Jan Artymiuk*, Erik Zachariasen**

NEW COMBINED DRILLING, WORKOVER AND SNUBBING RIG CONCEPT

1. HISTORY OF RACK AND PINION RIGS [17]

Rack and pinion technology has been with us in various applications for decades. The method is well known for long durability and high efficiency. Experience on using rack and pinion technology in the drilling industry dates back to the mid 80's, when it was used mainly for pipe handling equipment and other relatively slow moving machines. With the forming of Engineering and Drilling Machinery (EDM) in 1997, significant advances and refinements to the technology contributed to several patent applications which later have been granted internationally. During the late 90's EDM was engaged in several projects involving equipment for workover and snubbing operations in the North Sea area. At that time such operations were dangerous to people and surroundings, often consisting of suitable or not so suitable equipment stacked on top of each other without a consistent design and consideration to HSE and optimal functionality. To improve the situation, EDM designed [9], a workover machine utilizing rack and pinion technology allowing faster and simpler rig up and rig down, lower weight and higher safety level. The main value, however, was that the rig could easily shift from drilling, workover into snubbing and underbalanced operations, without modifications to the rig, such as use of temporary wires, sheaves and winches. The rack and pinion rig concept allowed for true multi-functionality in well operations. This form of operation was later discovered by U.S. oil company contractor Breitburn Energy, who bought a rack and pinion rig from EDM in 2001, for their planned drilling operations downtown Los Angeles. Breitburn needed a compact rig that could do drilling, workover and snubbing. Being in an urban district of LA it was imperative that the rig made little noise. The Breitburn rig was enclosed in a church-like building, put to work and has since been moving around on the property servicing about 40 wells, probably making the neighbors wonder what's going on in the backyard. Capacities of the

* Oil & Gas Faculty, University of Science and Technology, Krakow, Poland, e-mail: art@agh.edu.pl
** EDM, Kristiansand, Norway, e-mail: Erik.Zachariasen@sense-edm.com
*** Praca wykonana w ramach badań własnych

Breitburn rack and pinion rig is 250 sh ton pulling, 120 sh ton pushing, equipped with a top drive with similar capacities, manual pipe handling and mud systems. All movement is by AC motors [10], which runs off the LA downtown power grid (Fig. 1).

Fig. 1. New Rig Concept

Later development of rack and pinion rigs includes a series of 16 trailer mounted rigs to a Canadian rig operator with basically the same multi-functionality as the Breitburn rig, although with a lower ratingof 120 sh ton. Using the rack and pinion technology to package these rig reduce rig up and rig down time, enables less truck loads, and enables the rig owner to offer a wider variety of services in the same machine. In the midst of the delivery program, these trailer-mounted rack and pinion rigs have already proven their versatility and competitive edge. Other deliveries include modularized rack and pinion rigs for off-shore workover, rack and pinion land rigs, as well as other versions. Plans for helicopter rigs are on the drawing board, as well as rigs with higher ratings and capabilities. The rack and pinion technology described in here is thoroughly protected by international patents.

2. CWDS

In an industry in deep love with acronyms these multi functional rigs is the source of yet another. They have been designated CWDS (Combined Workover, Drilling and Snubbing) rigs by some operators to describe that they can deliver a wider array of functionality than standard or specialized rigs.

3. ONE MAN OPERATED LAND RIG

In 2005 an order to build a Rack and Pinion Land Rig for the European drilling market was awarded. It was decided to equip the rig with the latest technologies, not only related to rack and pinion drive, but also in level of automation, a „robotic" pipe handling system [12, 13, 16], state of the art operators chair [8, 11, 15], as well as offering increased safety with less people on drill floor. Consequently, the rig is equipped to enable one man operation of all basic drilling tasks.

4. RACK AND PINION TECHNOLOGY

The main concept of the rack and pinion technology is to replace the Drawworks, drill line, blocks and tackle with a linear, direct driven hoisting system, [5]. This leads to the use of a closed mast construction housing the entire hoisting system, instead of a conventional open derrick or mast with the hoisting system split in several elements (Fig. 1). The „secret" behind the rack and pinion technology is rack modules that are connected together in a special way to form a stiff linear rack when it travels on the (driven) load side. A turning wheel in the bottom of the mast makes the rack modules turn so the (non driven) dead side is vertically opposite of the load side. Pinions driven by reduction gearboxes and drive motors engage with the rack elements on the (driven) load side, making the rack move upwards for hoisting and downwards (around the turning wheel) for lowering. The rack elements slide in a special guide arrangement. As such, the design is attractively clever and simple, as of all great inventions. In fact, the rack and pinion rig is the first drilling system with a directly driven drill string, completely avoiding the use of a wire (drill line). This means that vertical movement of the drill string can be controlled with an unprecedented accuracy, for pulling, pushing and holding still. There is no stretch in wires, efficiency loss or inertia in sheaves, a fast line running at ridiculous speeds, gear ratios in Drawworks and blocks, layers of wire on the drum, cut and slip. In a direct comparison with a conventional rig setup the rack and pinion rig exhibits a better efficiency factor, less start and stop inertia, no cut and slip, drastically reduced need for maintenance, as well as reduced weight. In dollars, it is more cost efficient. In the R&P Land Rig application described in this paper the pull load rating is 250 sh ton, enabling efficient drilling operations down to 5000 m. For snubbing operations, the push rating is 125 sh ton. Fully equipped for drilling with doubles, the free height between drill floor and top drive is 23 m (75 ft). With a total mast height of 37 m it is necessary to split in two mast sections for transportation along roads. A mating system connects the sections together while in horizontal position before being raised to the vertical position. Mast erection is by two skid jacks operating raising bars fixed to the mast.

