

Impact case study (REF3)

Institution: University of Aberdeen		
Unit of Assessment: 12 (Engineering)		
Title of case study: [IC3] Development of design methodologies and standard for a friction-grip technology adopted by oil and gas exploration and production companies		
Period when the underpinning research was undertaken: 2011-2015		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Alfred R. Akisanya Richard D. Neilson	Professor of Engineering Professor of Engineering	1995 – to date 1988 – to date
Period when the claimed impact occurred: 09/2013-12/2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words)		
<p>Development of design methodologies and standards for a novel friction grip technology for securing concentric tubulars in oil and gas wells has enabled Plexus Ocean Systems Ltd to diversify their business portfolio. The extended durability of friction grip designs, determined by Aberdeen, allowed Plexus to extend their market reach to both short-term (approximately 6 months) and long-term (approximately 20 to 30 years) production wells, leading to considerable economic benefit. This technology has been licensed extensively to different operators in Russia, Norway, and the UK (North Sea). Additionally, the standards and guidelines underpinned by Aberdeen research formed a key part of the technical package used to support the case for the establishment of a new joint venture between Plexus and a major wellhead manufacturer in 2017. The technology has been used in more than 300 wells worldwide and encompasses close to one-third share of the most common sizes of casing hangers in operation (as of 2015), with each wellhead POS-GRIP® system costing between USD150,000 and USD350,000.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>Steel tubulars are integral to the design of oil and gas wells and are used to provide stability to the wellbore and as a conduit for the transportation of hydrocarbons from a reservoir (as far as 8 km below seabed or ground) to the surface. The tubulars are concentrically arranged, with each string supported by a casing hanger in the termination point for an oil or gas well, known as the 'wellhead'. The casing hanger supports the full weight of the tubulars below it and provides a seal to prevent hydrocarbon leaks and potential environmental damage. Traditional shoulder landing casing hangers have an internal gripping slip mechanism in the annulus, and the space required for the slip restricts the internal diameter of the inner casing and consequently the diameter of downhole repair tools that can be used. These hangers are designed to accommodate a limited range of operating conditions and result in excessive wear of the shoulder landing and consequently expensive repair and replacements. The search for a cost-effective casing hanger system that obviates these issues has therefore been a priority for the oil and gas industry.</p> <p>Plexus Ocean Systems Ltd, an Aberdeen-registered company, supplies the oil and gas industry with its proprietary, unique POS-GRIP® technology, which utilises friction to effect gripping and sealing between two closely fitted concentric tubulars inside a wellhead. The gripping mechanism is activated outside the wellhead, thereby eliminating the need for landing shoulders. No other oil or gas technology uses a similar mechanism for casing hangers.</p> <p>The POS-GRIP® system was originally developed by Plexus for temporary (exploration and development) wells where the casing hanger would be released within a relatively short time frame (i.e., a few months). Plexus was very successful in bringing this POS-GRIP® technology to the</p>		

temporary well market and by 2005 had achieved sufficient market share to indicate that further growth would require moving into new applications of the technology, such as production oil and gas wells where the casing/tubing hangers remain in place for up to 20 years. However, the performance of the POS-GRIP® friction grip system over this extended time period was not well understood, and there was no industry design standard for this new technology.

Alfred Akisanya, Professor of Solid Mechanics at the University of Aberdeen, has previously worked with oil and gas services and exploration, production and manufacturing companies through several government funded projects since joining Aberdeen. Relevant to the current REF period (2000-2005), these partnerships have enabled the design of hydraulically-activated friction-grip-based casing hangers for oil and gas production wells. [1] Richard Neilson, Professor of Dynamics and Design has worked on design optimisation of various downhole and subsea tools. Plexus entered into a Knowledge Transfer Partnership (KTP) with the University of Aberdeen (2006-2008) to draw upon the expertise of Akisanya and Neilson in failure analysis and design optimisation, [2] where they provided the necessary expertise to assess the long-term performance of the novel friction-grip technology in order to introduce the product to new markets (such as the oil and gas production well markets).

Through this KTP, Akisanya and Neilson provided a bespoke laboratory assessment of the long-term service performance of the technology – the first step in assuring the industry of the long-term integrity of the product in typical service conditions, in particular, quantifying the damage due to fretting (i.e. the contacting tubulars rubbing against each other). A custom experimental rig was designed, built, and used to quantify the fatigue life and fretting damage of existing POS-GRIP® designs and demonstrate their suitability for long-term application in oil and gas production wells.

The test rig, which can incorporate the unique features of the wellhead and casing hanger configuration and different material combinations, also enabled an assessment of the impact of design changes and new manufacturing processes on the performance of POS-GRIP® designs. [3] An analytical model was developed by Akisanya and Neilson and their team and was used to establish the relationship between POS-GRIP® design parameters (e.g. material properties, geometry of the machined profile teeth on the hanger, operating pressure, activation load, etc) and failure mechanisms (e.g. shearing of the profile teeth, large scale relative sliding of the contacting tubulars, etc); the model enabled the development of POS-GRIP® designs having an optimum gripping coefficient. [3] Clear evidence of the fatigue life confirming the long-term durability of the technology was obtained through this project for different friction-grip surface profile geometry and wide range of activation loads.

