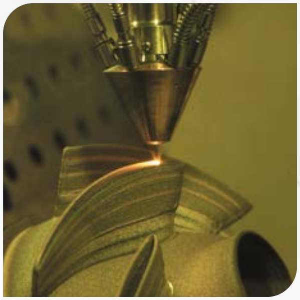
SAINT PETERSBURG STATE
MARINE TECHNICAL
UNIVERSITY

LASER AND ADDITIVE TECHNOLOGIES



ILWT
INSTITUTE OF LASER AND WELDING TECHNOLOGIES

SAINT PETERSBURG STATE MARINE TECHNICAL UNIVERSITY

SMTU is a legendary Russian university that develops unique traditions of national shipbuilding as well as participates in creation of the advanced technologies. It is the unique Russian university for training top-rated engineers in all shipbuilding specialties. Main activities are design, construction, maintenance and repair of sea-going vessels as well as technical equipment for the oil, gas and other seabed exploration and mining.

SMTU is the intellectual center of Russian shipbuilding industry, the pride of St. Petersburg – the maritime capital of Russia. During its more than 90-year history the university has trained tens of thousands of specialists in various fields. There are famous politicians and ministers, brilliant designers and engineers as well as outstanding figures of science and culture among our graduates.

MAIN SCIENTIFIC ACTIVITIES

- Methods of design, construction and repair of ships, vessels, platforms and structures
- Arctic and World Ocean research and development methods and technical means
- Laser and welding technologies, industrial robotics, additive technologies
- Physical and technological problems of power engineering in the marine equipment and other power machines and devices
- Methods and technical facilities for the improvement of energy saving technologies
- Technological equipment for manufacturing and repair of the power engineering equipment
- Methods of economical performance evaluation of industrial enterprises, improvement of their management system
- Ecology and Environmental Protection

INSTITUTE OF LASER AND WELDING TECHNOLOGIES

Institute of Laser and Welding Technologies (ILWT) was founded in 1998 for research and development in the field of laser and hybrid laser-arc material processing technologies.

Today Institute of Laser and Welding Technologies is the leading scientific school in Russia and one of the largest structures in the field of laser technologies in Europe.

The unique experience, qualified staff as well as technical and scientifical basis allow the Institute to build and maintain strong partnership with the enterprises and scientific organisations in the framework of Russian and international projects.

PRINCIPAL ACTIVITIES

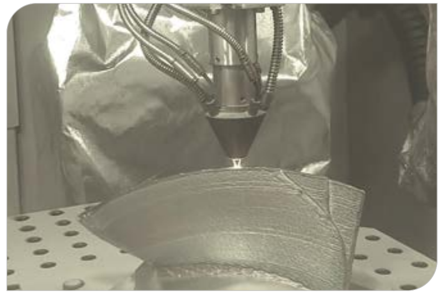
- Additive Technologies
- Laser and hybrid laser-arc welding
- Laser cladding and laser heat treatment
- Materials Science
- Numerical simulation
- Equipment design

