109	109.3	0.673	5.033
5.3	111	110.7	0.514	5.267
5.5	112	112	0.36	5.533
5.8	113	112.7	0.174	5.767
6	113	113	0.0496	6.033
6.3	113	113	0.16	6.267
6.5	113	114	0.305	6.533
6.8	116	115	0.296	6.767
7	116	116	0.184	7.033
7.3	116	116.3	0.097	7.267
7.5	117	116.7	0.093	7.533
7.8	117	117	0.129	7.767
8	117	117.7	0.161	8.033
8.3	119	118.3	0	8.267

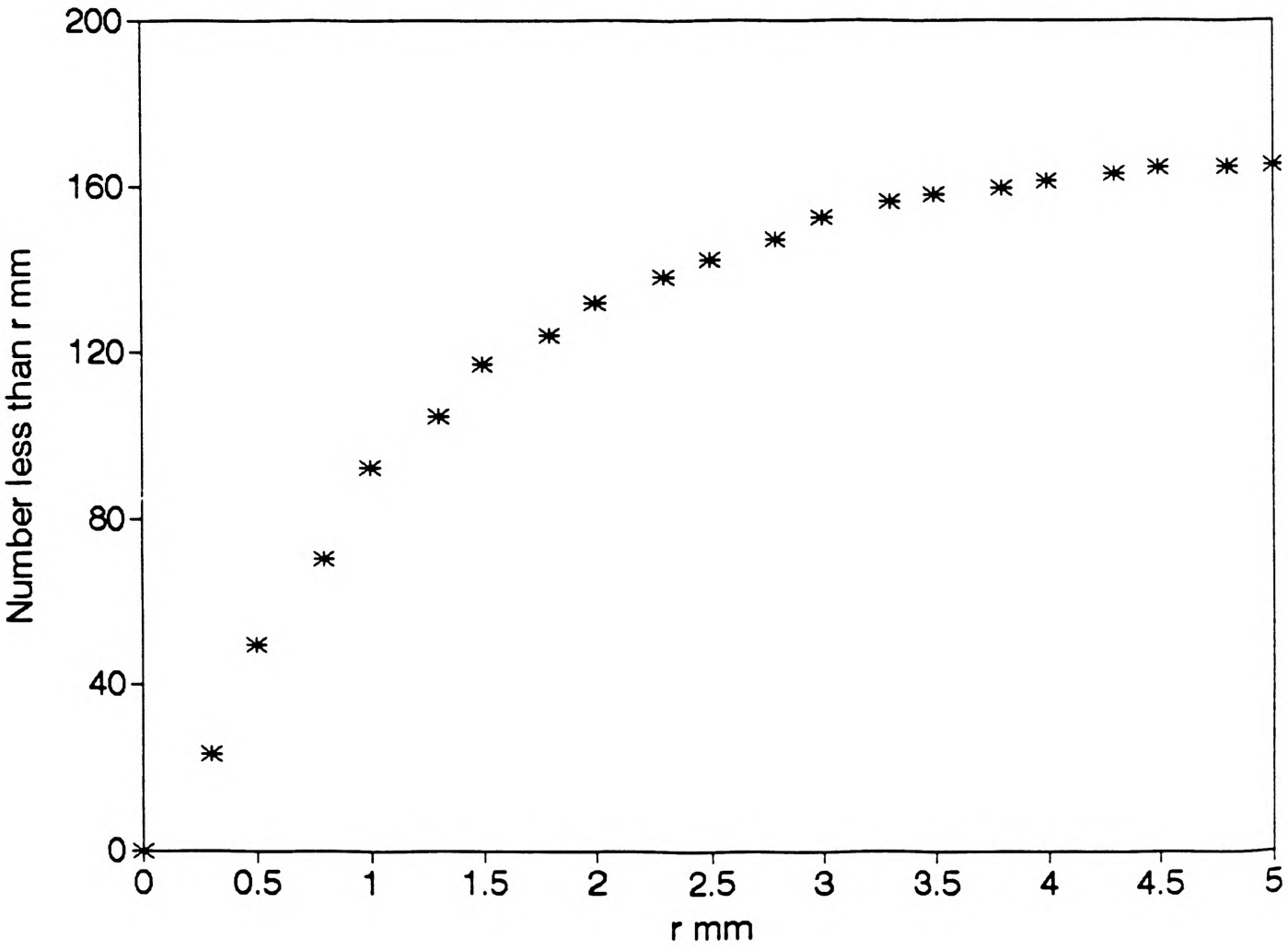

Figure 5. Cumulative gap size distribution for butyl acetate. Shows the number of adjacent cracks that occur below a gap of r mm

