OIL PRODUCTION STIMULATION AND RECOVERY INCREASE: ACOUSTIC TECHNOLOGIES

Urgency of the issue. Experts in the oil and gas industry all over the world know how

complicated, old and simultaneously urgent the problems of increasing oil recovery of formations (IOR), oil production stimulation (OPS) and methods realizing them (ARM and RSM) are. In the nearest decades, in conditions of objective permanent HC resource base deterioration (negative trends in the structure and quality of reserves – increasing part of watercut and other reserves difficult to recover, their increment and work-out level – increment increase slowdown, their general support on the account of hard-to-reach areas, heavy and high-viscosity oils, involvement of low-porosity and low-permeability formations, etc.), at decreasing rated oil recovery factor (ORF) in Russia, for example, these problems will be of strategic importance for oil recovery development in all countries. And this importance will be adequate to their energy preparedness and competitiveness of a country in its foreign economic activities.

For many reasons universal ARM which would applied in a wide range of geological-physical conditions, similar to waterflood - reservoir pressure maintenance systems (RPM), are not developed yet. In the complex of modern ARM and RSM, geophysical methods which, beside the known groups of tertiary methods (thermal, gas, chemical, microbiological), should be separated in an independent group, become more and more meaningful. Their typical feature is that they all use for the formation "treatment agent" (acting inside the well or from the surface) not a substance (hot water, steam, gas, chemical reagents etc.), as in all groups listed above, but physical (geophysical) fields of different nature (electromagnetic, elastic vibrations, nuclear-physical etc.), and also use equipment, instruments and technologies, which are virtually similar to those traditional for geophysical surveys and works in wells (GSW). Today, in this group (geophysical ARM) acoustic treatment (AT) methods, among which ultrasonic ones with the use of piezoceramic radiators are, are theoretically and in instrumental and technical aspect the most well-developed, especially at formation and WBZ treatment from wells.

The purpose of this article is to show some capabilities, modern potential and prospects of commercialization of instrumental and technical well complexes by Progress Industrial Systems SA (Switzerland) for AT (preferably ultrasonic) of WBZ, formation and some other technological production zones, though their economic and technical efficiency appears absolutely obvious.

It is common knowledge that reduction of the well bore zone permeability is stipulated by several fundamental factors:

1. Reduction of the well bore zone permeability stipulated by tangent circular compressing stresses formed during well boring due to formation pressure;
2. Solid phase settling from process liquids (killing, jetting, muds etc.) in the well bore formation zone, and other residues.
3. Bridgeover in perforations formed by formation returns, reaction product separation due to widely applied well bore zone treatments by chemicals and ARPD sedimentation.
4. Capillarity mudding of the pay section due to well bore damage by a colloid-dispersion system formed as a spatial network.

The indicated factors reduce oil production and the injector well rate.

Obviously, to obtain the maximum output by selecting stimulation method, these factors shall be taken into account, and the ways eliminating their adverse consequences shall be searched for.

Ultrasonic methods effectively solve the greater part of these problems…

General description of the acoustic method. AT methods unite a large group of methods and modifications, which use elastic fields of the wave nature (impact, vibration, seismic sounding, ultrasonic, etc.) for treatment of formation and WBZ from both the Earth surface and the well. Meanwhile, the methods and technologies of WBZ and formation treatment from wells by power ultrasound, ultrasonic treatment (UST), are currently the most developed both theoretically and instrumentally and technically, and the most abundant in practice of field operations. By the most abundant classification, AT technologies, which apply piezoceramic radiators for the sources, relate to the high-frequency (HFAT) type.

