Research Specification

Technical Assessment of Petroleum Tankers

1. Introduction

Following examination certain petroluem road fuel tankers have been found to not be fully compliant with the provisions of Chapter 6.8 of the European Agreement on the Carriage of Dangerous Goods by Road (ADR). Amongst other things, these tanks are seen to exhibit extensive lack of fusion defects in the circumferential weld seams, which based on a leak before break assessment could rupture under roll over and ADR load conditions (see Annex A).

2. Requirement

Further research is being considered to refine the analysis, look at the effects of fatigue, and undertake large scale testing of tanks, so as to assess the relative safety of non-compliant tankers in their current condition, after proposed modifications, and in comparison to compliant tankers. The work also has the potential to improve the safety and efficiency of all petroleum tankers, and to better regulation.

The research will likely include a peer review of existing work, the commissioning of various tests, detailed engineering analysis and technical assessments of the test and theoretical results, and also of any weld procedures developed for proposed modifications. Research activities are subject to modification in response to findings as the work progresses.

Given the potential impact on fuel supply and road safety, the research is to be undertaken and reported upon as soon as possible - initial work on non-compliant tankers (Phase 1) should be completed by the end of March 2014, and subject to the outcome of Phase 1, and any other factors, further work on non-compliant tankers and any work on modified and/or compliant tankers (Phase 2) should be completed between the end of June 2014 and the end of September 2014.

3. Objectives

The objectives of the research are to:

a) determine representative rollover, collision and in service fatigue loads based on relevant impact conditions and in service duty cycles as informed by review and analysis of accident data and related work, and by in service on board data collection,

b) determine relative safety and service fatigue life of non-compliant, modified and/or compliant tankers under those loads, using validated simulations and mathematical models, or other predictive methods, and in the case of representative loads using repeatable, representative and reproducible proof and / or large scale tests,

c) assess the effectiveness and viability of any proposed modification(s) and associated procedure(s) for the non-compliant tankers, and whether the level of safety provided would be equivalent (same or better) to that required by ADR,

d) assess relevant existing and potential non-destructive inspection methods to determine whether such methods would be an effective and viable means of checking conformity and condition of tankers at initial and subsequent inspections,

e) identify any implications and potential amendments for regulations that would improve the effectiveness of the regulations in ensuring proportionate levels of safety and minimising constraints on manufacturers, taking account of other measures

f) manage and co-ordinate the various activities so as to deliver the project to the agreed timescales, and compile a report on each activity and a summary report of the entire project to include, amongst other things, an assessment of the predictions and test results comparing relative safety and service fatigue life to determine whether the level of safety provided would be equivalent (same or better) to that required by ADR, and of any regulatory possibilities arising from the research, and

g) peer review relevant research, technical studies and reports to inform the project, and quality assure the various activities and research reports by way of peer review within the project, taking account of relevant views from peers external to the project.

4. Methodology

Technical Analysis and Assessment

The accident analysis, simulations and mathematical models of vehicle behaviour and weld integrity under the conditions specified, and other predictive methods and any associated small scale tests to, say, determine material characteristics, are to be robust and consistent with the state-of-the-art, drawing upon previous work successfully deployed in scenarios relevant to the objectives of the research.

It is envisaged that the analysis will include a review of all available radiography and macro sections of relevant welds, an “initial” fatigue assessment, and further refine the leak before break analysis undertaken by TWI so as to reduce unnecessary conservatism by way of a full fatigue and fracture Engineering Critical Assessment (ECA), which would involve in service on board data collection.

The research will also include a review of the relevant requirements of ADR, technical reports and other technical material, and models used by those contributing to the project and those used for similar purposes by others external to the project. Where possible, the models used in the project are to be validated against physical tests to allow for a wider range of test conditions to be modelled with confidence.

