DEVELOPMENTS OF FSUE CRISM «PROMETEY» IN THE FIELD OF MATERIALS FOR ARCTIC APPLICATIONS

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SHIPBUILDING STRUCTURAL MATERIALS

HIGH-STRENGTH AND COLD-RESISTANT STEELS

RADIATION-RESISTANT STEELS

ALLOYS WITH SPECIAL PHYSICAL PROPERTIES

BIMETALS

COMPOSITE POLYMERIC MATERIALS

WELDING CONSUMABLES

TITANIUM-, ALUMINIUM- AND COPPER-BASED LIGHT AND NONFERROUS ALLOYS

FUNCTIONAL MATERIALS
Design temperature for operating offshore facilities:
Tp down to -50°C…-60°C for freezing seas,
Down to -35°C – for open seas

Thickness range:
- for ice-breakers - up to 60mm-70mm;
- for stationary platforms and mobile drilling rigs – up to 70mm, with some components up to 130mm;
- for subsea pipelines -  up to 40mm.

Operating conditions:
- static, cyclic and dynamic loads;
- high internal pressure - up to 22-25 MPa;
- corrosion attack.

Ice loads: N \approx 10^7 cycles

Wave and wind loads: N \approx 10^8 cycles
<table>
<thead>
<tr>
<th>Structure type</th>
<th>Operational factors</th>
<th>Possible fracture mechanisms</th>
</tr>
</thead>
</table>
| Ice-resistant platforms, TLP- and SPAR-type platforms, riser systems | Specified temperatures: above-water parts: down to -40°C  
- bottom parts: -10°C  
Wave load: up to $10^8$  
Turbulent flow and vibration loads: up to $10^{10}$  
Ice load: N~$10^7$  
Thickness range: up to 130mm | Brittle failure, low- and high-cycle fatigue, corrosion-erosion ice belt failure  
All forms of corrosion failure |
| Ice-breakers, tankers                             | Specified temperatures: above-water parts: down to -40°C  
- bottom parts: -10°C  
Wave load: up to $10^8$  
Vibration load: up to $10^{10}$  
Ice load: N~$10^7$ | Brittle failure, high-cycle fatigue, corrosion-erosion ice belt failure  
All forms of corrosion failure |
| Underwater pipelines                             | Specified temperature: -10°C  
Thickness range: up to 40mm  
Pressure: up to 250 MPa | Brittle and ductile fracture  
Corrosion cracking |
CONTROL OF THE FORMATION OF NONMETALLIC INCLUSIONS AND STRUCTURE OF CAST SEMI-FINISHED PRODUCTS

With ladle treatment (addition of an alloying Si-Ca composition)

DIGITAL ANALYZER «THIXOMET». THE DEVICE ALLOWS SCANNING ELECTRON DIFFRACTION PATTERNS OF ANY SIZE TO BE EXAMINED

Volume fraction of oxides

Volume fraction of sulphides

Volume fraction of inclusions

SPECIAL PROCESSING MEASURES ALLOW THE REQUIRED STRUCTURE TO BE FORMED AFTER CRYSTALLIZATION

Pouring into moulds

Continuous casting

Melting

Ladle treatment

Degassing

Volume fraction of sulphides

0.00
0.05
0.10
0.15
0.20
0.25
0.30

Volume fraction of oxides

0.00
0.05
0.10
0.15
0.20
0.25
0.30

Al₂O₃ · CaO · CaS composition inclusions

Calcium aluminates CaO · 6Al₂O₃

Spinel MgO · Al₂O₃

Globular calcium sulphides CaS

max min
Nonuniformity of temperatures and strains across large-sized semi-finished products results in structure thickness heterogeneity if no measures aimed at forming their quasi-isotropic structure were taken.

