Scientific Petroleum
journal home page: http://scientificpetroleum.com/

Reservoir and petroleum engineering

DEVELOPMENT OF EXPANDABLE PIPE TECHNOLOGY: DOUBLE-ACTING EXPANDER

Sh. Z. Ismayilov, Y. Y. Shmoncheva*, G. V. Jabbarova
Azerbaijan State Oil and Industry University, Baku, Azerbaijan

ABSTRACT
Drilling wells presents a number of problems such as loss of circulation, wellbore instability, stuck pipe due to differential pressure or mechanical problems, and increased formation damage. Traditionally, these problems have been addressed by installing additional casing, resulting in a reduction in wellbore diameter. However, the use of expandable tubing technology within the wellbore can effectively mitigate these problems, potentially eliminating the telescoping effect associated with traditional well designs. This technology allows wells to be completed without reducing the planned diameter of the production string, which is critical for deepwater and highly deviated wells. The effectiveness of expandable tubing technology continues to evolve both offshore and onshore, offering solutions to a variety of operational challenges encountered during well construction. Steel pipe expanding requires specialized tools. During workover operations, these tools are used to isolate corroded or worn sections of casing, seal unwanted perforations and reinforce casing to stimulate flow and treat the wellbore. They also allow problem areas to be isolated without connecting to the previous casing string. However, dual-action expanders are required to drill constant-diameter wells. These expanders create sockets at the bottom of the large-diameter pipe and then expand the casing string to the smaller diameter. The paper describes the design and operating principle of a new expanding device that has been developed to solve the problems associated with efficiently expanding round steel casing and achieving double expansion in mono-diameter well construction. In conclusion, the developed new round steel casing expanding tool achieves double expansion, facilitating the construction of mono-diameter oil and gas wells.

KEYWORDS:
Well drilling;
Mono-diameter technology;
Steel pipe expanding;
Double expansion;
Expander.

***e-mail:** yelena.shmoncheva@asoiu.edu.az
https://doi.org/10.53404/Sci.Petro.20240100056

Date submitted: 29.01.2024 ***Date accepted: 31.05.2024***

1. Introduction

It is well known that drilling wells may encounter unforeseen circumstances such as loss of circulation, wellbore instability, stuck pipe due to differential pressure or mechanical problems, and increased formation fracture. These problems are usually solved by installing additional casing, which results in a reduction in well diameter [1].

Running an expandable liner into the wellbore can solve these problems and reduce (or eliminate) the telescoping effect of conventional well design. With the introduction of expandable casing into drilling practice, wells can now be completed by installing casing without reducing the planned diameter of the pay string [2].

The first run of expandable tubing was performed by Chevron in a shallow Gulf of Mexico well in November 1999 [3]. The goal of the first use of one-piece expandable tubing was to reduce costs by reducing casing sizes compared to conventional technology. After the first use in 1999, for more than 20 years, expandable pipe technology has been widely used in the oil industry [4- 6].

In cased wells, expandable tubing can be used to close perforation holes to minimize water inflow in short sections and to repair damaged or corroded casing in longer sections. When casing is damaged during operation, it is possible to prolong its operation by lining the worn casing from the inside using expandable tubing [7].

In open hole conditions, expandable tubing can be used with expandable open hole packers to reduce or shut off water inflow. When used in conjunction with an expandable filter system in well completions for sand control, an expandable liner can create a reliable mechanical barrier to fluid flow that allows selective shutoff of wellbore sections.

Expandable liner hangers allow for small-diameter wellbore construction, which is becoming increasingly important in deepwater wells and wells with large vertical deviation. In January 2002, an expandable liner hanger was run in a well in Prudhoe Bay, Alaska.

Scientific Petroleum
journal home page: http://scientificpetroleum.com/

Reservoir and petroleum engineering

Expandable liners have opened up the possibility of drilling a mono-diameter well. This opens up the possibility of drilling deep wells to deepwater horizons [8].

In addition to deepwater applications, expandable tubing can also be used to rehabilitate cased hole oil wells onshore.

