LETTER FROM THE PRESIDENT

Workshops for all interests

ENBIS
European Network for Business and Industrial Statistics
www.enbis.org

By Shirley Coleman

Many ENBIS members have met regularly over the past three years, as part of the pro-ENBIS project funded by the EU. It has been a great pleasure to have such continual contact. Now we have a few days to enjoy each other's company at the fifth annual ENBIS conference in Newcastle upon Tyne, from 14 to 16 September.

This year, for the first time, we have workshops before, during, and after the conference especially arranged by ENBIS special interest groups. The four optional workshops within the conference are carefully thought-out half-day sessions, with presentations and discussions led by experts in the field. These workshops are included in the conference fee of 295/345 euros and are: reliability; research methods in practice – customer and employee opinion surveys; advanced methods in statistical modelling; and the Wild River DoE workshop. The five pre and post conference workshops have an additional fee of 100 or 150 euros and can be attended separately from the conference. There is a full day workshop on practical data mining on 13 September; a choice of three half-day workshops on the morning of 14 September – on operational risk management, simulation of clinical trials, and statistics for innovation and the design process – and a full-day workshop after the conference on 17 September, on statistical consulting skills.

At the conference dinner on 15 September, we are celebrating Robin Plackett's 85th birthday. Robin has a long and varied career in statistics, including some fascinating practical statistical tasks during the Second World War. Our after-dinner speaker, Peter Armitage, will tell us some tales from Robin's life.

These statisticians are the only two people to have received the Guy Medals in Gold, Silver, and Bronze from the Royal Statistical Society for outstanding contributions to the development of the subject. We will be presenting our own ENBIS medal in the final session of the conference to Sir David Cox for outstanding contributions to statistics and look forward to hearing his acceptance speech. We are also delighted to welcome Doug Montgomery as our keynote speaker to open the conference.

ENBIS conferences have always been inspirational. We need to establish other opportunities to meet face to face. Hopefully a mini-conference will be arranged early next year before the main sixth ENBIS conference to be held in Wroclaw, Poland on 18-20 September 2006. We have the chance to discuss meetings and any other matters, for example the progress of our magazine in *Scientific Computing World*, at the General Assembly on the final day of the conference.

I look forward to seeing you in Newcastle.

In the heat of the furnace

Guido Berti, Manuel Monti, and Luigi Salmaso investigate the effect of oxide scale on hot forging

Hot forming is the controlled plastic deformation of heated metals into useful shapes. During heating, the metal oxidises and a layer of oxide – scale – can grow on the surface, before the material-deformation step.

The oxide scale will influence the heat transfer and friction between the tool and the work-piece during hot-forming operations, modifying the process (in respect of both its rheology and tribology) and, therefore, the characteristics of forged component. Thus if the process is to be correctly set up and optimised, an estimate is needed of the growth and evolution of the scale. These phenomena cannot be neglected when the process is numerically simulated by FEM (finite element methods) – the difference between conditions at the tool-work-piece interface in the presence and in the absence of a scale layer needs to be explicitly recognised. In spite of the long history of investigation of oxide scale, there are still many aspects of this phenomenon that limit the use of relevant knowledge in simulating the forming process.

In a physical experiment, we investigated the growth of scale, obtaining a simple heuristic model to include in numerical simulation of the forming process. There were two control variables, temperature and time. Thickness of oxide scale was the response variable. Then, having fitted the experimental data to the model, we used FEM simulation to study the effect on heat transfer and, therefore, on temperature distribution when different scale layers, as predicted by the experimental model, were present on the surface of a work-piece to be forged.

The experiment

We investigated the growth of scale on a medium carbon steel used in hot forming (C40) in different conditions and taking into account the effects of time and maximum heating temperature.

The experiments were in an electrically-heated muffle furnace equipped with a PID temperature controller able to maintain the imposed temperature, avoiding any overshoot and controlling heat-up rate. The furnace can reach a maximum temperature of 1200°C.

The cylindrical specimens (20mm diameter and 10mm length) were obtained by turning a rod (cylindrical- and face-turning). Sharp edges were removed and the surfaces were degreased using neutral cleaner in order to avoid any contamination or oxidation; the surface roughness (Ra) was measured as 0.48 Ìm in both radial and axial direction.

