# $11^{5}/8$-in. milled tooth bits developed for niche high-speed turbine applications in Russian field

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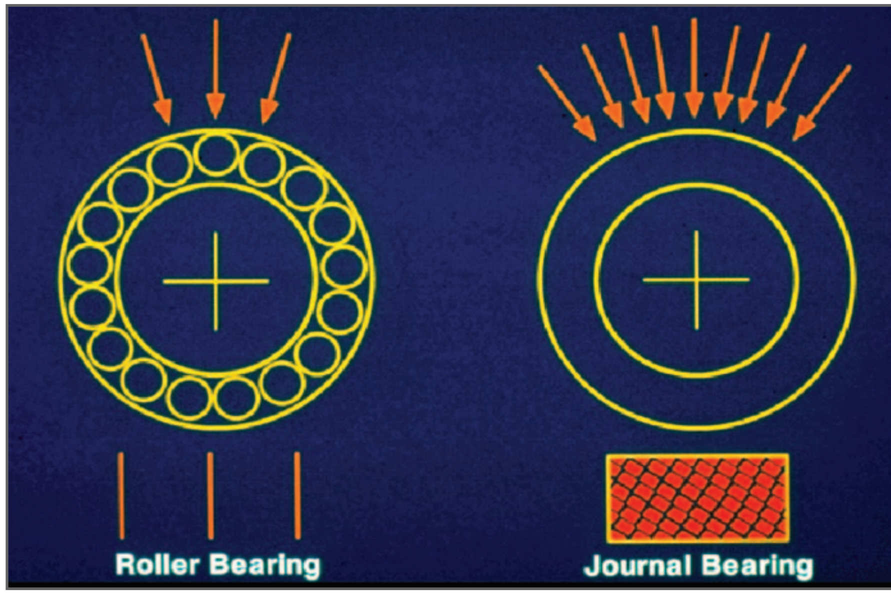
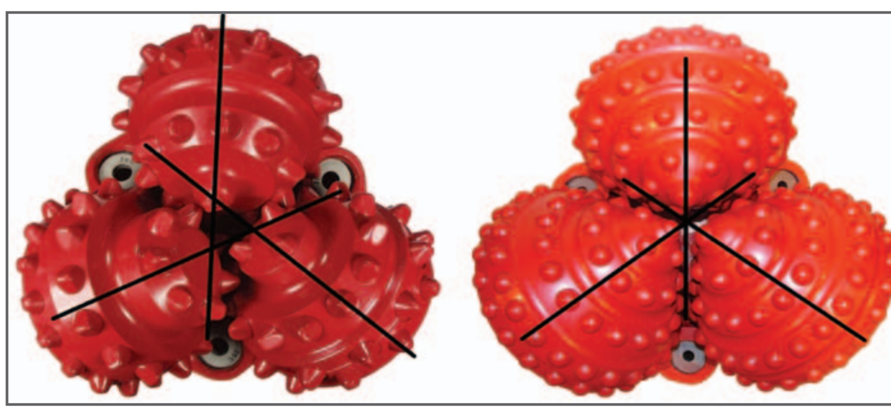
THE PRIMARY GOAL in drilling the 11 ⁵/8-in. section in the Samatlor field of Nizhnevartovsk, Russia, is to complete the section in one run with maximum ROP. All wells require directional work, so steerability was a constraint. Most cost-effective downhole systems are turbines that operate at 500-600 rpm. These high downhole speeds generate a great deal of heat that fatigues roller cone bearings and result in more than 1.5 million bit revolutions: a difficult goal to consistently achieve.

To achieve these objectives, a special roller bearing was developed to withstand these ultra high-speeds. A special cutting structure was also designed to match the application.

The first cutting structure design allowed the interval to be drilled in one run at 20 m/hr. However, further ROP improvements were achieved by designing an even more optimized cutting structure that drilled the interval in one run and with ROPs in excess of 30 m/hr, in addition to meeting the directional demands.




