

Friction and Oxide Strength Data for Forging and Rolling Process Modelling

Summary

Software process modelling and control packages can significantly enhance the understanding and efficiency of metal processing technologies. Reliable materials property data, obtained under conditions relevant to the metal working and forming industries are essential for these modelling packages to achieve their potential.

Following on from previous DTI funded projects, part of the Materials Measurement which affect Processability Programme, research is continuing at the National Physical Laboratory (NPL) into measurement methods to produce flow stress, friction and oxide strength data under industrially relevant conditions. An interim project on the metrology of friction and oxide strength is currently in progress, building on work undertaken in a previous project (MMP06) with the following aims :

- Development of present friction measurement facilities to include heated platens.
- Re-evaluation of friction data produced under previous project.
- Compilation of friction data into a user friendly searchable database.
- Further evaluation of a novel measurement method (Torsion Shear Force Test) to determine oxide strength data.
- A simplified approach for estimating the uncertainty of measurement relating to high temperature friction testing.

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December 2000

Development of Friction Measurement Methods

Under the previous DTI funded project, MMP06, work was undertaken to develop and evaluate two friction measurement techniques, namely the Pin-on-Disc and 'Big Friction Rig'. Further development work is currently under way :

Big Friction Rig

Friction coefficients are obtained from the Big Friction Rig by measuring the ratio of the horizontal load exerted by a hydraulic ram dragging a cylindrical billet across the face of two platens, compressed in a large 700 tonne press. Either 30 mm or 50 mm diameter cylindrical billets are pre-heated in a furnace up to temperatures of 1000°C, whilst the temperature of the billet monitored via a 1mm diameter Nicro-Nisil thermocouple and subsequently transferred to the Big Friction Rig for testing.

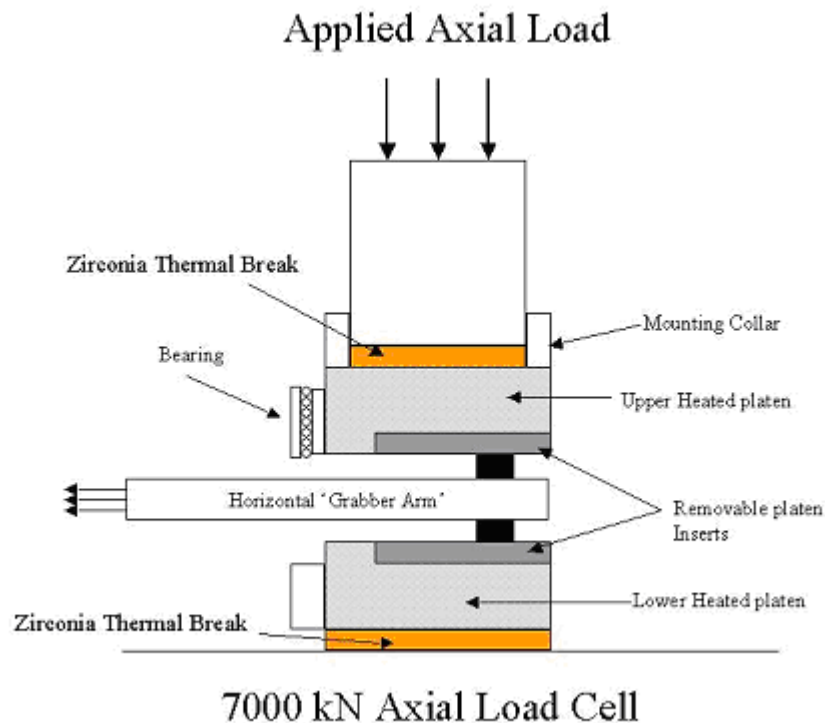


Figure 1 : Schematic of new heated platens for Big Friction Rig.

The existing system utilises unheated tool steel platens. Thus to bring the system in line with forging and rolling practice, heated platens have been designed, and are currently being manufactured. The new platens (see [Figure 1](#)) are heated using cartridge heaters, and it is anticipated that the maximum working temperature of the platens will be 400°C. Removable platen inserts enable the testing of different tooling materials and feature provision for instrumentation with up to four 1mm diameter Nicro-Nisil thermocouples for heat transfer measurements.