In the Ghawar oil field in Saudi Arabia, Saudi Aramco successfully applied an expandable liner that was run and cemented across the gas cap to avoid gas production and reduce the risk of lost circulation while drilling a horizontal wellbore.

Expandable patches have been used twice in Azerbaijan. The first installation of an expandable in-pipe patch was carried out in 2007 in the Shah Deniz offshore field in a production well, and the second installation and expansion of an in-pipe patch was carried out in the Azeri-Chirag-Guneshli offshore field in the Azeri sector of the Caspian Basin [9].

In Kazakhstan, the first expandable openhole liner was installed in 2016 in an old well to isolate zones of different pressures, prevent loss of circulation in low-pressure zones, and allow deepening of the well [10].

The scope of expandable liners has expanded over the years with the introduction of high-torque expandable joints and rotatable expandable liners, which has allowed the operation of expandable liners in more challenging environments and when drilling multilateral wells [6].

The liner pipes are expanded using mechanical expansion technology applied by many foreign companies such as Halliburton, Schlumberger, Enventure, Weatherford, Baker Oil Tools, READ Well Services. This utilizes an expanding device for irreversible mechanical deformation of pipes [7, 8, 11, 12]. The device is moved inside the pipe from bottom to top by a hydraulic pressure differential and a directly applied upward mechanical force. The pressure differential is created by pumping fluid into the inner string connected to the cone, and the mechanical force is developed by tensioning the inner string.

Creating a well of one bore diameter includes the following steps [9]:

1. A section of the wellbore is drilled and reamed to accommodate an expandable liner.
2. A reaming device is lowered into the well together with the expandable liner.
3. An estimated amount of cement is pumped in to cement the expandable liner.
4. Direct reaming of the liner body installed in the open hole is performed.
5. The shank expansion process is completed by expanding the top of the shank, with the elastomer placed between the pipes to act as a suspension device and seal.
6. After the cement hardens, the shoe of the expanded shank is drilled out.

The economic effect from the large-scale introduction of the monodiameter technology is estimated at about 30-50 % of the cost and time of drilling at present and is based on the reduction of the required amount of materials (cement, metal, drilling mud), cuttings removal and reduction of drilling time [9, 13, 14].

The advantages of the technology include the following:

- transition to a new well design, which will provide a reduction in the diameter and number of running casings;
- reduction of drilling waste, especially cuttings, reduction of the required number of materials (cement, drilling mud, metal);
- the possibility of using smaller equipment in terms of geometric parameters and power (subsea equipment, riser, drilling rig, etc.);
- reduction of energy costs and atmospheric emissions;
- possibility to construct wells with extra-large deviation from the vertical.

For practical application of mono-diameter technology in the drilling process, it is necessary to perform reamers from top to bottom or bottom to top and develop a simple technology of transition between reamers, so that it is possible to form a reamed part. This is a more complex task than a simple bottom-up reaming. In a top-down expansion, it is necessary inside the expanded pipe to transition to a larger reamer to further form the expanded portion at the lower end of the pipe. In bottom-up expansion, it is necessary to transition within the expanded pipe to a smaller expander to form a less expanded upper portion of the pipe.

The purpose of this study was to develop the design of a round section steel casing reamer and to describe the principle of its operation, which makes it possible to create a double casing reamer for drilling oil, gas and other wells using mono-diameter technology.

2. Expandable pipe technology

A single diameter wellbore refers to a wellbore whose diameter remains constant along its entire length (fig. 1).

This uniformity of diameter distinguishes it from conventional wells, which often have different diameters at different depths. Mono-diameter wells are typically created using specialized drilling techniques and equipment, such as expandable drilling systems or casing while drilling (CwD) technology. These wells offer a number of advantages, including improved wellbore stability, increased drilling efficiency and reduced operational complexity. They are particularly useful in

Scientific Petroleum
journal home page: http://scientificpetroleum.com/

Reservoir and petroleum engineering

challenging drilling environments where maintaining a constant borehole diameter is critical to well integrity and productivity.