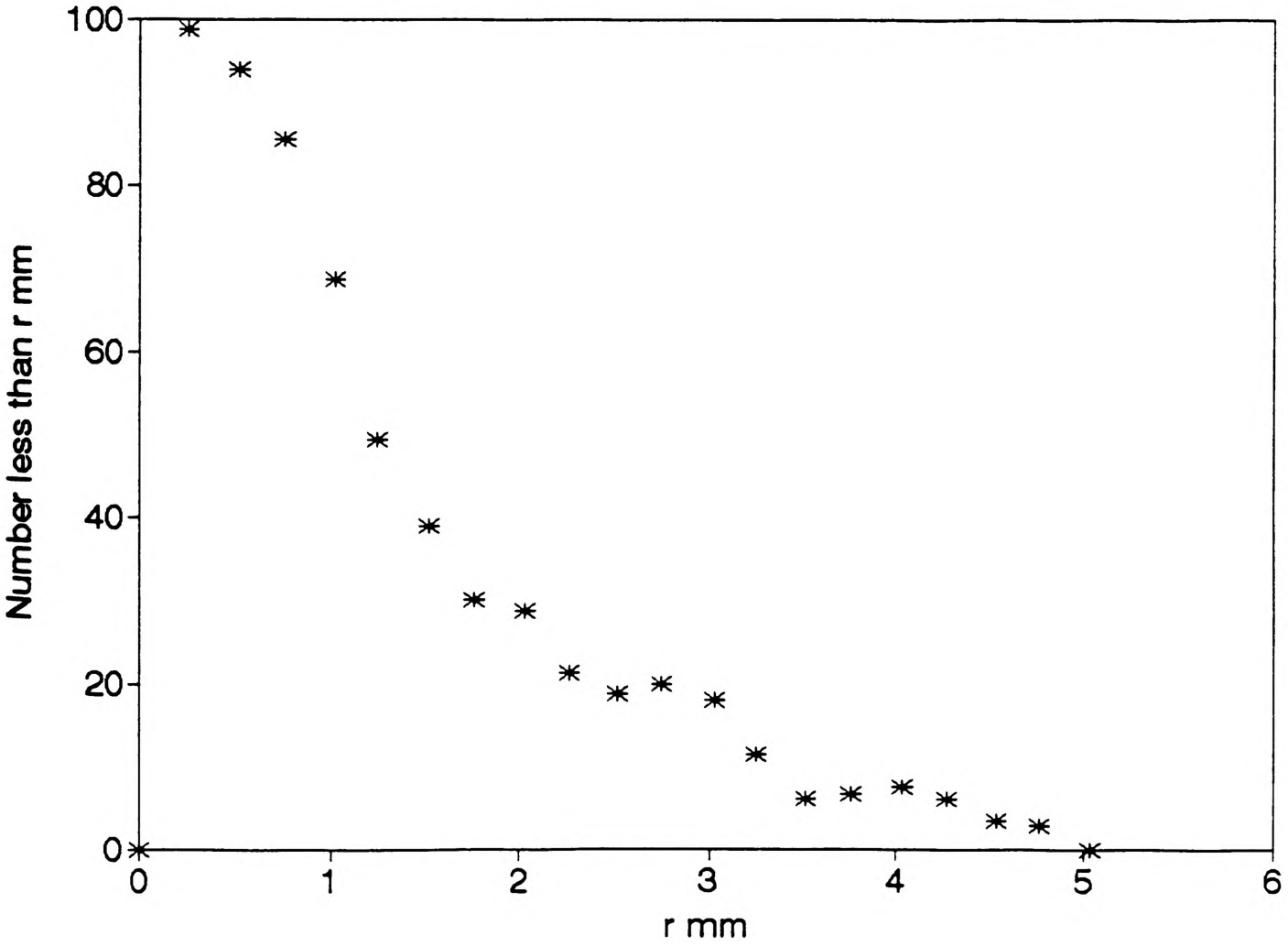

Figure 6. Derivative of Figure 5. Shows the frequency distribution of adjacent cracks with a gap of r mm