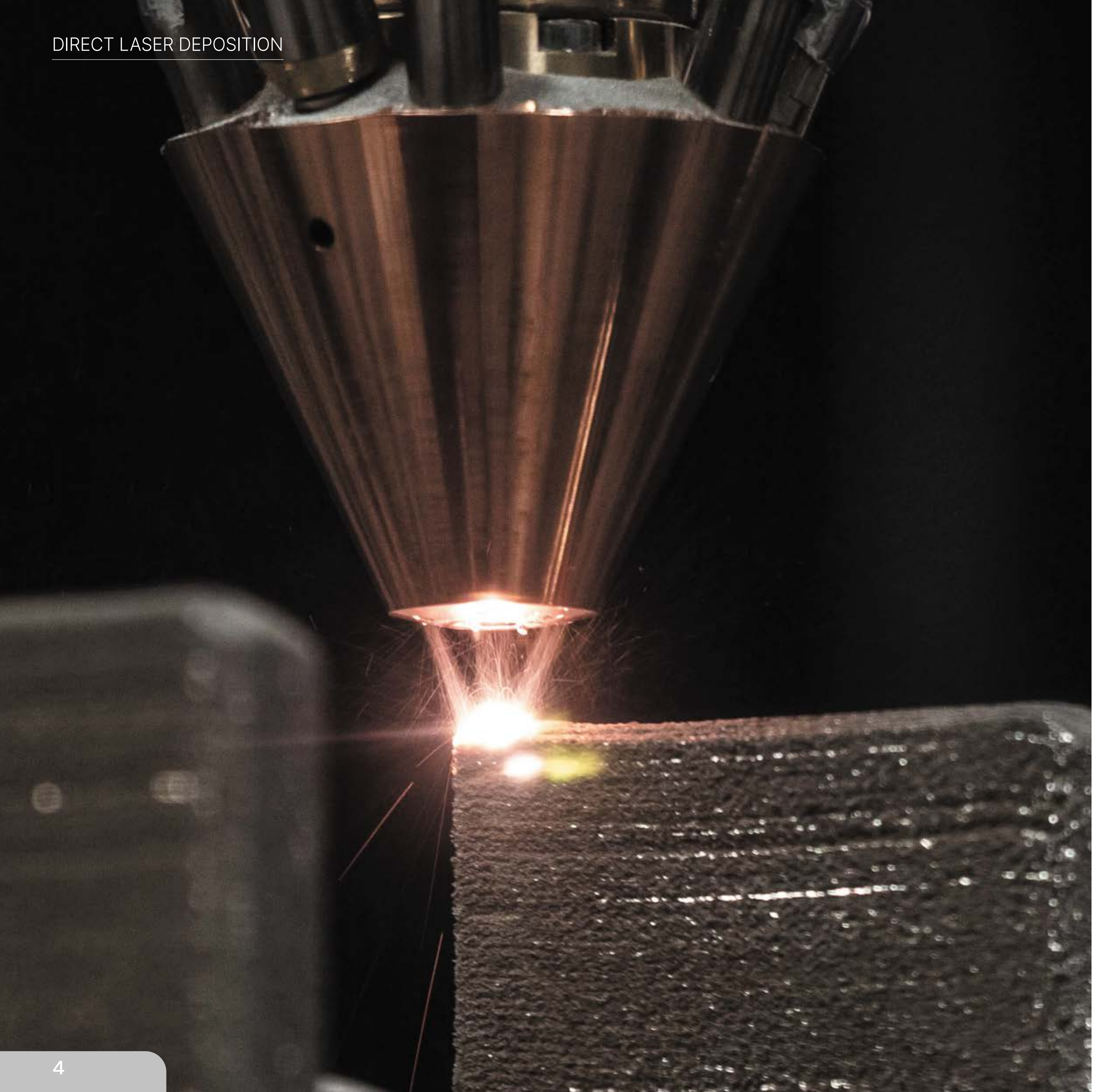
TECHNOLOGY: DIRECT LASER DEPOSITION

Technology for creating high-precision blanks of complex-shaped parts from metal powders according to specified 3D-models. The part is built from the powder fed into the laser beam impact zone. The geometry is determined by the program-defined trajectory of the technological tool.

ADVANTAGES OF THE TECHNOLOGY

- Production of large parts – up to two meters in diameter, weight – up to 8000 kg
- Absence of pores, lacks of fusion and cracks
- Mechanical properties similar to wrought material
- High deposition rate – up to 2.5 kg/h
- Ability to create complex thin-wall parts
- Ability to create gradient parts with variable chemical composition and physical properties
- Minimum machining allowances
- Creation of hybrid structures: combination of additive and conventional technologies (welding, casting, stamping, machining, etc.)
- Application of functional coatings during deposition
- Multifunctionality of technological units: laser welding, cladding, heat treatment, cutting in one machine





PRODUCT LINE OF DIRECT LASER DEPOSITION MACHINES "ILWT"

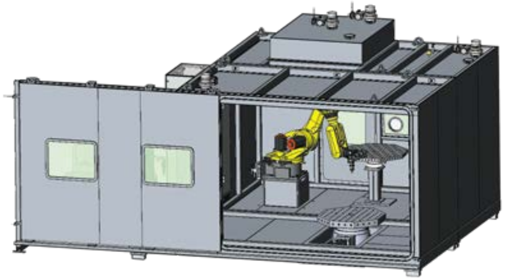
ILWT-L – Basic model of a robotic direct laser deposition machine. Dimensions of the build parts: Ø 1300 mm, h – 800 mm, weight – up to 400 kg.

ILWT-M – Dimensions of the build parts: Ø 600 mm, h – 400 mm, weight – up to 100 kg.

ILWT-L+ – Dimensions of the build parts: Ø 1500 mm, h – 1000 mm, weight – up to 1000 kg.

ILWT-XL – Dimensions of the build parts: Ø 2200 mm, h – 600 mm, weight – up to 1200 kg.

ILWT-2XL – Dimensions of the build parts: Ø 2200 mm, h – 1000 mm, weight – up to 8000 kg.



ILWT-XXL – Dimensions of the build parts: Ø 3000 mm, h – 2000 mm, weight – up to 8000 kg. In development.

