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HALF-CENTURY EXPERIENCE OF REPUBLIC OF TATARSTAN IN STUDIES OF CRYSTALLINE BASEMENT'S ROLE IN FORMING AND RENEWAL OF REGIONAL RESOURCE BASE

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Abstract. The paper reviews the history of studies of the crystalline basement in Tatarstan, and the progress of the ultra-deep drilling program.

The paper offers scientific rationale of produced oil and gas fields' replenishment at the cost of hydrocarbons' deep inflow through oil-bearing channels connecting the deep-seated hydrocarbon source with the deposits in the sedimentary mantle. From a standpoint of the search for hydrocarbon reserves, the crystalline basement is a promising target, however its role as a transiter for replenishment of deposits in the sedimentary mantle with hydrocarbons in the process of continued degassing of the Earth is far more important and justified. A principally new approach to building of geologic and geologic-dynamic models with consideration of fundamental geological concepts concerning forming and re-forming of oil and gas fields and deep degassing processes is offered.

Prospects of development of "old" fields that have been produced for a long time, methods of oil recovery factor estimation considering oil migration into a deposit from the entrails of the Earth, necessity to modify methods of reserves auditing and in-place reserves' estimation, change of material balance equations are justified; theoretical and practical suggestions regarding consideration of fundamental concepts of subsurface reservoir geology are provided.

Waterflooding methods have not yet exhausted their potential, on the contrary, in the light of the discovered processes of replenishment of deposits with hydrocarbons and re-forming of oil and gas fields at the late stage of development their importance will only increase.

Key words: *forming and re-forming of oil and gas fields, degassing of Earth, crystalline basement, oil-bearing channels, North-Tatarian and South-Tatarian Arches, abnormal and normal wells, carbon, hydrogen, hydrocarbons, oil replenishment, replacement of hydrocarbons, geologic and geologic-dynamic models, water-flooded development, innovative development projects, unconventional hydrocarbons.*

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GEOLOGICAL ASPECTS OF PK_1 RESERVOIR OF KHARAMPURSKOYE OIL-GAS CONDENSATE FIELD

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Abstract. Seismic-geological approach has been applied in this study for detailed description of the internal structure of PK_1 reservoir.

During the first stage, well logging and core data were used to create a conceptual depositional model for the Cenomanian deposits in the region of interest. Individual units were identified within the Cenomanian sediments (PK1-1, PK1-2, PK1-3, PK1-4, and PK1-5) as well as their confinedness to facies environments: coastal-marine, tidal and continental. The study involved rock typing of the units associated with continental environment and ranking in terms of their production potential.

Based on qualitative seismic attributes, channels were mapped within the middle and lower zones of the reservoir section (PK_{1-3}, PK_{1-4}, PK_{1-5} units). Comparative analysis of channel deposits distribution according to seismic surveys and well logging was performed. Optimistic and pessimistic geological models were built, risks of water front breakthrough were assessed.

Key words: *Kharampurskoye field, PK_1 reservoir, facies environment, geological and reservoir simulation model, development.*

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CHARACTERISTICS OF SUSTAINED-PRODUCTION STAGE OF LONG-LIFE OIL FIELDS

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Abstract. Recently, a growing number of papers have been published discussing the phenomenon of depleted oil deposits' replenishment. The paper discusses the main factors causing oil migrate into a deposit and analyze the modeling study results. The discussed oil reserves' replacement model is based on a radically new concept involving the latest achievements in physics, i.e. broadened concept of matter, nonuniformity of space, and interaction thereof. It has been shown that replacement of hydrocarbon reserves is associated with the change of dimensionality of space in a hydrocarbon reservoir in the process of production, rather than with the reservoir pressure decline. As soon as the synthesis of hydrocarbons has been completed, the dimensionality balance is restored. This trend is unmistakably characteristic of the fields, with a large portion of OOIP having been recovered. The mathematical model shows that as the recoverable reserves are depleted, the rate of hydrocarbon synthesis practically approximates the level of production. The thus formed oil production plateau can continue for an indefinite time. In view of this fact, the notion of "the final stage of development" should be considered erroneous. Some time ago Gavrilov V.P. made an assumption that oil can be classified as renewable minerals, though production after original recoverable oil in place has been extracted is rather low and does not exceed 5 % - 30 % of the peak production, on the average. The amount of oil produced during this closing long-continued stage of the field life depends on the reservoir performance in the preceding years, including production rates, the injected-produced water ratio, and many other factors.