The liner reaming process is accomplished through the use of an expansion tool (fig. 2), for which various names are used in the literature, such as pig, mandrel, cone expander, mandrel or conical mandrel [11], expansion cone/mandrel [12], or expansion cone [7, 8].

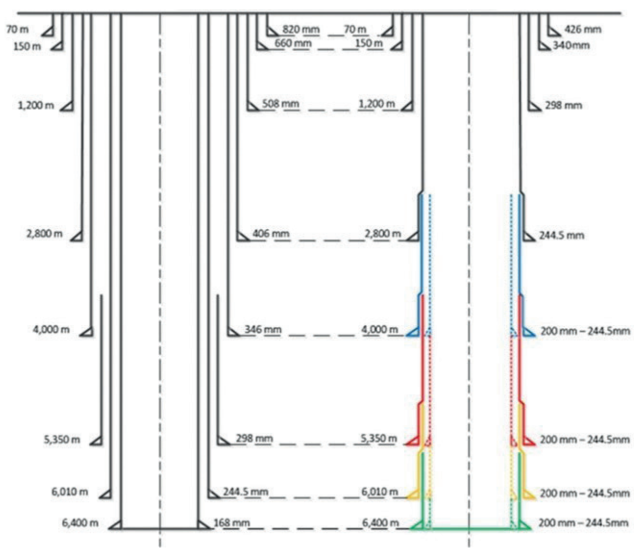

Fig. 1. Conventional and mono-diameter well designs

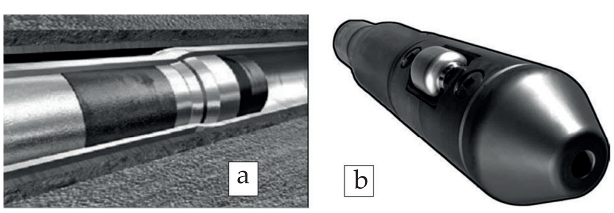

Fig. 2. Fixed cone reamer (a) and rotating reamer (b)

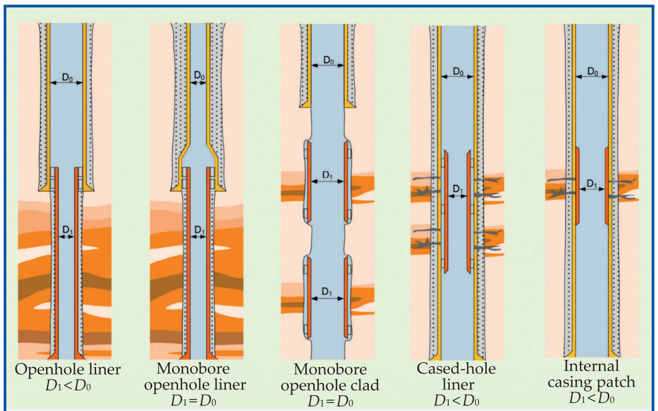

Fig. 3. Possible applications of expandable pipes [2]

These expansion cones are designed to expand liners and patches in various well situations by only one diameter. They can be used to solve loss-of-circulation problems, isolate problem zones such as small water flows and subsalt rubble zones, isolate a high-pressure zone, run additional casing while maintaining well size, maintain casing diameter when completing under difficult drilling conditions, reach reservoirs with larger casing to increase production, and use them in sidetracking.

During workover operations - to isolate corroded or worn casing sections, close off unwanted (or old) perforations, provide casing repairs with minimal internal diameter restriction, strengthen casing for stimulation, wellbore treatment and fracturing operations.

It is possible to isolate problem areas without connecting to the previous casing string. Possible applications for one-piece expandable tubing and reamers are shown in figure 3.

The reaming tool is usually tapered, allowing the end of the casing string to expand as the tool moves inside the casing string. This process can be performed mechanically or hydraulically.

3. Device description

However, to drill a full borehole of one diameter using liners, double-acting reamers are needed. These reamers must create a bell-shaped socket at the lower end of one pipe length and then ream the pipe string to another smaller diameter.