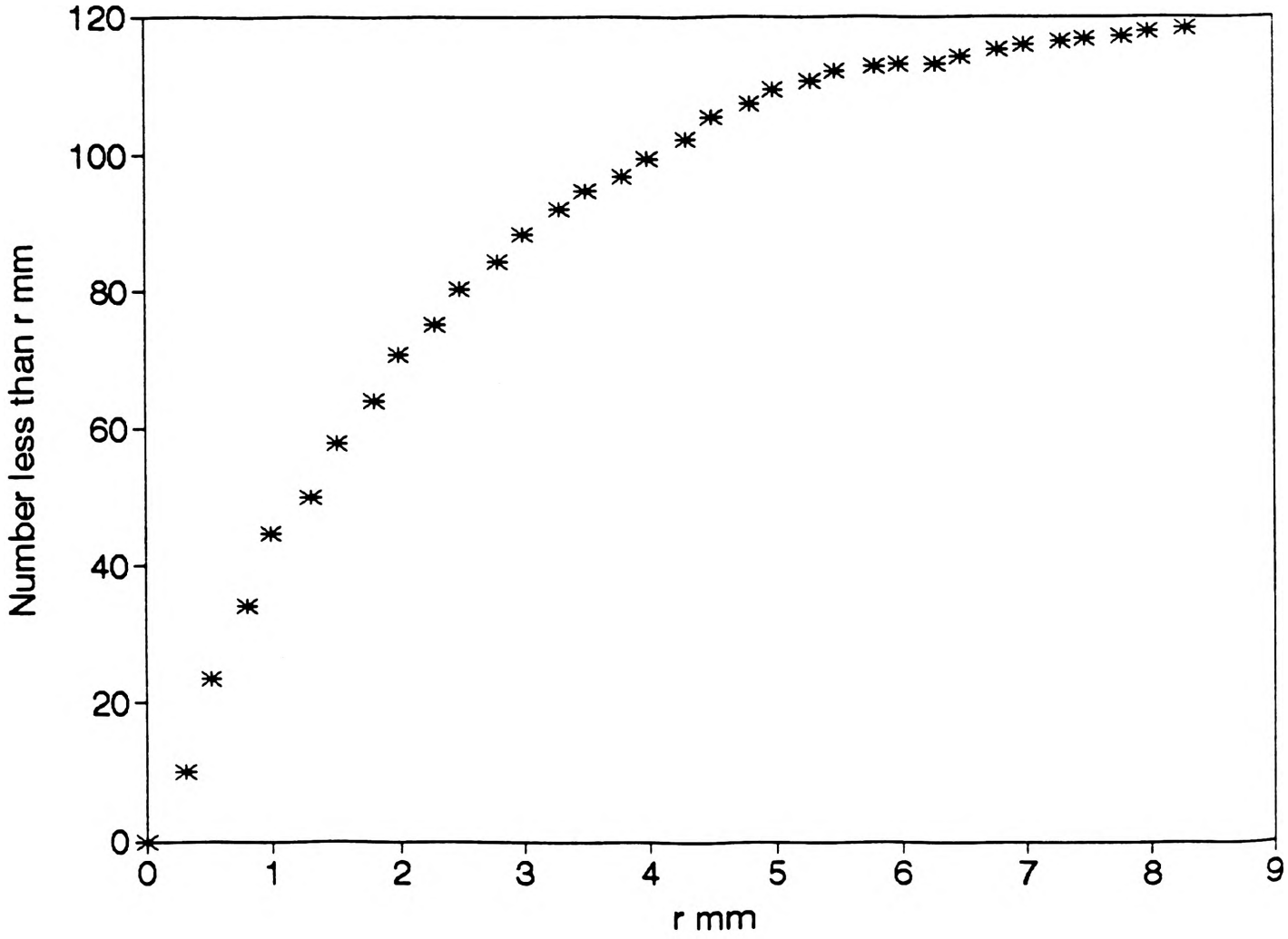

Figure 7. Cumulative gap size distribution for acetone. Shows the number of adiacent cracks that occur below a gap of r mm