**Above: Schematic of bearing loading – roller bearing on the left and journal bearing on the right. Below: This diagram of cutter skew shows the bit on the left has a large cutter skew and the right bit has a small one.**



## BEARING DESIGN FEATURES

The extended bearing life was made possible by using specific features in the bearing design that are not usually found in this size:

- Logarithmic roller bearings (typically only found in sizes 12 ¼-in. and larger);
- Zero-degree skew to achieve true rolling action and to withstand high rotational speeds;
- Ball bearing retention designed to act as a secondary load carrier;
- Special texturized radial seal used to reduce seal torque due to high rotating speed;
- Lug material changed to allow specialized heat treatment to inhibit fatigue stresses; and
- Unique grease with a high temperature rating.

This project is an excellent example of using unconventional design criteria and employing industry-leading material components to meet unusual constraints, in this case high downhole RPM.

**A special roller bearing was developed to withstand very high downhole speeds.**

## BILLION TONS OF RESERVES

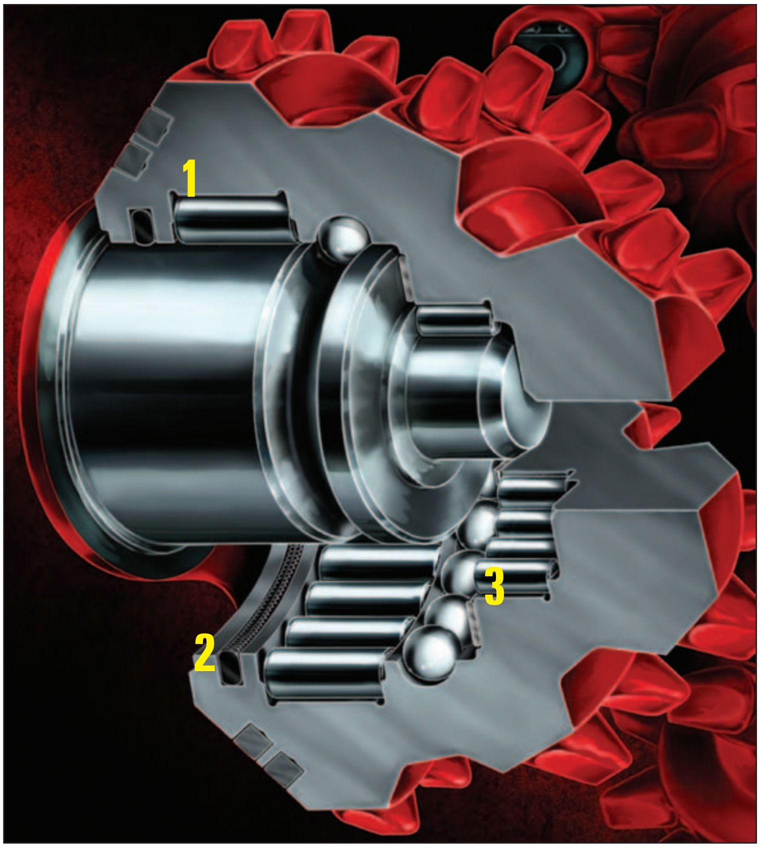
The Samatlor field, located at Lake Samatlor, West Siberia, is the largest oilfield in Russia. More than 17,000 wells have been drilled there since operations began in 1965. It still has an estimated 7 billion bbls (1 billion tons) of reserves and is being operated by a joint venture of TNK and BP.

The section drilled in 11 ⁵/8-in. hole size is directional and usually from 500 m to 1,000 m in length. Water-based mud was used to drill the section, which contained medium soft sands/shales with a reactive shale band midway.

The application is interesting in that 2 downhole systems were used: mud motors and Russian turbines.

The primary objective was to drill to section TD in one bit run. Secondary objectives were to do so with reasonable ROP to be able to maintain direction and to hit the section target. This requires a steerable bit and BHA combination.