Methods of forming a quasi-isotropic structure across the thickness:

1. Selection of chemical composition with a wide range of forming structures similar in their morphological type.

2. Development of special temperature strain rolling conditions providing:
   - no anisotropy;
   - austenitic grain refinement and fragmentation in high- and low-temperature regions.
PRINCIPLES OF STRUCTURE FORMATION IN STEELS WITH YIELD STRENGTH OF 235-460 MPa

REQUIRED STRUCTURE

CHOICE OF OPTIMAL CHEMICAL COMPOSITION AND STRUCTURE

METALLURGICAL QUALITY ASSURANCE
Without technological optimization

DEVELOPMENT OF PROCESS PARAMETERS
Formation of a heterogeneous structure across the thickness without optimization of parameters

T_{brittleness} = -20°C

Formation of a homogeneous structure across the thickness with optimization of parameters

T_{brittleness} = -70°C

Anisotropic structure
Quasi-isotropic structure

OPTIMAL PRODUCTION TECHNOLOGY

Melting
Ladle treatment
Multistage deformation
TMT

Higher characteristics
Mechanical properties and impact energy
Resistance to stress-corrosion cracking
Weldability
Cold resistance and crack resistance
PRINCIPLES OF STRUCTURE FORMATION IN HIGH-STRENGTH STEELS WITH YIELD STRENGTH OF 500-690 MPa

REQUIRED STRUCTURE

CHOICE OF OPTIMAL CHEMICAL COMPOSITION AND STRUCTURE

METALLURGICAL QUALITY ASSURANCE
Without technological optimization

OPTIMAL PRODUCTION TECHNOLOGY
Melting
Ladle treatment
Multistage deformation
TMT

Formation of a heterogeneous structure across the thickness without optimization of parameters

Formation of a homogeneous structure across the thickness with optimization of parameters

T_{brittleness} = -20°C

T_{brittleness} = -70°C

Higher characteristics

Mechanical properties and impact energy
Resistance to stress-corrosion cracking

Weldability
Cold resistance and crack resistance
SELECTION OF CHEMICAL COMPOSITION FOR FORMATION OF A STRUCTURE WITH SPECIFIED RATIO AND MORPHOLOGY OF STRUCTURAL CONSTITUENTS

Carbon equivalent

$CE = 0.53$

$CE = 0.61$

$CE = 0.73$

A HIGH-SPEED DILATOMETER «DIL 805 BAHR TERMOANALYSE» IS USED FOR PHASE TRANSITION INVESTIGATIONS AND SIMULATION OF COMMERCIAL STRAIN AND COOLING CONDITIONS
EXAMINATION OF FRACTION AND SIZE OF STRUCTURAL ELEMENTS

Microhardness of bainitic steel specimens varies according to the fraction and size of fragments.

- Average size: 2.71 µm, fraction of fragments less than 500 nm - 20%
- Average size: 1.1 µm, fraction of fragments less than 500 nm - 37%
- Average size: 1.24 µm, fraction of fragments less than 500 nm - 29%
COLD-RESISTANT STEELS SHOWING HIGHER BRITTLE FRACTURE RESISTANCE

Ordinary structural steel

Cold-resistant steel

Test temperature is -40°C

Full-thickness specimens

Brittle fracture

Ductile fracture
MECHANICAL PROPERTIES OF ROLLED STEEL PLATES
MADE BY TMCP

FRACTURE PHOTOGRAPHS OF FULL-THICKNESS SAMPLES

Grade F32W, 50mm thick, TMCP
Grade F36W, 40mm thick, TMCP
Grade F460W, 50mm thick, TMCP
Grade F500W, 30mm thick, DQ + tempering
SOUND WELDED JOINTS ARE OBTAINED WHEN COLD-RESISTANT STEELS ARE WELDED WITHOUT PREHEATING AT ASSEMBLY OF ARCTIC STRUCTURES

Ordinary structural steel

Cold-resistant steel

Cracks

Welding temperature is -100°C

No cracks
COMMON-USE CENTRE

Resolution – 0.1 nm
Locality of measurements – 10 nm
Magnification – over x1,000,000