Despite this significant outcome, challenges remained in transitioning from laboratory demonstration of the long-term durability to the licensing and marketing of the technology. The lack of a centralised design standard for this unique technology was a significant barrier to potential licensing of the technology to other companies for worldwide use. Akisanya and Neilson secured a second KTP project with Plexus (2009-2011) to focus on the development of a design standard for the friction-grip technology. [4] Using a systems approach, Akisanya and Neilson and their team carried out a reliability analysis to assess and quantify the effect of variations in key design parameters on the grip coefficient and the reliability of the overall performance of POS-GRIP® designs. [5] The results of the analytical reliability analyses coupled with system-level finite element analysis were used to develop a robust POS-GRIP® design standard and guidelines. [5] The implementation of the reliability analysis on a POS-GRIP® system designed by the recommended methodology of Akisanya and Neilson and their team was used to quantify the reliability of the friction-grip system under a variety of operating conditions found in offshore oil and gas production wells. [5]

3. References to the research (indicative maximum of six references)

Whilst the fundamental underpinning research and development work has had major industrial and commercial impact, the commercial sensitivity of the technology has prevented publication in open technical journals. Plexus Design specifications can be made available upon request, these are being retained by UoA due to their strictly confidential nature.

[1] **Akisanya, A.R.**, Khan, F., Deans, W.F. and Wood, P. (2011) "Cold hydraulic expansion of oil well tubulars", *International Journal of Pressure Vessels and Piping*, Vol. 88, pp 465-472.

Grants

[2] **Akisanya, A.R.** and **Neilson, R.D.** "Development of an extended hold friction grip system for securing oil and gas casing and tubulars in hostile surface and subsea conditions", 2006-2008; GBP140,000, KTP with Plexus Ocean Systems, Partnership Number KTP1446, funded by Department of Trade and Industry, EPSRC and Plexus Ocean Systems.

[3] **Akisanya, A.R.** and **Neilson, R.D.** "Development of an extended hold friction grip system for securing oil and gas pipe casing and tubulars in hostile surface and subsea conditions." KTP Final Report, Partnership Number KTP1446, Technology Strategy Board, 2009. The report was graded "Very Good".

[4] Wang, B. and **Akisanya, A.R.** "Development of design standard for a friction grip system for securing oil and gas casing and tubulars." 2009-2011; GBP108,000, KTP with Plexus Ocean Systems, Partnership Number KTP7078, funded by Innovate UK and Plexus Oceans Systems.

[5] Wang, B. and **Akisanya, A.R.** "Development of design standard for a friction grip system for securing oil and gas casing and tubulars." KTP Final Report, Partnership Number KTP7078, Technology Strategy Board, 2011. The report was graded "Very Good".

4. Details of the impact (indicative maximum 750 words)

Research carried out by Akisanya and Neilson has led directly to commercial impacts through the licensing and international (e.g., Russia, Norway, North Sea UK [S1-S4]) adoption of POS-GRIP® technology.

The successful completion of the first KTP (2006-2008, [2, 3]) between the University of Aberdeen and Plexus enabled the use of POS-GRIP® technology to be extended from the short-term exploration well market into the long-term production market with the development of a new wellhead product line, which makes use of the optimised POS-GRIP® design to create a weld quality gas tight metal-to-metal connection that is reversible and adjustable. The development of this product line enabled access to contracts that were previously inaccessible to the company, [S2-S4] and reduced the overall cost of oil and gas production by eliminating the need to repair or frequently replace previously used short-term casing hangers. This access to new markets contributed to POSGRIP® having one-third share of the most common sizes of wellhead casing hangers in operation in 2015 with each wellhead costing between USD150,000 and USD350,000 depending on the pressure rating. Over the past decade, several major contracts have been secured by Plexus partly as a result of the research from the University of Aberdeen, for example, GBP1,000,000 contract from Premier Oil Norge (Norway) in 2015 for a 18 ¾" POS-GRIP® surface wellhead [S2], GBP3,300,000 contract from Total EP (UK) in 2015 for 18 ¾" POS-GRIP® Jack-up drilling system [S3], and a contract from Centrica (now Spirit Energy) in 2017 for the supply of POS-GRIP wellhead for production wells.

The test rig and methodology developed by Akisanya and Neilson and their team for the assessment of POS-GRIP® fretting behaviour has been adopted and incorporated into Plexus' design approach to friction-grip technology. Nearly 1,000 individual tests using the test rig have been carried out between 2013 and 2019. Similarly, the methodology developed for finite element analysis has been retained as the standard approach for assessing POS-GRIP® technology and is still in extensive use for the design and analysis of new variations of the POS-GRIP® system.