The results of the study suggest that there is a need for a paradigm shift in the concept of development of "old" fields and in basic approaches to field development (change of material balance equations, new reservoir simulators basing on oil replacement concept, new methods of oil recovery factor estimation, optimal production rates, EOR/IOR methods, reserves auditing, and others).

Key words: *field development stages, reserves replacement, oil replenishment, synthesis, hydrocarbon field, oil recovery factor, oil-bearing channels, first matter.*

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COMMENTS AND SUGGESTIONS TO PAPER "CHARACTERISTICS OF SUSTAINED-PRODUCTION STAGE OF LONG-LIFE OIL FIELDS" BY IKTISSANOV V.A. AND ZAKIROV S.N.

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Abstract. Iktissanov V.A. and Zakirov S.N. in their paper "Characteristics of sustained-production stage of long-life oil fields" justify the prospects of development of "old" fields that have been produced for a long time, methods of oil recovery factor estimation considering oil migration into a deposit from the entrails of the Earth, necessity to modify methods of reserves auditing and in-place reserves' estimation, change of material balance equations, etc. In this paper, we offer our comments to the paper of these authors and provide some theoretical and practical suggestions regarding consideration of fundamental concepts of subsurface reservoir geology and the most recent proven phenomena of re-forming of oil fields and replenishment by oil from the Earth's deep interior while reserves' estimation and field development planning. Scientific, operational, and logistical problems are discussed, as well as possible ways to deal with the challenges.

Key words: *crystalline basement, reserves estimation, oil replenishment, synthesis, field development planning, oil-bearing channels, geologic models, oil recovery factor, hydrocarbons, geologic prospecting, in-place potential resources.*

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ALTERNATIVE SOURCE OF NATURAL GAS AND ITS PRODUCTION POTENTIAL

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Abstract. To date, producing natural gas fields are substantially depleted. Gas hydrate fields are promising production targets, which can enable manifold increase of the resource base and unlock the potential of existing fields under development, particularly given that this is the largest undeveloped unconventional gas source.

Russia is currently lagging too far behind global trends in natural gas hydrate research, while some countries are planning to proceed to the pilot development stage in the nearest future. That is why this issue is of particular interest.

This study is targeted at gas hydrate accumulations of West Siberia associated with the highest production potential.

The purpose of this project is to validate a replicable method for identification and evaluation of promising gas hydrate deposits based on detailed study of mode of occurrence, geological and field analysis and properties of gas hydrate-bearing rocks. Other objectives include assessment of gas-hydrate resources, production potential and cost-effectiveness analysis through the example of NK Rosneft' field.

The study involved analyses and systematization of Russian and international experience in identification, characterization and development of gas hydrate accumulations; definition of the main criteria of the presence of gas hydrate accumulations, identification of potentially productive gas hydrate accumulations in West Siberia. Methods for identification of gas hydrate accumulations and estimation of porosity and saturation were proposed and validated. A gas hydrate accumulation was identified within the field under study; a simplified reservoir simulation model was used to assess the resource potential of gas hydrate in-place and development opportunities. The project is economically viable.

Results obtained to date provide significant insight into geological and geophysical aspects of gas hydrates, principles of prospecting, identification and assessment of resource potential of gas hydrate accumulations as demonstrated by the example of NK Rosneft's field.

Key words: *natural gas hydrates, natural gas, hydrate stability, permanently frozen rocks (permafrost), potentially productive zone, resources, gas hydrate development.*

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VOSTOCHNO-URENGOISKOYE+SEVERO-YESETINSKOYE FIELD: DETERMINATION OF FLUID CONTACT DEPTHS IN GAS-CONDENSATE RESERVOIRS WITH OIL RIMS

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Abstract. This paper presents solutions for detecting fluid contacts based on downhole logging, flow testing, and well logging in gas condensate reservoirs with oil rims.

The horizon under study is BU_{16}^{1-4} which is a heterogeneous reservoir made of shelf sediments. The reservoir comprises a number of lenticular bodies containing oil, gas, and condensate. In some of the lenses, oil rims and underlying aquifers are present. Problems of determining reservoir fluid content and fluid contact depths are attributed to:

- Lithological variation due to reservoir geology
- Uncertainty of formation water salinity due to poor quality of the available downhole water samples
- Influence of secondary rock changes on well logging results.

These issues will be discussed later in details. The reservoir under study is characterized by lithological variation of rocks. Facies have different porosities and permeabilities depending on pore size and configuration, as well as on grain size and packing. Procedure for facies identification from core data and well logging data has been developed. Individual porosity-permeability relationships have been obtained from SCAL (special core analysis) to update their distribution.

