Noah's Ark and the new round hulls of the offshore world

The offshore sector has come to accept round-hulled FPSOs and MODUs over the past decade. However, before designers quibble about design rights, they might wish to cast an eye back to innovators of the past – spanning more than four millennia, reasons Peter Lovie, FRINA

This is a tale of how, in the last decade, the offshore world has started to accept a simple but quite new hull form – namely, the round hull – which, it transpires, was already tried millennia ago, around the time that Noah is credited with building his Ark. It raises entertaining questions, about prior art on these new and patented round hull designs for today's offshore drilling, production and construction in the oil and gas business!

Archeological evidence recently uncovered concerning a sizeable, round-hulled ark constructed in ancient Mesopotamia has led to conclusions on its design and how it was actually constructed. Today, we have all kinds of resources and technology to build these round FPSOs and MODUs, and many project management disciplines to ensure the job is done in time to satisfy critical schedules. In Noah's day, it was a truly amazing feat to design the Ark, procure the necessary materials, plan construction and then build it, plus complete it in time before the Flood arrived.

Wild idea?

Back in 2000/2001, when I worked in Houston for a leading contractor (Bluewater) that designed, built and operated FPSO vessels, I traded emails with Gary Quenan, the founder of SSP Offshore, who had what sounded to me like a wild idea of making FPSO hulls round. One sees a lot of unusual things in the business development world and so I thought nothing of it.

Then, at the Offshore Technology Conference (OTC) in Houston in 2003, a Norwegian company promoted the same idea of a round hull, also for use in FPSOs. Again, one sees many concepts at OTC, some that later become reality and others that disappear. Then it got more serious. In late 2006, I visited the first round FPSO being outfitted in the Netherlands for Sevan Marine, to check out its feasibility for projects for Devon Energy, my then employer. In 2007, Sevan's FPSO started oil and gas production in the Piranema field, Brazil, under a lease contract with Petrobras. So the round hull idea really had been accepted, and by a leading offshore production company!

Peter Lovie, FRINA: "In the conservative marine world, the relatively rapid acceptance of the round hull for service in the offshore oil and gas business is truly remarkable"

SSP Offshore was thus not the first to commercialise the idea. It was not for want of trying; in 2008, SSP Offshore invited me to a two-day meeting about the design and operation of its round FPSOs. There were representatives from a number of other oil companies with offshore field developments that possibly might employ a floating production system like this. Lots of questions and discussion ensued and it certainly seemed that the round hull design was workable.

The funding of a route to commercialisation was quite different for the two round hull FPSO companies:

(i) The Sevan organisation was based in Stavanger and succeeded in attracting early venture capital and then in doing an IPO in 2004 on the Oslo Stock Exchange (OSX) that helped its trek towards early commerciality;

(ii) SSP Offshore continued its development with private funding until an IPO on the Toronto Ventures Exchange (TSX) five years later in 2009.

Along the way, the two competitors settled patent differences between them.

Industry acceptance

The round hull idea had indeed attracted growing attention in the offshore industry. In September 2012, the Emerging FPSO Forum was held in Galveston, Texas, featuring "The First Annual Texas FPSO Round Up and Shoot Out". I devised this session to explore how an offshore-savvy audience viewed the pros and cons of three round-hulled FPSO designs submitted by different designers, and to see how this audience felt about incorporating each concept into a project they might be responsible for, in contrast to the usual conventional ship-shaped hull for an FPSO.

The "Shoot Out" saw three designers of round-hulled FPSOs each make a presentation to the audience. Then the audience voted on which they would prefer for their field development, were they to make a choice: a traditional ship-shaped FPSO hull, or one of the three round hull designs. The results were surprising; the audience equally favoured both Sevan's new round design and the traditional ship-shaped hull. Less surprisingly, the two round-hulled designs that had not been built received significantly fewer votes.

There were approximately 200 people in the audience. It is not known exactly how many people voted, since the voting system's

Sevan Piranema, credited as being the first round-hulled FPSO; her 64.3m diameter is not so far from the Ark's diameter of 63.2m

software simply tracked percentages, but it is fair to say that it was a good sample of offshore industry-savvy people.

Later, I went back and assigned a Technology Readiness Level (TRL) to each of the designs, to check for a correlation between that vote and how far each design had advanced. Common sense would indicate the design actually built would be more credible, and it was no surprise to see that the TRL rating pretty well tracked the level of design maturity the audience had indicated. TRLs come in 7- and 9-level scales, tailored to different industries (space, military, nuclear, US Department of Energy, etc). I used the DeepStar scale, which was set up to deal with new deepwater technologies and systems such as this.