The main effects and physicochemical mechanisms. As ultrasonic (in more general case, acoustic) field interacts with a porous, fluid-saturated medium, depending on its mechanochemical properties, including properties of fluids, energetic and other parameters of the field (frequency, specific power, displacement amplitude, etc.), a wide spectrum of realistic effects (nonlinear, as a rule), such as WBZ unclogging, including with degradation of colloid-dispersion systems (coagulation structures), "break opening" of new forfeit intervals (laminations), the change of rheological properties (viscosity decrease) of oils at the expense of paraffin and other ARPD dissolution, for example, fluid degassing, mixture phase permeability variations, occasional porosity increase, etc. is observed. The direct consequence of these effects is the well productivity (production rate or injection rate) increase with the average success over 85%. In case of proper physical reasoning and instrumental and technical support, the aforesaid effects allow for solving multiple applied tasks aimed at production stimulation (well production rate stimulation) and increase of ultimate oil recovery of the formation for a large range of production zones (about this, see directly below), hence, with high production effectiveness, minimal financial investment and perfect ecological friendliness.

Instruments and technologies. Having its own design bureau on acoustics, manufacturing capacity on electronic installation, high-precision mechanical processing facilities, Progress Industrial Systems SA designs and since 2007 produces in lots powerful ultrasonic complexes, applying the experience accumulated in the field of ultrasonic technologies and the experience in designing sonar systems for various purposes. In recent years, the company succeeded greatly in designing of powerful ultrasonic instrumental and technical complexes (ITC) and analogous low-frequency (1-100 Hz) ones based on piezoelectric converters able to operate at high depths and high temperatures. At present, a unique geoacoustic complex for oil recovery stimulation is designed, comprising powerful ultrasonic and low-frequency generators (in a shock-resistant, vibration protected case), two ultrasonic and two low-frequency radiators of different diameters (of different designs also - stainless steel, titanium, including for operation in aggressive media), which are supplied via standard geophysical cable. All equipment realizing the acoustic treatment technology is compatible with the standard equipment of geophysical crews that eliminates special difficulties in its assimilation by geophysical staff.

The AT technology consists in reservoir bed treatment (in the open hole, in the filter or perforation interval) by a powerful ultrasonic field (or low-frequency field or both consecutively) for the purpose of restoration of their fluid loss properties. Treatment is performed pointwise (with 0.5-1.0 m resolution or with slow oscillatory displacement in the interval), selectively on the principle of "influx profile – stimulation profile" type (places and number of radiator stops). Well preparation, equipment etc. do not differ from these for standard geophysical surveys in the well. In this case, the wholeness of the oil column and set cement behind it is preserved and the process of impacting is technically and physiologically safe and ecologically friendly.

Technical characteristics of the complex:

Characteristics	GAK-4500	GAK-10000
Generator output, W	4500	10000
Generator output voltage, V	650	750
Generator bandwidth, kHz	20±5	10-50
Generator efficiency factor, %	93	93
Generator dimensions, mm	540x600x450	540x600x450
Generator weight, below, kg	30	40
Radiator power, W	1500	1000-3000
Radiator efficiency factor, not less, %	95	95
Specific acoustic power per radiator surface, W/cm^2	10,2	15,4
Actual frequency of the radiator, kHz	20	20
Radiator dimensions, diameter, length, mm	44x1500 75x2240	44x1500 75x2240
Radiator weight, below, kg	10/25	10/25
Geophysical cable length, below, m	3000(±500)	5000(-500)

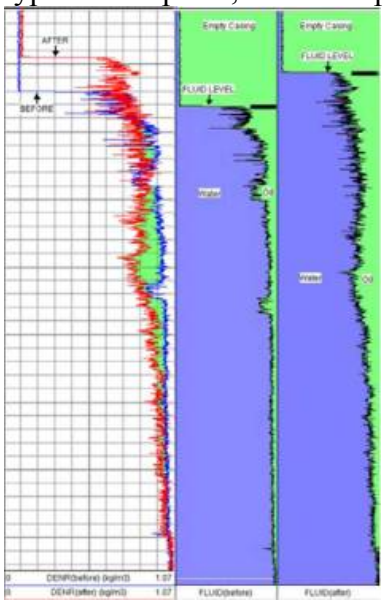
AT capabilities. Analysis of the experience existing on AT performance in wells allows to conditionally divide all technologies and, consequently, potential objects – the wells, into three categories:

a) corrective or prophylactic (designed for productivity adjustment of wells operating not for long and showing quite "good" production rates, which are, however, below their potentials);