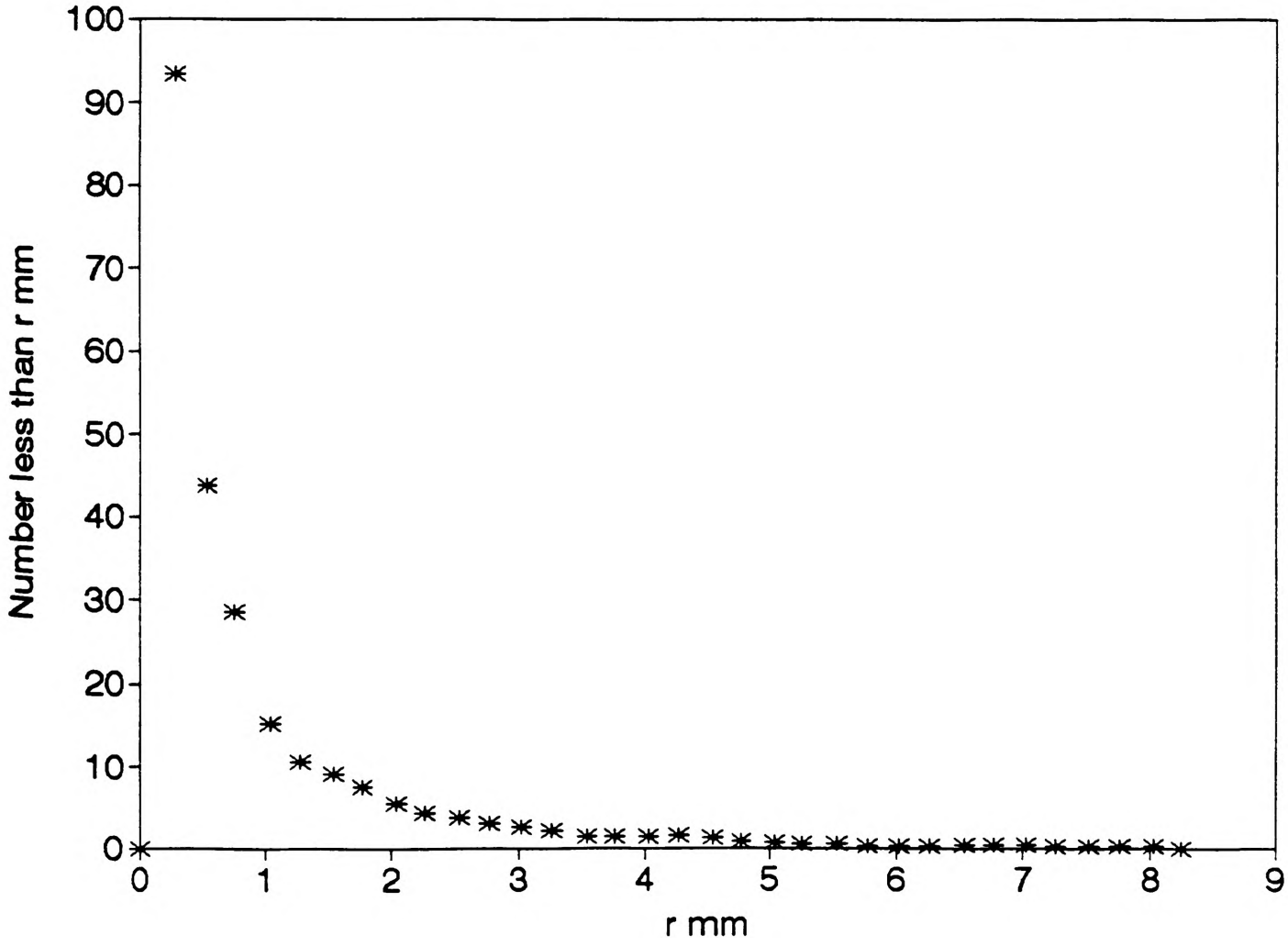

Figure 8. Derivative of Figure 7. Shows the frequency distribution of adjacent cracks with a gap of r mm