During the current REF period (2013-2020), over 25 variations of the POS-GRIP® system have been analysed using this methodology.

The main outcome of the second KTP (2009-2011, [4, 5]) was the development of a written POS-GRIP® design standard; [S5] prior to the KTP, no POS-GRIP® design standard was available to the company. POS-GRIP® is a unique technology that requires specific critical considerations in its design (e.g. friction grip surface profile geometry, external activation load, material properties, and operating pressure and temperature). If POS-GRIP® products are to be designed by a broad, worldwide base of engineers, then robust controls need to be instated to ensure that all unique considerations are accounted for. Without a design standard in place, there is an increased possibility of a licensee designing a POS-GRIP® system incorrectly and risking a failure that leads to an oil or gas leak. With the POS-GRIP® design standard produced as part of the work carried out at the University of Aberdeen, Plexus was able to cede design control of POS-GRIP® products to individual licensees. For example, Plexus licensed a Russian partner (Gazprom) to manufacture and sell POS-GRIP® products in 2016 [S6]. The design standard and guidelines developed by the University of Aberdeen [S5], were a key contribution to the technical package used by Plexus to support the case for the sale in 2017 of the exclusive use of POS-GRIP® for jack-up exploration drilling worldwide to a major international wellhead manufacturer (TechnipFMC) for GBP42,500,000 [S7]. POS-GRIP® system has been used in more than 300 wells worldwide [S8].

The reliability analysis conducted by Akisanya and Neilson provided a robust method for demonstrating that the test matrix was sufficient to achieve confidence in a given result. This method was applied to the full set of results achieved from testing with the experimental rig mentioned above. Several sets of test data were found to be short of the target confidence level and were re-tested between August and December 2013 to determine the grip coefficient after changing the configuration of the friction grip surface profile and the activation load, thereby ensuring the wellhead design functioned at a high level of reliability, reducing the likelihood of incurring future costs due to potential product failures and serving to potentially reduce customer concerns about using a novel wellhead technology.

Plexus was awarded the Northern Star Business Award (Aberdeen Chamber of Commerce) for Commitment to Innovative Use of Research and Development in 2014 and was nominated as a finalist in the Outstanding Contribution to the Energy Sector category in recognition of its pioneering, safer and technically superior wellhead, based on proprietary POS-GRIP® technology. [S9]. The Northern Star award is in recognition of a company in North East Scotland that has demonstrated an innovative use of research and development to create commercial growth and gain competitive advantage. This award recognised Plexus' overall commitment to research and development, which included the collaborations with the University of Aberdeen.

5. Sources to corroborate the impact (indicative maximum of 10 references)

- [S1] Letter from the CEO of Plexus Holdings Ltd (the parent company of Plexus Ocean Systems Ltd.) which corroborates the commercial and other benefits to Plexus stemming from the research at the University of Aberdeen.
- [S2] News article, which corroborates the award of POS-GRIP contract worth GBP1,000,000 by Premier Oil Norge (Norway). Offshore Energy Today, May 2015. <https://www.offshoreenergytoday.com/plexus-bags-pos-grip-order-from-premier/>
- [S3] News article, which corroborates the award of POS-GRIP contract worth GBP3,300,000 with Total EP. Offshore Energy Today, June 2015. <https://www.offshoreenergytoday.com/plexus-wins-pos-grip-order-from-total/>
- [S4] News article which corroborates the collaborative agreement between Plexus and China Oilfield Services Ltd, Red Sea Technologies Ltd and Yantai Jereh Oilfield Services Group. Offshore Energy Today, July 2015. <https://www.offshoreenergytoday.com/plexus-signs-collaboration-agreement-with-cosl-rst-jereh/>
- [S5] Plexus Design Specification DS-022: Design Specification for POS-GRIP® Wellhead Systems. Revision DRAFT 6.1, 2019, (strictly confidential, available on request)
- [S6] News article which corroborates the licensing of POS-GRIP® to Gazprom, a Russian-based company: <https://www.proactiveinvestors.co.uk/companies/news/903305/plexus-boosted-by-first-gazprom-pos-grip-installation-903305.html>

- [S7] News article which corroborates Plexus' sale of exclusive use of POS-GRIP® for jack-up exploration drilling worldwide to TechnipFMC, a major international wellhead manufacturer: <https://polaris.brighterir.com/public/plexus/news/rns/story/x53mllr>
- [S8] News article, which corroborates the use of POS-GRIP® in more than 300 wells: <https://www.proactiveinvestors.co.uk/companies/news/217988/plexus-s-pos-grip-technology-offers-way-to-cleaner-gas-217988.html>
- [S9] Aberdeen & Grampian Chamber of Commerce Northern Star Business Awards, 2014, Innovative Use of Research and Development award given to Plexus Oceans Systems; <https://www.offshore-energy.biz/plexus-recognized-at-northern-star-business-awards-2014/>