

Credible Data for Forging and Rolling Process Modelling

Current modelling packages used to simulate processing, can result in reduced manufacturing costs, optimised processing, defect-free forgings first time, and shorter times to market. However, the acquisition of the technology and expertise to use it has been slow. This has been partially attributed to the lack of relevant test methods and validation of the materials data.

Credible data are, however, now becoming available, helping to remove these barriers and significantly enhancing the value of such predictive modelling techniques. New measurement related work at the National Physical Laboratory (NPL), in collaboration with the Universities of Bath, Sheffield and Swansea is aimed at

- i. developing reliable methods for obtaining credible data,
- ii. generating Measurement Good Practice Guides, and
- iii. generating appropriate data on
 - flow stress
 - friction
 - heat transfer coefficients
 - interfacial shear stress
 - strength of oxides

The work is strongly supported by industry involvement in testing and participation in advisory project groups.

A booklet describing the methods developed and illustrating typical data produced in order to help with modelling of the forging and forming processes, will be available on request before the end of the year.

Malcolm S Loveday and Bryan Roebuck

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Friction Coefficients

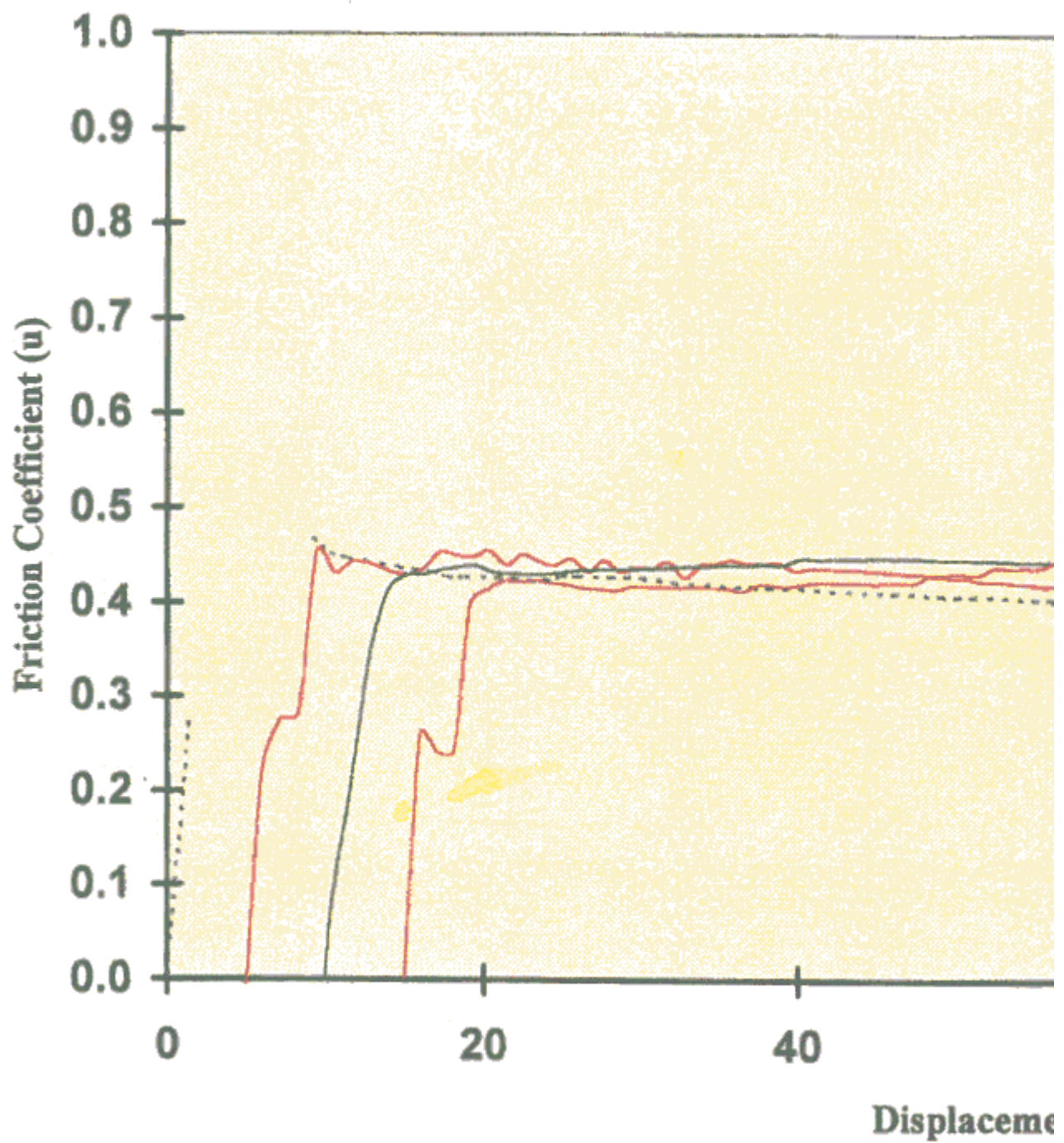
One of the most important parameters for modelling forging and forming processes is the friction coefficient, which quantifies the amount of friction between the deforming metal work- piece and the tool. Although these coefficients can be estimated, a number of simplifying assumptions have to be made which can lead to large errors and uncertainties. Moreover, since the values vary with other parameters such as relative velocity and contact pressure, any estimate can only be an average.

At NPL three new test rigs have been developed to determine friction coefficients directly:

- a. a large friction rig attached to a 700 ton press;
- b. a novel DC heated pin-on-disc rig;
- c. a reciprocating arm rig.

These three test rigs are now being commissioned, and inter-comparison of results confirms the credibility of the data generated.

