ses, and to thermal insulating coatings. Presently, however, the improvement to more traditional materials, *e.g.* metals, are such that new ceramics have a serious problem in making themselves acceptable alternatives.

In spite of the generally high level of skills available to make ceramics, to bond them to metals and to achieve well controlled surface finishes, besides the understanding of the behaviour of the materials under service conditions, it can be concluded that the introduction in technological structures intended for mass production is seriously behind schedule. But this should not lead to the conclusion that interest in engineering ceramics is reducing. Defect control and reliability during fabrication deserve more attention, along with promoting a willingness to accept materials which still have a lower reliability level than metals. In this respect, the particular advantages of ceramics such as chemical or thermal resistance and wear properties, are presently in an exploratory stage over a broad range of applications. Slightly outside the scope of the workshop, it was emphasized that in the process industry and activities related to energy production and the environment, a number of applications of advanced ceramics are within reach. These applications often involve porous ceramic materials to control processes and fulfill tasks involving separation and clearing.

M. Veringa
ECN Petten

Design In Practice

The EIW-5 workshop emphasized that the recent journalistic excitement describing a modern stone age involving ceramic automotive engines and the like has a counterbalance in a cautious industrial appreciation of the important possibilities.

Industry's view was essentially that a ceramic component for a specific application must be carefully designed on an individual basis. Two contributions illustrated different approaches towards developing design tools for ceramic components: one makes use of a careful application of classical stress modelling; the other exploits a more exciting statistical method that should allow designers to work with higher stress levels. But the latter has serious limitations so a novel, complementary strategy was outlined.

A Reliable Classical Approach

The particularly successful application of classical modelling was presented by **J.T. van Konijnenburg, C.A.M. Siskens** and **S. Sinnema** of Hoogovens Industrial Ceramics, The Netherlands. It concerned highly abrasion resistant rings set in dies for ironing the walls of aluminium beer cans as they are extruded (Fig. 1). The basis of the approach is a very precise application of finite element analysis, where the grid size and its arrangement are carefully adjusted, and the relevant properties for the simulation of the actual material measured (and not simply estimated). The result was an accurate prediction of the stress throughout the ring. It was then a simple matter to generate a design that ensured compressive stresses everywhere, with a relatively low level of stress relative to the failure strength of the ceramic.

Fig. 1 also shows the calculated stresses for a prestressed ring in its shrinkage holder after loading: the stresses are compressive and nowhere more than 0.30 times the failure strength. This fairly conservative, perhaps unspectacular, approach clearly works as the company has been using the rings to produce cans at a rate of four each second, where a failure could be disastrous.

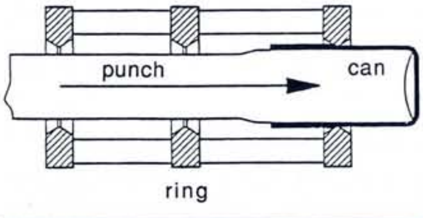
Towards An Accurate Statistical Approach

So-called weak-link or statistical failure prediction is based upon estimating the strength of a brittle material in terms of a global description of the critical defects. In the standard approach, the failure probability P_f, for volume defects is given by

$$P_f = 1-\exp[-(1/m!)^m (V/V_u)\ (S_n/S_u)^m\ I(V)]$$

where V_u and S_u denote the volume and stress of a reference, S_n is the nominal stress on the material and $I(V)$ is the stress-volume integral (the parameter m is the so-called Weibull modulus). Leaving aside how one estimates experimentally all the parameters in the model, **L. Dortmans** and **G. de With*** (Centre for Technical Ceramics, Eindhoven *and Philips Research Laboratories) pointed out in their presentation there still remains the problem of applying data for a uniaxial test to a multiaxially stressed component. To do this the transformation stress-volume integral (or stress-surface integral if surface defects are critical) must be known. It has been shown [1] that analytical formulae for these integrals can be used for a simple one-dimensional bend test as they yield results accurate to 1%, when compared with integrals calculated numerically by finite elements.

The problem is that one does not know how to apply these formulae to a multiaxial stress state. Several models have been proposed based upon different criteria for the



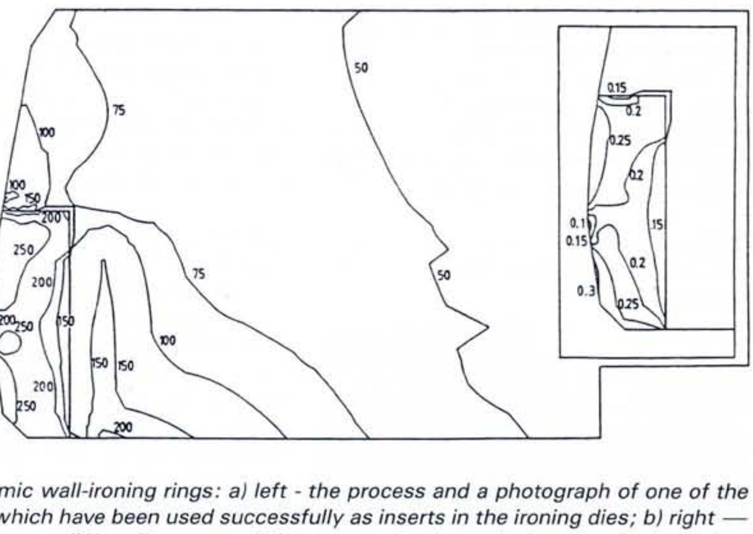


Fig. 1 — Ceramic wall-ironing rings: a) left - the process and a photograph of one of the ceramic rings which have been used successfully as inserts in the ironing dies; b) right — contours of stresses (N/mm²) over a radial cross-section through the ceramic ring calculated from the finite element analysis (after shrinking the ring into its holder and loading). The inset for the region close to the working face shows that the stress is compressive and nowhere more than 0.3 times the failure stress.

conditions leading to failure. For some stress states (*e.g.* those arising in the three-point bend test), the three currently most popular criteria predict identical results using parameters obtained in four-point bend tests. For others (*e.g.* equibiaxial stress states found in the ball-on-ring test), the strengths predicted from the four-point data differ from each other by 10% (see Fig. 2). This may not seem large but in fact it translates to a 10 times larger failure probability.