The paper also reviews the problem of uncertainty in formation water salinity. The available water samples have been analyzed to exclude zones with flush fluid. Only one out of all the available BU_{16}^{1-4} water samples proved to be of good quality, with salinity of 4.7 g/l. This data was used when developing a petrophysical model to estimate oil and gas saturation by a resistivity method.

A factor that complicated development of a reservoir saturation model was the effect of secondary rock changes, including zeolitization which amounts to 7%. Zeolitization significantly affects well logging results. Reservoirs containing zeolite are often mistaken for gas-bearing formations, which in turn complicates determination of fluid content and fluid contact depths. The paper presents an attempt to identify reservoir intervals prone to zeolitization based on well logging results.

The paper considers a problem of determining fluid contact depths in gas condensate reservoirs with an oil rim by the example of $BU16^{1-4}$ horizon of the Vostochno-Urengoiskoye+Severo-Yesetinskoye field. A suite of methods has been proposed to determine fluid content and fluid contact depths that recognize complex lithological structure and formation water salinity uncertainty. This allowed updating WOC and GOC, as well as developing a program of further reservoir study.

***Key words**: horizon, reservoir, oil rim, fluid contact, Lithotypes, fluid content*

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IDENTIFICATION OF CRUDE GAS CONDENSATES BASED ON FLUID COEFFICIENTS (BEREGOVOYE FIELD)

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Abstract. Crude gas condensate is an essential refinery feedstock. Volume of produced condensate directly depends on current operation conditions in wells producing from gas condensate reservoirs. However, differences in reservoir fluid composition and properties within one development target cause uncertainties in hydrocarbon production planning.

The paper reviews methods based on fluid coefficient analysis which are aimed at precise definition of condensate type. This will enable efficient planning of production volume and forecasting quality of condensate feedstock. The suggested method of condensate type identification allows more consistent estimation of C_{5+} reserves for the whole field.

Key words: *condensate, crude gas, gas condensate studies, fluid coefficient, C5+ potential reserves*

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MODELING OF SATURATION BEHAVIOR BASED ON SEISMIC FORECAST OF PETROPHYSICAL PARAMETERS (on the example of Achimov deposits of a field in YANAO)

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Abstract. The paper considers a problem of water saturation determination in the interwell space based on comprehensive analysis of well logging and seismic data, as well as identification of reservoirs with high potential of water breakthrough.

The authors analyze relations between elastic parameters and petrophysical properties and saturation, and present procedure for generation of a resistivity cube using a neural network algorithm. Quality assessment has been performed, as well as analysis of production operations effect on input data used for resistivity cube forecasting. The paper presents actual drilling data confirming water saturation forecast made from seismic data. It also demonstrates how the results obtained affect the final geologic model and reserves estimation.

Key words: *sedimentary deposits, gas field, water producing interval, seismic forecast, neural network*

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HYDRODYNAMIC MODULAR UNIT FOR PREVENTING ASPHALT-RESIN-PARAFFIN DEPOSITS

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Abstract. In recent years, formation of asphalt-resin-paraffin deposits on the inner surface of tubing strings has been one of the main complicating factors in oil production. Consequently, it is necessary to move in the direction of improved methods directed at eliminating and preventing the formation of asphalt-resin-paraffin deposits.

The application of the hydrodynamic method to prevent and remove borehole deposits from the inner walls of tubing has become one of the promising methods.

The study identified the problem concerning the formation of asphalt-resin-paraffin deposits in downhole equipment which leads to a number of negative consequences. Methods for deposits preventing and removing already formed deposits were considered and analyzed.

The main disadvantages of existing methods were identified. The improved hydrodynamic method is proposed which is free of the problem of blocking the flow section of the tubing string.

The method involves special equipment including a direct-flow swirler. The downhole process module with fluid direct-flow swirler has been developed.

When the fluid flow passes through the direct-flow swirler it is converted into a pulsating turbulent flow by pressure fluctuations in the peripheral zone, flow velocities redistribution takes place. This leads to effects on the walls of the tubing.

Simulation flow modeling in the direct-flow swirler was carried out using the SolidWorks Flow Simulation software. It was found out that increasing the temperature of the oil and gas flow has a positive effect on preventing the deposits formation on equipment walls. The graphs of swirling and flow temperature were analyzed.

The authors of the article revealed that an increase in the intensity of the flow swirling intensifies heat release in the system. As a result, the simulation proved the effectiveness of the design and revealed the right cross-section of the swirler.