"ILWT-M" ROBOTIC DIRECT LASER DEPOSITION MACHINE

MACHINE OPTIONS:

Max. build volume – up to Ø 600 mm, h – 400 mm
Max. build part weight – 100 kg
Laser source – 1,5 кW fiber laser
Build rate – up to 50 cm^3/h
Controlled atmosphere chamber – 4,5 m^3
Powder feeder with 1 hopper
Fanuc M10iD/12 Robot
Air filtering system
Vacuum airlock

OPTIONAL:

Laser cutting

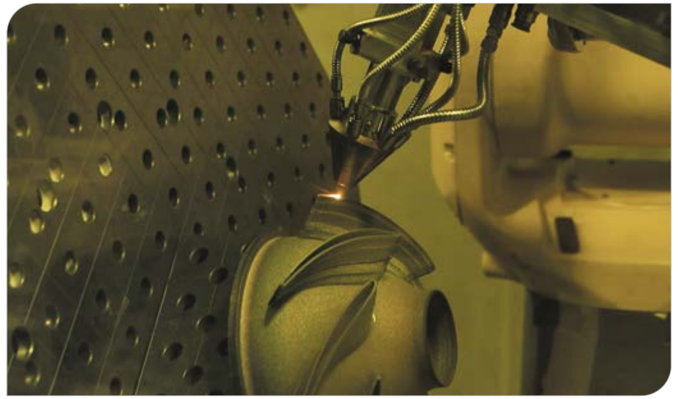
"ILWT-L" ROBOTIC DIRECT LASER DEPOSITION MACHINE

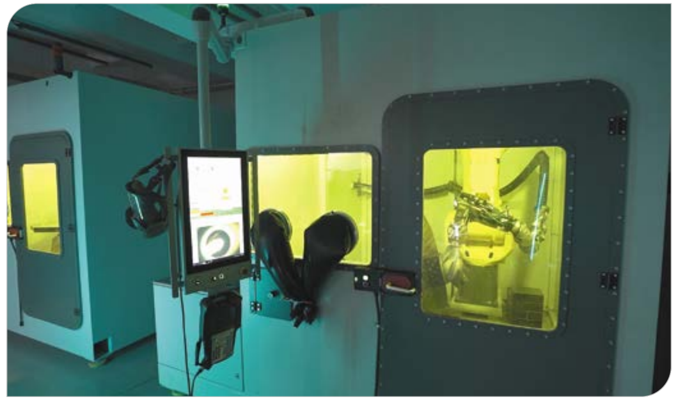
MACHINE OPTIONS:

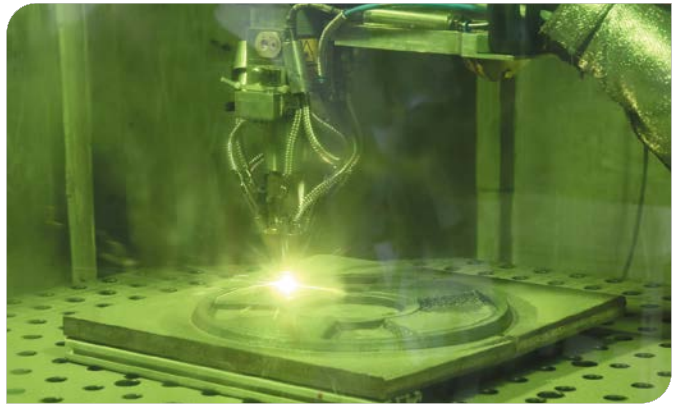
- Max. build volume – up to ∅ 1300 mm, h – 600 mm
- Max. build part weight – 400 kg
- Laser source – 3 kW fiber laser
- Build rate – up to 125 cm^3/h
- Controlled atmosphere chamber – 9 m^3
- Powder feeder with 2 hoppers
- Air filtering system
- Number of synchronously operated axes – 8
- Quick-change powder nozzle set
- Vacuum airlock

OPTIONAL:

- Increased part height – up to 1200 mm







"ILWT-L+" ROBOTIC DIRECT LASER DEPOSITION MACHINE

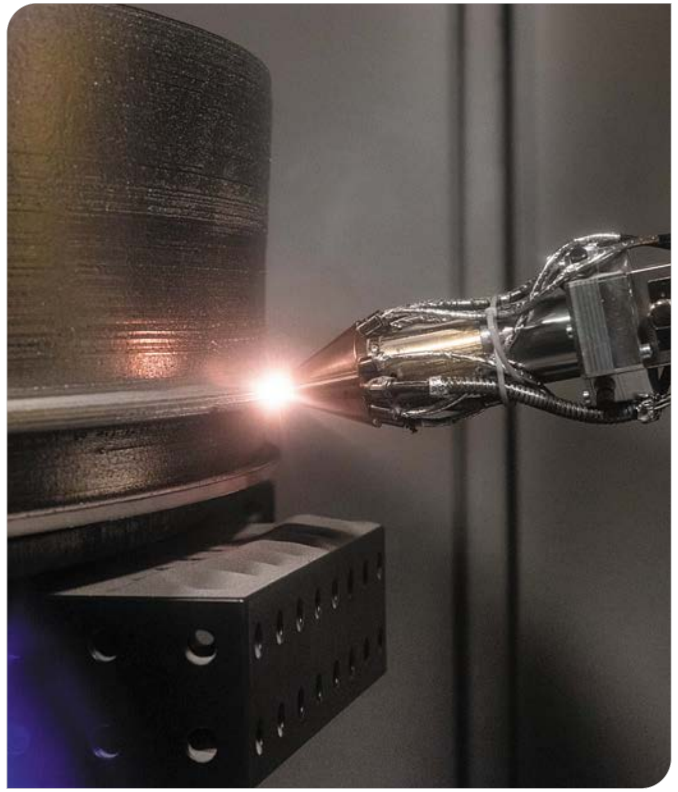
MACHINE OPTIONS:

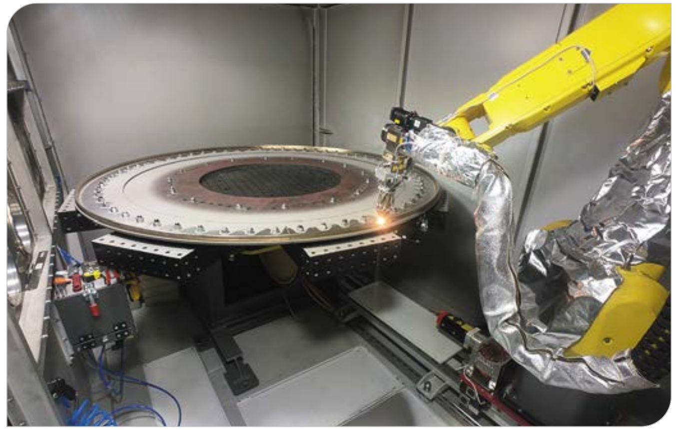
Max. build volume – up to ∅1500 mm, h – 1000 mm
Max. build part weight – 1000 kg
Laser source – 3 kW fiber laser
Build rate – up to 125 cm^3/h
Controlled atmosphere chamber – 12 m^3
Powder feeder for 2 hoppers
Number of synchronously operated axes - 8
Quick-change powder nozzle set
Vacuum airlock

"ILWT-XL" ROBOTIC DIRECT LASER DEPOSITION MACHINE

MACHINE OPTIONS:

Max. build volume – up to ∅ 2200 mm, h – 600 mm
Max. build part weight – 1200 kg
Laser source – 3 kW fiber laser
Fanuc M20iB/25 Robot
Fanuc positioner with two axes
Build rate – up to 125 cm^3/h
Controlled atmosphere chamber – 15 m^3
Powder feeder for 2 hoppers of 5 L
Number of synchronously operated axes – 9
Powder nozzle set with quick-change system
Vacuum airlock

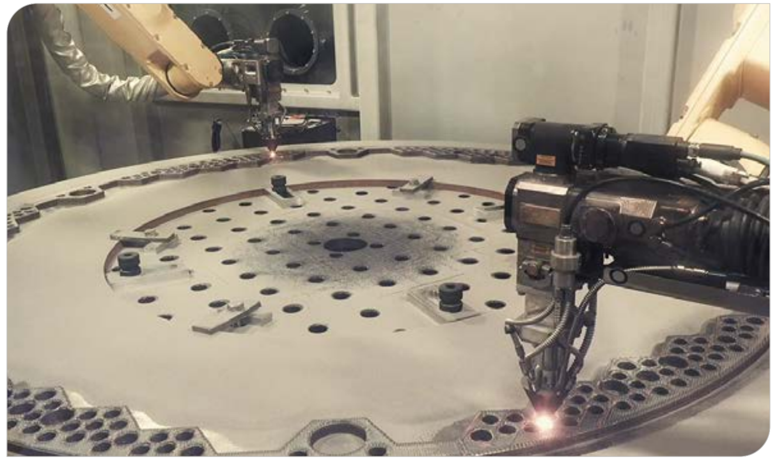


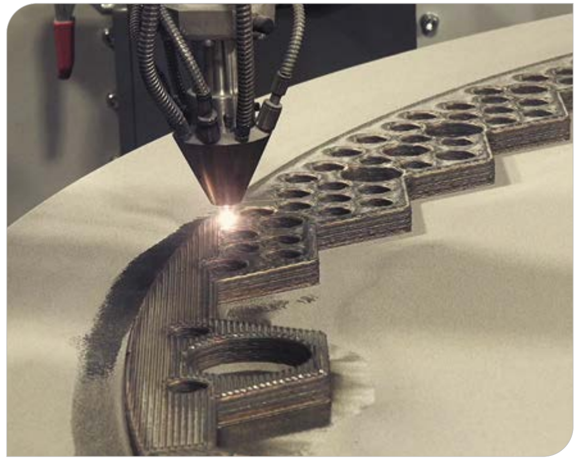


"ILWT-2XL" ROBOTIC DIRECT LASER DEPOSITION MACHINE

MACHINE OPTIONS:

Max. build volume – up to ∅ 2200 mm, h – 1000 mm
Max. build part weight – up to 8000 kg
Laser source – two fiber lasers of 2 kW
Two Fanuc M20iB/25 robots
Build rate – up to 250 cm^3/h
Controlled atmosphere chamber – 20 m^3
Powder feeder with 4 hoppers of 5 L
Number of synchronously operated axes – 13
Quick-change powder nozzle set
Vacuum airlock



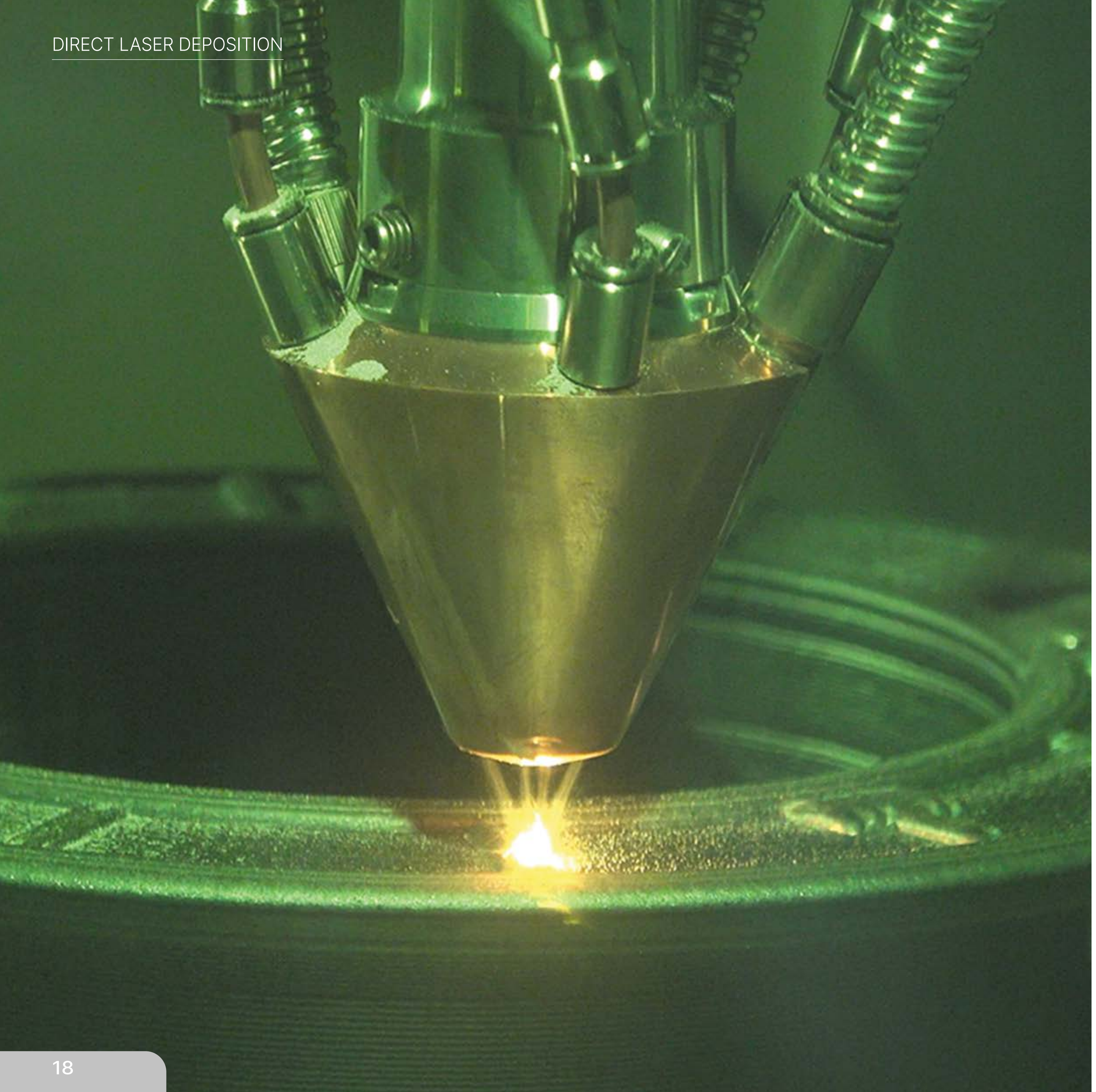


DIRECT LASER DEPOSITION

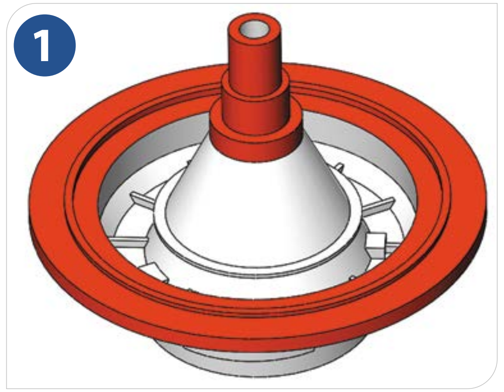
HYBRID UNIT OF DIRECT LASER DEPOSITION BASED ON A CNC-MACHINE

UNIT PARAMETERS:

Direct laser deposition + machining
Maximum build part weight – 500 kg
Maximum size of the build part – ∅ 1100 mm, h – 400 mm
Precise positioning along the X, Y, Z axes: ± 0,005 mm
5 simultaneously controllable coordinate axes
Spindle power – 36 kW
Laser source – 3 kW fiber laser
Build rate – up to 250 cm^3/h
Integrated control and automatic monitoring system – Siemens Sinumetrik 840D
Renishaw OMP60 optical transmission probe. Accuracy of measurement – 1 μm



EXAMPLE OF A WORKFLOW FOR BUILDUP AND POST-PROCESSING OF INDUSTRIAL PART



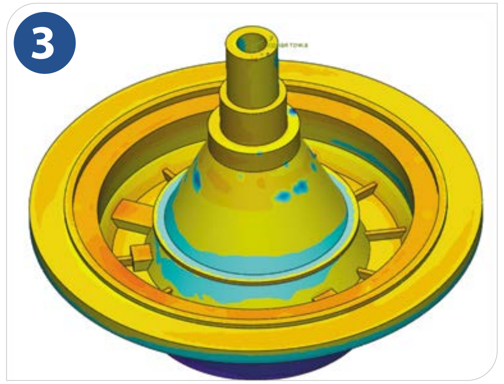
1 – CAD-model of the part

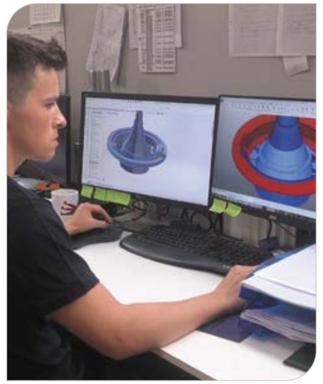
2 – deposition billet

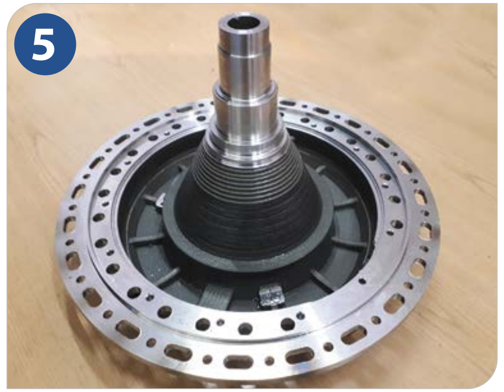
3 – geometry control

4 – postprocessing

5 – finished part







Diameter – 324 mm
Height – 201 mm
Weight of the deposited billet – 13 kg
Deposition time – 20 hours
Material – Inconel 625
Spindle power – 36 kW
Stock for machining – 0,5–2 mm
Weight of the final part – 9,3 kg

GTE-65.1 inner housing
Heat-resistant alloy.
Weight – 33 kg. Manufacturing time – 48 hours.

Topologically optimized blade of water-jet propeller
Stainless steel.
Weight – 12 kg. Manufacturing time – 12 hours.

Gas collector inlet ring GTE-65.1
Heat-resistant nickel alloy.
Weight – 15 kg. Manufacturing time – 37 hours.

Mock-up sample of outer gas collector shell GTE-65.1
Stainless steel.
Weight – 20 kg. Manufacturing time – 20 hours.

INDUSTRIAL PARTS OBTAINED BY DIRECT LASER DEPOSITION

Billet of impeller water-jet propeller
Stainless steel.
Weight – 27 kg. Manufacturing time – 32 hours.
Finishing machining is shown

Blade.
Stainless steel.
Weight – 45 kg. Manufacturing time – 60 hours.

Flame tube section GTE-65.1
Heat-resistant nickel alloy.
Weight – 6 kg. Manufacturing time – 14 hours.

Spherical tank.
Titanium alloy. Weight – 3 kg.
Manufacturing time – 6 hours.

Propeller with topologically optimized hollow blades.
Stainless steel. Weight – 160 kg.
Manufacturing time – 100 hours.

Mock-up of the center support.
Heat-resistant nickel alloy.
Weight – 23 kg. Manufacturing time – 29 hours.

Mock-up sample of the outer shell of gas collector GTE-65.1
Stainless steel.
Weight – 12 kg. Manufacturing time – 15 hours.