Thus the ship-shaped hull had a TRL of 7: that shape has been in use for centuries, on countless thousands of ships. Sevan's round hull design had been tried and operated for at least five years and used on at least five round hulls in service in 2012, and so from the definitions attached to each TRL in the scale, also qualified to have a TRL of 7.

The other two designs (by SSP Offshore and Nagan Srinivasan) were taken to have lower TRLs according to the stage to which these designs had been developed, based on the extent of studies, model tests, and engineering development evidence in the presentations. The results of the vote are shown in Table 1 (page 12).

By 2015, the round hull had accomplished considerable acceptance in the offshore world – not just for FPSO service, but also in dynamically positioned hulls in MODU service, and most recently with moored accommodation facilities. A conference presentation by Sevan Marine in November 2014 cited round-hulled projects either in operation or under construction as covering six FPSOs, four MODUs and three accommodation units, for a contracted total of 13 round-hulled vessels committed to offshore service – six more than at the time of the "Shoot Out" two years earlier.

So what happened to the other two round hull designs since "The First Texas Round Up and Shoot Out"? SSP Offshore continued to promote its round-hulled designs and, in late 2014, became a subsidiary of Sembcorp Marine of Singapore, through which these designs are now offered. Gary Quenan, with whom I had discussed the round hull in 2000-2001, went on to become president of another engineering company. Nagan Srinivasan, the third round hull designer, appears to have abandoned active promotion of his design, joining Chevron in 2013 as a lead engineer.

Back to the Ark

Most people know the story of Noah's Ark and the Flood as recounted in the Book of Genesis. Since the 1870s it has been known that a similar but much older story existed centuries before in ancient Babylon, but much was shrouded in mystery.

In 2008, Dr. Irving Finkel, a curator in the British Museum and an authority on ancient Mesopotamia, found himself involved in a detective story of decipherment and discovery when a member of the public arrived at the museum with a particular cuneiform tablet which he had inherited from his father. Not only did the tablet reveal a new version of the Babylonian Flood Story, but the ancient writer (from about 1850 BC) had described the size and a completely unexpected shape of the Ark, giving detailed shipbuilding specifications. The gradual decoding of this ancient message reveals where the Babylonians believed the Ark came to rest and has led to a new explanation of how the old cuneiform story ultimately found its way into the text of the Bible.

In January 2014, *The Ark Before Noah: Decoding the Story of the Flood* was published, in which Finkel revealed how decoding the symbols on that almost 4,000 year-old piece of clay enabled a radical interpretation of the Noah's Ark story, indicating it may not be a myth after all. Where this gets particularly interesting for the offshore community is Finkel's discovery that the Ark was large and round.

Millennia ago, people built and used round, rowboat-sized 'coracles', which

were used in the region well into modern times. But the Ark was big; Finkel uncovered how the Ark had multiple compartments and decks, according to what was on that tablet. Back in Noah's day there was no steel to build a big vessel like an Ark. Finkel's investigation showed that the Ark was constructed with reeds of the kind commonly found in the delta areas and along the banks of the Euphrates and Tigris rivers located in modern day Iraq. The hull was caulked with bitumen. There were no processing plants around back then to order bitumen by the tonne whenever it was needed. This was in what we now know as Iraq with its huge oil reserves, and so it is logical to believe that this bitumen came from seeps from petroleum reservoirs.

Hull diameter coincidence

Finkel's book estimates that it took 520km of rope, woven from reeds, to help hold the hull components together: this was quite an industrial operation! To a modern-day offshore engineer, Finkel's book was quite an education. These tablets were from an era before written language – instead, symbols were engraved in the clay. Unlike paper, which is easily burned or destroyed over the years, clay tablets last forever. Apparently, they were used for recording all kind of commercial transactions and daily events. Thus, literally thousands of them exist today and it becomes an onerous task to interpret one or two, let alone sift through a large number of them, making Finkel's discoveries all the more remarkable. When these tablets were 'written', people did not have the mathematics to rigorously describe a circle – 'pi' was not yet invented – and so areas of circles were not exact but estimated as a 'ground plan'.

Page 314 posits a ground plan of 15,000 cubits as the most reliable number. A cubit was an ancient measure of length, being the distance from the elbow to the tip of an outstretched middle finger. Today, it is accepted to be 0.4572m. Going from the area of the circle, estimated at 15,000 square cubits, using Microsoft Excel we arrive at an Ark diameter of 63.2m – coincidentally, almost the same as the diameter of the first round FPSO, *Sevan Piranema*, at the Piranema oil and gas production development offshore Brazil in 2007, which featured a diameter of 64.3m.