DC Heated Pin on Disc Rig

This apparatus heats U shaped samples up to 1000°C in a few seconds, using a DC electrical current of up to 200 A. The sample is then brought into contact with a rotating tool steel disc and friction coefficients are obtained from the ratio of the horizontal to the axial forces.

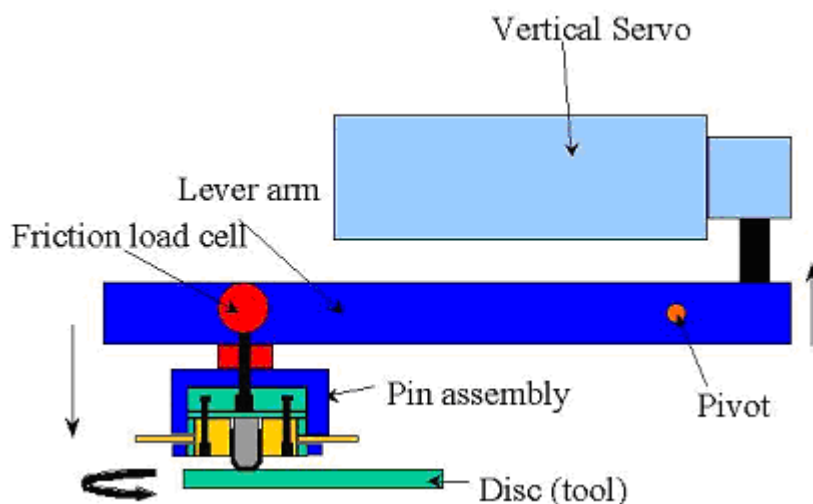


Figure 2 : Schematic of the Pin on Disc Friction test rig

As with the Big Friction Rig, this apparatus currently has no provision to heat the tool steel discs, with the result of

rapidly quenching the U shaped test piece during the initial stages of a test. A feasibility study is underway, with a view to consider possible methods of heating the rotating tool steel discs.

Friction Data

A significant quantity of friction data were generated as result of the test method evaluation exercises carried out under the previous project. The materials tested include Commercial purity Aluminium and Copper, Mild Steel and IN718 with the range of test conditions including displacement rates over the range 0.2 mm/s to 100 mm/s and temperatures up to 1100°C.

In order to enhance the usefulness and encourage the adoption of these data, the data sets have been re-evaluated and classified in order to identify pedigree friction data. Figures 3 to 5 illustrate typical friction plots from the Big Friction Rig against their classification. Class 1 data rapidly attains a steady state value which is maintained for the duration of the test, class 2 friction data, though essentially the same as class 1 data, has a slight variation over the duration of the test whereas class 3 friction data continually varies throughout the test.

It should be highlighted that so far as data classification is concerned, it is the shape of the friction curve which is important, rather than the absolute values on each plot. The differences observed in the friction plots, right, especially with regards to the examples of the class three friction results, can be attributed to material and or the conditions under which it was tested.

Gaps in the existing friction data sets for both NPL test rigs have been identified and a small testing program is currently underway to complete the data sets. Once complete, the data will be compiled into a user-friendly database, detailing over 360 test results from the Big Friction Rig, and over 150 tests from the Pin on Disc Rig.

A consultation exercise is currently underway to ascertain the preferred format of the friction database.

