BUCKLING OF LIQUID - FILLED THINWALLED CONICAL SHELLS: A LONG - STANDING PUZZLE RESOLVED

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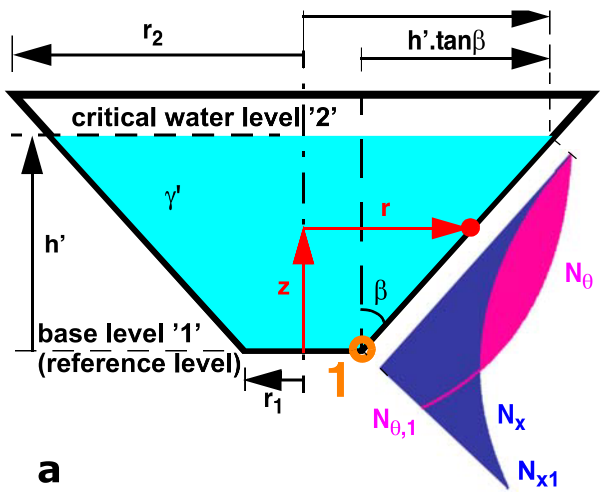
1. Overview

Following the catastrophic collapse of a steel water tower in Belgium (1972) a comprehensive programme of experimental research on small - scale liquid - filled conical shell models has been initiated at the Laboratory of Model Testing at Gent University. This systematic experimental research had been carried out over the time span of more than one decade (1977 - 1987) and was complemented by a few theoretical investigations of limited scope [6, 7]. On the basis of the results of this research pro-gramme finally a design proposal has been worked out and presented to the engineering public. This design proposal is based on unique straight - line bounds on the complete set of test results in a non - dimensional log - log plot respresentation (Fig. 1-b). However, despite the considerable research effort that has been put into this problem up to the present time, there is a basic lack of understanding the mechanics of the underlying buckling problem. In order to achieve such understanding and systematically address the open gaps in basic understanding a thorough investigation of the mechanical behaviour of thin-walled *L*iquid - *F*illed *C*onical shells (*LFC*) is needed (Fig. 1-a). Thereby the buckling - relevant membrane stress distributions under hydrostatic loading are of concern as well as characteristic details of the resulting *LFC* - specific buckling phenomena and related buckling strengths.

This paper presents the results of a detailed theoretical re - investigation and re - examination of the *LFC* shell - Gent testing programme. This is done in a step - by - step fashion, particularly by investigating the effect of the individual problem parameters each on its own (shell slenderness r_1/t, cone opening angle β, critical water level h'/r_1 and maximum nondimensionsal hydrostatic pressure level $\bar{p}$) and by introducing novel and powerful new representation and interpretations.

Finally the Belgium (1972) and Canada (1991) steel water tower failure cases have also been re - examined, firstly for verification purposes and secondly, for checking possible roles which might have been played by plasticity effects during collapse.



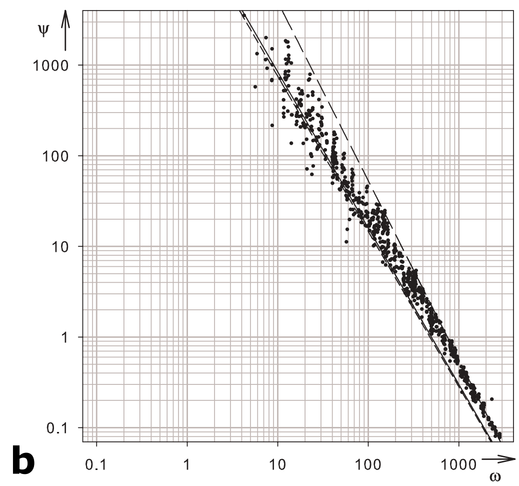


Fig. 1(a) Geometrical parameters and membrane stress section forces N_x and N_θ,
(b) Log - Log plot of Gent test data points and bounding straight lines

2. Basic ideas, results & conclusion

The first principal idea of our in - depth re - analysis and re - examination [3, 5] of the Gent test programme was to firmly base this investigation on the original test data and desription of these test data which were generously provided by the Laboratory of Model testing of Gent University [4]. When working through this bunch of original information, we could recognize very soon that the individual all these more than 800 (!) individual laboratory tests have been carried with great care and sophistication, which meant that the materialistic starting point of our work was excellently structured and described. The second principal idea was to base our work on the newly established powerful framework of thin-walled steel shell buckling strength design as it is presented in the novel European Standard EN 1993-1-6 [1]. On the basis of these principal ideas combined with applying elementary membane shell analysis a successful theoretical re - analysis of the original Gent test programme (Figs. 2-a, b) and a subsequent straightforward re - interpretation of the original Gent buckling design recommendation could be carried out.

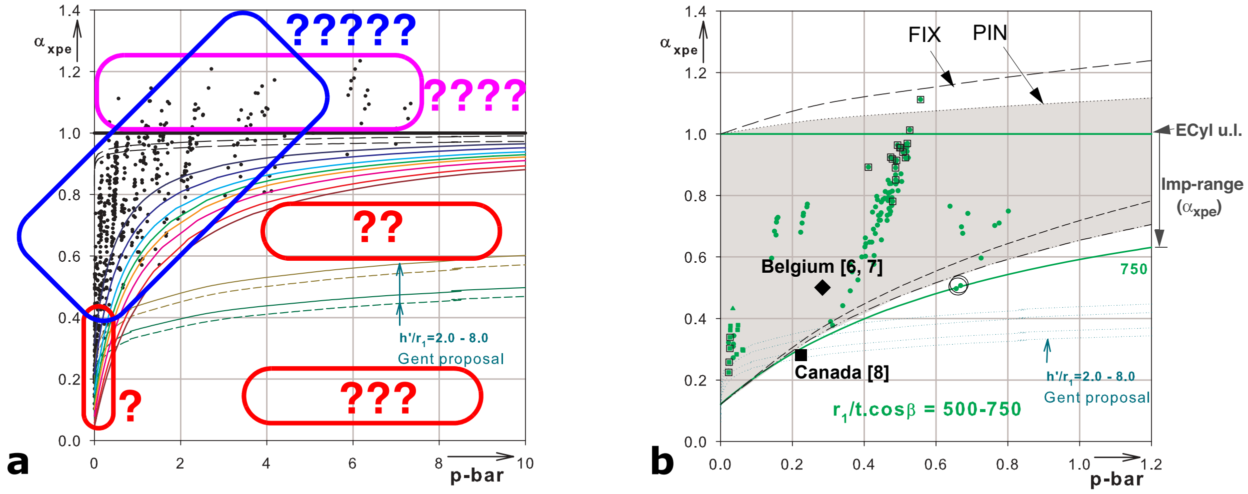


Fig. 2(a) *LFC* equivalent cylinder buckling curves, Gent test data points and bounding curves, (b) Laboratory test results for $r_1/(t.\cos\beta) = 500 - 750$ and water tower collaps cases

3. References

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