A dual-beam microscope
FEI Quanta 3D FEG

An IFT-1500M internal friction measuring system

A transmission electron microscope
Tecnai G2 30 S-TWIN

An atomic-force microscope
NanoScan

A time-of-flight mass spectrometer
with gas-discharge ionization
ЛЮМАС-30
COMMON-USE CENTRE
(The centre is provided with process equipment including 76 units)

A supersonic cold gas-dynamic spraying system チメテ-403
A microplasma spraying system with a robot-manipulator MPS-004
A magnetron spraying machine МАГНА-TM5

Nanostructured and functional coatings

Vibrodamping coatings
Wear-resistant coatings
Catalytic bulk-porosity coatings
Electromagnetic protection system nanocomposites

An ultra-high speed desintegrator Дези-11
A plasmochemical synthesis plant ПУР-1
A laser synthesis plant LENS
An electrochemical surface alloying plant ЭЛОП

SURFACE NANOStructURING OF CONVENTIONAL MATERIALS ALLOWS A SET OF CONSUMER PROPERTIES TO BE IMPROVED CARDINALy
ADVANCED MATERIALS INTENDED FOR USE IN MODERN ENGINEERING
COMMON-USE CENTRE
(The centre is provided with on-line control equipment including 30 units)

Chemical and phase composition

- A high-resolution diffractometer Bruker D8 Advance
- An X-ray fluorescence analyser Niton XL3

Structure

- A nanostructure scanning hardness gauge Super Nanoscan
- An atomic-force microscope NanoScan

Properties

- A catalytic activity measuring system BICATrCH4
- A porosity measuring system Sorbtometre M
- A wear-resistance measuring system

FSUE CRISM «Prometey»
MANUFACTURING OF DISPERSED NANOSTRUCTURED POWDER MATERIALS USING SUPERSPEED MECHANIC SYNTHESIS

Manufacturing of reinforced powders

Manufacturing of clad powders

Advantages of this technology:
✓ material structure is not disturbed;
✓ high efficiency of plants as compared to planetary, ball mills.

- High-speed mechanic synthesis of nanostructured reinforced and clad powder materials (the speed of a working rotor is 300 s⁻¹).

- Milling and manufacturing of powder materials of different classes and purposes (including magnetic, magnetostrictive, catalytic, wear-and corrosion-resistant materials and soldering alloys) with a dispersion from 1μm and more and hardness up to a value of 10 on the Mohs scale.

- The capacity of plants is from 5 up to 100 kg/h, powder materials can be processed in air, inert medium and vacuum.

SUPersonic Cold Gas-Dynamic Spraying Technology

Applying metallic coatings to metallic and nonmetallic surfaces

Advantages:
- Applying of temperature-sensitive materials (the temperature of sprayed particles does not exceed 150°C)
- Possibility of forming functionally graded coatings
- Thickness of a layer to be applied is practically unlimited, till some millimetres
- Possibility of applying nanostructured coatings
- Special surface preparation is not required
- High mobility, low power consumption (2.5 kW)

Tasks to be solved:
Development of technologies and production of coatings of the following classes: corrosion-resistant, wear-resistant, catalytic, electrically conductive, heat-resistant, vibrodamping ones.

- Applying of metals and ceramic metals
- High adhesion – up to 70 MPa
- Development of composite nanostructured coatings with hardness up to 800 HV
- Low porosity of coatings, less than 1%
- Applying of amorphous soldering alloys
- Filling-in of cracks, cleavages and caverns
- Restoration of shape and dimensions of worn-out parts

They developed:
- a technology of forming coatings using nanostructured composite powders by the method of mechanical activation synthesis;
- a technology of forming functionally graded coatings using more than one feeder.