When isolating areas with complex problems, localized well support equipment (LHSE) is used with profile reamers. This technology utilizes special reamers (cone and roller) that ream the profile pipes (double channel, eight-beam and twelve-beam) [15]. Special reamers are used to expand the corrugated section inside the casing. Their purpose is to eliminate casing problems in wells, restore their integrity and strengthen the casing walls by installing a steel patch.

Usually such a device contains a cone-punch with longitudinal profile grooves. The body contains a self-sealing tubular diaphragm, windows of stepped cross-section and retractable sectors located inside them [16]. However, the disadvantage of these devices is the inability to expand a round section steel casing made of expandable material and to perform double expansion of the casing to construct a well of the same diameter.

Also, a constricted pipe reamer can be used to rehabilitate deformed casing in deep wells [17]. It consists of a body with a tapered head, a mandrel and a plurality of holes and balls. The mandrel may have multiple grooves coinciding with holes in the casing wall, each of which has a tapered, inclined or curved

Scientific Petroleum
journal home page: http://scientificpetroleum.com/

Reservoir and petroleum engineering

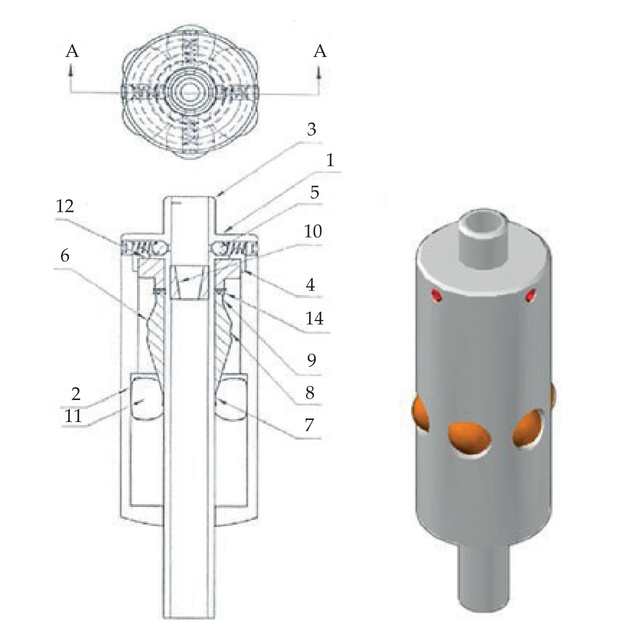

Fig. 4. Pipe expander in initial position

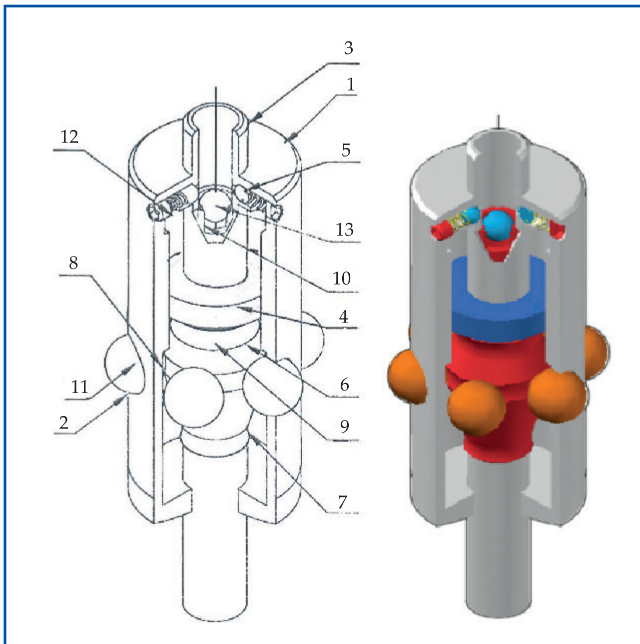

Fig. 5. Pipe expander in working position

surface for fixing a steel ball. The groove surface may be designed so that the steel balls protrude more from the housing when traveling away from the housing head than when traveling back toward it. Functionally, this device works as follows: when inserted into the expandable pipe in the downward direction, the expander encounters resistance as it advances, forcing the steel balls to move in the opposite direction for forward expansion of the pipe. When the body crosses the expandable pipe, the steel balls are lowered and return to their original position.

