



Measurement of the Properties of a High Density Polyethylene Fibre Optic Covering

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ABSTRACT

The polymer processing industry in the UK is seeking to find the optimum balance between speed of production and product quality. High density polyethylene fibre optic coverings provide an ideal example of the relationship of processing to properties. Assurance is needed of the quality of the coverings produced from the extrusion process. Of particular importance are dimensional variations and surface properties. Using heat reversion measuring equipment, the dimensional changes were ascertained and correlations with the processing conditions investigated. Reductions in length were approximately 85% and increases in thicknesses were approximately 170%.

Surface roughness was quantified using a laser surface profiler. Differences in the surface finish of samples with different quenching conditions were clearly identified.

This report serves to illustrate the value of quantitative property measurements when seeking to define optimum processing conditions.

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Director, Centre for Materials Measurement & Technology

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TABLE 1

FIGURES 1 - 12

1 INTRODUCTION

Fibre optic cable coverings are produced from extruded high density polyethylene (HDPE). Assurance is needed of the quality of the coverings produced from the extrusion process. Of particular importance is the adequate protection of the optical fibre. A factor which may affect this is the presence of residual stresses within the HDPE covering material. Other factors to consider, although not connected to the protection of the optical fibre itself, are the surface finish and optimisation of the production process.

The residual stresses in the HDPE covering will be related to the way it has been manufactured. The extrusion process causes stresses to be frozen into the covering material. The dimensional changes which might result from the relaxation of the residual stresses may, in extreme cases, cause receding of the covering leaving the optical fibre exposed and vulnerable to damage. Stresses in the covering may also lead to unacceptable stresses being transferred to connectors or the optical fibres themselves, again potentially leading to failure. The dimensional changes caused by the stresses will be related to the storage times and temperatures of the coverings. These dimensional changes need to be characterised in order to optimise the covering performance. This report describes using a simple heat reversion method to measure dimensional changes in polymer extrusions.

The surface properties of the coverings are also important. Customers will be reluctant to accept products with poor surface appearance. The quality of the coverings surface will be related to the way it has been manufactured. To determine the quality of the coverings surface, traditional methods of surface characterisation such as gloss measurements may not be adequate due to the large curvature over a small area. Other techniques such as a laser surface profiler may provide the required level of characterisation. This report describes the measurement of surface properties of optic fibre coverings using these techniques and relates the results to the processing conditions. This work was carried out as part of the "Materials Measurement Programme" investigating the "Relationship between Component Properties and Processing Parameters" Task 4.2.

2 MEASUREMENT METHODS

BICC Cables provided 15 samples of HDPE fibre optic covering, which had been produced under various controlled conditions, the conditions are shown in Table 1. After extrusion the samples were quenched in a water bath, at either ambient temperature or 80 °C

2. HEAT REVERSION

Sections were cut from the 15 samples provided and measured using a calibrated vernier caliper ($\pm 0.005\text{mm}$). The sections were then heated at a controlled rate up to 140 °C (± 2 °C) and left to anneal for one hour, then allowed to cool to room temperature before re-measuring.

2.2 SURFACE PROPERTIES

Initially, the samples were inspected visually and graded from one (good) to ten (poor) to assess which surface measuring device gave the greater correlation to visual inspection. Three types of feature were identified, micro-roughness, roughness and mm size features.

A Novogloss gloss meter was used initially, however, the gloss values proved to be unreliable due to the highly curved surface of the covering, (radius of curvature 3 mm). Previous work (1) had shown that gloss meters only work successfully on surfaces with radii of curvature greater than 20 mm.

More success was achieved using a Rodenstock RM600 laser surface profiler (2). Scanning a 20 mm length along each sample, the three features previously identified by visual inspection, were successfully identified and quantitative values obtained.

3 RESULTS AND DISCUSSION

3. HEAT REVERSION

Table 1 shows the length and thickness values obtained from the samples prior to and after testing. Figures 1 and 2 show the plots obtained from the data as percentage change. It can be seen from Table 1 and Figure 1 that there is a length reduction of approximately 85% and from Figure 2, a thickness increase of approximately 170%. There does not appear to be any

very significant variation between these values and different processing conditions. However quenching to ambient does seem to give a slightly higher change in length, implying a slightly higher residual stress.

3.2 SURFACE PROPERTIES

Figure 3 shows a bar chart plot of the results of the visual inspection of the coverings. Figure 4 shows a schematic representation of the three features identified on the coverings surface. A dimensional definition of the three features is as follows: micro-roughness 0-10 microns, roughness 10-100 microns, mm sized features 100+ microns. Figures 5 and 6 show two of the sample profiles produced by the laser surface profiler. Differences in the surface profiles can be seen quite clearly on Figure 5, sample 6, compared to Figure 6, sample 12. Table 1 shows the visual inspection ranking, the micro-roughness and the roughness values obtained from the laser scanner. The Ra value quoted is the average roughness of the profile scan, the greater the Ra value, the greater the roughness.

Figures 7 and 8 show bar chart plots of the data obtained. It can be seen that the roughness plot bears the closest resemblance to the visual inspection plot. Therefore this value is the more reliable measure to use when assessing surface finish. Figures 9 to 12 show plots of various extrusion parameters against the roughness values obtained. It can be seen that the only plot that gives an obvious correlation between processing conditions and surface finish is the quenching condition, Figure 12. The samples that were quenched in an ambient temperature water bath have a significantly better surface finish than those quenched in a water bath at 80 °C.

The optimum processing conditions can be narrowed down significantly from the results of this study. Ambient temperature quenching is preferred (as it gives superior finish) and the higher processing speed is preferred (as it leads to a lower cost process and it does not appear to give poorer properties). Samples 12, 14 and 16 (Table 1) were all processed at high speed with ambient temperature quenching. Sample 16 has a marginally better residual stress performance than samples 12 or 14. However, the process may be more economical if the melt temperature is kept lower, in which case sample 14 would be the recommended optimum (200°C extrusion temperature, 40m/min extrusion speed, 9mm die size, ambient temperature quenching).

None of the results in this report would suggest that any of the potential problems identified in the introduction are likely to occur in practice.

4 CONCLUSIONS

Surface roughness can be quantified using a laser surface profiler.