Applications:

Oil-and-gas production

Corrosion and erosion protection
- Protective coatings applied to the inside surface of offshore drilling platform risers
- Al-Zn alloy coatings

Marine engineering
Wear-resistant and friction coatings
- Ship slide bearings used in ships

Nuclear power engineering
Soldered joints
- Applying of amorphous soldering alloys for heat exchanging modules

- Wear-resistant coatings applied to the mounting surface of a turbine bearing liner

Repair-and-reclamation operations
- Repair of corrosion areas and restoration of products to their original appearance
A robot-manipulated microplasma spraying system is intended for applying functional coatings from 0.05 mm up to several mm in thickness to metallic surfaces of parts and assemblies by the above method.

**Potentials of microplasma spraying:**
- repair of casting defects (pores, cavities, discontinuities) and operational ones (nicks, cracks) defects;
- restoration of geometrical dimensions and strengthening of friction surfaces of high-alloy steel and cast high-temperature Fe- and Ni-based alloy parts;
- restoration of worn-out parts of different machines and mechanisms including gas-turbine aircraft engines;
- local applying of wear-resistant and high-temperature materials to the parts and assemblies of different equipment;
- applying of bronze, titanium, nickel, aluminum and other materials of 0.5 mm and more in thickness with their porosity of 1-3% to different parts and assemblies.

**Advantages of the technology over conventional methods:**
- use of a flexible supply line allows work in hard-to-reach places to be done and makes the process of powder material applying mechanized;
- high adhesion strength (not less than 40 MPa);
- minimum heating and deformation of a product to be treated;
- possibility of using thin-walled structures;
- possibility of restoring sharp edges, e.g., end faces of compressor blades, combs of compressor labyrinths and bandage flanges of working blades;
- high efficiency of the process.

**Materials to be sprayed:**
- pure metals, wear- and corrosion-resistant alloys, oxides, nitrides, borides;
- materials with different structure (intermetallic, amorphous, quasi-crystalline and nano-structured materials)
**MAGNETRON SPRAYING**

Applying of metallic and non-metallic coatings in dynamic vacuum using autonomously controlled magnetrons with a variable power

**Advantages**
- efficient ionization
- low temperature of sublayer
- absence of drop phase
- no contaminations in coating
- full stoichiometry of cathode material
- coating thickness - up to 5 μm

Magnetron spraying allows for applying of coatings with complex compositions practically upon any material.

Developed is a technology of vacuum magnetron precipitation using three simultaneously operating cathodes made of dissimilar materials. This allows for carrying out efficient control over technological process and obtaining a coating with a set chemical phase composition. This unique method provides for creation of functional-gradient coatings due to gradual increase of pressure of reaction gas in working chamber by a selected law. At first this method provides for applying adhesion layer, and then, growth of a coating with set properties.

**Tasks which could be solved**
Development of technologies and production of coatings of the following classes: corrosion-resistant, wear-resistant, catalytic, current conducting, refractory, vibration absorbing, decorative.

- applying metals, oxides, nitrides, carbides and their different compositions
- high adhesion of coatings up to 90 MPa
- creation of nano-structured coatings with a strength up to 25 MPa
- coatings can be applied upon ceramic materials, glass and metals

**Ships and marine equipment**
- elements of marine equipment control systems
- anticorrosion protective coatings based on titanium nitride

**Oil industry**
- anticorrosion coatings of threaded joints operating in contact with aggressive media
- parts of different shut-off and commutation valves
- protective membranes

**Water purification and freshening systems**
- water purification systems without using changeable cartridges (Ti-RuO)

Industrial anode made of punched nets covered with coating of OPTA type base of titanium (70%) and ruthenium (30%) oxides obtained using two simultaneously operating magnetrons out of dissimilar materials.

