Numerical simulation and design tool for an oil pipe centralizer: A case study of a cost driven adaptation by an SME

A.M. Hedayetullah[1a], R. Fletcher[2], E. James[2], P.A. Flay[2], G. R. Tabor[1] and C. W. Smith[1a]

[1]CEMPS, University of Exeter, Exeter, EX4 4QF, UK

[2]Centek Ltd, Newton Abbot TQ12 4AE, UK

[a]a.m.hedayetullah@exeter.ac.uk

Abstract. Centralizers play an important role in achieving successful cementing operations when establishing production wells in the oil and gas industry. Current practice in new centralizer development relies on empirical calculations and personal experience with repeated prototype trial experiments in order to create a centralizer of optimized design. This approach reduces product development efficiency in terms of time and cost. In this research, Finite Element Analysis (FEA) and surface response methods have been used as a primary design tool for faster product development. Some results of the implementation of this design process versus the original experience based process are given, notably time in development and to first sale. This is a case study about adoption of simulation design tools in an SME.

Introduction

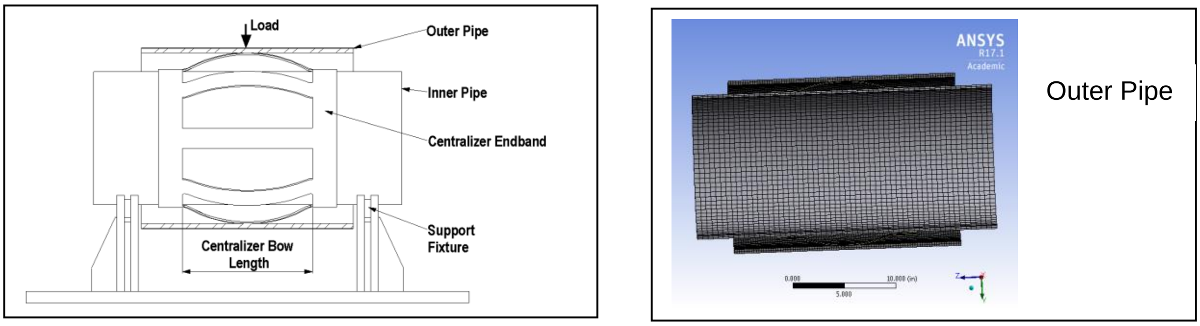
Casing centralizers are devices fitted to the outside of a casing string (steel pipe) to hold it centrally within the oil well borehole. The pipe must be central for uniform distribution of cement flow around the casing [1], or if not there is a risk of imperfect zonal isolation with the potential for oil or gas to “leak” by the outside of the annulus rather than up the inside of the pipe. Release of hydrocarbons outside of the pipe like this has the potential for disasters similar to Macondo [2,3,4].

There are many different types of centralisers, with Bow Spring centralizers the most common [3]. Their performance is primarily dependent on the material thickness, bow length, bow cross sectional curvature and end band width, and see Fig. 1 (a). The American Petroleum Institute (API) 10D standard is used sector-wide to assess centralizer performance experimentally, and particularly the restoring force, see Fig. 1(a) [5].

Development of new centralizer products currently involves iterative design, production and testing of prototypes. This can take between 4 and 13 weeks depending on complexity. Costs for delaying drilling operations are extremely large, hence centralizer customers prefer short development times. Modelling tools such as Finite Element Analysis along with surface response methods, can be used to reduce product development times, primarily by rapidly suggesting a near-best solution to be confirmed via testing. The main aim of this research is to develop a cost effective and reliable design tool based on FEA and response surface methods, suitable for an SME with resource constraints. By iterating FEA models across ranges of centralizer dimensions and deriving the response surface, it is possible to avoid requirements for *ad hoc* FEA for new products, which can be difficult to do in the context of an SME

API 10D experimentation and models

Fig. 1 (a) shows a typical test set up for the API 10D restoring force test and Fig. 1 (b) the corresponding FE representation (Ansys v17.1 was used throughout). The centralizer is supported by an inner pipe, and loaded by a larger outer pipe representing the borehole wall. Load is applied centrally on the outer pipe of the assembly up to a value defined by API 10D. The centralizer’s bows are loaded sequentially in a series of tests.