- 2 A significant variation in surface finish between different quenching conditions was found.
- 3 Internal stress within the HDPE covering does not appear to be strongly related to the processing conditions of the samples provided.
- 4 Heat reversion results show length reduction is approximately 85% and thickness increase is approximately 170%.
- 5 Sample 16 achieved the best overall performance, but sample 14 is expected to give the best balance between cost of processing and properties.

5 ACKNOWLEDGEMENTS

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The authors would like to thank members of the NPL Industrial Partners' Working Group on Measurement Methods Relating to the Processing of Plastics. Particular thanks are due to A Mosquera (BICC) for the supply of samples and useful discussions.

6 REFERENCES

- 1 Cook, A, and Duncan, B C: The Performance of gloss meters on curving surfaces, NPL Report DMM(A)111, 1993.
- 2 Fox-Murphy, K and Seah, M P: Non-contacting Profilometry and Surface Roughness Measurement using the Rodenstock Laser Stylus Topography Measuring Station RM600-D, NPL 1991.

Sample I.D.	extrusion temp °C	speed m/min	die size mm	quenching temperature °C	surface finish	% change of length	% change of thickness	visual inspection	micro-roughness Ra µm	roughness Ra µm
HBF001	250	20	9	80	poor	-83.70	162.91	8	2.90	53.0
HBF002	250	40	9	80	poor	-85.03	183.81	9	1.31	59.4
HBF003	200	20	9	80	poor	-84.75	173.15	7	1.03	39.3
HBF004	200	40	9	80	poor	-85.03	168.28	9	1.22	50.5
HBF005	200	20	8	80	poor	-84.56	179.61	7	1.31	42.3
HBF006	200	40	8	80	poor	-84.65	161.36	10	0.94	64.3
HBF007	250	20	8	80	poor	-83.69	157.41	6	2.09	58.8
HBF008	250	40	8	80	poor	-84.25	162.54	10	1.84	89.4
HBF009	200	20	8	Ambient	good	-84.87	169.21	3	1.50	13.6
HBF011	250	20	8	Ambient	good	-85.48	189.17	4	0.92	20.7
HBF012	250	40	8	Ambient	good	-86.25	168.24	3	1.03	29.4
HBF013	200	20	9	Ambient	good	-85.08	189.16	3	1.08	28.0
HBF014	200	40	9	Ambient	good	-86.87	187.23	4	1.10	22.3
HBF015	250	20	9	Ambient	good	-85.78	161.16	3	1.26	24.4
HBF016	250	40	9	Ambient	good	-85.21	169.11	4	1.01	19.1
					average=	-85.01	172.16	average=	1.37	40.9
					std dev=	0.86	10.95	std dev=	0.54	21.3

Table 1 Extrusion parameters and results of heat reversion and surface property measurements.
(Laboratory book reference CSB\CRGA\001)