**Aircraft equipment**
- elements of control systems
- gas turbine blades

**Medicine**
- medical tools
- antibacterial coatings based on titanium oxinitride

Nano-structured coating out of tantalum. Specimens are used in surgical operations of head vessels without skull trepanation.
Sublayer – polyurethane, coating thickness – 24 μm

Industrial specimen of a head used in operations by laparoscope method
LASER SHAPING OF PARTS AND COATINGS

This technology is based on selective laser sintering of metal powder layers according to computer model data

A laser scanner MODELMaker D for digitizing of physical objects

Plants for layer-by-layer synthesis of models made of metal-powder compositions by the method of laser surfacing (PLANT LENS 750) and laser sintering (PLANT EOSINT M270)

Materials to be used: metallic powders made of pure metals and Ti, Ni, Co, Al, Cu alloys as well as other alloys and steels of different purposes.

Capabilities of the plants:
- 3D- and CAD-modelling of complex-shape products with possibility of further use in RP-technologies;
- ideally suited for reverse-engineering tasks;
- control and analysis of product shape deviations;
- quick development of complex-shape products (including those with complex internal cavities) in one work cycle, including products which are difficult or impossible to obtain by conventional methods (turbine blades, pump impellers, thin wire dies, control system elements, etc.);
- restoration and repair of complex-shape parts and products;
- production of functionally graded coatings;
- manufacturing of custom-made and individual medical products (prostheses, implants, instruments);
- possibility of producing unique-design products and exclusive souvenirs.

Advantages of the technology:
- local and minimum heat input in modelling and restoration of parts;
- development of functionally graded materials, mosaic alloys and artificial structures;
- economic and quick manufacturing of parts of desirable shape with unique properties;
- quick cooling down (>10^4 K/s) and structure control;
- use of controlled shielding atmosphere.
MAGNETIC AND ELECTROMAGNETIC PROTECTION SYSTEMS

Materials used in these systems: nanocrystalline Fe-Nb-Cu-Si-B and Co-Ni-Si-B alloys

Technical characteristics:

**Shielding systems**
- Magnetic screen width - 510 mm length - up to 150 m
- Thickness of one layer - from 80 up to 85 μm
- Weight of 1 m² of a single-layer screen - 0.25 kg
- Screening factor in the 50-10³ Hz frequency range - from 10 up to 250 (depending on the intensity of magnetic field and the design of a screen)

**Radio absorption systems**
- Amorphous powder fractional composition - from 3 up to 100 μm
- Weight of 1 m² of radio absorption material - from 3 up to 45 kg
- Electromagnetic field attenuation factor (1 MHz-1GHz) - more than 10 dB/mm
- Reflection factor by power (100-10000 MHz) - lower than 10 dB

**Applications**
- Magnetic field shielded rooms
- Shielded power cables
- Personal protective equipment
- A shielding jacket
- Screened room
- A radio absorption composite
- PC, mobile phone, digital camera and camcorder, GPS radiation protection.

The Research & Production Experimental Complex of FSUE CRISM “Prometey” provides the small-scale production of the materials.
Applications:
- survival equipment (a life buoy, a life jacket, a lifeboat, a life raft);
- navigation safety systems (leak sensors)
- underwater and diving equipment;
- deep-water equipment, including that operating at a depth reaching 6000 m;
- standby power supply systems

Basic technical characteristics:
- nominal voltage, V - 2.5-6.0
- specific mass energy, W·h/kg - 200-220
- warm-up time, s ........10

Advantages as compared to similar products:
- stability of discharge characteristics;
- no self-discharge;
- storage time .......... up to 10 years;
- environmental safety in storage and service;
- high reliability and ease of service.

Independent chemical current and heat sources for search-and-rescue equipment used at sea, underwater and diving equipment, leak sensors

An efficient nanocomposite-base catalytic system used for water purification and desalination

Independent plants of “KASKAD” type with a capacity up to 15 m³/h are developed for the water purification and desalination systems of ships and vessels, different objects of the Ministry of Emergency Measures, remote settlements.