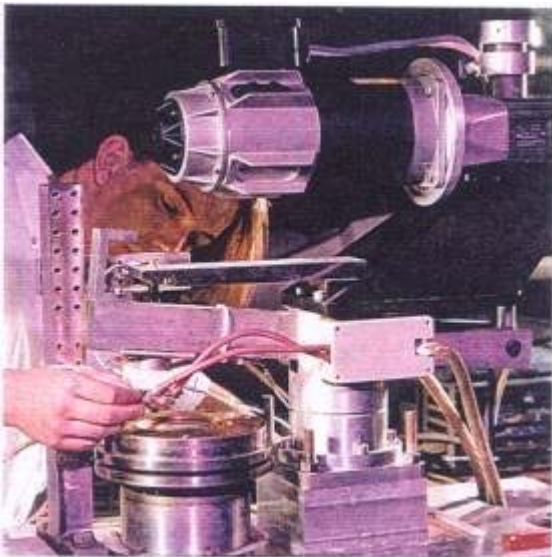
Contact: Malcolm Loveday, Ext 6900 or Mark Gee, Ext 6374



Example of the repeatability of friction coefficient data generated using four different samples on the large friction rig (mild steel at 550°C; axial stress; 10^7 MPa; ram speed 10 mm/s)



Hot billet being loaded into the "Grabber arm" of the large friction rig on the 700 ton press.



DC Heated Pin-on-Disc Rig

Heat Transfer Coefficients

Platens and billets instrumented with thermocouples are being used to derive coefficients of heat transfer. The resulting data, analysed using a simple I-D model developed at NPL, are being compared with those from a more sophisticated model from Sheffield University, and with other procedures developed elsewhere.

In addition, the robustness of a novel Vatel Heat Flux sensor at the loads and temperatures encountered during rolling and forging, is being assessed. This flux sensor was originally developed as part of a NASA programme to measure the heat flux on Shuttle protective tiles during re-entry into the earth's atmosphere. Such a sensor has never been used before under the conditions of forging or rolling. If the assessment is successful the sensor could be fitted to a commercial hot strip mill, using a specially manufactured roll, and used to measure heat transfer directly.

Contact: Malcolm Loveday, Ext 6900

Flow Stress & Fracture Strength

Industrial forming processes involve deformation over a wide range of strain rates (10^{-4} – 10^3 s $^{-1}$), and to maximise

the use of finite element models to predict loads, flow stress data are required over a range of temperatures. Models for hot working generally define stress in terms of strain, strain rate and temperature, and any test method must be able to measure these parameters accurately.

NPL is working with Sheffield and Swansea Universities to investigate and develop a number of test methods for appropriate combinations of temperature, stress, strain and strain rate, inc:

- a. uniaxial tension
- b. axisymmetric compression
- c. plane strain compression

In particular FE models of test-piece deformation are being evaluated. This work will result in a number of testing **Good Practice Guides**.

A particularly versatile benchtop instrument, an **Electro-Thermal Mechanical Tester** (ETMT), has been developed to carry out miniature uniaxial (tension or compression) or fatigue strength tests under isothermal or cyclic temperature conditions. It can also be used to measure thermal properties such as expansion, diffusivity, and conductivity, as well as electrical conductivity, required for modelling purposes. The ETMT can provide data at extremely high temperatures, and will shortly be available commercially. Complementary work at Swansea University is aimed at developing a test system for strength measurements in the mushy zone relevant to casting models.

Contact: Bryan Roebuck, Ext 6298 or Prof Russell Evans IRC Swansea or Prof Mike Sellars University of Sheffield

Shear Force

Data on interfacial shear during the hot forging of billets is important for successful predictive modelling. NPL has manufactured forging platens incorporating a new type of shear force pin, to aid in the measurement of such data. The equipment is currently being evaluated at Bath University, as a precursor to using it on NPL's *hot rolling* mill.

In a parallel exercise, measurements of shear force during the *cold rolling* of metals are being pursued using a specially designed elastic cantilevered strain gauge probe supplied by Prof. J Jeswiet of Queen's University, Ontario, which is now installed on the 50 ton precision cold rolling mill at NPL.

Contact: Malcolm Lovedav. Ext 6900

Thermophysical Properties

A number of thermophysical parameters are required for modelling forging and rolling processes, including thermal expansion coefficient, thermal diffusivity, specific heat, and density. NPL has generated methods for deriving reliable data as a function of temperature for these properties, and these are described in detail in a booklet, *"Reliable Data For Process Modelling"* available on request.

Contact: Peter Quested, Ext 6141

In addition, NPL has developed MTDATA software specifically designed to model thermo- physical data and calculate phase diagrams. The approach is, in essence, materials chemistry by computer applied to particular interests of the industry. A booklet describing the MTDATA approach, together with a demonstration disk, are available on request.

Contact: Hugh Davies, Ext 6497

Workshops

Several events are being organised in the near future, including:

- **Measurement of heat transfer coefficients for forging and rolling process control models**

Round table workshop; Wednesday 9th December 1998. Sheffield University

- **Measurement of friction at high temperatures for forging and rolling process control models**

Open seminar; Tuesday 26th January 1999. The National Physical Laboratory

- **Component optimisation from materials properties and simulation software**

COMPASS 99; 29 March. 1 April 1999. Swansea University.

Contact: Malcolm Loveday, Ext 6900

FORGE-NET

NPL is involved in a European network of industrial companies, universities, and research centres, called FORGE-NET, aimed at increasing the take-up of these improved technologies, especially by small manufacturing companies. FORGE-NET, led by the University of Bath, enables technology transfer into national industry by direct involvement and via workshops and seminars.

Experts

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