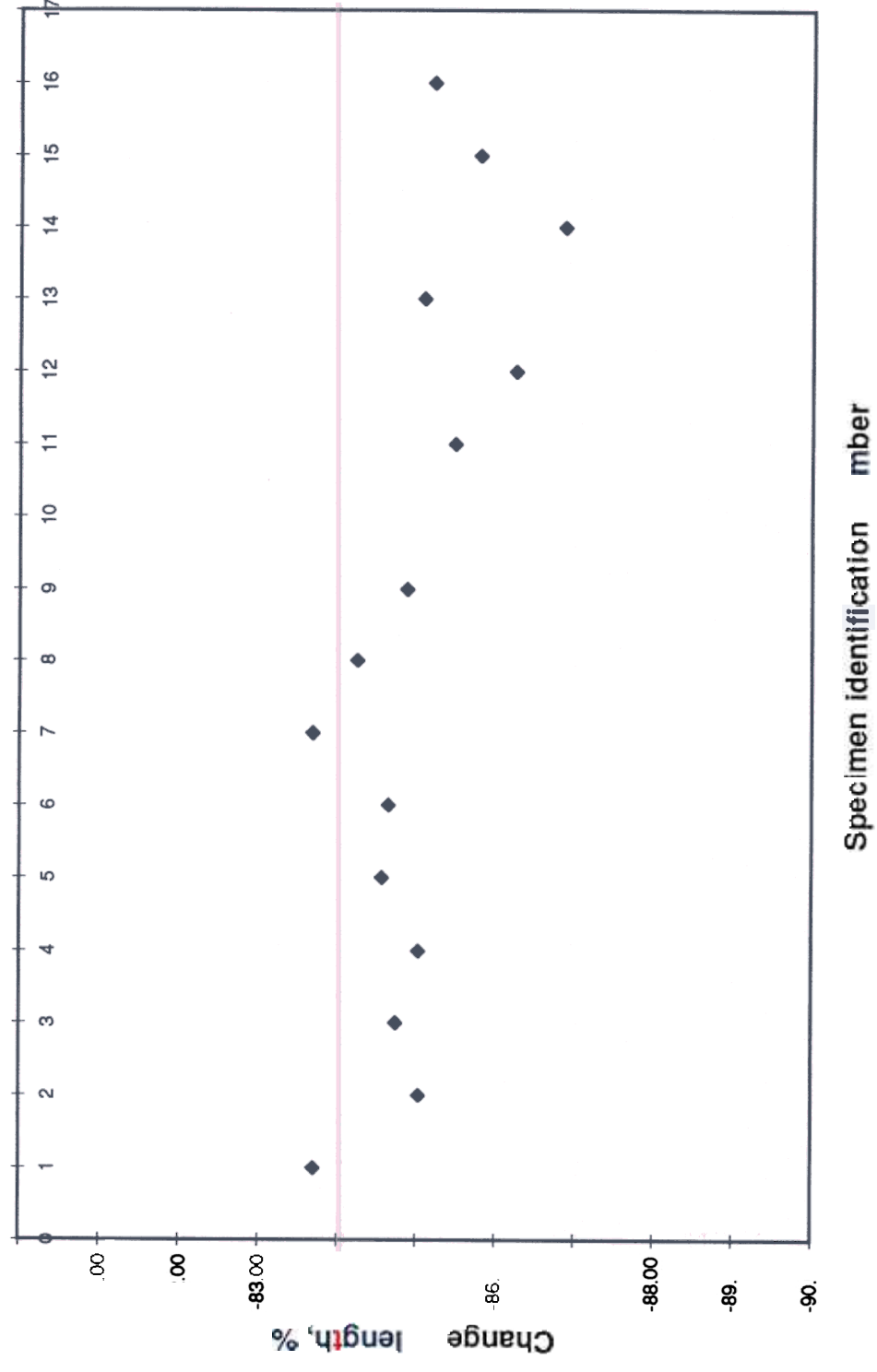


Fig 1 C ange of length due to heat reversion

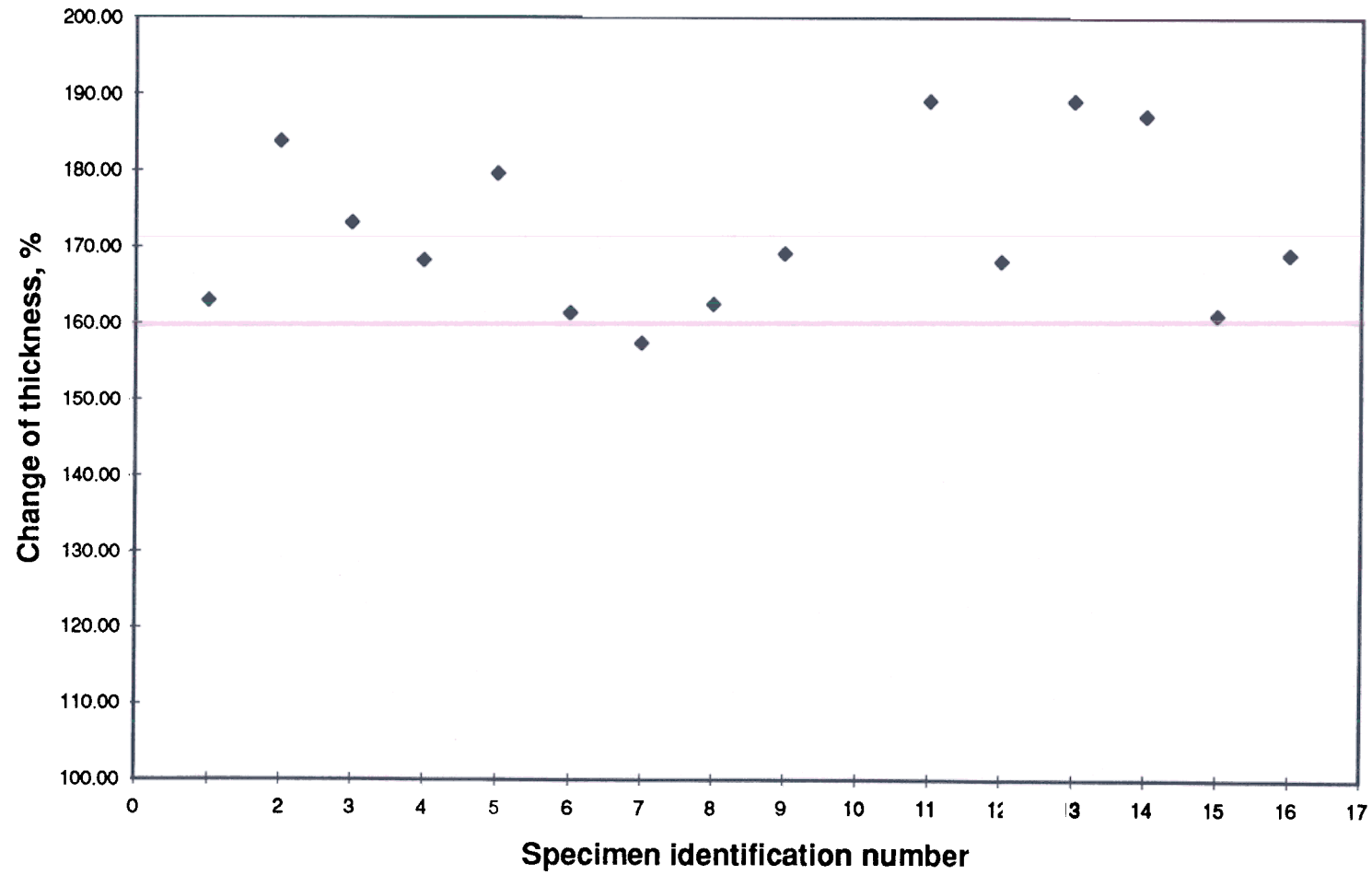


Fig. 2. Change of thickness due to heat reversion

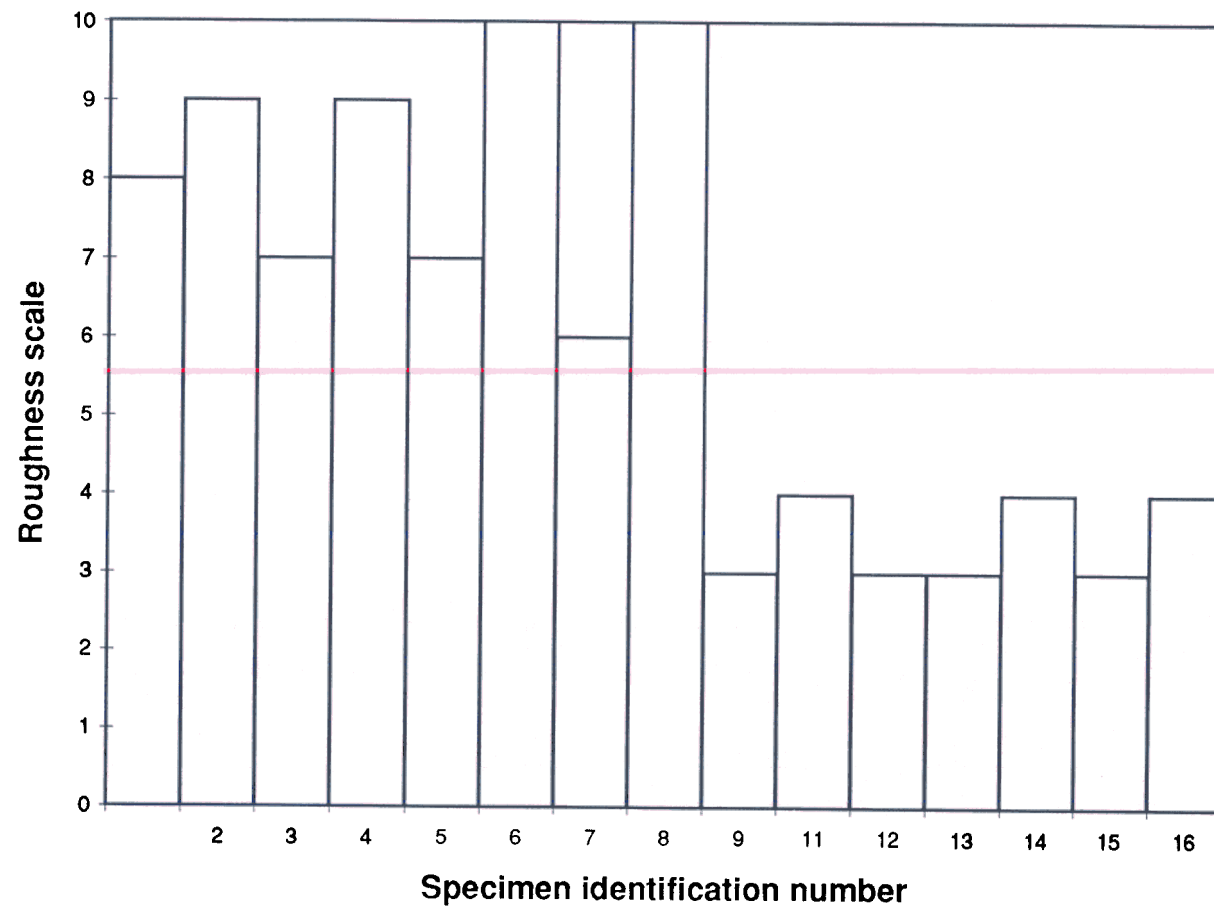