Tanker Purchase and Testing

Amongst other things, in Phase 1 up to three tankers are to be acquired and subject to large scale tests representative of roll over load conditions – a GRW or other tanker of known condition to validate the test method, a worst case GRW tanker and possibly a best case GRW tanker.

Before test the tankers need to be subject to a full ADR and radiographic examination to determine whether the tankers are suitable candidates for the project, and whether any necessary repairs to all but the circumferential weld seems need to be undertaken before test so as not to invalidate the results.

In Phase 2, subject to the outcome of Phase 1, and any other factors, a further worst and possibly best case or modified and / or compliant GRW tanker may be tested. Further tankers may be needed if it is decided to assess any other test method that would be more suitable for regulation.

5. Work Packages

To facilitate an early start, allow for parallel working and to better target the appropriate expertise, the research activities are to be packaged as follows:

5.1 WP1 – Large scale testing and associated modelling

This work package contains the following requirements:

1.1 Develop and validate independent non-proprietary structural hydrodynamic models of GRW tanker against results of tanker tests
1.2 Report findings of modelling, including of an Engineering Critical Assessment (ECA) to analyse critical crack lengths for basic strength / fatigue conditions
1.3 Design, construct and commission test rig for tests of tankers
1.4 Select and procure suitable instrumentation (for first and second tanker tests)
1.5 Fit out first tanker with instrumentation to record results, and prepare for test
1.6 Undertake first test on non-compliant tanker and record results
1.7 Assess tanker test method and results of tanker test and report findings
1.8 Report findings of subsequent tanker test, and
1.9 Engage in peer review activities (with up to eight meetings) as required

Extensions to this work package include the following as appropriate:

1.10 Capture collision/deformation data, e.g. by laser scans, from relevant impacts to corroborate the modelling / tanker tests and reconcile any inconsistencies
1.11 Acquire and radiograph deformed and control sections for WP2 post mortems
1.12 Acquire suitable guinea pig tanker and undertake proof of concept test
1.13 Determine suitability of tankers for large scale tests and acquire tankers as appropriate in accordance with project objectives as specified by DfT (process to include periodic, external and internal inspections, radiography and repairs as appropriate of candidate tankers using expert and relevant third parties, taking advantage of any opportunity to compare back-to-back hydraulic and gas pressure tests as used in periodic inspections of tankers, assessing safety, representivity, repeatability, reproducibility and equivalence, i.e. whether the gas test produces the same or a more onerous result)
1.14 Fit out second tanker with instrumentation to record results, prepare for test, undertake second test on non-compliant tanker and record results
1.15 Procure suitable instrumentation (for third tanker test), fit out third tanker with instrumentation to record results, prepare for test, undertake third test on non-compliant tanker, record results, and report findings of tanker test
1.16 Compare and contrast non-proprietary model used in WP1 with finite element model used in WP2
1.17 Reconcile any inconsistencies attributable to model used in WP1 and extend ECA to include other relevant strength / fatigue conditions
1.18 Extend modelling / tanker tests to analyse safety of GRW tanker under representative rollover and collision loads based on relevant impact conditions, taking into account data collected in WP2 and findings of WP3
1.19 Extend modelling / tanker tests / ECA to include modified and/or compliant tankers as well as non-compliant tankers and determine relative level of safety

and fatigue life in comparison with that required by ADR, and

1.20 Undertake detailed technical post mortem of any loss in integrity arising from tanker impacts as appropriate

5.2 WP2 – Leak before break and full Engineering Critical Assessment (ECA)

This work package contains the following requirements:

2.1 Determine typical in service life cycle fatigue loadings at worst case locations on circumferential weld seams, including if possible the effects of filling and dispensing from compartments

2.2 Review proprietary finite element model of GRW tanker and crack growth and leak before break analyses undertaken by GRW and TWI

2.3 Address deficiencies as appropriate (such as fracture toughness properties, fatigue crack growth rates and weld residual stresses, wherever possible using strength and fatigue tests of samples taken from tankers to validate the model) or deploy / develop suitable alternative to proprietary tanker model

