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THE PHILOSOPHY AND PRINCIPLES OF WELDING DESIGN

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The philosophy and principles of welding design

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- by -

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S U M M A R Y

The welding designer requires a philosophy for his design responsibilities and a thorough understanding of the basic principles in the subjects covering his responsibilities. The education of the welding designer must provide a spectrum of studies which will define these responsibilities and which will help him to understand and apply the science and technology relevant to his work.

La Philosophie et les principes du dessin de soudage

Le dessinateur de soudage a besoin d'une philosophie pour ses responsabilités de dessin et une compréhension complète des principes fondamentaux dans les sujets qui couvrent ses responsabilités. L'éducation du dessinateur de soudage doit fournir un spectre d'études qui définira les responsabilités et qui l'aidera à comprendre et à appliquer la science et la technologie qui ont rapport à son travail.

Introduction

A disappointing commentary on the present teaching and practice of welded design is that too many engineers place an exaggerated significance on the stressing of the welded joint for ductile failure due to static loading. In the United Kingdom, this arises from the teaching of the majority of colleges and universities, where welded design is often included in an analytical course on the strength of materials or structures. Textbooks on welded design are not comprehensive, because most authors have not had the broadly based training of the modern welding technologist and this lack of suitable literature inhibits the process of self education by lecturers. Experience of welding technology by lecturers is generally rare.

It is probable that this situation exists in the majority of countries and it means that a philosophy for welded design has not been defined in basic engineering education. Inevitably, this lack of understanding has had in the past, and is still having, disastrous consequences in incorrect design of welded fabrications for many applications and in the subsequent cost of failures or recurring maintenance.

The pressure on the syllabus, in basic engineering education, does not allow welding design to command a bigger proportion of the overall time but it would be valuable for the 'good name' of welded structures, if the available time were spent on a sound philosophy for welding design, rather than on the manipulation of a few empirical formulae for butt and fillet welded joints.

The Philosophy

The welding designer is responsible for the economic design of a welded fabrication to the requirements of the purchaser. His experience and ability in the field of welding technology should ensure that the fabrication will be manufactured efficiently, is capable of being delivered at the promised time and will perform satisfactorily in service. He must have the confidence to achieve these objectives: he requires a sound philosophy.

A welding designer is a welding technologist who understands welding design in its widest sense, who can identify the problems of welding metallurgy, who understands the economics, flexibility and limitations of welding processes and who knows the capacity of quality control and inspection procedures.

The efficiency of the designer must ultimately be judged by his capacity to produce an economic structure without being overcome by the diversity of his technological responsibilities. As many aspects of his work are empirical, he must guard against the tendency to build in too many safety factors, conditioned by lack of information or confidence.

It can be argued that, in many organisations, the welding engineer takes the majority of the welding decisions and the welding designer is relieved of many of his responsibilities, especially with metallurgical and process problems and with quality control and inspection. This approach demands much of the welding engineer, whose opinions will be accepted without contradiction, and it must inhibit progress where there can be no informed challenge to the opinions of an individual. The welding engineer has a most important part to play but he should have the stimulus of discussions with informed and critical welding designers.

Probably, the welding designer who lacks any knowledge of quality control and inspection in welding is potentially the most likely to run into trouble. It is easy, but quite wrong, to put a weld on a drawing and assume that the weld will be perfectly sound metal, that the shape of the weld will be very close to the ideal shape which appears in the textbook and that the weld can be successfully examined by non-destructive testing. The designer must dictate his requirements for the quality and shape of the welded joint: it is futile to hope that the fabricators will read the mind of the designer. Where any doubt exists, the designer must state clearly his requirements for the welded joint and, if these requirements cannot be achieved, the fabricators must come back to the designer to re-assess the problem.

It must be admitted that, for the majority of welded structures, a welding designer can concentrate on weld stressing and can neglect other aspects of his technology, without running into serious trouble, particularly where there is a code of practice to act as a partial safeguard. This philosophy is a dangerous one for two inter-connected reasons: without a full understanding of welding technology, there can be troubles in production or in service and where there is any trouble there must be a loss of confidence in welding which is bad for the design organisation and, more important, for public confidence in welded structures, which are facing increasing competition with concrete, fibre reinforced plastics and other materials.