b) stimulating (designed for wells with significantly reduced production rate compared with their put to production);

c) reviving (designed for almost OOA wells). The same analysis representing the experience of ourselves on well treatments indicates that it's time to pass from single, "cosmetic" treatments of separate wells to a systematic impacting an object (deposit) via a group of wells (accounting for AT of neighbor wells) that with high probability may provide for a significant (by times) increase of production by the entire object during rather short period of time, with increased ultimate oil recovery. Further development of this idea (transition from the classical systems of oil field treatment to control over power engineering of industrial hydrocarbon systems), in the context of primary designing of such systems using AT, in prospect shall κ lead to methodology of "active geophysical monitoring", where our ATC (acoustic treatment complexes) may already now become the irreplaceable "stimulation" element of the "smart well" (the intellectual well).

Another important factor is the possibility of combining AT technologies with other types of impact , for example, thermal, reagent (chemical) and others, which significantly broaden the field of their application, including objects with high-viscosity oils and other untraditional sources of hydrocarbons and much more increase the efficiency of combined stimulations due to synergism effects. Thereupon, we are already on the way of realizing the technology of "intra-method" combining of ultrasonic-infrasonic impact, which allows consecutive and effective stimulation of WBZ and remote formation zones. We produce radiators in anticorrosion casing that allows AT implementation simultaneously with acid treatment and other chemical stimulations. Finally, we have tested similar ultrasonic treatment techniques, which might be realized for elimination of paraffin plugs in tubing (including long ones) and improvement of rheological properties of oils (dynamic viscosity decrease, etc.).



Results and experience. In 2006-2009, durability, fabricability, reliability, and efficiency of our complexes was proved by pilot and industrial tests performed on Chibiyusk,

North-Iraelsky, and Sotchemiyusky fields in Russia, and massed tests in Romania on low-rate wells of Vata, Tazlau, Baltani fields. In Russia, these tests were supervised by the cathedral on "Geophysical methods, geoinformation technologies and systems", Ukhtinsk State Technical University, and in Romania by the oil company PETROM (OMV Osterreich) under the auspices of geophysical company ATLAS GIP (Weatherford, USA). In Russia, all self treatments were found successful with the average efficiency not less than 200% (double production rate) by oil. On of the primarily treated wells (North-Iraelskaya No. 501/2) continues operation in the same mode for, at least, 2 years, wheras expenses for its treatment were paid during 5 days of its operation. As calculated from result of well treatment in Romania, on average, by 5 wells with positive oil influx results, showed the efficiency of the ultrasonic method for well stimulation equal to additional production volumes of 0.5 ton/day per well, giving annually 180,000 USD.

Our global advantages.

1. The science-based and system-wide approach to selection of AT objects (fields, deposits, wells-candidates) that allows formulation and setting particular geological-technical AT tasks for each well (a group of wells), achieving their effective solution.
2. Unique characteristics of the instrumentation-technical AT complexes (power flux, overalls, coordination with the generator-cable-radiator system, depth, and other parameters) and the technology of the well stimulation itself, which allow for operational treatments of almost any well up to 5000 m deep, including tubing, i.e. practically without work termination.
3. Information-financial optimization of the complex of accompanying geophysical surveys, which allows performance of AT, selective (point) and controlled by different parameters according to the “influx profile - impact profile” principle, and, as well, promptly estimating quantitative results and efficiency (payback) of the treatments.
4. Basing on the wide spectrum for cooperation, from consulting and purchase of geoacoustic ATC to leasing and methodological and technical service of operations implemented by your reliable partners in geophysics, please make the optimal decision.
5. The unique opportunity to realize the technology of combined treatment of the formation, both intramethod (at different frequencies in the range of infrasonic (1-100 Hz) and ultrasonic (about 20 kHz)), and other, including “reagent” methods (acid treatment, etc.) that significantly broadens the field of AT application and increases its efficiency.