2.4 Engage with GRW to solicit and incorporate views as appropriate

2.5 Undertake detailed leak before break assessment and full fatigue and fracture ECA to predict crack growth, likely fatigue life of weld seams and critical crack lengths for basic strength / fatigue conditions

2.6 Compare and contrast finite element model used in WP2 with non-proprietary model used in WP1

2.7 Reconcile any inconsistencies attributable to model used in WP2 and extend ECA to include other relevant strength / fatigue conditions, and

2.8 Undertake detailed technical post mortem of any loss in integrity arising from tanker impacts as appropriate

2.9 Engage in peer review activities (with up to eight meetings) as required

Extensions to this work package include the following as appropriate:

2.10 Engage tanker operator to collect in service data for determination of typical worst case fatigue loadings

2.11 Capture collision/deformation data, e.g. by laser scans, from relevant impacts to corroborate the modelling / tanker tests and reconcile any inconsistencies

2.12 Assess existing / proposed non-destructive inspection methods to determine whether such methods would be an effective and viable means of checking conformity and condition of tankers at initial and subsequent inspections, and

2.13 Extend modelling / ECA to analyse safety of GRW tankers under representative rollover and collision loads based on relevant impact conditions, taking into account data collected in WP2 and WP3

2.14 Extend modelling / ECA to include modified and/or compliant tankers (in addition to non-compliant tankers) and determine relative level of safety and fatigue life in comparison with that required by ADR, including as appropriate metallographic examination of sections from said tankers and mechanical tests of samples taken from those sections so as to determine, amongst other things, characteristics of circumferential welds and any flaws identified therein

2.15 Assess feasibility and cost of proposed modification(s) and associated procedure(s) of tanker design and construction

2.16 Undertake NDE / DE / DT / modelling / ECA assessments of various other aspects of tanker construction to compare tankers and check for compliance

2.17 Develop and validate model of stress response to duty cycle so as to synthesise life cycle inputs, determine stresses at worst case locations, and better predict fatigue life

5.3 WP3 – Review and analysis of accident data, impact conditions and regulations

This work package contains the following requirements:

3.1 Review and analyse accident data and related work and determine representative rollover and collision loads based on relevant impact conditions, taking into account any data collected in WP2
3.2 Review and identify implications and potential amendments for regulations to ensure proportionate levels of safety and minimal constraints on manufacturers taking account of other measures such as roll stability control
3.3 Compile a summary report for phase 1 of the project to cover, amongst other things, the findings from all work packages and any relevant work undertaken by parties external to the project, subject to mutual agreement, and
3.4 Engage in peer review activities (with up to eight meetings) as required

Extensions to this work package include the following as appropriate:

3.5 Develop specific and detailed proposals to improve regulations as above
3.6 Compile a summary report for the entire project to cover, amongst other things, an assessment of the predictions and test results comparing relative safety and service fatigue life to determine whether the level of safety provided would be equivalent (same or better) to that required by ADR, and of regulatory possibilities arising from the research

Further / remaining research within the scope of this project will be covered in additional extensions and subsequent packages as appropriate.

6. Contractors

Research proposals for the various activities will be invited from potential suppliers with relevant expertise and resources to contribute effectively to the overall aims and objectives of the research. Suppliers would likely be drawn from a number of independent expert bodies such as Cambridge University Engineering Department, Cranfield University, Health and Safety Laboratory (HSL), Ministry of Defence (MOD), MIRA (Motor Industry Research Association), TRL (Transport Research Laboratory), TWI (The Welding Institute) or any other suitable supplier, and from various transport, hire and leasing companies, and tanker dealers.