However, the disadvantage of this device is the use of a large number of steel balls and the inability to realize double reaming of circular steel strings for constructing wells with the same borehole diameter.

The first device proposed by the authors [18] is further developed and aimed at solving these problems by creating a device for effective reaming of round section steel casing and creating double reaming during well construction using mono-diameter technology.

A reamer for round casing pipes has been created, having a cylindrical body with round holes in the middle part, attached with its upper end to drill pipes by means of a hollow rod passing through the body. On the body is a piston which, when moving downward, forms a hydraulic chamber connected to the rod through check valves. Attached to the lower surface of the piston by bearings is a shaped cone of variable diameter, which has three transverse grooves and is capable of rotating about its axis. Steel balls protrude from the housing holes and are supported by the holes and grooves of the cone itself, providing free rotation.

Figure 4 shows the reamer in its original position: a housing with bores attached to the drill pipe by a hollow rod, a hydraulic chamber, a piston, check valves, a shaped cone of variable diameter and grooves, bearings providing rotation and vertical movement and steel balls in contact with each other supported by the groove of the cone.

Figure 5 shows the pipe expander in operation.

The figures show the following parts: housing 1 with holes 2, attached by means of a hollow rod 3 to the drill pipe, hydraulic chamber 12 and piston 4 located inside housing 1 in its upper part, four check valves 5, shaped cone 6 with variable diameter with three grooves 7, 8, 9, connected with the piston 4, bearings 14 having the possibility of rotation around its axis and vertical movement along the rod 3, which has a seat 10 inside for the reset ball, steel balls 11, located inside the body 1 in the holes 2 and supported by groove 7 of the cone 6.

In the initial position, the hydraulic chamber 12 (fig. 5), representing the volume of the internal cavity of the housing 1 between the valves 5 and the upper plane of the piston 4, has a minimum volume (fig. 4). Steel balls 11 are arranged in the housing 1 around a shaped cone 6 in a groove 7 along the smallest diameter of the cone 6 (fig. 4). After the cement slurry injection operation, the ball 13 (fig. 5) is discharged into the well through the stem 3 located in the body 1, which sits in the seat 10 and closes the central channel of the stem 3. Drilling fluid through check valves 5 enters the

Scientific Petroleum
journal home page: http://scientificpetroleum.com/

Reservoir and petroleum engineering

inner cavity of the housing 1 and exerts pressure on the piston 4, which moving downward, increases the volume of the hydraulic chamber 12 and pushes the shaped cone 6 downward. Steel balls 11 are pushed by the cone 6 out of the holes 2 to the maximum distance and are located in the groove 8 of the cone 6 by the largest diameter of the latter (fig. 5).

The drilling fluid supply is stopped. By rotation of the casing through the drill string and simultaneous lifting of the device upwards, the 12 m long steel pipe of circular cross-section is expanded to the maximum diameter (the first stage of expansion). Next, the drilling fluid supply is resumed. The drilling fluid enters the hydraulic chamber through check valves 4, increases its volume and pressurizes piston 4. The piston 4 pushes the shaped cone 6 downwards, the steel balls 11 are located in the groove 9 by the smaller diameter of the shaped cone 6 and extend from the holes 2 to a smaller distance. The drilling fluid supply is stopped. By rotating the casing again by means of the drill string and simultaneously lifting the device upwards, the steel pipe of circular cross-section is expanded to a smaller diameter over the remaining design length (second expansion stage).

4. Conclusion

Thus, the application of the proposed reamer for round steel casing pipes will make it possible to create a double casing reamer for drilling oil, gas and other wells using mono-diameter technology.

Scientific Petroleum
journal home page: http://scientificpetroleum.com/

Reservoir and petroleum engineering

References

1. Shiri, Y., Shiri, A. (2021). Discrete fracture network (DFN) modelling of fractured reservoir based on geomechanical restoration, a case study in the South of Iran. *The Mining-Geological-Petroleum Engineering Bulletin*, 36(4), 151-162.