**Fig. 3. Roughness by visual inspection,
scale: 1 good, 10 poor**

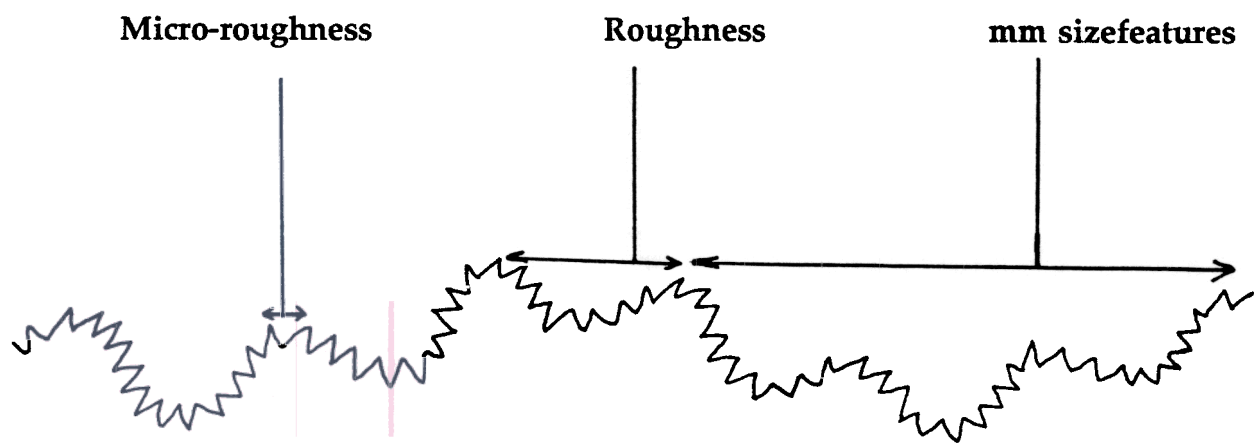


Fig. 4. Schematic representation of surface profile, identifying three main features.