Conclusions. Progress Industrial Systems SA (Switzerland) is the world leader in designing and production of geoacoustic ATC for oil recovery stimulation. Say the least of it that acoustic stimulation of wells (in the infrasonic and ultrasonic modifications) is the modern high-technology geophysical method, using no chemicals, for controlled and selective impact on the formation and WBZ for intensification of influxes (injection rate) and oil recovery increase, applicable in a broad range of geological and technical conditions of the field facilities with rather long (2 years or longer) and sufficient (frequently by times) effect. Moreover, it causes no damage to the formation and the well, and ecologically friendly. This method may also be easily combined with the known stimulation and IOR methods.

We suggest.

Progress Industrial Systems SA readily suggests the most modern equipment for acoustic stimulation of oil recovery. Our equipment will provide the reagent-free, ecologically friendly and mobile method for increasing the well productivity. It also assists in saving materials and manpower by decreasing cost value of the oil recovery. At any time, our company modernizes the equipment and strives to complete fulfillment of customer's demands.

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PLAN

of the organizational and operational activity on the oil and gas production fields at ultrasonic treatment operations within the well producing zones.
Preparatory organizational and operational activity

Customer data analysis;
selection of wells for the sonic treatment considering their production characteristics and output trends since commissioning. Data should include:
- cardboard maps,
- influx profile,
- interlayer permeability,
- technical data and performance of the well,
- information on repair and process operations for the oil and gas production stimulation.

Development of the operation plan for ultrasonic treatment of the well by the customer and its coordination with the contractors.
Geophysical party equipment includes geophysical elevator and mobile geophysical laboratory, providing background temperature survey, gaging and binding the immersion and wireline to the well productive zone.

Preparation of the geophysical elevator and wireline with small geophysical head (38mm dia.).
KG-3 cable parameters:
- resistance per unit length of the conductor R is 12 to 15 Ohm/km,
- cable length - 3000 to 5000 m.

Equipping of the mobile geophysical laboratory with power supply cable for the 3 ph., 380 V, 50 Hz mains (having power up to 15 kW), standard 3-phase plug and circuit breaker with maximum current limit up to 25 A

Preparation of the measurement equipment for carrying out the preparation and control checks of the ultrasonic treatment (UT) system equipment and measurement of the wireline characteristics.
Measurement equipment composition: master oscillator, oscilloscope, megohmmeter, AC voltage meter.

2. Preparatory activity on the geoscientist base

2.1. Delivery of the ultrasonic treatment (UT) system equipment to the geoscientist base. Typical equipment configuration contains one set of the ground generator and two types of the well acoustic radiating elements. Total equipment weight with package is 50-75 kg.

2.2. Functional check of the ultrasonic treatment equipment in accordance with the operation instruction, connecting to the geophysical laboratory equipment and geophysical elevator cable.

2.3. Measuring of the geophysical cable transfer ratio within the operating frequency band of the ultrasonic treatment system. Checking of the cable peak characteristics when the generator and acoustic radiating element work on the dummy load via the cable.

2.4. Preparation of the ultrasonic treatment system and the special geophysical equipment for departure to the well operations.

2.5. Improvement of the work program for the specific wells,

- determination of the ultrasonic treatment duration,
- irradiation modes,
- number of stations and their position within the producing zone. Coordination of the works with leading field geologist and customer supporting services, determination of ultrasonic treatment beginning and ending time.

3. Preparatory operations and ultrasonic treatment of the wells

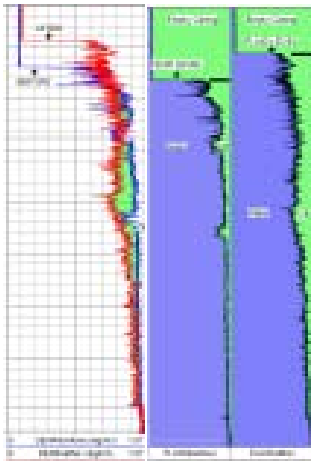
3.1. Delivery of the geophysical party and ultrasonic treatment system equipment to the place of work on the well.
3.2. Checking of the well technical readiness for the ultrasonic treatment, including availability of the power supply, availability of the going-in equipment.
3.3. Positioning of the geophysical elevator and geophysical laboratory, ground generator, ultrasonic treatment system and measuring equipment.
3.4. Performing of the geophysical measurements before ultrasonic treatment, including:
- binding,
- background temperature survey of the producing zone,
- gaging of the open hole or tubing lift when operating with ultrasonic tool having large or small diameter.