While the field was being developed by the ex-Soviet Union, it was drilled entirely with Russian bits. Their ROP was reasonable, ranging from 10 m/hr to 25 m/hr. Their life expectancy, however, wasn't long, with an average on-bottom time of about 10 hours. Multiple bit runs were needed to drill to TD: 2 to 5 bits per well. There were concerns that if the run times were pushed, cones would be lost, leading to time-consuming fishing jobs. Issues also arose with bit balling when the reactive shale section was drilled.




**Overview of bearing design: (1) logarithmic roller bearings; (2) texturized radial seal; (3) ball retention system.**

It is a significant challenge to run roller cone bits under these circumstances because the high speeds of a turbine (greater than 500 rpm) are not friendly to a roller cone bit's bearings. A roller cone bit is normally run from 50 to 150 rpm. The higher speeds used by these turbines – from 400 to 600 rpm – create higher seal and bearing temperatures and produce high bearing revolutions.

The main reason turbines were even used was because downhole turbines developed in the former Soviet Union were more cost-effective than imported Western mud motors.

Roller cone bearing revolutions are a function of distance drilled and of downhole RPM. The table below gives the total bearing revolutions as well as bearing speeds.

The total bearing revolutions could be tolerated by a bigger bit (i.e., 14 ¾ in. or bigger), but it is a lot for a relatively small bearing package like an 11 5/8-in. bit. The same is true of the main bearing and gauge and seal velocities. They are almost 4 times what an 11 5/8-in. bit would normally see. These speeds and total bearing revolutions would tend to generate:

- Abrasive wear on the bearing surfaces;
- High temperatures at the bearing surface interface; and
- Increased risk of spalling, galling and fatigue-related issues.

Therefore, the bit selection criteria for this application were:

- Survive the high total bearing revolutions;
- Tolerate high bearing speeds;
- Require low bit torque (since turbines generate less torque per gallon pumped than downhole mud motors);
- Resist bit balling in reactive shale; and
- Generate acceptable ROPs.

Turbines generate less output torque than mud motors, therefore roller cone bits fit this criterion. The reactive shale midway through the section can lead to bit balling. Coupled with the hydraulic limits of the land rigs used, this meant that efficient bit hydraulics were needed. Previous runs have shown that the ROPs are possible with a mill tooth cutting structure.

The problem is that there are no bits in this size range designed to withstand these high speeds and the large number of revolutions. Therefore the design team looked at bearing design.

The first consideration is bearing type. Due to the available space in the lug and cutter, roller cone bits smaller than 12 ¼ in. are made with journal bearings. The flip side is that bits bigger than 12 ¼ in. are made with roller bearing.

A roller bearing takes up more room inside the bit but provides a more efficient bearing and runs at lower temperatures than a journal bearing for the same WOB and RPM because it distributes the load across moving cylindrical bearings. It's also easier to lubricate. However, the bearing surface is subjected to a cyclical load as each bearing

| Case | ROP (m/hr) | Distance drilled | Downhole RPM (rev/min) | Surface RPM (rev/min) | Bearing Revolutions | Main Bearing Velocity (in/min) | Gauge & Seal Velocity (in/min) |
|---|---|---|---|---|---|---|---|
| Roller Cone Bit on Turbine | 20 | 1,000 | 500 | 50 | 1,650,000 | 6,692 | 20,076 |
| Roller Cone Bit on Mud Motor | 20 | 1,000 | 100 | 50 | 450,000 | 1,825 | 5,475 |

rolls over it, and the load is concentrated along the bearing rollers. At high loads, this can cause spalling and other fatigue-related wear mechanisms.

On the other hand, the journal bearing works not by a rolling action but by a sliding action, which is more of a loading action than that of the roller bearing. The potential problem here is that it generates higher temperatures for the same load and RPM regime.

At Samatlor, the conditions were as follows:

• Moderate loading (the WOB required to fail the formation was not very high);

• High bearing speeds (due to turbines being used); and

• Long bearing lives (due to the run lengths and high RPM).

As a result, a roller bearing was selected for the bit, even though space was limited. This would be a special application bit that could potentially work well at the application conditions but likely would not tolerate higher loads.

