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Introduction to Deformation processing of metals. A Discussion Meeting held at the Royal Society on 21 and 22 October 1998

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THE ROYAL SOCIETY

Deformation processing of metals

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The control of microstructures and textures during the deformation and annealing of alloys is of great importance and has been of wide scientific interest for many years. Our understanding, however, of the plastic deformation of metals is far from complete and this is now recognized as an important limitation in developing the quantitative models for thermomechanical processing that are required by the metals industries. The development of new methods of modelling and new techniques for characterization of microstructure and texture are having an impact in this field, and it was therefore timely to hold a Discussion Meeting on deformation processing.

The schematic of figure 1 gives the perspective. The physicists' dream of an ability to compute the properties of engineering materials (bottom two rows) from the nature of fundamental particles and the forces which act between them (top box) has not yet become a reality, although equilibrium properties of perfect crystals are now within their scope (second box). Materials scientists and engineers are continually striving to extract more performance from the materials they develop and use, and to do so more economically. They are prepared to start at the highest level of structure, and to combine fundamental understanding with empiricism, if it is the only way forward (with the knowledge that empiricism can be replaced by a more basic approach as this develops).

This leads to the levels of structure and the numerous links between them contained in the grey-shaded box. Its contents give examples of structural features and averages of these ('dislocation density', 'mean cell size', 'texture', and many more), which can, by various increasingly sophisticated techniques, be measured or otherwise characterized. It is these which the process engineer can manipulate to obtain the desired properties, by control of the process parameters shown as an input:

$$\varepsilon_{ij}(t), \qquad \dot{\varepsilon}_{ij}(t), \qquad T, \qquad (t).$$

Along with composition and prior processing, these are principal tools at the engineer's disposal: strain, strain rate, temperature, and the history (time, t) of them all.

The conference focused on the contents of the grey-shaded box, and particularly on the links it contains and the way that processing can increase or dilute their influence. The excellent talks, and the papers based on their content in this issue, touch on almost all the structural levels and links shown here. They reveal the real

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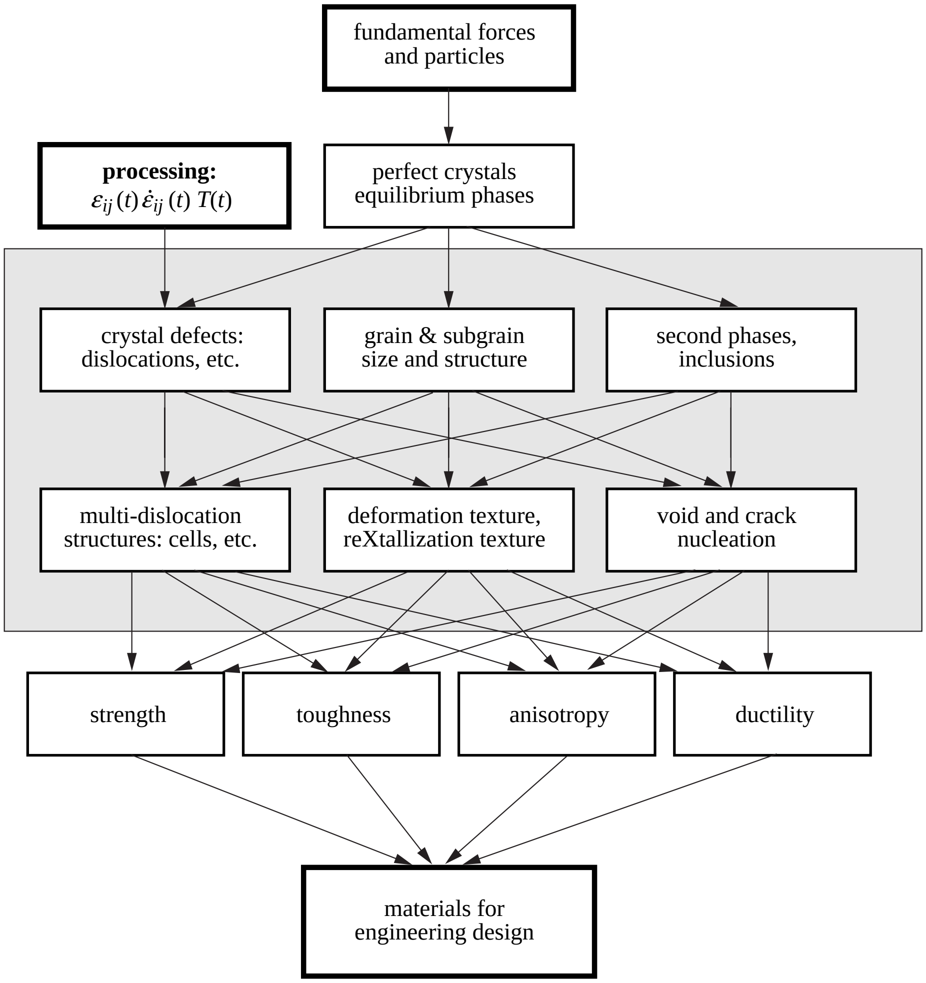

Figure 1.

complexity of the ways in which structural features evolve with strain, strain rate and temperature, and of the ways in which one structural feature influences the evolution of others.