Level	Temperature [°C]	Time [min]
1	900	10
2	925	20
3	950	30
4	975	40
5	1000	50
6	1025	60
7	1050	
8	1075	
9	1100	

Table 1: Factor levels.

Figure 1: Scale measured and relevant experimental conditions.

We assigned nine levels to temperature and six levels to time as shown in Table 1. The ranges of these were based on experience.

There were two replicates of a full factorial design for an independent estimate of experimental error. The observations were in random order.

Each of the 108 specimens was heated at the prescribed temperature for the period of time as defined in the plan, without any shield gas, so as to allow oxidation. Finally the specimens were embedded in a thermoplastic resin and sectioned, for measurement of scale thickness using a digital microscope. Figure 1 shows a typical image.

A regression analysis gave:

$$S = 2187 - 5.03\,x_1 - 81.2\,x_2 + 0.0029\,x_1^2 + 0.150\,x_1x_2 - 0.000065\,x_1^2\,x_2$$

where S is the thickness of the oxide scale (μm), x_1 represents Temperature (°C), x_2 represents Time (minutes).

There is a 98 per cent fit over the data range and every term included in the equation is highly significant. Such a good fit justified our use of the function in the subsequent simulation.

Scale layers and temperature

The cutting edge of a tool is exposed to both mechanical stress and severe temperature changes. These often lead to loss of strength and hardness and to thermo-mechanical fatigue failure. Temperature changes are directly affected by operating conditions, such as the forging temperature, interface conditions, thickness of oxide scale, contact time, and the policy of cooling and lubricating tool surfaces.

The evolution of temperature distribution at the surface of tools in forging operations cannot be directly measured, but it can be estimated by numerical simulation using an equivalent heat transfer coefficient (HTC) that summarises all contributions to the thermal resistance of interface.

To evaluate how the thickness of the oxide scale affects the temperature distribution at the surface of tools the following steps were followed:

1. HTC for two different scale thickness were estimated; and

2. a hot upset forging operation was simulated for two values of HTC using FEM.

The regression equation was used to predict two different oxide thicknesses as functions of time and maximum temperature of heating, as shown in Table 2 where the last column reports the values of HTC relevant to oxide scale thickness. These values were determined by Li Y H and, Sellars C M (1998): 'Comparative investigations of interfacial heat transfer behaviour during hot forging and rolling of steel with oxide scale formation'. *J. of Materials Processing Technology*, *80-81*, *282-286*.

To evaluate the temperature distribution at the surface of tools, it was necessary to use an FE model capable of a 2D fully coupled thermo-mechanical (elastic-plastic) analysis of the deformation phase with HTC constant at the work-piece-die interface and over time as well; variation of HTC during the deformation is not considered, because the forming is limited to few tenths of a second and the oxide layer is supposed not to be disrupted.

The commercial software Forge 2 was used for numerical simulation. The heat generated by plastic deformation inside the work-piece and by friction at the die-work-piece interface was included, as well as the heat lost through radiation and convection at the free surface.

The deformation phase of the forging operation of a cylindrical billet of 10mm height and 20mm diameter was simulated adopting the 2D model shown in Figure 2 and was carried out under axial symmetric conditions. The simulation plan is shown in Table 3.

The evolution of temperature during the deformation phase was predicted and recorded at different positions on the tool surface. Figure 3 shows the thermal histories calculated using the FE model and relevant to simulation 1 and 2. Comparing the temperature evolution calculated at the surface of tool, it can be seen that a higher value of oxide thickness (as shown in Figure 3) due to longer heating time of the work-piece (Table 2) reduces the temperature of tools by about 100°C.

We concluded from this that a higher value of oxide thickness resulting from a longer heating time of a work-piece can reduce the temperature of tools by approximately 100°C.

Temperature [°C]	**Time** [min]	**Oxide thickness** [μm]	**HTC** [W/m2K]
1000	28	180	12300
1000	46	250	5100

Table 2: Oxide thickness predicted by the experimental model and relevant HTC.