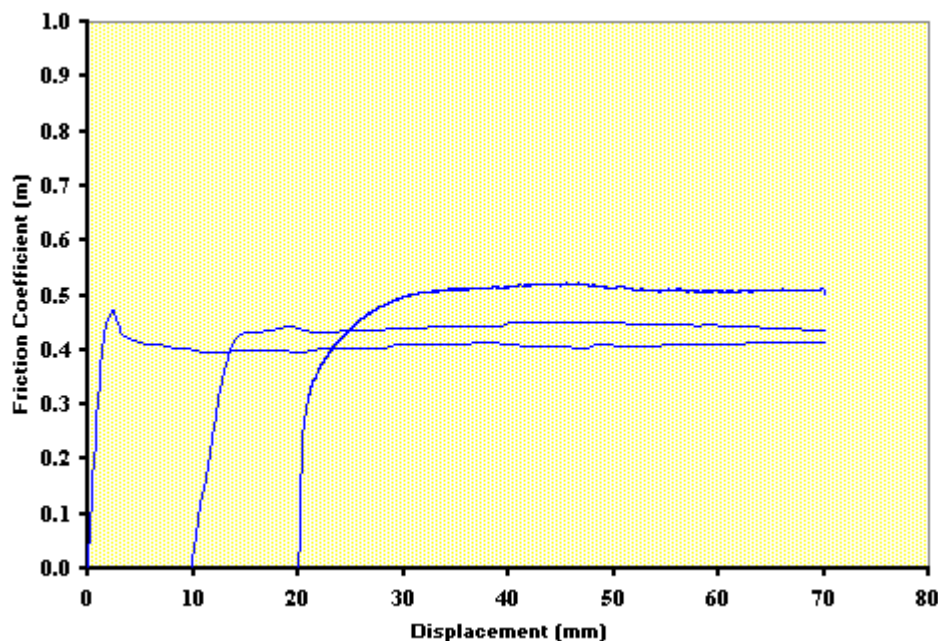


Figure 3 : Examples of Class 1 friction results for the Big Friction Rig, plots offset against displacement for clarity.

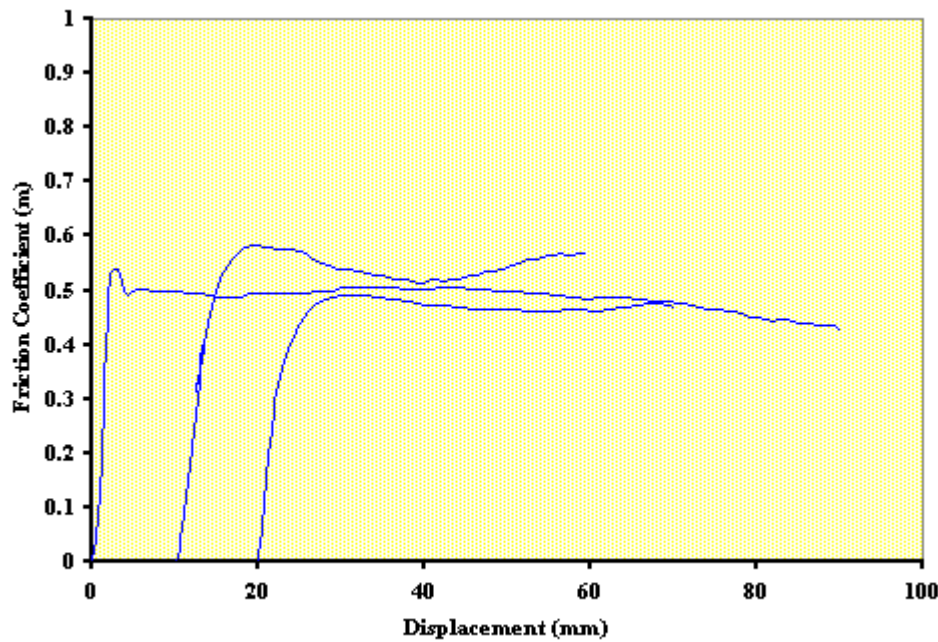


Figure 4 : Examples of Class 2 friction results for the Big Friction Rig, plots offset against displacement for clarity.