So the work at the Centre in cooperation with the ECN, Petten now aims to establish which criterion should be applied to a given multi-axial stress state. The conclusion at present is that statistical predictions can only be relied upon for simple components under simple loading conditions. They are also effectively limited to isotropic, homogeneous materials having a sufficiently high density of defects for statistics to be meaningful. With these restrictions, time dependent effects owing to slow crack growth at moderate temperatures can be handled to some extent.

The contributors emphasized that even this limited application of statistical fracture mechanics requires very careful procedures. A small systematic error in the model parameters extracted from a test translates into a large error in the failure probability predicted for a different configuration. Features of the test and the specimen that must be considered in detail include: friction effects, local stresses at the supports,

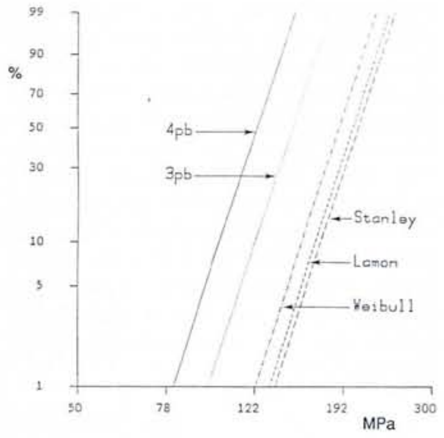


Fig. 2 — A Weibull plot of the biaxial strengths for a ball-on-ring test (with surface defects as the critical defects) predicted by applying statistical fracture mechanics parameters obtained in a four-point bend test. The probabilty of failure in % is given as a function of the strength in MPa. Three different criteria for failure (after Weibull, Lamon and Stanley) predict failure probabilities varying by a factor of 10.

the specimen's surface condition and internal stresses, procedures for extracting the model parameters from the test data, *etc.*

Damage Mechanics — A Complementary Alternative

L. Dortmans and G. de With suggested that one way around the problems may be to adopt a completely different, and novel, approach involving continuum damage mechanics [2] instead of fracture mechanics applied to microscopic defects. The simplest form involves introducing a damage parameter describing the amount of isotropically damaged material. The evolution of this damage with time is postulated and failure occurs when a certain level is reached.

The theory was originally completely phenomenological — indeed microstructural information was still neglected. The trick may be to use recent analytic descriptions of the micromechanics of brittle materials [3] to describe the damaged regions. This hybrid approach should allow the effects of structural anisotropy to be handled *via* continuum deformation theory, but for it to work it will be necessary to determine from the microstructure a concise description of the relevant defects.

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Europhysics Notes

Compiled from correspondents' reports. Contributions should be sent to the Editor.

● EPS

The Society's stock of back issues of journals and review copies of books and conference proceedings formed a useful part of 20 t of materials that were distributed last October to **Romanian universities**. Other important contributors were Professor G. Busch of the ETH Zürich, who donated 2.5 t including invaluable sets of journals from his private library, and several of the ETH's institutes who were happy to put duplicate copies to good use.

Sudents and staff from the Faculty of Physics unloading books in front of the University of Iaşi.

The initiative was organized by Werner Reichart, a nuclear physicist with the Physik Institut, Schönberggasse 9, CH-8001 Zürich. He arranged collection of lots weighing more than about 50 kg by unpaid volunteers and obtained credentials from several organizations to ensure a speedy passage by truck. The six Romanian universities or their equivalents are expanding rapidy, with student intakes set to increase by 3–5 times this year. The exception is Braşov which aims to build dormitories at first. Timişoara's physics department received the EPS book collection and part will be distributed to sudents. Craiova, Cluj, Iaşi and Braşov, the latter is building a new mathematics/physics building, received conference proceedings and abstracts for their libraries. Dr Reichart hopes to finance another distribution so the collection scheme still operates. He would also like to introduce greater precision by encouraging the Romanian universities to specify detailed requirements, and to then find some way of meeting them by perhaps having individuals pay for the purchase of specific titles.

Members of the EPS Condensed Matter Division have been offered a special **20% discount** on the prices of all Adam Hilger and American Institute of Physics books (including some 50 titles in condensed matter) by IOP Publishing, Bristol, BS1 6NX, UK.

● European Astronomical Society

Following this year's ballot showing that there was considerable interest for a European Astronomical Society, astronomers met during the 12th Regional Meeting of the IAU in the Hôtel Europe, Davos, Switzerland on 2 September to announce the formation of the **new society.** It was decided that L. Woltjer would chair a group including M.C.E. Huber, the Chairman of the A. and A. Division, charged with establishing the society. A committee chaired by R.M. West was also set up to nominate members of an EAS Council within about six months. Proposals on how EPS collaboration with the EAS could be structured to preserve the strong links between physicists and astronomers are being discussed. Dr. Huber has in the meantime proposed that the A. and A.