2. Stringer, J. A., Farley, D. B. (2013). The evolution of expandables: A new era of monobore expandable well-construction systems. SPE-164171-MS. In: *SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain. Society of Petroleum Engineers.*

3. Grant, T., Bullock, M. (2005). The evolution of solid expandable tubular technology: lessons learned over five years. OTC-17442-MS. In: *Offshore Technology Conference, Houston, Texas.*

4. DeLange, R., Gandikota, R., Osburn, S. (2011). A major advancement in expandable connection performance, enabling reliable gastight expandable connections. *SPE Drilling and Completion*, 26, 412–418.

5. Mason, D., Duhrkopf, D., Morgan, Q., et al. (2011). The use of slotted expandable liners in multizone openhole frac-packs: a new completion concept. SPE-147044-MS. *In: SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA. Society of Petroleum Engineers.*

6. Wold, A., Berge, F., Paulsen, E., Baker, R. (2020). Innovative use of solid expandable liners as host in multilateral well construction applications. SPE-201271-MS. In: *SPE Annual Technical Conference and Exhibition, Virtual. Society of Petroleum Engineers.*

7. Benzie, S., Huey, T., Cooper, C., Bufkin, C. (2018). Expandable liner system provides option for repairing corroded, small-diameter casing. SPE-192331-MS. In: *SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition, Dammam, Saudi Arabia. Society of Petroleum Engineers.*

8. Dell, D. M., Jenkins, K., Noel, G., Reque, J. V. (2019). The value of solid expandable tubulars in cased-hole environments. In: *Solution Mining Research Institute (SMRI) Spring 2019 Technical Conference, New Orleans, Louisiana, USA.*

9. Mamedtagizade, A., Babayev, E., Jabbarova, G., Abishev, A. (2018). Practical implementation of technology expandable pipes at oil-gas fields. *Herald of the AEA Journal*, 1, 63-68.

10. Aidoo, A., Berto, P. P., Gabdullina, M., et al. (2016). Installation of longest openhole solid expandable tubular technology on a deepening well in Western Kazakhstan. SPE-181932-MS. In: *SPE Russian Petroleum Technology Conference and Exhibition, Moscow, Russia. Society of Petroleum Engineers.*

11. Al-Abri, O. S., Pervez, T. (2013). Structural behavior of solid expandable tubular undergoes radial expansion process – Analytical, numerical, and experimental approaches. *International Journal of Solids and Structures*, 50, 2980-2994.

12. Park, M., Teasdale, P., Cowling, M. (2015). Application of uncemented solid expandable liner for combined openhole isolation and casing repair. SPE-173134-MS. In: *SPE/IADC Drilling Conference and Exhibition, London, England, UK. Society of Petroleum Engineers.*

13. McKee, R. Jr., Fritsch, J. (2008). Successful field appraisal well makes single-diameter wellbore a reality. SPE-112755-MS. In: *IADC/SPE Drilling Conference, Orlando, Florida, USA. Society of Petroleum Engineers.*

14. Waddell, K. (2005). Realizing single-diameter wellbore technology. SPE-96655-MS. In: *SPE Offshore Europe Oil and Gas Exhibition and Conference, Aberdeen, United Kingdom. Society of Petroleum Engineers.*

15. Abdrakhmanov, G. S., Akhmadishin, F. F., Khamityanov, N. K., et al. (2017). Advances in local well casing technology. *Oil Industry*, 6, 34–36.

16. https://patents.su/4-1745873-gidromekhanicheskaya-dorniruyushhaya-golovka-dlya-rasshireniya-gofrirovannogo-plastyrya-v-obsadochnojj-kolonne.html

17. https://www.freepatent.ru/patents/2497623

18. Dong, H., Shmoncheva, Y., Jabbarova, G. (2016). Expandable casing expansion tool for oil and gas wells [The well casing with the expandable reamer tool]. *Patent CN 205605117U.*