- Connecting the equipment to the ground circuit and routing of the cable links;
- Connection of the network cable;
- Checking of the mains voltage;
- Connection of the ultrasonic radiator to the output of geophysical cable.
- Checking of the insulation resistance,
- Connection of the generator output cable to the geophysical elevator commutator.

Connection of the power supply to the generator; activation of the equipment in accordance with the operation manual.
Checking of the connection accuracy, testing of the load impedance and operation of the ultrasonic radiator.
Delivery of the well ultrasonic treatment device to the producing zone on the station as per work program.
Setting of parameters in the irradiation mode.
Recording the radiation parameters in the logbook (generator output voltage, generator output current, acoustic vibration sensor indications, radiation mode and frequency).
Performing of the ultrasonic treatment as per agreed program with changing of radiation modes and work stations.
Recording of the radiation parameters for each work station.

Completion of the ultrasonic treatment at the program accomplishment. Lifting of the radiator, functional check; disconnection of the power supply, disconnection of the cable connections; preparation of the system equipment for the transportation. Performing of the geophysical measurements after ultrasonic treatment including background temperature survey in the well producing zone. Finishing of the geophysical party operation on the well.

4 Monitoring of well operation after ultrasonic treatment.



Analysis of geophysical survey data after ultrasonic treatment.
Evaluation of placement precision and treatment energy efficiency.
Analysis of the well activating results and preliminary conclusion on the effectiveness of ultrasonic treatment for oil and gas production stimulation.
Preparation and coordination of the further well performance monitoring program.
Recommended measurement interval is at least once a week at the first month of operation and once a month at the first year.
Creation, preparation and coordination of the activity log for UT on the specific wells and the statement on entire works.

Customer

Contractor

Information required for organization of activities on acoustic treatment of the oil and gas wells

for determination of required set of acoustic equipment and optimization their operating modes, provide the contractor with the following information on the specifications of the objects, proposed for acoustic treatment by the customer

No	Name / parameter	Value
1	Name of location, well number	
2	Year of putting on production	
3	Casing diameter (internal)	
4	Internal diameter of the tubing string	
5	Maximum well curvature	
6	Maximum well depth	
7	Perforation interval (depth and length of the perforation area)	
8	Thickness of the productive formation	
9	False bottom:	
	- initial.	
	- current	
10	Formation pressure, MPa (atm)	
	- initial	
	- current	
11	Bottom hole pressure, MPa (atm)	
	- initial	
	- current	
12	Wellhead (buffered) pressure, MPa (atm):	
	- initial	
	- current	
13	Type of pore space (collector):	
	- porousness	
	- permeability	
14	Well bottom temperature	
15	Well column with indication of the oil-water contact (OWC) position	
16	Daily production rate (ton/day):	
	- at the beginning of production activity	
	- at the present time	
17	Water production (%):	
	- at the beginning of production activity	
	- at the present time	
18	Gas ratio	
19	Oil viscosity:	
	- at formation conditions	
	- at surface conditions	
20	Paraffin content	
21	Oil density:	
	- at formation conditions	
	- at surface conditions	
22	Borehole graphic log	
23	Current state of the well (in operation, in repair or decommissioned by any reason)	
24	What kind of treatment the well was subjected for increasing of the production.	
25	Estimation of the well casing condition	

Reference information for acoustic emitting system. maximum depth of emitters immersion to the well is 5000 m. maximum operating pressure in the perforation area is 350 bar maximum operating temperature at the well bottom is +90C. ambient temperature for operation of the ground generator is -50C to +50C. electric power supply is 3x400 V, 50 Hz, 12 kW.

Additional conditions:

- residency of the specialists in the 4* hotel.
- providing the car with driver for the body of specialists for the work period.
- organizing the three meals daily in field conditions.
- providing the clothes for the field operation.