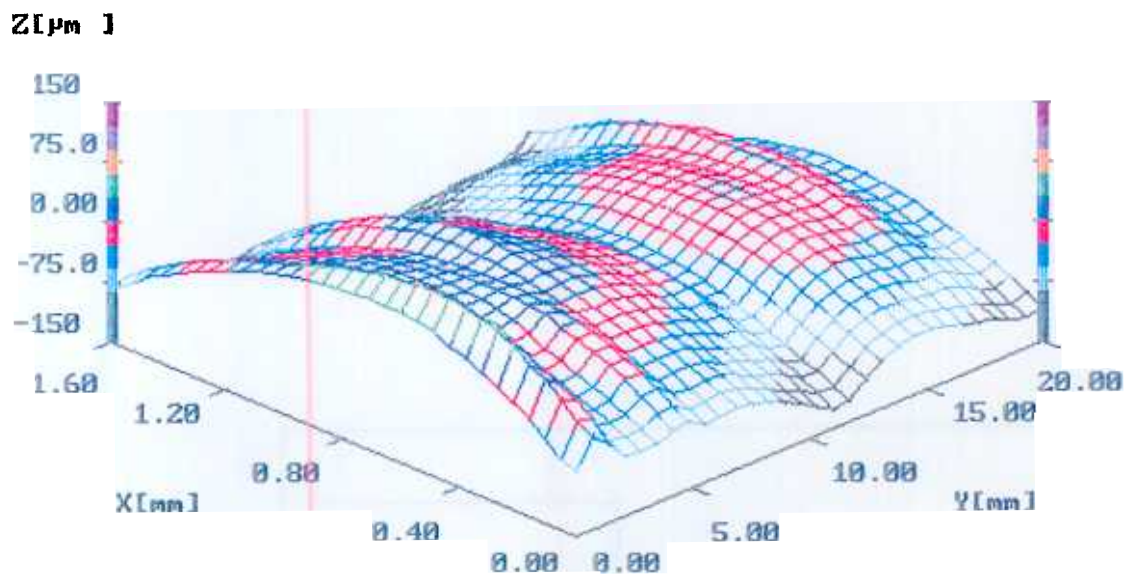


Fig. 5. Laser scanner profile of specimen number 6

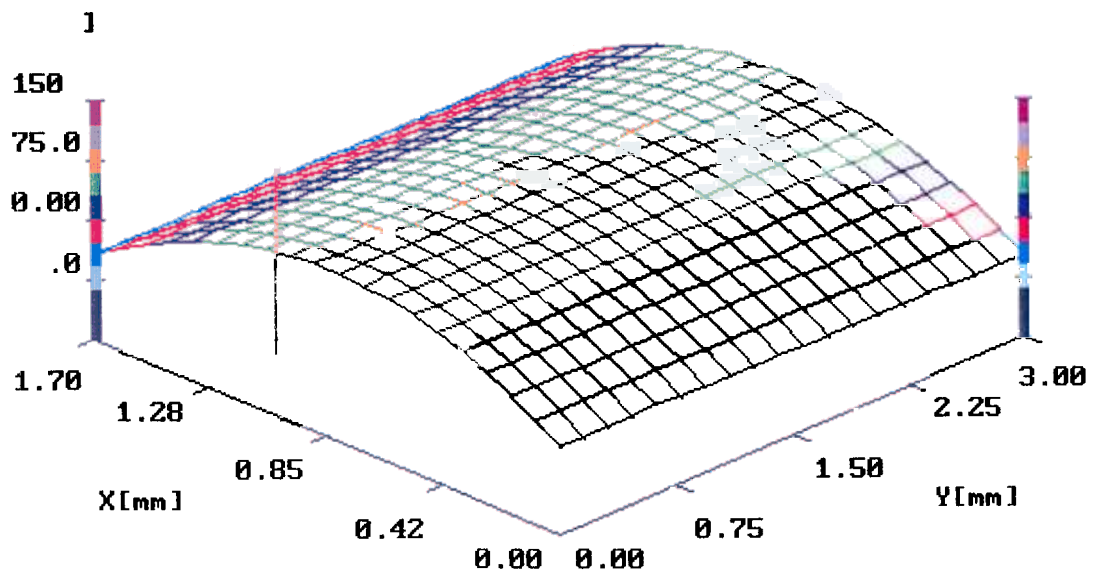


Fig. 6. Laser scanner profile of specimen number 12