Simulation	**Press type**	**Material**	**Friction law**	**Height reduction** [%]	**HTC** [W/m2K]
1	constant velocity press	C40	Coulomb	30	12300
2	20 [mm/s]		(μ=0.3)		5100

Table 3: Simulation plan.

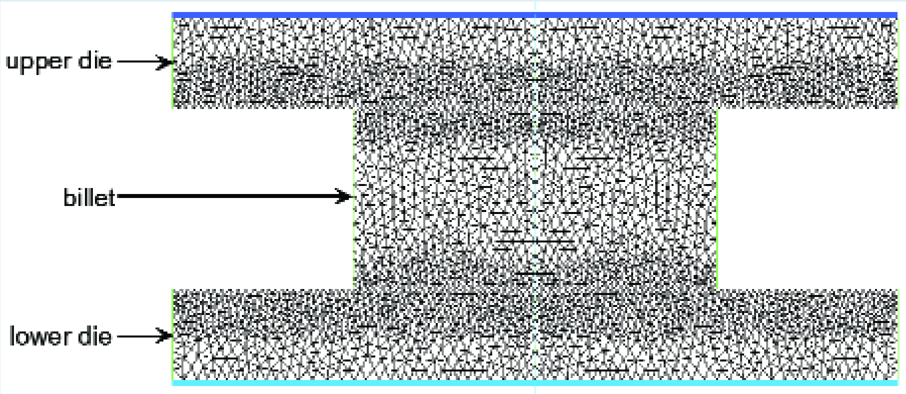

Figure 2: 2D axial symmetric model.

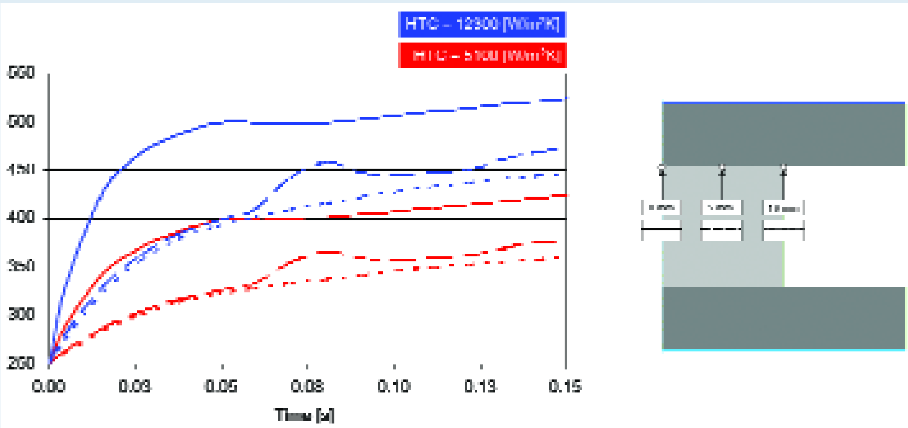

Figure 3: Temperatures calculated during the deformation phase of simulation 1 and 2.

The authors are at the Department of Management and Engineering of the University of Padova, which supports courses in management engineering, mechatronics, and mechanical engineering with more than 2000 students. The department's scope includes economics, management, manufacturing, automation, informatics, and design. It is involved in several European and national projects and cooperates with companies such as Tele System, Whirlpool, and the Carraro Group.

guido.berti@unipd.it

www.mecc.unipd.it/~tecno

Guess who's coming to dinner?

John Logsdon looks at what it takes to be a statistician and how statistics relates to other disciplines

In the last issue, I discussed the present data-intensive world of science, business and industry and how statistics and statistical thinking can help to clear the mind. I now pose the questions: What does it take to be an applied statistician in business and industry and how does applied statistics relate to other disciplines?

Ask a hundred members of the public what they think statisticians do every day; the answers would place us down there with accountants and train spotters, meaning statisticians are not popular dinner guests.

I divide the skills we statisticians require into two: technical; and non-technical. Technical skills include the ability to understand statistical concepts, manipulate mathematics, understand the applied field, and use computers. Non-technical skills include an ability to listen and speak, present findings and write – all of which may be included in communication skills. We need the ability to understand people, and we have to work as part of an interdisciplinary team with the particularly sensitive responsibility of calculating or qualifying the conclusions of the team that owns the problem.