Key words: *asphalt-resin-paraffin deposits, borehole deposits, preventing, tubing, downhole equipment, hydrodynamic effect, swirler*

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APPROACHES TO THE ESTIMATE OF CHEMICAL REAGENTS EFFICIENCY ON THE DOMANIC DEPOSITS CORE MATERIAL

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Abstract. Due to the depletion of developed fields with conventional hydrocarbon (HC) reserves, it is currently important to study the impact of chemical reagents being part of acidic compositions for bottomhole zone treatment in tight Domanic rock wells. In the Bavlinskoye field, productive reservoirs of low permeability Domanic sediments are represented by carbonaceous differences of rocks, with interlayers of low permeability and rich in organic matter lime-siliceous or siliceous-calcareous rocks, as well as minor fractured rock interlayers in the cross-section.

The basic method of enhanced oil recovery from carbonate reservoirs is compositions based on hydrochloric acid (HCl), the application of which allows to restore reservoir permeability due to the formation of new highly conductive pore channels ("wormholes"). The effectiveness of this method depends primarily on the depth of penetration of the active acid into the reservoir and on the completeness of reservoir rock dissolution in the acid solution. Experimental studies have shown that the structure of these channels is determined by the operating conditions of the formation, including temperature, the rate of injection of the acid solution, the filtration properties of the formation, and the properties of the reagents.

In the process of treating the bottom-hole formation zone (BHZ) with industrial hydrochloric acid HCl, its maximum impact on the rock occurs in the near-wellbore zone (NWZ). In the remote zone of the reservoir, the reaction of acid with the rock is less intense due to the partial loss of its activity. As the result, this wellbore zone is treated more intensively to form the maximum number of dissolution channels at the expense of the depth of channels penetration into the remote reservoir zone. Often, the low efficiency of acid treatments on low-permeability reservoirs of Domanic deposits necessitates their repeated implementation. Therefore, physicochemical improvements of the composition formula and designing acid treatment with due consideration for the whole variety of factors affecting the efficiency are of topical importance.

To increase success of carbonate matrix acid treatment, it is necessary for wormholes to penetrate deeply into the reservoir with the minimum volume of acid. It is the optimal injection rate of a certain acid composition that creates the conditions under which a minimum volume of acid solution is required to form the most effective wormhole channel.

The full consideration of factors that significantly affect the efficiency of the impact (geological and physical parameters of productive strata and technological parameters related to the characteristics of reservoir development) would very likely help to choose the optimal structure and design of acid exposure.

The main function of acids during the reservoir bottomhole treatment is relatively fast and complete dissolution of the rock matrix and the components in contact with reservoirs that clog the void space. The mechanism of this interaction is determined by their mineralogical composition and surface condition, as well as, to a large extent, by the nature, concentration of acids, and physical conditions of the dissolution process. Due to this, the rate and completeness of dissolution of solids can vary within wide limits depending on the specific downhole conditions.

Under Agreement 14.607.21.0195 and as part of the Federal Target Program “Research and Development in Priority Directions for the Development of the Russian Science and Technology Complex in 2014–2020”, Almetyevsk State Oil Institute carries out work on the theme “Development of Scientific and Technological Solutions for the Development of Unconventional Reservoirs (Domanic Deposits) and Hard-to-Recover Oil (Bituminous Oil) Based on Experimental Studies”, which is focused on improving the process of production intensification with application of acid compositions in wells drilled in Domanic deposits.

Emerging new conditions of development of non-conventional oilfields provide for application of enhanced approaches in studying the features of acid treatments on Domanic sediments. Based on the assessment of existing standards governing the conduct of flooding research, the authors propose a methodology for conducting filtration experiments with acidic compositions for wells bottomhole treatment. In this work we show the results of studies evaluating the efficacy of compositions used for BHT with intensifying fluid influx into wells drilled in Domanic sediments.

Key words: *domanic sediments, flooding research, core material, permeability, acid composition, low permeability reservoir.*

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STATE-OF-THE-ART TECHNOLOGIES IMPROVE THE QUALITY OF CASING CEMENTING IN OIL AND GAS WELLS OF THE ROMASHKINSKOYE FIELD AREAS AT LATE STAGES OF DEVELOPMENT

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Abstract. The paper addresses one of the urgent oil production issues: extending the life of oil and gas production wells due to improved quality of casing cementing.

This issue is very important because of poor technological and economic performance of squeeze cementing operations required to eliminate casing leaks and cross flows between beds, which commonly result from reservoir pressure changes and chemical corrosion of cement sheath behind the casing. Shortcomings of modern casing cementing technologies and inadequate cement slurry formulation aggravate these negative effects.