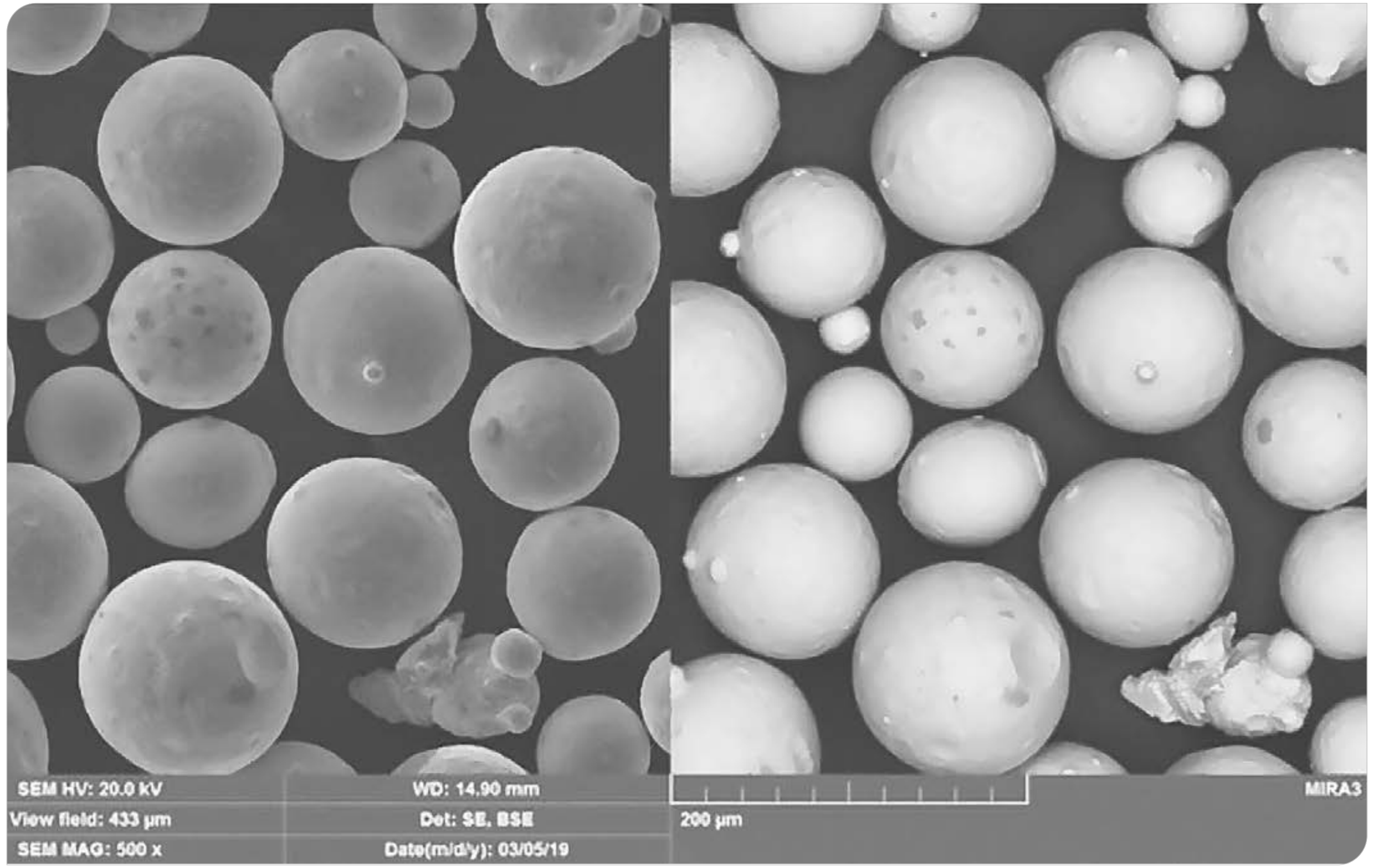
Housing.
Stainless steel.
Weight – 28 kg. Manufacturing time – 33 hours.

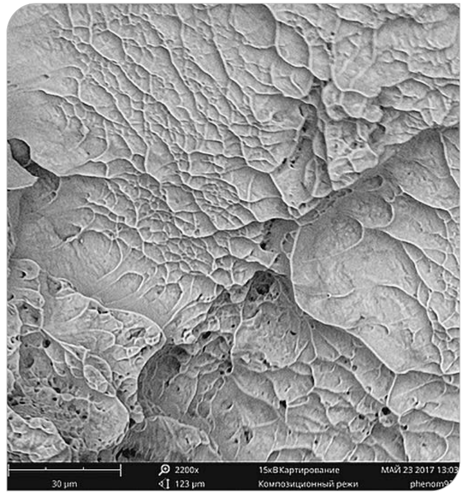
Impeller billet for water jet propeller with hollow blades.
Stainless steel.
Weight – 17 kg. Manufacturing time – 16 hours.

