

Practical 2P6

Extrusion

What you should learn from this practical

Extrusion is a process used widely in industry. The forces involved are large and the metal flow patterns are complex, much more so than in a simple tension test of a single crystal. This practical is related to the macroplasticity lecture course and should provide some insight into industrial metal working. You may find it useful to read a little about the extrusion process, so three simple text books are listed at the end of this sheet, but do not copy from these books when writing your report.

Extrusion involves forcing metal (or another material) through a die. It is an efficient, high deformation metal forming process for manufacturing products with a variety of shapes. Good metal quality, dimensional accuracy and surface finish can be achieved at high production speeds with relatively low die costs. Extrusions are widely used for everyday items such as window frames and toothpaste tubes; a recent 'high-tech' application is the Lotus Elise sports car, the chassis of which is built up from extrusions glued together with epoxy resin.

Practical skills

You will learn to handle liquid metal in small quantities, cast at the right temperature and the importance of cleanliness; modelling in plasticine (not as easy to do well as you might think!); operation of the tensile testing machines.

Overview of the practical

The practical is in two parts. The first part uses a soft metal to obtain extrusion pressure vs ram travel curves illustrating the various features of the process and which are then analysed to determine the various parameters involved in the process. In the second part, coloured plasticine is used to simulate a rigid-plastic metal, which allows the material flow during extrusion to be analysed.

An elementary analysis of extrusion, assuming some friction between the billet and container wall, gives an expression for the extrusion pressure

$$P = \sigma_y \ln R \cdot \left(1 + \frac{4\mu L}{D} \right)$$

where σ_y is the yield stress of the metal, R is the extrusion ratio, μ is the coefficient of friction, and L and D are the length and diameter of the billet respectively.

Redundant work is taken into account by multiplying by a factor β , and die friction can be added to give a semi-empirical expression of the form:

$$P = \left(\alpha \sigma_y + \beta \sigma_y \ln R \right) \left(1 + \frac{4\mu L}{D} \right)$$

where α and β are dimensionless constants.

Experimental details

Divide up the tasks so that each of you has a go at exercising every skill. Although your numerical data will be the same, your analysis, the drawing of graphs etc must be done on an individual basis. Part I is concerned with

the forces involved in the extrusion process and in analysing and evaluating various parameters. In Part II, the flow of material is observed and analysed.

Part I

With the apparatus provided cast a set of indium billets.

Safety note: Although indium melts at only 157°C, it can still give you a burn. Wear a lab coat, gauntlets and glasses, and hold the Pyrex tube with the clamp provided.

Remove the ingots carefully from the mould avoiding any deformation. Each billet should be 20 mm long. Fit the small extrusion apparatus to the Tensometer and record extrusion load vs ram travel curves for each of the dies using the laptop. Solid soap may be used as a lubricant. Extrapolate the main part of the extrusion graph to zero billet length and measure the load P (using Excel's Trendline and the displayed equation will be very helpful). Plot the corresponding pressure, p , against $\ln R$ and use this graph to evaluate the dimensionless constants α and β . Tabulate P , p , R and $\ln R$ for reference.

N.B. Set the cross-head speed to 3 mm/min

Data

Yield stress of indium: 2-5 MPa (use data derived from your extrusion curves).

Container diameter: 10 mm.

Die identifier	2	4	8	16	32
Orifice diameter (mm)	7.07	5.00	3.54	2.50	1.77

Part II

This part of the experiment uses the extrusion chamber mounted on the Hounsfield Tensometer and is done using plasticine of different colours.

- (a) Make a composite billet from at least 12 layers of alternating colours. Extrude this billet through the large die marked '4', stopping the extrusion process after the ram has travelled about half the possible distance. Carefully remove the extrusion from the press and section with the cutting wire. Examine and photograph (or sketch) the resulting flow patterns labelling the features of interest and explaining why they are there.
- (b) Make a composite billet that has a cylindrical layer about 3 mm thick of different colour to the core. Extrude through the die marked '8' until the extrusion pressure rises markedly near the end of the process. Carefully remove the extrusion from the press, section, examine and make a labelled sketch as before.

- N.B.**
- (i) It is important to keep the extrusion press clean throughout the experiment, and to clean off all plasticine at the end of the experiment.
 - (ii) The plasticine sections can be photographed using the digital camera.
 - (iii) Set the cross-head speed to 15 mm/min.

Safety considerations

Avoid splashing molten metal on yourself or anyone else. Keep your fingers out of the jigs when the motor is on and know beforehand the crosshead velocity settings.

Work schedule

Day 1: Make plasticine billets

Extrude, slice and draw sections (labelled!)

Day 2: Cast indium billets

Extrude billets

Day 3: Finish any experimental work

Analyse data, write-up.

What should be in the report

Experimental method (refer to sheet but add any special details), presentation of results, discussion, conclusions. It should contain drawings, graphs and (copies of) the Tensometer charts but long descriptions of different extrusion processes are not required and will be penalised.

Make sure you show your calculations in algebraic form as well as in a table of computed values.

Questions you should try to answer

- Why has indium been used?
- What is the yield stress of the indium billets used by you?
- Why does the extrusion curve have its characteristic shape?

- What is happening at each stage during the extrusion process?
- Discuss the elementary analysis. Can you obtain the first expression?
- What assumptions have been made in evaluating α and β ; can you improve on the method used and how does it affect your values?
- Is it possible to evaluate μ ? Value?
- How well does plasticine represent the ideal plastic solid and what relevance does the latter have in the real world of industrial extrusion?
- What are the two plasticine composite billets designed to show?

Background reading

1. G E Dieter **Mechanical Metallurgy** McGraw-Hill (1976)
2. W A Backofen **Deformation Processing** Addison-Wesley
3. G W Rowe **Principles of Industrial Metalworking Processes** Edward Arnold (1977)