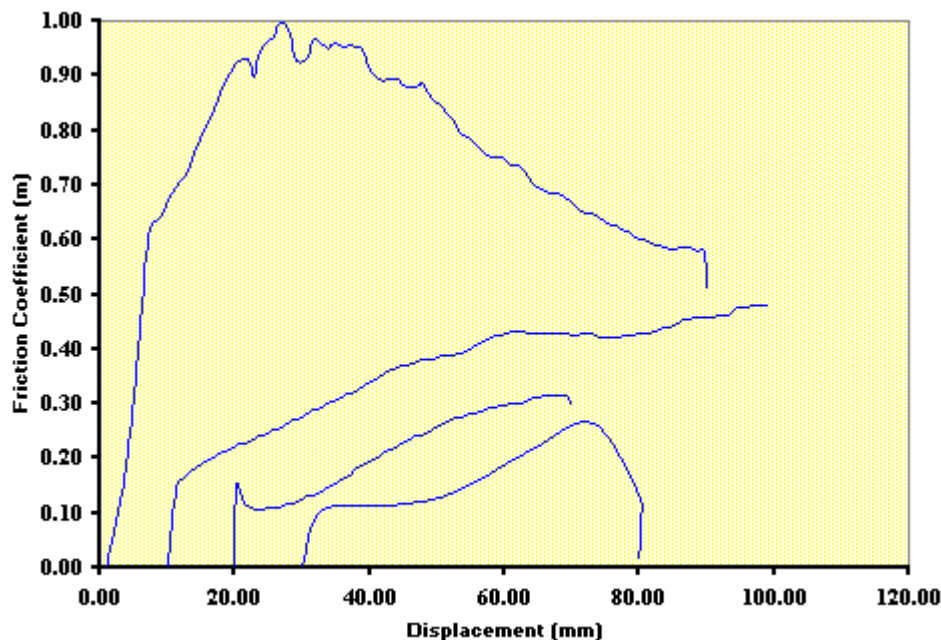


Figure 5 : Examples of Class 3 friction results for the Big Friction Rig, plots offset against displacement for clarity.

Uncertainty Evaluation

The Cockroft-Male ring test is widely used, both as a simple ranking test for assessing friction characteristics of die / workpieces during forging and for the measurement of friction factor data. To date, the measurement uncertainty of this method has not been evaluated.

A simplified approach has been used to generate estimates for two new methods developed at NPL, viz the Pin on Disc and the Big Friction Rig, as well as the conventional Cockroft - Male Ring test

The results from this uncertainty estimation have been compiled into an NPL Measurement Note, which will be available from December 2000. [CMMT(MN)070, Loveday & Brooks, 2000]

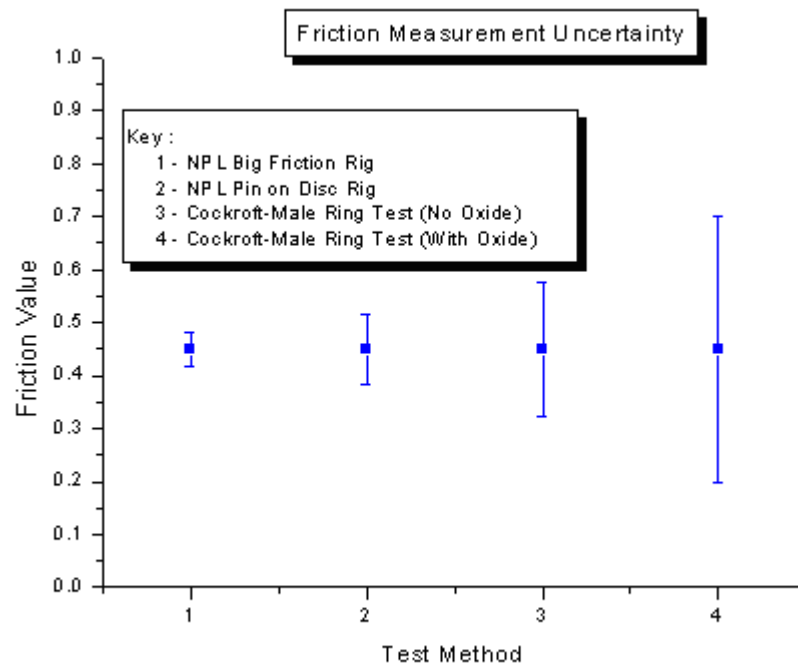


Figure 6 : Plot illustrating relative magnitudes of friction measurement uncertainty for the NPL friction Rigs and the Cockroft-Male friction test.