Hence, lecturers in welding design and technical management in control of welding designers have to define the responsibilities of the welding designer. It is better to over estimate the responsibilities of the welding designer and to cut back in practice than to under estimate and run into trouble.

Implications of Philosophy

If the welding designer is to be more than a stressman, there must be opportunities for him to broaden his education. Two obvious choices are available, if it is accepted that the previous education has not fitted him for his task: either he is trained by his employers or he is trained outside.

In the United Kingdom, with few exceptions, there seems to be a general reluctance to carry out internal training for welding designers, although

this can be the most effective and economic way of achieving an all round improvement in the understanding of welding technology. It has several vital advantages including the availability of staff who are being trained, a course orientated to the products of the firm, and none of the travelling and subsistence expenses incurred in outside courses.

The usefulness of day-release and evening classes at colleges close to the firm must depend on the ability of the lecturers and, for the present, the number of experts in welding technology is very limited. With the availability of more lecturers with advanced training and the increasing pressure to put on courses for the corporate membership examination of the Institute of Welding, there will be a general improvement at local colleges in the United Kingdom.

A one year postgraduate course^{1,2} in welding technology should provide the basis for an efficient welding designer. In the large countries, it has proved possible to run courses in undergraduate as well as postgraduate welding technology. With this category of training, the implications of the philosophy for the welding designer are recognised.

The Principles

The welding designer must have the following capabilities:

- 1) He must be able to determine the size, shape and distribution of the welds in a structure, which will give a trouble-free service life wherever possible.
- 2) He must be able to recognise the metallurgical problems which occur with the welds in the materials he has chosen.
- 3) He must know whether the welds can be made satisfactorily with the processes which are available and, further, he must have some knowledge of the relative economics of different processes.
- 4) He must know the capabilities of quality control and inspection.
- 5) He must be conversant with pre-welding and post welding manufacturing processes.

These factors cannot be taken in isolation and their interaction must be taken into consideration by the designer.

The Welded Joint

This paper is completed by a brief survey of the approach which has been adopted at Cranfield in one-year postgraduate courses, covering the first principles tested above.

In the mythology of welding technology, it is assumed that the 'weld metal is similar to the parent plate' and the discontinuities of the welded joint are overlooked. A further myth is that 'the ductile fracture is assured by the use of a ductile weld metal'.

There are so many peculiar ideas associated with welding design that a start with the very basic principles is essential.

The weld thermal cycle causes stress and metallurgical discontinuities at the joint. The stress discontinuities include deep notches at the surface, internal flaws and a disturbance in the applied stress pattern from the residual stresses associated with manufacturing processes including welding; the metallurgical discontinuities cause a change in the properties such as stress strain relationships and notch toughness in the region of the welded joint.

The implications³ of the discontinuities, when the fabrication is loaded in different ways, are considerable and it is most important to draw attention to the possible modes of failure in which a structure may no longer be able to withstand its service conditions. Conventional textbooks on strength of materials and theory of structures concentrate largely on ductile fracture and buckling, where most welded structures fail by fatigue cracking or low stress brittle fracture. Where an engineer's education has not made him familiar with a particular mode of failure, either in lectures and in demonstrations in the laboratory, it stands to reason there will be a barrier to its acceptance as a critical factor in design. Visual proof in the laboratory makes a strong impact and endures and there is a responsibility among lecturers to be convincing in the structural and mechanical testing laboratories as well as on the blackboard.

Conclusions

The terms of reference for a welding designer must be clearly defined by his employers, as the subject has so many facets other than the stressing of the welded joint; they will vary - dependent upon the structure and staff of the organisation in which he works.

The designer must recognise the particular importance of the following three factors; the type of loading on the fabrication, the possible modes of failure and the discontinuities of the welded joint. Process, inspection and metallurgical problems have to be recognised.

Where the designer lacks the understanding of the basic principles, the welded steel structures which he designs could prove to be unreliable.

References

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