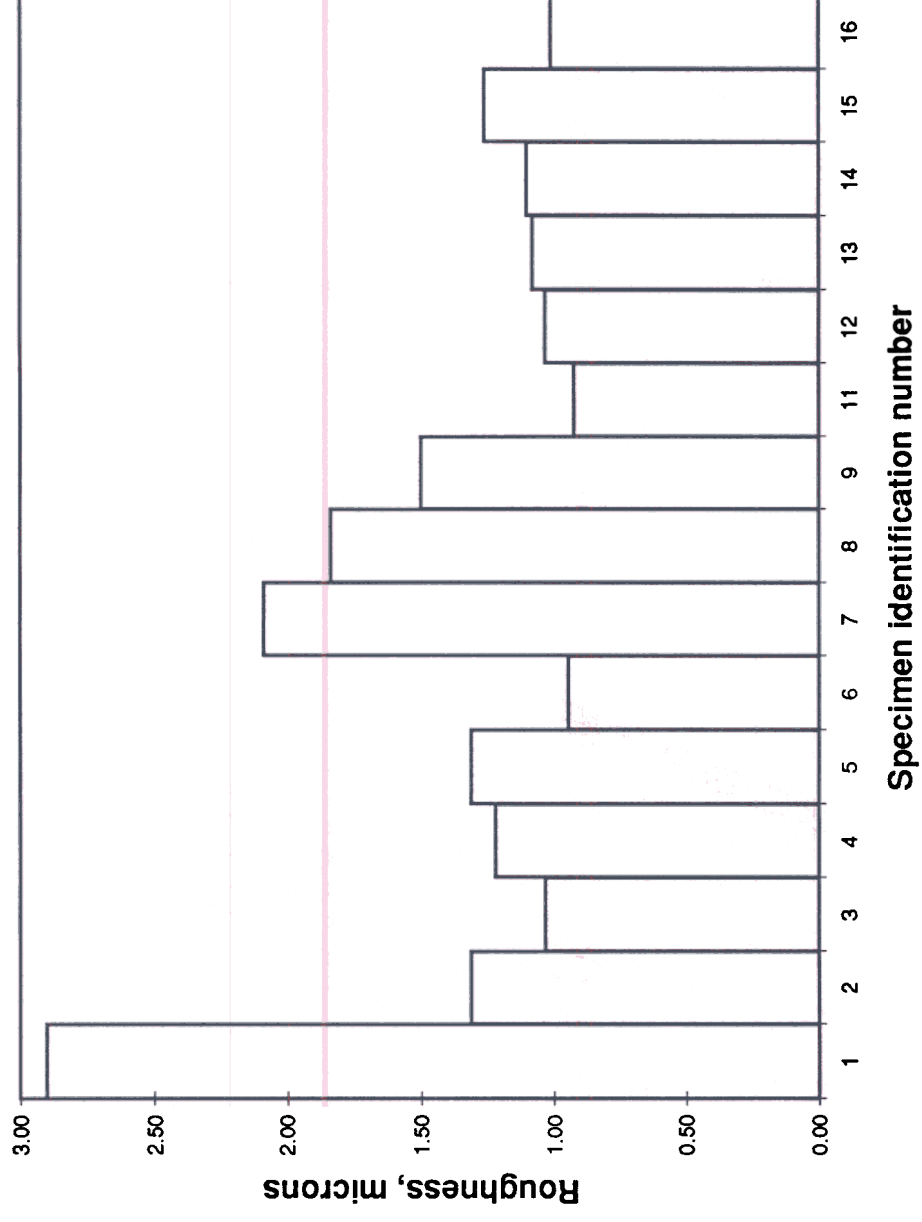


Fig. 7. Measured micro-roughness of fibre optic covers

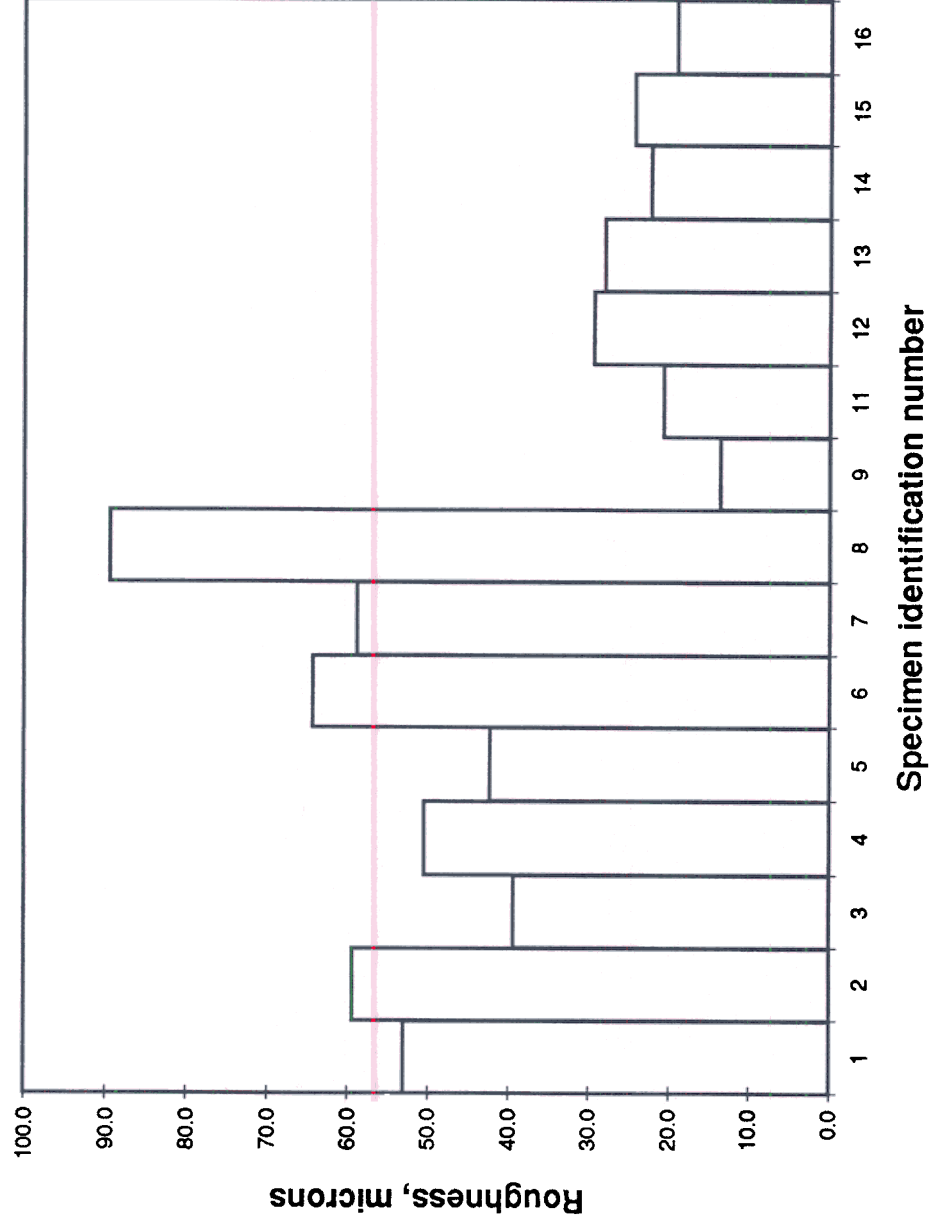


Fig. 8. Measured roughness of fibre optic covers