Round hulls in modern times

Just before completing this article, I learned of another and earlier round-hulled FPSO design.

In 1984, Houston-based engineering company Marine Technology Corporation created a design with a flared deck, as featured on the modern round FPSO hulls. The arrangement drawings showed use of this hull with a hybrid riser system akin to that used with the ship-shaped FPSO at Cascade/Chinook in the GoM, which started production in 2012. The originator of this round hull FPSO was Peter Noble, who later became chief naval architect at ConocoPhillips and who has just finished a term as national president of SNAME.

Noble comments: "Circular ships are not a new idea. Admiral Popov built a series of circular warships in the late 1800s in Russia, and the circular Arctic drilling unit *Kulluk* entered service in the early 1980s. Most of these vessels reported significant problems with motions in a seaway. At the time the main reason for developing our Circular Offshore Moored Production And Storage System [COMPASS] concept as a round unit was driven by seeking ease of manufacture [the assembly of pie-shaped sub-modules] and by deck layout. The hydrodynamic studies showed some issues with combined pitch and roll but the large mass of the unit [~ 300,000tonnes displacement and about 150m in diameter] took care of these within operational limits. Our conclusion was that a circular FPSO would be a good solution as long as it was big enough and the environment wasn't too severe."

Noble's COMPASS design for a round-hulled FPSO may not offer the dramatic impact of prior art coming from Mesopotamia in the distant past, but it would seem to represent some other prior art on round-hulled FPSOs that is worth a look. Then there is the round *Kulluk*,

Hull Shape	Designer	T R L (a) (b)	Comments	Audience Response System (ARS) vote. %
ShipShape FPSO	Many	7	About 165 now operating, FPSOs been in use for many years	41
Round FPSO	Sevan	7	3 hulls in use as FPSOs, 2 hulls in use as MODUs	43
Round FPSO	SSP	2-3	None built or contracted, multiple model tests, many studies	9
Round FPSO	Nagan Srinivasan	1-2	None built or contracted, limited model tests and studies	7
				100
Notes				
(a)	The TRL scale used here is that adopted by Deepstar, consisting of seven levels defined carefully for petrolium industry use. The TRL values given here are by Peter Lovie.			
(b)	The TRLs estimated here for round FPSOs show some correlation with a vote by a conference audience on their willingness to accept these different designs in Session IX at the Second Emerging FPSO Forum, Galveston, 26-27 September 2012.			

Table 1: the vote results of the attendees of "The First Annual Texas FPSO Round Up and Shoot Out"

now preparing once more to drill in US Arctic waters.

The fact that construction of the Ark was with reeds, instead of heavy wood beams as employed later in ships for three millennia, is significant for what might be left of it today. Despite the fabled resting place of Noah's Ark on Mount Ararat, no heavy wooden ribs, nor the keel of a large wooden hull, have been found there. Construction using reeds would have rotted away in perhaps a century or two and so nothing would be found today.

Closing thoughts

1. In the conservative marine world, the relatively rapid acceptance of the round hull for service in the offshore oil and gas business is truly remarkable: 13 of these round hulls have entered service or are under construction inside less than a decade. It makes one wonder why it was so rapidly accepted now and not tried before! And it is a tribute to the commercialisation skills of its developer.
2. Compared to modern offshore projects, Noah's achievement in building that 60m+ diameter round hull with the resources available back then, in designing the Ark, mustering the procurement of 'shipbuilding' materials, and planning and executing the construction – all in time for the impending flood – was a design and project management marvel, making one wonder how he did it without extraordinary outside guidance!
3. Now, with the precedents of Noah's Ark plus modern day round hulls in offshore service, it would seem that our civilisation will be encouraged to use this hull form even more broadly, with patent authorities being now challenged by prior art on a truly biblical scale.

Acknowledgements

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Peter Lovie's 48 years of experience in engineering and management in the offshore industry have all been in Houston, initially on offshore drilling related business. Over the last 20 years Peter has become known as something of an industry authority on FPSOs, from his unusual combination of working on both the contractor and operator sides of the FPSO business as well as the necessary shuttle tanker side (Bluewater, American Shuttle Tankers, Devon Energy). He is known for his contributions leading to the first FPSO and shuttle tankers to enter service in the GoM.

He is author of five US patents, numerous technical papers and conference presentations. Credentials include: Professional Engineer in Texas (PE), Project Management Professional (PMP) and Fellow of the Royal Institution of Naval Architects (FRINA). He earned his Master of Applied Mechanics degree at the University of Virginia where he was a Fulbright Scholar, and his B.Sc. in Civil Engineering from University of Glasgow in Scotland. *OMT*