(a) (b)

Fig. 1: (a) API 10D restoring force test set up [5] & (b) cut away view of FE modelling for (a)

For FEA the mean measured inner and outer diameters were applied to the models, which were assembled using thin solid shell elements (SOLSH190). The inner pipe was considered as fixed, i.e. zero displacement at the inner and outer surface nodes; the centralizer and the outer pipe were unconstrained except rotations around the long axis of the centralizer were blocked. Several centralizers were modelled and compared against associated experimental data.

Product Design Tool.

The surface response tool takes the form of an n–dimensional polynomial function fitted to the bow spring rate data from the FEA and experiments where available (the objective or performance criterion) across the range of centralizer dimensions. Fitting was done with a least squares algorithm available in the FEA software. The response surface can be implemented in practice as a function in a spreadsheet, a graphical tool, or as an app, and quickly points users to the near-best set of centralizer dimensions for a required restoring force.

Results.

Fig. 2 shows the load – deflection curve comparison of one eight-bow centralizer's experimental results with the FE predictions. The numbered lines are from individual bows. The FE model over estimates stiffness very slightly but captures reasonably well the performance of the centralizer considering experimental uncertainties.

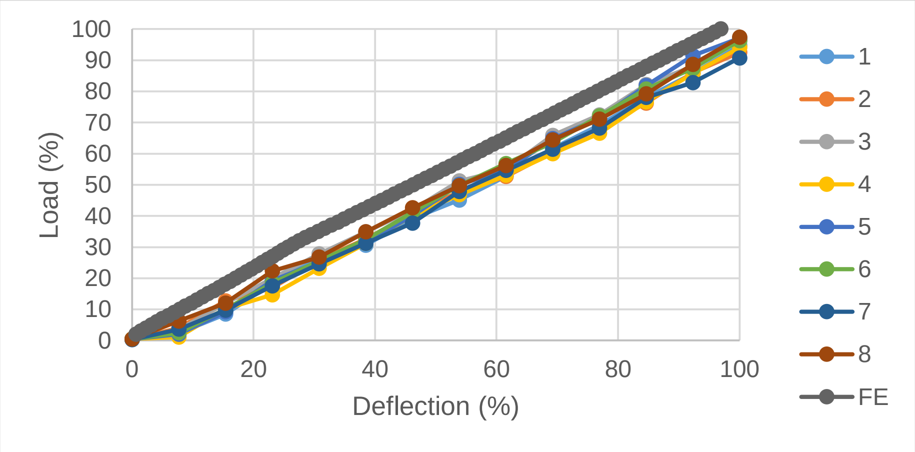


Fig. 2: Comparison of FEA with experimental results.

Conclusion

The drive for shorter development lead times leads to strong demand for rapid product development and often for multiple designs. In this case the cost for each traditional design and test process is estimated to average £2k, and the iterative approach usually requires five concurrent designs to be pursued concurrently, hence giving development costs of approximately £10k. Invariably final refinements are required, meaning typical new products would have total development costs of £12k for a new design. This process can take up to 13 weeks for more complex designs. It is expected that using the proposed design tool, development costs of a single design, without periods of trial and error, would be approximately £2k and offer turnaround times within 1 week. Implications for the company using the tool are lower costs, faster response to customers and possibly increased sales.

References

[1] *Standard Handbook of Petroleum and Natural Gas Engineering (Third Edition)*, edited by W.Lyons, J. Plisga and M.Lorenz Gulf Professional Publishing, Waltham, MA (2016)

[2] Final Report on the Investigation of the Macondo Well Blowout, Deepwater Horizon Study group Center for catastrophic risk management, Berkley, CA (2011)

[3] V. S. Tikhonov, O.S. Bukashkina and R. Gandikota: 5th European Conference on Computational Mechanics Vol 2. (2014), p. 667-675

[4] *Macondo Well – Deepwater Horizon Blowout: Lessons for Improving Offshore Drilling Safety,* National Academies Press, Washington, D.C. (2011)

[5] *API 10 D Specification for Bow Spring Bow-String Casing Centralisers* American Petroleum Institute, 6th Edition (2002)