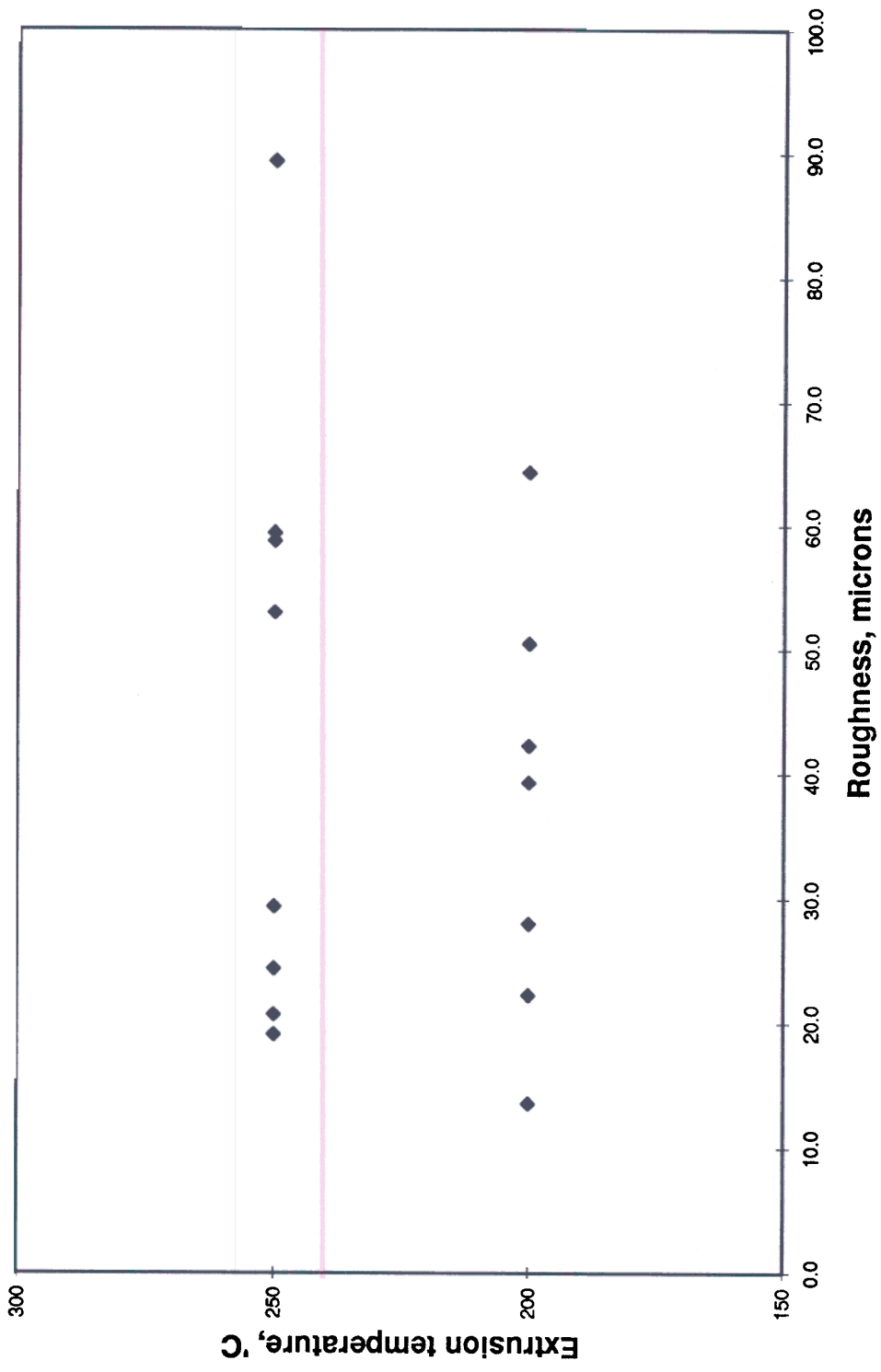


Fig. 9. Effect of extrusion temperature on roughness

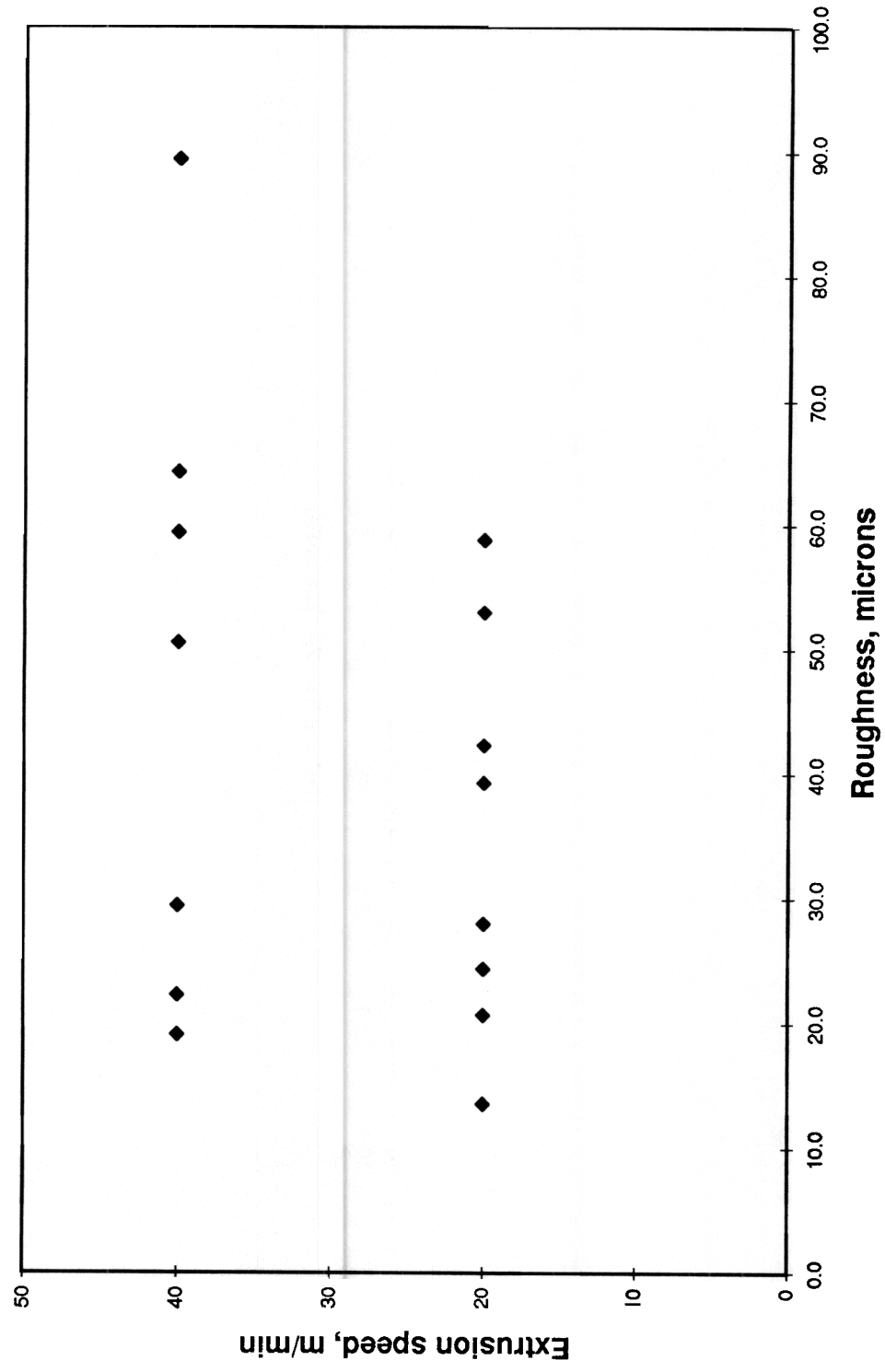


Fig. 10. Effect of extrusion speed on roughness