Torsion Shear Force Test Rig

During the 1970's, NPL developed machines for high temperature torsion testing. One of these machines was modified under the previous project, MMP06, so that shear stresses in oxide layers could be evaluated. A tube / spigot testpiece geometry has been utilised, the two pieces being brought together using a loading train surrounded by a muffle furnace capable of reaching temperatures of up to 900°C.

An oxide layer is grown across the interface of the two part testpiece while under zero load and subsequently subjected to a shear force, by applying a twisting moment from load on a scale pan connected to the lower part of the loading train via a flexible wire wrapped around a horizontal pulley wheel.

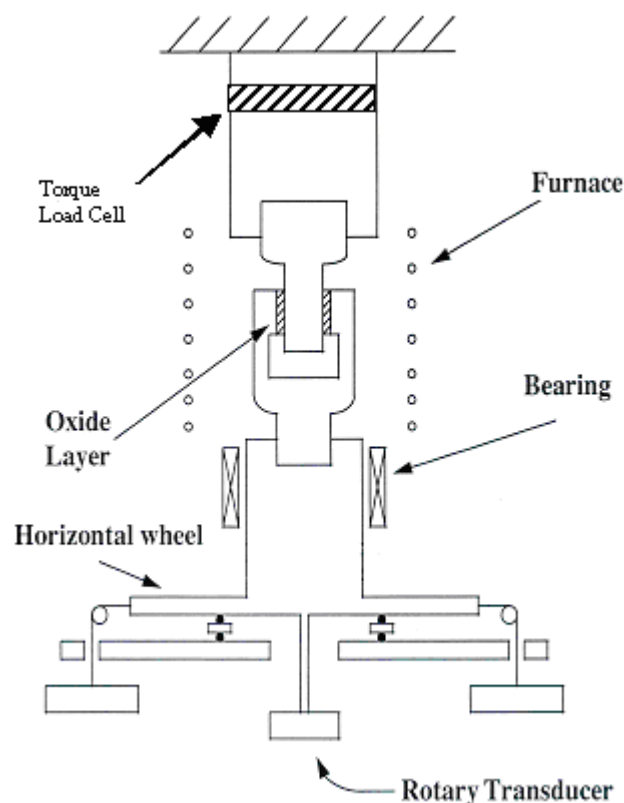


Figure 7 : Schematic of the Torsion Shear Force Test Rig.

Torque is measured via a 10Nm loadcell incorporated into the fixed upper loading train, rotation of the testpiece is measured via an ASL high precision rotary capacitance transducer. Testpiece temperature is monitored via Pt-Pt/13%Rh (Type R) thermocouples tied on to the outside of the tube testpiece. All signals are logged using a PC data logger written in Labview®.

A series of tests using two geometries of Mild Steel testpiece, i.e full length and half length testpieces, are currently underway to evaluate the test rig.