**The first new bits, the 11 5/8-in. ETS13, had a successful bearing design but showed dull conditions.**

**The second series of bits ran to TD with effective bearings in 1 run and drilled at an average ROP of 30 m/hr.**

The next design feature considered was cutter skew, which refers to the orientation of the cutters. Cutter skew is the angle at which the center of rotation of the cutters intersect. A bigger skew angle means that the cutter teeth have a bigger gouging and twisting action on the formation. A small skew angle (or even 0°) means that the cutters tend to run true with the rotation of the bit, therefore putting less stress on the bearings.

Less stress means less wear and less bearing friction. The compromise is that the cutting structure is less aggressive, all else being equal. Therefore, for the Samatlor bits, a 0° skew angle was selected to maximize bearing efficiency to give the best opportunity for long life under the circumstances.

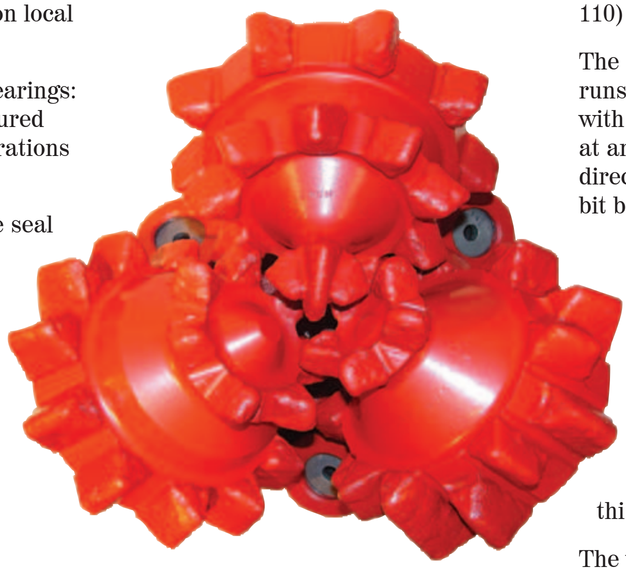
The first bit was accordingly designed with a roller bearing and 0° cutter skew. An IADC 135 cutting structure was initially chosen to ensure that the bit was durable enough to survive the entire section. Additional features chosen to help it to survive the application were:

• ArmorClad II Hardmetal: This Mill Tooth hardmetal welded coating has generally been found to be more wear-resistant than the overlays used on local Russian bits;

- Precision Logarithmic Roller Bearings: The ends of the rollers are configured to reduce the high stress concentrations normally present at these points;
- Texturized radial seal to reduce seal torque and friction at high rotating speeds;
- Ball retention to act as a secondary load carrier – to overcome the issue of less meat on cutters and lugs due to using roller bearings; and
- Special grease to allow higher operating temperatures.

## BEARING DESIGN

The first new bits were called 11 5/8-in. ETS13. The bearings were still effective at the end of all runs, cutting structure was minimal, and the bits drilled to TD. However, the ROPs were not high enough, averaging from 20 m/hr to 25 m/hr, and there was some bit balling. However it was encouraging that the bearing design was successful.



**The new bit, the ETS11, used a more aggressive cutting structure, the IADC 115.**

The bearing package was kept for the next design iteration, but to improve ROP and to reduce bit balling (by opening the cutting structure face to provide better cleaning), the more aggressive IADC 115 cutting structure was selected.

The new bit has less main teeth (54 vs. 110) and fewer gauge teeth (29 vs. 55).

The results of the second series of bit runs were very good. The bits ran to TD with effective bearings in one run, drilled at an average ROP of 30 m/hr, were directionally steerable and did not suffer bit balling.

## CONCLUSIONS

In an application that was somewhat unusual for roller cone bits — running roller cones on turbines — bits were designed based on techniques used in other applications and sizes. This created a niche solution that worked well in this application.

The wells now being drilled at Samatlor can match the bit to the system. The ETS11 turbine mill tooth bit tends to be run when downhole turbines are used. When downhole mud motors are used, higher torque fixed cutter bits tends to be run. Although these are more expensive, they can usually be run again and are slightly faster.

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