Yet despite this complexity, progress is very significant. It has come about through the conjunction of at least five related developments. Figure 2 gives a simplified overview. In a research and development field such as this, data are the first essential. Improved experimental techniques of testing, allowing the control of multi-axial strain and strain-rate history, and of temperature and its evolution have become available. Increasingly sophisticated diffraction and microscopy tools contribute to the physical understanding of mechanisms—the insight into the nature of the underlying microscopic processes—and enable dislocation structures and texture to be routinely quantified. These, in turn, are captured by refined modelling techniques: advanced simulation methods, many based on finite-element or finite-difference software packages; physically based models, including refined texture predictions and

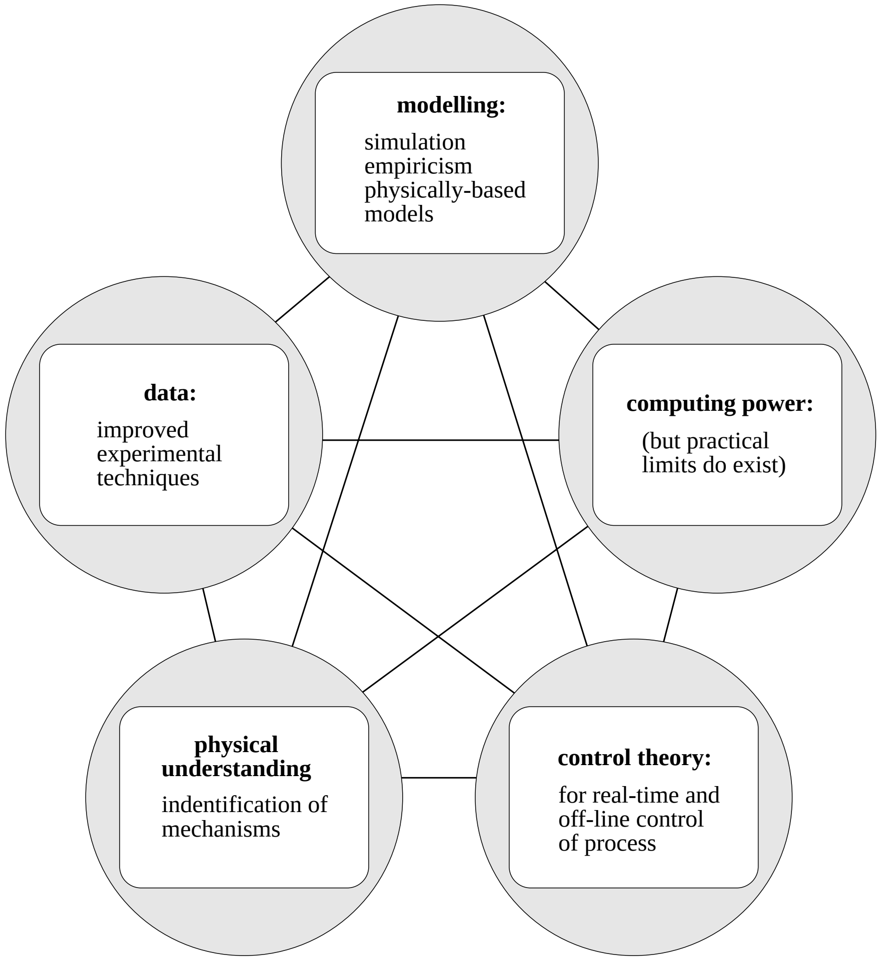

Figure 2.

crystal plasticity, to explain physical understanding; and new statistical methods for data-capture and data-mining. They depend, of course, on computer power, though throughout the meeting speakers emphasized that 'intelligent' rather than simple 'brute-force' methods were essential. And finally, if all this information is ever to be of use in the control of processing, there must be a major input from control theory and systems analysis. Interdisciplinary research groups are clearly essential for the further advancement of this subject.

All these, and more, appeared in the talks and the animated discussion of this exceptionally useful meeting, in which academic and industrial research ideas, motives and progress were shared to great mutual profit. The papers that appear in this issue detail the proceedings. They include contributions from university-based research surveys, from industrial research laboratories, and from managers and planners who spoke of the needs and aims perceived by the industrial sectors. Taken together they give a comprehensive portrait of the current status of understanding of the deformation processing of metals.