5. THE TOP DRIVE [1, 2, 3, 4, 6]

Supplementing a modern drilling operation, the rack and pinion rig contains an AC-driven top drive system [10], permanently mounted by a retractable dolly to the mast by sliding pads and a pin engaged into one of the rack modules. Accordingly, during transportation the top drive resides horizontally with the full service loop connected down to interface at drill floor level. When mast is raised the top drive is ready with little hook up. The top drive is fully equipped with a mud swivel, gearbox, rotating head, torque wrench and two IBOP's, one remote operated. With lower and upper thrust bearings it can be rotated during both drilling and snubbing operations.

6. A PIPE HANDLING MAST

To offer a safe and "hands-free" drilling operation, a fully automated pipe handling system is used [12, 13, 16]. With a basis in a patented fingerboard design the pipe handling machine is smart and easy to operate. Using „curved rows", circular to the rotational center of the pipe handling machine, the movement of tubulars into and out of rows is simplified, (Fig. 2). Vertical movement of tubulars is of course by a rack and pinion system, enabling accurate, safe and simple remote control. Necessary lifting height is achieved by an H-structure design allowing telescopic elevation.

Fig. 2. The pipe handling machine

Thus the pipe handler can be compacted for road transportation. On location, the pipe handler mast is simply raised to vertical using skid jacks and raising bars, and then ready for operation. The gripper head uses a wedge design with push safety latches to equally facilitate horizontal and vertical handling. With the design tubulars of various sizes are picked up without the need to change claws or dies. Furthermore, the gripper head engages on the flush area of tubulars and is not dependant on tool joints. Tubulars are picked up by the pipe handling machine by extending the arm to well center position, gripping the pipe, lifting off the stick up, turning to fingerboards on either side of the mast, then lowering down to simple "setback mats". All weight of tubulars in setback is thus supported on the ground (no load on the rig structure).

7. CATWALK MACHINE AND STAND BUILDING

A Catwalk Machine is attached to the H-structure of the pipe handling mast. A cylinder tilts the catwalk from horizontal to drill floor elevation. Singles are moved towards the drill floor using a pusher. When at correct position the pipe handling machine pick up the single, turn it to vertical and into a mouse hole, which is located between well center and the iron roughneck. Using the hydraulic slips the single is secured. The catwalk machine returns to get another single, using a pipe feeder mechanism to tilt singles onto and out of the catwalk machine. With the second single picked up by the pipe handling machine it is stabbed and made up by the iron roughneck. The pipe handler picks up the double, elevate, turn and rack back to the finger boards or – racks it to well center for the drill string. All movement of catwalk machine, pipe handling system, fingerboards and iron roughneck is fully automated. The operator use pushbuttons to advance the machines in predefined steps. As no manual intervention is necessary, pipe handling operations are safer, faster and more efficient.

8. DRILL FLOOR (Fig. 3)

When transporting the pipe handling mast, both the drill floor main sections and finger boards are attached as folded wings. Using cylinders, the wings are unfolded when the pipe handler mast is raised [2, 3, 4, 5]. Both the drill floor and fingerboards „wings" are attached to the rack and pinion mast. The two masts with the cross connected „wings" form a strong and rigid structure, and with the setback load in the ground, makes the rig capable of high winds forces, without the need for guy wires. The drill floor supports hanging and pushing (upwards) loads. Again the R&P Land Rig is prepared for fast rig up and rig down with minimum of assembly and mounting work. Drill floor extensions are used to mount the driller's cabin, and the iron roughneck.

Extensions are used to mount the driller's cabin [8, 9, 14] and the iron roughneck [15], forming a rather large drill floor area compared with other land rigs of similar capacities. Underneath the drill floor there are adequate space for a 13 5/8″ BOP, easily rigged up as a parallel activity during raising of the R&P Land Rig.

