

Data for Forging and Rolling Process Modelling

Summary

Research at the National Physical Laboratory (NPL), aimed at improving materials production in the rolling and forging industries, is developing new measurement methods to provide data for process modelling and control.

Reliable measurement methods are needed for obtaining data under conditions encountered in industrial metal working and forming.

Data are needed on parameters such as:

- friction and heat transfer coefficients
- interfacial shear stress
- flow stress
- strengths of oxides
- various other thermophysical properties.

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High Temperature Friction

Three new test rigs have been developed to determine *friction coefficients*:

- (a) a big friction rig attached to a 700 ton press;
- (b) a novel DC heated pin-on-disk rig;
- (c) and a reciprocating arm rig.

Big friction rig

Friction coefficients are obtained from measuring the axial load applied to a cylindrical billet that is compressed between platens in a large 700 ton press, and from the horizontal load exerted by the big friction rig as the billet is dragged across the face of the platens at up to 100 mm/s. The rig can be used with two sizes of billet, 30 mm and 50 mm in diameter. The billets are preheated in a furnace up to 1000°C and then transferred to the yoke in the big friction rig.

The temperature of the billet is monitored using a 1 mm diameter Nicro-Nisil thermocouple. The data are recorded on a PC using customised Labview software.

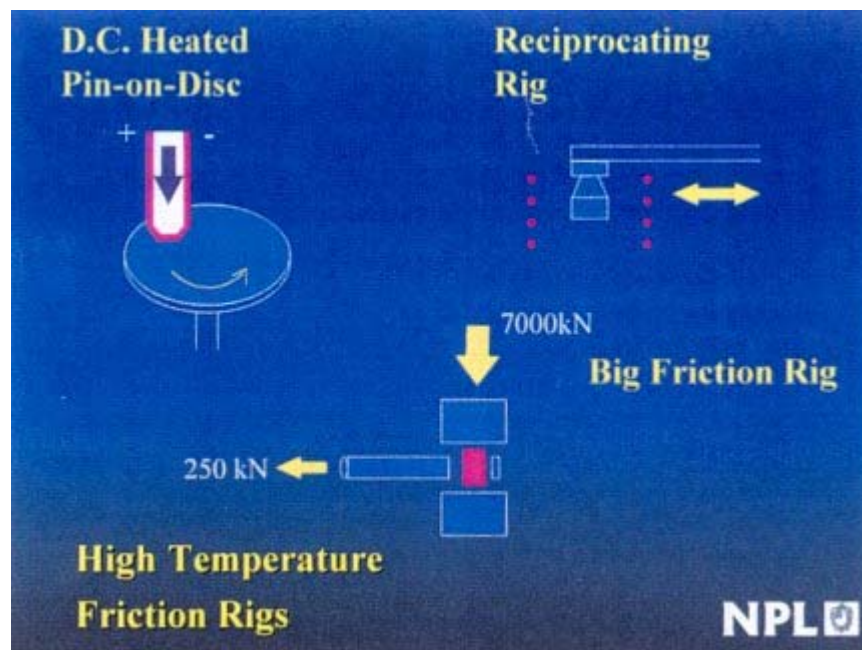
The 700 ton press incorporates a three column load cell designed and manufactured at NPL, and calibrated in accordance with EN 10002 Pt 3 to provide traceability to the National Measurement System. Similarly, the load cell in the big friction rig which measures the horizontal force is calibrated in accordance with EN 10002 Pt 2, using a specially designed reaction frame which incorporates a force proving device.

DC heated pin-on-disk rig

This apparatus heats strip samples up to 1000°C in a few seconds using a DC electrical current of up to 200 A. The sample may then be rapidly brought into contact with a rotating disc of tool steel using a motorised drive mechanism. The vertical and sideways forces on the sample are measured using transducers connected to a PC data logger using customised Labview software. To prevent the thin strip sample collapsing it is supported on a zirconia thermal insulator and its temperature monitored using a thermo-couple. In principle this rig could be fully encased so that measurements may be carried out in an inert atmosphere. The sample size in contact with the disc is typically $5\text{ mm} \times 5\text{ mm} \times 2\text{ mm}$, while the disc is 100 mm in diameter. Contact speeds up to 2 m/s are obtained.



NPL's big friction rig is used to determine friction coefficients



Schematic showing NPL's three friction rigs for measurements at high temperatures

Reciprocating arm rig

A slow speed rig allowing small samples, approximately $5\text{ mm} \times 5\text{ mm}$, to be moved in a linear mode across a small tool steel platen has been developed. The applied loads and motion of the sample are recorded using

transducers connected to a PC data logger incorporating customised Labview software. The sample may be heated up to about 800°C using a small muffle furnace while the platen is mounted on a water-cooled loading arm.

Friction summary

The two smaller rigs are based on modifications to existing wear test rigs and are now in the final commissioning stages. Results from the three rigs are being compared.

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Determination Of Heat Transfer Coefficients

Measurements are being carried out to determine the *coefficients of heat transfer* from billets and platens instrumented with thermocouples. The data are being analysed using a simple I-D model developed at NPL, and compared with results from a more sophisticated inverse model from Sheffield University. In addition a novel Vatel heat flux sensor is being assessed to see if it can survive the load and temperatures encountered during rolling and forging. If the device survives then it is proposed to fit the sensor into a specially manufactured roll for use on a commercial hot strip rolling mill

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Shear Force Measurements

Forging platens have been manufactured to include a new type of *shear force pin* which should allow interfacial shear forces to be measured during the hot forging of billets. The equipment is currently being evaluated at Bath University and if it performs in a satisfactory manner the design will be adapted so that the sensors may be used in the hot rolling mill at NPL.

In addition, a specially designed elastic cantilevered strain gauged probe produced by Professor J Jesweit from Queen's University, Ontario, Canada, is being installed on a precision cold rolling mill at NPL, for measuring shear forces during the cold rolling of metals.

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Flow Stress Measurements

To generate data for metal working process control models, measurement methods are being standardised to produce reliable hot flow stress data under the following deformation modes:

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

Collaborative work is underway at Sheffield and Swansea Universities.

Measurement Good Practice Guides are being produced.

Reference: 'Measuring Flow Stress in Hot Axisymmetric Compression Tests' by B. Roebuck, J.D. Lord, R.K. Varma and M.S. Loveday. Measurement Good Practice Guide No 3, ISSN 1386-6550, 1997.

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Thermophysical Properties

NPL has developed measurement methods for obtaining a range of property input data for various forging and rolling models. NPL now has facilities for measuring the following as a function of temperature:

- a. density
- b. specific heat
- c. thermal conductivity / diffusivity
- d. solidus temperature.

In addition there is expertise available for modelling thermophysical data and calculating phase diagrams using MTDATA software. A further booklet and demonstration disk are available on request.

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Experts

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