These systems provide efficient water purification from:
- all kinds of microparticles – bacteria, viruses, protozoa (with their waste products);
- humus particles and minerals;
- insoluble oil products;
- ions of heavy metals, phosphates, sulphides, nitrites, cyanides, phenols and so on.

Water purification and desalination plant “KASKAD”

Water purification efficiency

The Research & Production Experimental Complex of FSUE CRISM “Prometey” provides the small-scale production of the materials.
Simulation of processes of hot deformation and thermomechanical treatment of metals, welding processes, phase transformations

- Achievable heating rate – 13.500°C/s
- Achievable cooling rate – 9.500°C/s
- Maximum linear strain rate – 2.5 m/s
- Achievable strain rate – 200 s⁻¹
- The number of controlled heating, cooling and deformation operations is not limited

Simulation of hot and cold rolling processes

Simulation of bending loading. Study of cold hardening and structural recrystallization

Unit for obtaining nanostructured specimens. Severe plastic deformation
HOT-ROLLING MILL «QUARTO 800»

Shears

Drive

Cooling zone

Stand «Quarto 800»

Manipulator

6420 mm

12760 mm

17850 mm

2580 mm

600 mm
TEST LABORATORY «Promtest KM» MECHANICAL TEST DEPARTMENT

- A set of test machines (tension-compression, bend; static, cyclic, dynamic load): 32 facilities from 5 kN to 10 000 kN load.
- Drop-weight and pendulum hammers: 8 facilities of the capacity from 300 to 60 000 J.
- Heating and cooling chambers: 4 facilities.
- Modern metrological instrumentation.
- Computerized recording and analysis of the data

ACCREDITED BY THE FEDERAL AGENCY OF TECHNICAL REGULATION AND METROLOGY AND BY THE RUSSIAN MARITIME REGISTER OF SHIPPING
POLYMERIC AND METAL-POLYMERIC HULL STRUCTURAL MATERIALS

Set of properties:
- density
- strength
- rigidity
- vibration damping
- sound insulation
- heat insulation
- heat resistance
- fire resistance
- environmental safety
- habitability

Base layer materials

Glass-reinforced plastics

Light alloys

Steels

Combinations of developed three-layer compositions

Plastic foams
  - PVC
  - Polyurethane foam

Syntactic foams
  - Glass
  - Ash
  - Polyester
  - Epoxy

Macrononuniform plastic foams

Macrononuniform syntactic foams

Macrononuniform three-layer composites

Vibration damping

Erosion-resistant, chemical-resistant

Decorative, fire-resistant

Polymeric coatings

Centre fillers
MULTIPURPOSE POLYMERIC AND METAL-POLYMERIC HULL COMPOSITES

Fibreglass

- High specific bending rigidity - 20 MPa/(kg/m³)

Polyfoam

- Low EMW reflection level – 0.1
- High specific strength 0.20 MPa / (kg/m³)

Radio absorption coating

- High heat-insulation properties - 0.4 W/(m · K)

Reinforced polyfoam

Elastomer

- High vibration-damping properties - 10-15 dB

Metal

- High specific strength 0.20 MPa / (kg/m³)

Fibreglass

Syntactic foam

- High sound transparency - 0.85-0.95
Compositions and technologies of producing new materials and making structures of them have been developed.

A three-layer material for the corvette superstructure sections.

ADVANTAGES:
- a 20% lower labour intensiveness;
- an extended operation life of 25 years;
- a 30% reduced weight;
- improved shock-absorbing properties (a mechanical loss factor is up to 0.05);
- nonmagnetic properties;
- their specific ultimate strength is 4 times higher than that of E40 steels.

A shock-absorbing frame structure weighing 20 t for the main corvette engines.