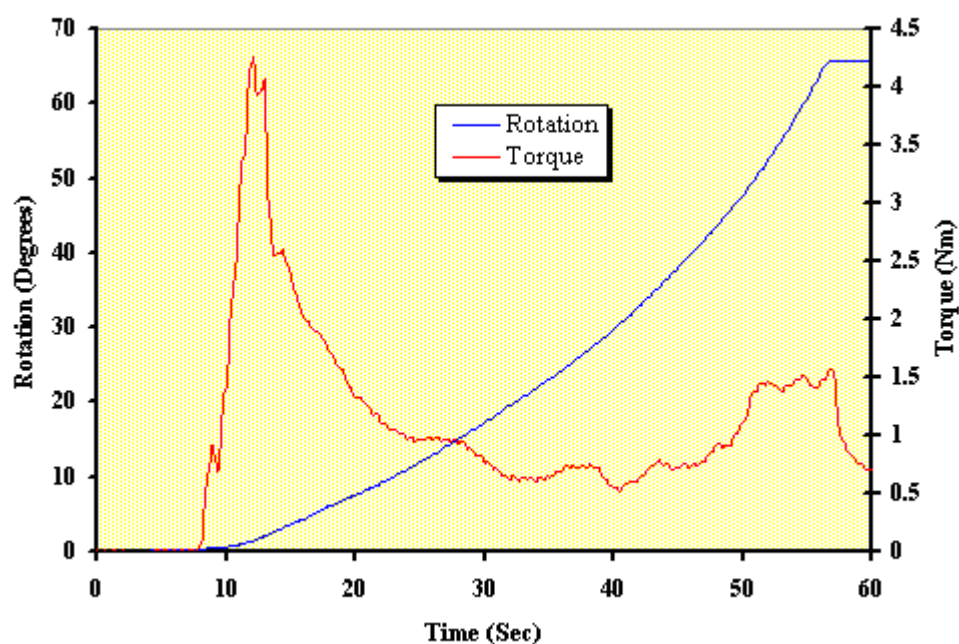


Figure 8 : Typical torque, rotation trace for the Torsion Shear Force Test Rig.

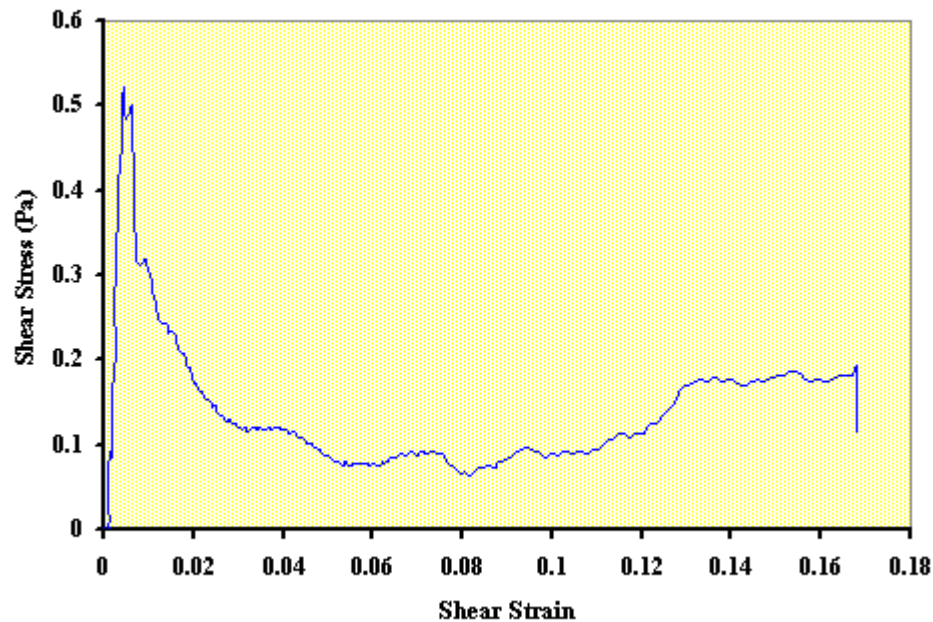


Figure 9 : Typical Oxide Stress - Strain plot for Torsion Shear Force Test Rig.

References

1. Male A.T & Cockroft, M.G (1968), "A Method for determining the Coefficient of Friction of metals under conditions of bulk plastic deformation", Institute of Materials, 1993, p.38-46.
2. Loveday, M.S & Saunders, S.R & Gee, M.G (1998) " Some methods for determining the strength of oxides", CMMT(A)96, Pub. National Physical Laboratory.
3. Loveday M.S, Brooks, M.R, "High Temperature Friction : A simplified Approach for estimating uncertainty of measurement", CMMT(MN)070, Pub. National Physical Laboratory.

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NPL Materials Centre

The Centre primarily develops methods for materials measurement in support of UK industry and trade. The results of the research are channelled into European and International standards organisations to produce standards and codes of practice for the efficient and competitive use of advanced engineering materials and processes.

The Centre is one of the UK's most advanced laboratories for materials measurement with extensive facilities for characterising metals, polymers, adhesives, ceramics, composites and for assessing materials behaviour and performance.

Particular expertise includes:

- mechanical testing
- physical properties measurements
- modelling
- corrosion and environmental degradation of materials
- processing and process control
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CMMT(MN)071

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