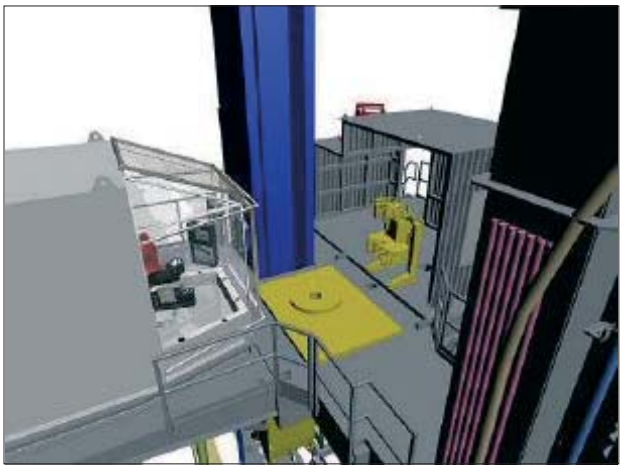

Fig. 3. Drill floor sections in new rig concept

9. SNUBBING SLIPS

As a part of a development program, Sense EDM patented a special type of slips that are used efficiently for holding both pulling and pushing loads, [17]. A wedge design makes the slips function safe and versatile for a wide range of tubular sizes. For the R&P Land Rig, it means that no special operation is necessary to go from drilling to snubbing operation, other that "reset" the slips. The hydraulic slips are remotely controlled from the operator's chair.

10. IRON ROUGHNECK

A conventional iron roughneck mounted on a pedestal is used for make up and break out of drill pipe and casing [15]. The roughneck is remotely controlled from the operator's chair.

11. ROTARY TABLE

A dummy 37 1/2″ rotary table is used to hang off loads. Future options include rotary table rotation to position tubulars for make up, as well as two hydraulically operated slips with bearings and a locking brake to safely handle light drill strings.

12. OPERATORS CHAIR

Complimenting a modern, automated rig system is an X-COM operator's chair, housed inside of the climate controlled driller's cabin (Fig. 4) [8, 11]. The operator has a nice view over the rig with large windows.

Fig. 4. X-COM operator's chair

The operator uses two large LCD screens to monitor all equipment, systems and operations. This is the operator's information central, where traditional gauges, indicators, bar graphs and video screens are integrated into one, compact, graphical interface that may take any shape. Control of equipment is by two touch pads and two joysticks mounted in arm consoles attached to the chair. This substitutes traditional switches, buttons and throttles. As all interface is graphical and drawn on screens, the X-COM chair change to reflect the status of the current operation. This makes operation of the R&P Land Rig more intuitive and simple, as the user is only exposed to the information and functions that are currently used. Additional information is provided with a full alarm system, rig status screens, trend screens.

13. RIG SUPPORT SYSTEMS

The R&P Land Rig is equipped with diesel generators, electrical distribution, AC drive systems [10], two mud pumps, well control equipment, mud system. The mud system is prepared for Underbalanced drilling operations.

14. CONTROL & POWER SYSTEM

A networked control system connects the different modules/skids together to operate as single system. During rig up, the operator can "see" as the skids are being connected and started up, getting access to sensors, motors and functions as they come alive. This also makes troubleshooting easier. The rig is equipped with a full set of drilling sensors enabling monitoring of loads, torque, speed, volumes, strokes, loss/gain, trip tank volumes, steel displacement etc. All information is stored in a historical database for later retrieval.

15. REAL TIME DATA DELIVERY

Becoming increasingly popular, real time data delivery enables drilling contractors and operators to make critical drilling as they happen. The R&P Land Rig is equipped with a satellite dish and a data acquisition system that can forward drilling and well data to any secure Internet location in a matter of seconds. Using the industry's well site data format of choice – WITSML – users can tap into the data stream to look at trends, directly load data into 3D reservoir simulations, and automatically populate reports, to mention some. The same system is used to enable remote troubleshooting facility. With a secure access, monitoring, problem solving and, if necessary, re-programming of the entire R&P Land Rig control system can be done from the company offices in Norway, independent of where the rig is located.

16. RIG CAPABILITIES

As discussed earlier, the R&P Land Rig concept has a number of advantages in terms of how an efficient rig can be realized with low weight, fewer truck loads, and smart rig up and rig down.

Operationally, the rig delivers a unique portfolio of capabilities:

- drilling,
- under balanced drilling,
- slim hole drilling,
- workover,
- well intervention,
- snubbing operations,
- re-entry,
- sidetracking.

For driller's, such flexibility opens up new possibilities. For example, with the ability to push, top holes may be drilled with less drill collar weight. Shallow depth horizontal wells may be drilled differently, as the need to trip to get drill string weight is not necessary. With the direct vertical drive of the Drill string (and no wire), extremely accurate control of tools in the reservoir section can be achieved. This is true both if the well is in overbalance or in under balance, with the well flowing. With it's built in multi-functionality, the R&P Land Rig replace conventional drilling rigs, hydraulic workover units, snubbing units, and to a certain extent coiled tubing units.