A full-scale fragment of the corvette superstructure 52 m in length and 70 t in weight.
NEW STEELS FOR HYDROCARBON EXTRACTION AND TRANSPORTATION IN NORTHERN REGIONS

STEELS FOR OFFSHORE STRUCTURES

<table>
<thead>
<tr>
<th>Steel Category</th>
<th>Maximum Thickness, mm</th>
<th>Operating Temperature, °C</th>
</tr>
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<tbody>
<tr>
<td>235, 315</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>355, 390</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>420, 460</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>500, 620</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>690</td>
<td>40</td>
<td>-40</td>
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Impact energy, KV, J

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</table>

Impact energy, KV, J

<table>
<thead>
<tr>
<th>Strip Category</th>
<th>Maximum Thickness, mm</th>
<th>DWTT, at-20°C</th>
<th>KV, at -60°C, J</th>
</tr>
</thead>
<tbody>
<tr>
<td>X70 (K60)</td>
<td>40</td>
<td>≥ 90</td>
<td>≥ 78,5</td>
</tr>
<tr>
<td>X80 (K65)</td>
<td>35</td>
<td>≥ 90</td>
<td>≥ 128</td>
</tr>
<tr>
<td>K70</td>
<td>30</td>
<td>≥ 90</td>
<td>≥ 128</td>
</tr>
<tr>
<td>X90</td>
<td>20</td>
<td>≥ 90</td>
<td>≥ 128</td>
</tr>
<tr>
<td>X100</td>
<td>20</td>
<td>≥ 90</td>
<td>≥ 150</td>
</tr>
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STRUCTURAL STEELS WITH NANOSTRUCTURED CONSTITUENTS
CLAD CORROSION-RESISTANT STEEL

- High bimetal strength combined with high corrosion-erosion wear
- Welding to steel without removing a cladding layer

<table>
<thead>
<tr>
<th>Thickness, mm</th>
<th>Yield strength, Re, min, MPa</th>
<th>Impact energy KV_{60}, min, J</th>
<th>Shear strength of cladding layer, min, MPa</th>
<th>Elongation, A_5, min, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 - 45</td>
<td>355</td>
<td>50</td>
<td>200</td>
<td>21</td>
</tr>
<tr>
<td>20 - 60</td>
<td>500</td>
<td>60</td>
<td>355</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>620</td>
<td>80</td>
<td>330</td>
<td>18</td>
</tr>
</tbody>
</table>

Base layer - steels differing in strength (355, 500, 590 and 620 MPa).

Corrosion resistance under ice conditions

- Nitrogen-bearing alloys as promising materials

Shipbuilding steel

Clad steel

Cladding layer – corrosion-resistant steel grades 08Cr18Ni10Ti; 8Cr19Ni10Mo2Nb; 03Cr17Ni14Mo3; (316L, 317L as per ASTM).

Outside cladding layer

Inside cladding layer

Side cladding layer as to the mandrel

32
Cold-resistant steels were applied in the offshore ice-resistant stationary platform *Prirazlomnaia*, multipurpose platforms as part of «MOSS MARITIME» series, the floating drilling rig *Arkticheskaia*, the Varandeiski deposit loading terminal.

They supplied ≈38,000 t of cold-resistant steels of E and F category.

**APPLICATIONS OF ROLLED PLATES**

- Offshore ice-resistant stationary platform *Prirazlomnaia*
- MOSS MARITIME CS 550
- Steels for nuclear power engineering
- Steels for icebreakers and compact power plants
- Steels for high-pressure vessels
FULL-SCALE GROUND TEST OF PIPES GRADE X80

THE TEST RESULTS OF PIPES DEVELOPED BY “PROMETEY” EXCEEDED THOSE OF OTHER PIPES: THE LENGTH OF CRACK PROPAGATION WAS MINIMUM – 4.5 m. THAT POINTS TO THE EXCELLENT STEEL QUALITY. THE LENGTH OF CRACK PROPAGATION IN OTHER PIPES BOTH OF HOME AND FOREIGN PRODUCTION MADE UP FROM 6 TO 77 m.
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THANK YOU FOR ATTENTION!