In universities, statistics is usually part of a mathematics department. Is statistics really a branch of mathematics? Let's compare it to physics or engineering, subjects that I used to know well. The mathematics required at least for applied statistics is generally less advanced. The main requirement is an understanding of high dimensional space, a good grasp of linear algebra, possibly matrix or tensor operations, a little calculus and a clear head. Of these, perhaps the most difficult to acquire is the clear head. Some branches of statistics do need knowledge of high dimensional mathematics, vector spaces and advanced matrix calculus, but let's start with the simple. So statistics should be treated as a separate discipline, as are physics and engineering.

These days, statistics is most closely allied to computer science. Many techniques used require extensive programming skills, and many, for example in data mining or neural networks, have evolved from computing.

Computers used to be seen as a convenient tool to do the statistical dirty work. Now they have become a model exploration tool. In the future, machine-learning will enable more complicated models to be devised, that will be impossible to study without computing.

Computing is now an essential skill for a statistician, perhaps more important than mathematics. At a recent statistics meeting, a leading expert on machine-learning gave a fascinating view of the future. But what was equally interesting was the number of computer-science people there and the interesting questions they posed.

Without input from statisticians, computer scientists can make some expensive mistakes. I recall the case of the automatic reading of hand-written US Zip codes that was an early application of neural networks. After many millions of dollars of computing and many man-years of effort by a large team of people, something like 99.8 per cent of all Zip codes were read correctly from a training set. Along came a couple of statisticians who, in six months or so, produced the same result with minimal computation.

I take it as read that a statistician should be well acquainted with the techniques and models that have been developed. This is made much more difficult as good applications – and even original models – are often revealed in publications other than mainstream statistical journals. Many interesting approaches, such as random coefficients, have been reported, for example, in the educational testing literature. Others such as Kriging have grown out of geology.

To keep abreast of such developments, it may be necessary for a statistician to attend courses routinely, even if the applications area of a course is irrelevant to the statistician's work area. This is particularly true for statisticians working on their own in industry.

I once attended a course on multilevel modelling. To be honest, I didn't have a clue what this would mean in my job, particularly as much of it referred to issues in education. As an ex-physicist, I wasn't really sure what it meant anyway. But, by making the continuous professional development argument, I persuaded my company that the time would not be spent in the bar and that rubbing shoulders with real statisticians would be very profitable.

The knowledge I gained was extremely useful in understanding data structures and seeing solutions to various engineering problems. Suddenly a whole new area opened up, and I realised that calculations of corrosion rates that I had carried out some 10 years before were in effect a multilevel model – all done with pencil, a large piece of A3 paper, calculator and a copy of *Kendall and Stuart Volume 2* to prop the drawing board up and occasionally to consult.

The non-technical requirements for a statistician really revolve around the ability to communicate effectively, and writing is the most difficult. Much statistical writing is still aimed at the author's peers: those who can understand the complex ideas they are trying to explain. This may be all very well in academia, but in business and industry it is wrong. The idea of writing is to communicate with the reader, not show him or her what a clever person you are.

In many cases, obscure writing has the opposite effect – not only do the readers not understand it, but they may conclude that the author either has parroted it from a book or has a serious ego-to-writing ratio problem. I have long advocated that all scientists, including statisticians, should attend a course in writing. It is essential, particularly as we usually work in a team of people, most of whom do not understand statistics. In addition, it should be part of a statistician's role to educate and inform so that, for the next project, the team leader either includes a statistician at the outset or at least follows a statistically coherent line.

Other non-technical skills revolve around personality. To be a statistician means being able to listen and learn, to be able to analyse and synthesise, to be able to see all opinions yet filter out the wrong, to criticise gently and praise fulsomely, bringing a wide variety of knowledge and techniques to bear on a problem, recognising structures and algorithms. We should do this all with humility, humanity and even humour working with our colleagues and treating them and their data with the utmost respect.

So in sum, statisticians need to be good team workers with a broad knowledge of many issues, clear thinkers with good analytical brains. They sound like excellent dinner guests.

John Logsden runs a statistical consultancy in Manchester, UK.