7. Evaluation Criteria

Proposals for research activities will be evaluated on the basis of best overall quality and value according to the following factors:

Quality

Quality factors will comprise 70% of the total score based on the following weighted quality evaluation criteria:

Understanding of the research requirement (25%)
Experience and expertise in areas relevant to the research requirement (30%)

Reputation and suitability of facilities and personnel (25%)
Ability to deliver (20%)

Each individual weighted criterion will be scored from 0 to 5.

Value

Cost factors will comprise 30% of the total score with the lowest tendered price scored as 100 and others scored pro-rata, such that a proposal which is 20% more expensive on price than the lowest tendered price will be allocated a score of 80 and a proposal which is 100% more than the lowest (i.e. twice as expensive) will score 0.

Conflict of Interest

Any potential or actual conflicts of interest are to be declared and will be scored as a pass / fail.

8. Bibliography

Simulation of Nonlinear Dynamics of Liquid Filled Fuel Tanker Shell Structure Subjected to Rollover Collision With Validation, S U Park Chrysler Corp, [redacted] Pennsylvania State University, R R Singer US Department of Transportation, ASME Journal of Mechanical Design, December 1998
http://mechanicaldesign.asmedigitalcollection.asme.org/article.aspx?articleid=1445436

The Generation of Internal Pressure in Tanker Rollover, [redacted], Frazer-Nash Consultancy Limited, HSE contract research report No. 109/1996, May 1996
http://www.hse.gov.uk/research/crr_pdf/1996/crr96109.pdf

ANNEX A

Technical assessment of the circumferential weld seams on GRW manufactured road tank vehicles

Mistras Group Ltd has, on behalf of some owners and operators of GRW manufactured road tank vehicles, undertaken computed radiography of a small number of tanks to the fullest extent possible. These examinations found that the total length of the indications that are considered to be lack of fusion defects seen in a circumferential weld seam depend on when the tank was manufactured and the location of the weld seam. The results to date show that for the most susceptible seams[1] the total overall length of the indications as a percentage of the overall length accessible for radiography range from around 30% for a tank manufactured in 2010 to 95% for a tank manufactured in 2007.

The Welding Institute (TWI) has been commissioned by DfT to assess the likelihood of rupture failure of the circumferential weld seams on GRW manufactured road tank vehicles, without the prior occurrence of leaks, under worst case roll over and ADR load conditions, i.e. to assess whether a tank weld could break before a detectable leak would occur. The assessment compared the maximum tolerable length of a flaw through the thickness of the material with the length of weld experiencing the greatest range of fatigue stress. In addition, TWI also assessed the effect of an internal fillet weld made between the extrusion profile toe and the shell plate adjacent to a circumferential weld seam.

The preliminary findings, based on a conservative approach, suggest that a short flaw through the thickness of the material would unlikely remain stable under roll over load conditions, meaning that in the event of a roll over the tank could experience a rupture failure before the welds begin to leak. To put this in context, the preliminary findings also show that under roll over loads a flaw in a "perfect" weld seam could also result in a rupture failure without the prior occurrence of a leak. Similarly, the preliminary findings suggest that under ADR load conditions the tank could also experience a rupture failure of the welds without prior occurrence of a leak, although in the case of a "perfect" weld a leak would more likely occur prior to a rupture failure. The results also show that where well made fillet welds are present between the extrusion profile toe and the shell plate adjacent to the circumferential weld seams, the fillet welds would provide an alternative load path such that the stresses acting on a flaw would be greatly reduced. Further work is being considered to refine the analysis, look at the effects of fatigue, and undertake large scale testing of tanks.

Similar results have been found by HSE in related work, although the HSE would not expect a "perfect" weld to fail under roll over load conditions or for there to be a rupture failure of the circumferential weld seams under ADR load conditions. The HSE work also found that well made fillet welds sited in the appropriate locations would resolve the concerns regarding the integrity of the circumferential welds.

DfT / DGD 13 December 2013

---

[1] The seams located towards the rear of the tank or local to the change in cross section of the tank near to the articulation point of the semi-trailer.