value of the lower shear stress, and it is consequently not possible to calculate meaningful collapse pressures. From Figure 24 it will be seen that there is reasonable agreement between theory and experiment. Table 6 gives the experimental and computed values of collapse pressure.

The pressure-expansion curves at large strains have been computed from the maximum and minimum shear stress-strain curves and they are plotted for instance in Figure 19. From this figure it will be seen that there is exceptionally good agreement between the theoretical and experimental pressure-expansion curve in the region before failure. However, the cylinders failed at diametral strains well below the strain at the maximum or ultimate pressure. Consequently it cannot be expected that there will be good agreement between the calculated and experimental values of ultimate pressure. The method of calculating the pressure-expansion curve from shear stress-strain data is proved beyond reasonable doubt, but there is insufficient knowledge or data available to predict when fracture will occur. The equivalent shear strain at the bore at failure can be computed by the analysis given by Crossland (1964), and it is found to be very much less than the strains to failure in simple torsion given in Table 2.

The values of ultimate pressures computed from shear stress-strain data are compared with experimental values in Table 7 where the mean diameter values of ultimate pressure are also given. It will be seen that the errors are much greater than for Hykro and Vibrac but they are less for values based on the shear stress-strain data than for those calculated from the mean diameter formula which is based on tension data.

Figure 25 shows curves of the ultimate pressures calculated from shear stress-strain data against the diameter ratio K for various temperatures. If it were not for premature failure of the cylinders it will be seen that they would be stronger at elevated temperatures up to 300°C than at 20°C, and a serious drop in strength is only experienced at 370°C.

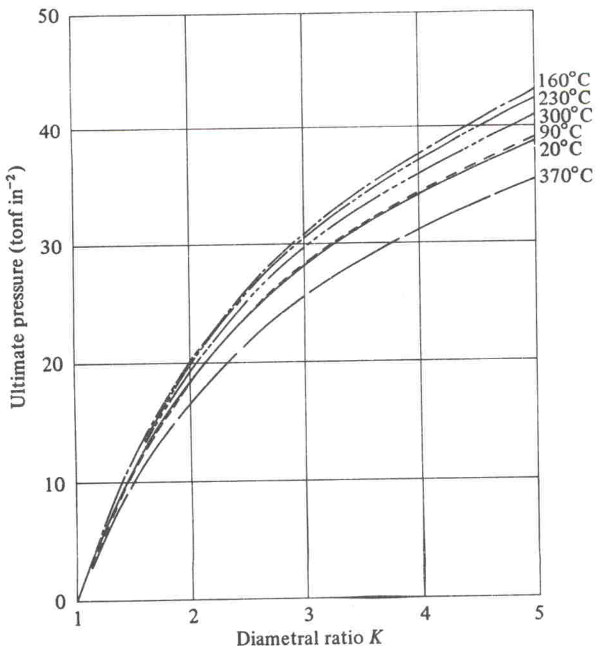

Figure 25. Ultimate pressure of EN3A cylinders at temperatures calculated from torsion data.

Table 7. Theoretical and experimental values of ultimate pressure for mild steel EN3.

Diameter ratio K	Temp. (°C)	Experimental ultimate pressure (tonf in^{-2})	Calculated ultimate pressure (tonf in^{-2}): mean diameter	based on shear stress-strain: maximum	based on shear stress-strain: minimum
1·365	20	7·55	9·16 (+21·3%)	–	–
1·4	20	8·6	9·9 (+15·1%)	9·26 (+ 7·7%)	8·82 (+ 2·6%)
1·6	20	11·32	13·7 (+21%)	12·90 (+14%)	12·26 (+ 8·3%)
1·8	20	14·72	17·0 (+15·5%)	16·05 (+ 9%)	15·21 (+ 3·3%)
2·0	20	17·3	19·8 (+14·4%)	18·8 (+ 8·7%)	17·83 (+ 3%)
3·0	20	26·9	29·7 (+10·4%)	28·8 (+ 7%)	27·34 (+ 1·6%)
5·0	20	37·2	39·6 (+ 6·5%)	39·8 (+ 7%)	37·78 (+ 1·6%)
1·365	160	8·0–8·4	9·97 (+21·6%)	–	–
1·4	160	9·55	10·75 (+12·6%)	10·0 (+ 5%)	9·75 (+ 2·1%)
1·8	160	15·8	18·5 (+17·1%)	17·38 (+10%)	16·88 (+ 6·9%)
1·365	300	7·70	10·3 (+30%)	–	–
1·4	300	9·08	11·1 (+22·2%)	9·73 (+ 7·2%)	9·49 (+ 4·5%)
1·6	300	12·4	15·4 (+24·2%)	13·45 (+ 7·8%)	13·11 (+ 5·7%)
1·8	300	14·6	19·0 (+30%)	16·74 (+14·5%)	16·33 (+11·8%)
2·0	300	18·7	22·2 (+18·8%)	19·58 (+ 4·7%)	19·12 (+ 2·3%)
3·0	300	26·1	33·3 (+27·6%)	30·02 (+15%)	29·24 (+12%)

Conclusions

From relaxation tests it would appear that creep is becoming of significance at 370°C for Hykro and more importantly so for Vibrac. In the case of EN3 there is significant relaxation even at 300°C, which is in agreement with creep work on a mild steel being carried out in Belfast.

The agreement between yield pressures and collapse pressures computed from shear stress-strain data and experimental values is excellent for all materials and temperatures. Again there is reasonable agreement between the theoretical pressure-expansion curves based on shear stress-strain data and the experimental curves. However, with EN3 most of the cylinders failed at strains well below those associated with the ultimate pressure.

For Vibrac and Hykro it was found that there was reasonable agreement at all temperatures between experimental values of ultimate pressures and those computed from shear stress-strain data or those based on the mean diameter formula. For EN3 cylinders the agreement between experimental values of ultimate pressures and those computed from shear stress-strain data is poor and the disagreement with values based on the mean diameter formula is even worse. The reason for this disagreement is that failure occurred on a rising pressure-expansion curve before reaching the peak value predicted by theory. The final fracture of materials is still not clearly understood and no method of predicting the strain to failure in a thick-walled cylinder has yet been established which explains these results.

The present work has continued to demonstrate the simplicity and desirability of using shear stress-strain data in the design of cylinders, and the simplicity of getting such data has also been demonstrated. It should be noted that it would be extremely difficult to get large strain tensile data at elevated temperature, as some means of measuring the diameter and radius of curvature of the neck would be necessary.

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