The proposed solution to these problems relies on a well-proven method of vibration of oil well cement combined with well-established acoustic logging technology. For this purpose, the geological and technological package “Zaboy” was developed to integrate a vibrator module and acoustic cement bond logging module.

Field testing of the “Zaboy” package has demonstrated slower water cut upturn in wells treated during waiting on cement for a long time (up to 14-15 years) compared to the rest of the wells, while maintaining initial productivity over a longer period of time.

Moreover, integration of the effects of vibration with acoustic cement bond logging tool enabled monitoring of cement-to-formation bonding and selective treatment of individual intervals (caverns, low-permeable formations, etc.), this significantly improved the quality of cementing.

Key words: *cementing, vibration effect, waiting on cement (WOC), geological and technological package, acoustic well logging method.*

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RESEARCH OF RESERVOIR PRESSURE ERROR AFTER WELL SERVICING BY SPECIAL WELL TEST EXPERIMENTS

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Annotation. Due to increasing of low-cost reservoir pressure control approaches without special well stopping approved on certain oilfields there is a necessity of their applicability conditions and restriction definition.

The aim of the work is establishing applicability of some pressure formation control approach published in the references and based on usage of borehole washing density and static level after well servicing as formation pressure estimations. In the present work pressure estimation error was arrived by designing, accomplishing and analysing special well test experiments. Reservoir pressure error was estimated with regard to reservoir pressure from buildup tests. Bottomhole pressure was being recorded during experiments by downhole pressure and temperature gauges.

As results of work empirical relationships between reservoir pressure and formation transmissibility for two geological layers were established – the greater transmissibility, the less the reservoir pressure error. In spite of economical advantages of approach under discussion for low permeability formations and layers with high viscosity fluid reservoir pressure determination error is over 10%.

Results are valid only for fixed well killing operation technology: water or oil-based well-killing fluid application, well washing through casing or tubing. There is no guaranty of test result pretension for another technologies. Necessity of pressure calculation from static level to pressure will increase reservoir pressure estimation error.

Key words: *Formation pressure control; formation pressure; static fluid level; well servicing; borehole washing.*

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COMPARATIVE ANALYSIS OF EFFICIENCY OF DRILL AND MILLING PERFORATION IN PRODUCTION AND INJECTION WELLS OF NGDU AZNAKAEVSKNEFT – PJSC TATNEFT

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Abstract. In this paper, efficiency of various modifications of drill perforation intended for deep reservoir drainage and core sampling is analyzed. Real field data obtained from production and injection wells at different production areas of NGDU Aznakaevskneft from 2011 to 2014 were used.

Field testing of perforators demonstrated that PS-500 drill perforator with increased drill exit (up to 40 cm) has undeniable advantages over the PF 112/35 milling perforator-core sampler with milling cutter exit of not more than 5 cm.

PS-500 perforator produces 20-mm holes while milling perforator PF-112/35 yields 35-mm holes. It was proved, however, that the difference in perforators' field performance is not attributable to diameter but rather to the depth of penetration, which enables, at least partially, to pass through formation damage area in bottomhole formation zone resulting from invading mud and cement filtrate.

The authors make a reasonable conclusion that such an advantage of the PS-500 perforator makes it the most technological and cost-effective well intervention solution to increase the productivity of old production wells.

Key words: *drill perforation, milling perforation, formation damage area, perforator exit, specific production rate, idle time.*

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EFFECT OF WATER ON PERFORMANCE OF SUMMER DIESEL FUEL CONTAINING OXYGENATES

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Abstract. The paper discusses the effect of water on performance of diesel fuels containing various mixed oxygenates (alcohols, ethers). Maximum water amount has been determined that does not cause deterioration of low-temperature properties, oxidation and ignition characteristics of summer diesel fuels containing mixtures of oxygenates.

Key words: *diesel fuel, additives, water, oxygenates*

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CONCEPT OF COMPUTER-AIDED PLANNING OF LAB EQUIPMENT AND MAN LOADING BASED ON "RN-LAB" IS PLATFORM TO OPTIMIZE WORKFLOW

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Abstract. The paper discusses the problem of planning of the workflow of laboratories involved in core analyses and PVT-studies. An approach to planning of laboratory equipment and man-loading based on the method of multiparametric optimization considering the probability distribution of activities and application of the Pareto principle of optimality is offered.

The novelty of the offered planning approach consists in the capabilities of computer-aided distribution of resources and making the job schedule in such a manner that any change of the operating procedures differing from the planned activities would extend the period of the whole volume of lab studies execution.

Key words: *distribution of resources, planning of activities, core analyses, PVT studies, Pareto, multiparametric optimization.*