17. SENSE EDM [17]

Late in 2005 the two Norwegian companies EDM and Sense Technology merged to form Sense EDM. The merged company has a unique product portfolio, skills and experience in drilling machinery, pipe handling systems, advanced control systems, drilling packages, and has an extensive delivery program to the international oil and gas industry ongoing.

REFERENCES

[1] Artymiuk J., Hollekim H., Sokalski M.: *New Drilling Technology-Top Drive System*. VII Międzynarodowa Konferencja Naukowo-Techniczna, Kraków 20–21.06.1996

[2] Artymiuk J.: *Kierunki rozwoju hydraulicznych napędów urządzeń wiertniczych*. IX Międzynarodowa Konferencja Naukowo-Techniczna, Kraków 2–3.07.1998

[3] Artymiuk J.: *Kierunki rozwoju w urządzeniach wiertniczych – głowica obrotowa i hydrauliczna konstrukcja wyciągowa*. Konferencja Naukowo-Techniczna, Jasło 19.06.1998

[4] Artymiuk J.: *Kierunki rozwoju hydraulicznych napędów urządzeń wiertniczych*. IX Międzynarodowa Konferencja Naukowo-Techniczna, Kraków 2–3.07.1998

[5] Artymiuk J., Rudshang B., Skibelid T.: *Modern use of closed-loop hydraulics for controling and powering of cylinder-based hoisting systems*. X Międzynarodowa Konferencja Naukowo-Techniczna „Nowe metody i technologie w geologii naftowej, wiertnictwie, eksploatacji otworowej i gazownictwie", Kraków 24–25 czerwca 1999

[6] Artymiuk J.: *Directions of development of the „Top Drive" heads*. X Medzinárodná Vedecko-Technická Konferencia. Nové poznatky Oblasti Vŕtania Ťažby, Dopravy a Uskladňovania Uhľovodikov, Podbanskě, 5–7 October 1999

[7] Artymuik J.: *Stare wiertnie do lamusa*. Nafta & gaz biznes, nr 12, 2003, 18–23

[8] Artymiuk J., Zachariasen E.: *New technology in drilling – Internet technology reveals significant potential for drilling sites*. Wiertnictwo Nafta Gaz, 18/1, 2001, 33–40

[9] Artymiuk J., Loland J.: *Use of computer stimulation during designing early stage. 13th international scientific-technical conference*. Kraków, WWNiG AGH, 20–21 czerwca 2002, 29–31

[10] Artymiuk J., Loland J.: *Top drive technology-electric PTD*. Nové poznatky v oblasti vrtania, tazby, dopravy a uskladnovania uhl'ovodíkov Podbanské 2002, XI Medzinárodná Vedecko-Technická Konferencia, 29–31 októbra 2002, Podbanské, Slovensko, conference contributions Technická Univerzita v Kosiciach, Fakulta Baníctva, Ekológie, Riadenia a Geotechnológií, 3–11

[11] Artymiuk J., Wróbel Ł.: *Nowoczesne systemy decyzyjne w wiertnictwie.* Rocznik AGH Wiertnictwo Nafta Gaz, 20/1, 2003, 33–38

[12] Artymiuk J., Sokalski M.: *Nowe technologie w wiertnictwie – automatyzacja procesu manewrowania rurami*. 14th Internacional Scientific and Technical Conference "New Methods Technologies in Petroleum Geology, Drilling and Reservoir Engineering", Zakopane 11–13 czerwca 2003

[13] Artymiuk J., Sokalski M.: *Nowe technologie w wiertnictwie ľ automatyzacja wybranych procesów wiercenia*. XIV Międzynarodowa Konferencja Naukowo-Techniczna „Nowe metody i technologie w geologii naftowej, wiertnictwie, eksploatacji otworowej i gazownictwie". Zakopane 11–13 czerwca 2003, 1–4, 15

[14] Artymiuk J., Sokalski M.: *New technologies in drilling: assurance of appropriate tubular torque moment values*. Nowe technologie w wiertnictwie: zapewnienie właściwego momentu skręcania rur. Rocznik AGH Wiertnictwo Nafta Gaz, 21/1, 2004, 51–59

[15] Artymiuk J., Sokalski M.: *The new drilling control and monitoring system*. Acta Montanistica Slovaca, 2004, R. 9 \v{c}, 3, 145–151
[16] Bednarz S., Artymiuk J.: *Principles of Drilling and Production machinery Admittance in Operation*. Międzynarodowa Konferencja Naukowo-Techniczna, Ostrawa 12–14.11.1998
[17] Sense EDM-papers and catalogs