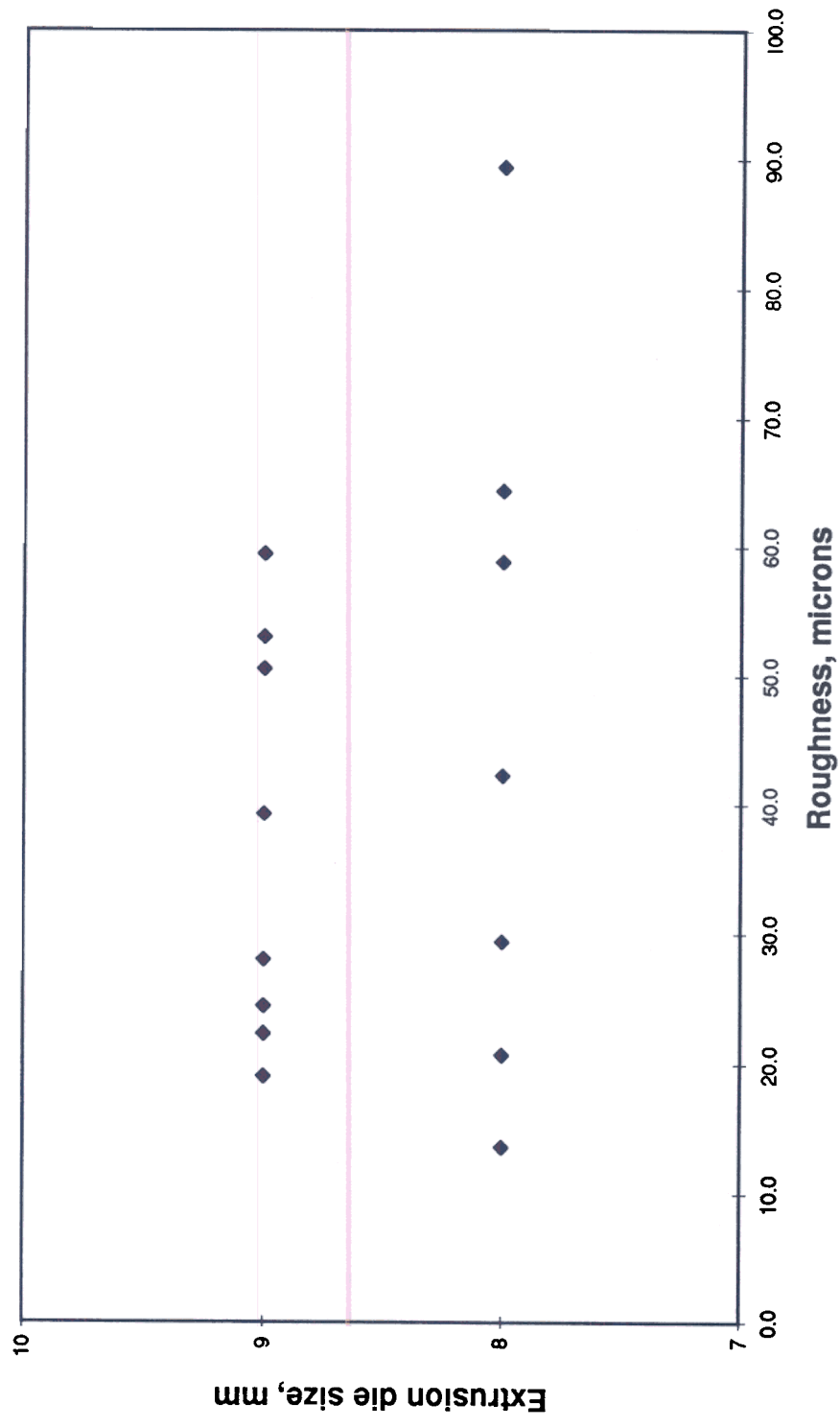


Fig. 11. Effect of die size on roughness

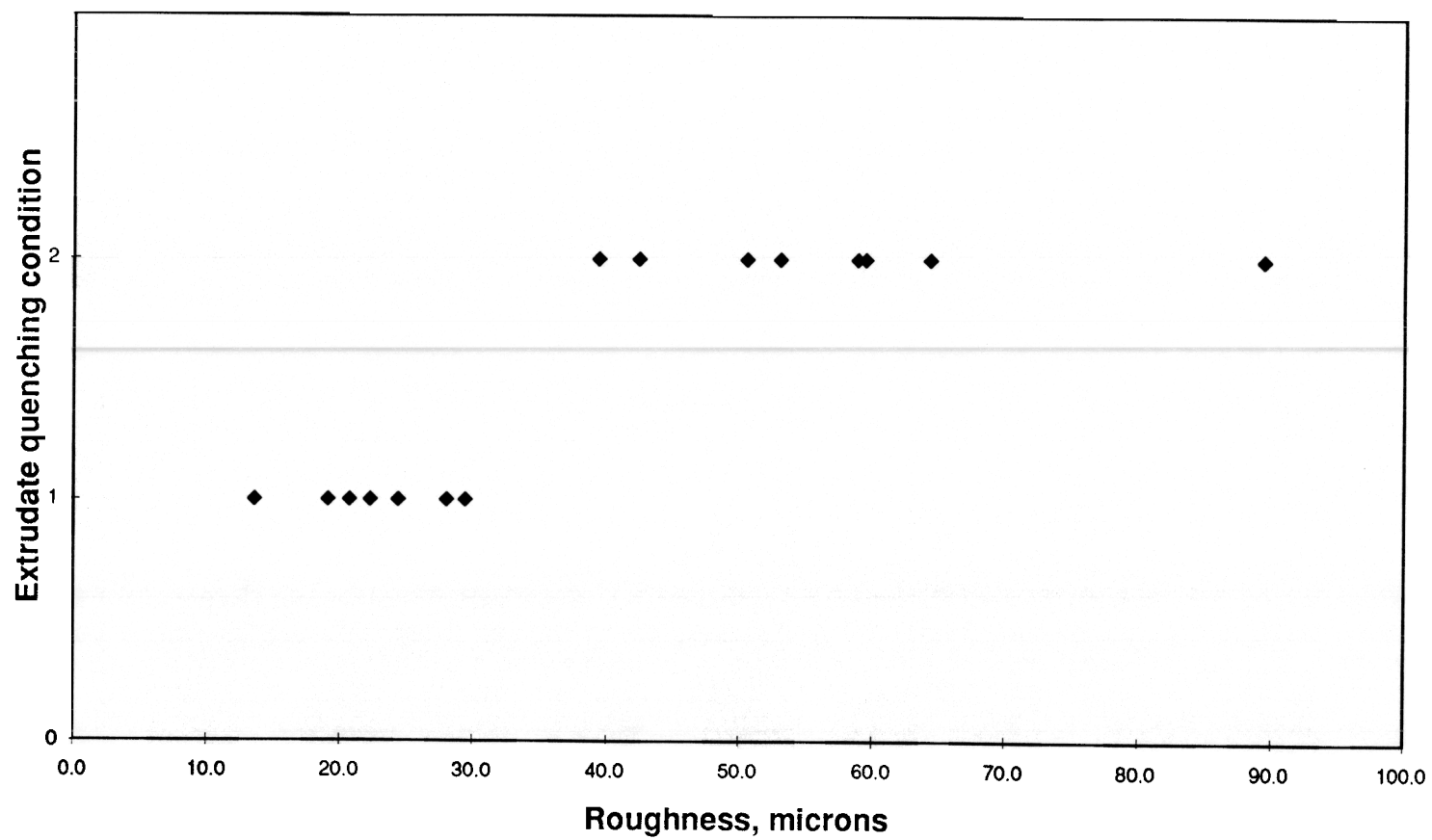


Fig. 12. Effect of extrudate quenching conditions on roughness
1 = ambient, 2 = 80°C