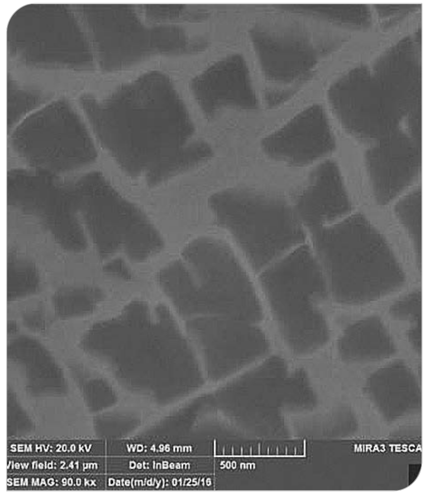
Terminal box.
Stainless steel.
Weight – 17 kg. Manufacturing time – 26 hours.

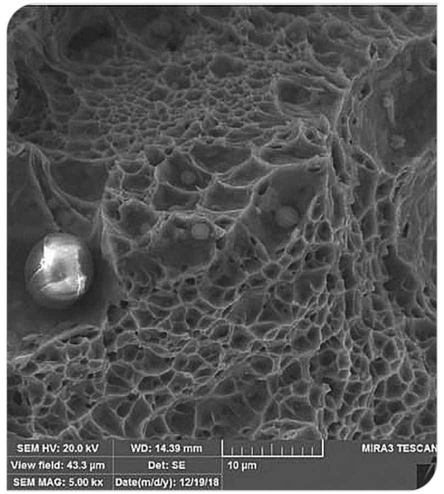
External housing of gas collector GTE-65.1
Stainless steel.
Weight – 33 kg. Manufacturing time – 56 hours.

Mock-up of tank equipment of pressure and volume compensation system of coolant for small capacity nuclear power plant.
Stainless steel. Weight – 76 kg.
Manufacturing time – 108 hours.









DIRECT LASER DEPOSITION: MATERIALS AND PROPERTIES

The filler material for direct laser deposition is metal powders with a fractional composition from 20 to 200 μm. The technology allows the use of both spherical and aspherical powders of weldable and hard-to-weld alloys:

- Stainless and high-strength steels: 316L, 410, SP28 and others
- Heat-resistant and corrosion-resistant nickel-based alloys: Inconel 625, Inconel 718, EI698P, EP648 and others
- Titanium alloys: BT6, BT10, BT20 and others
- Cobalt-based wear resistant alloys: Stellite 6 and others
- Bronze, nickel- or cobalt-based composites, intermetallic and many others

SUMMARY TABLE OF MECHANICAL PROPERTIES OF PARTS OBTAINED BY DIRECT LASER DEPOSITION

Alloy		DLD-processed			Wrought or Cast (ASTM, GOST)		
		σ_{T}, mPa	σ_{B}, mPa	δ, %	σ_{T}, mPa	σ_{B}, mPa	δ, %
Steels	12Х18Н10Т	339	607	59	225–315	550–650	46–74
	08Х18Н10	359	616	55	205	510	43
	316l	327	553	51	170	485	40
	09ХН2МД	609	685	21	588	637	18
	06Х15Н4ДМ	532	784	19	620	790	19
	СП28	1069	1667	11	1275	1570	8.5
Nickel alloys	Inconel 625	512	805	30	345	760	25
	Inconel 718	1087	1293	18	930	1240	12
	Haynes 230	413	884	38	310	760	35
	ЭП648	476	781	38	350	800	25
	ЭИ698	837	1021	18	706	1128	16
Titanium alloys	ВТ6	925	1026	14	–	885	8
	ВТ20	1100	1159	10	–	930–980	6–12
	ТЛ3	539	588	8	440	490	10
	ТЛ5	745	827	14	590	640	8–14
	ПТ-3В	800	855	19	590	635–885	11
Aluminium alloys	5356	118	237	21,2	138	275	15
	АМг6	153	290	15,9	150	310	15
	1575	240	340	12,7	290	400	11
	1580	139	256	19,9	265	370	15

INDUSTRIAL LASER AND ELECTROPHYSICAL TECHNOLOGIES

ILWT conducts applied research and development in the field of laser, arc, plasma and hybrid material processing technologies: welding, cutting, surface heat treatment and cladding.

A new direction of research and development is additive manufacturing of large-scale parts by highly efficient methods of direct arc and plasma deposition with the use of both wire and powder as a filler material.

ADVANTAGES:

- reduction of technological operations and transitions
- higher material utilization factor
- higher productivity
- lower production cost

Processed materials are alloys based on copper, aluminum, titanium, nickel, cobalt, iron, metal ceramics.

Developed technologies and produced equipment are used in the following industries: shipbuilding, aircraft construction, pipe industry, machine building, engine building, nuclear power, automotive industry, aerospace industry and other strategically important areas of Russian industry.

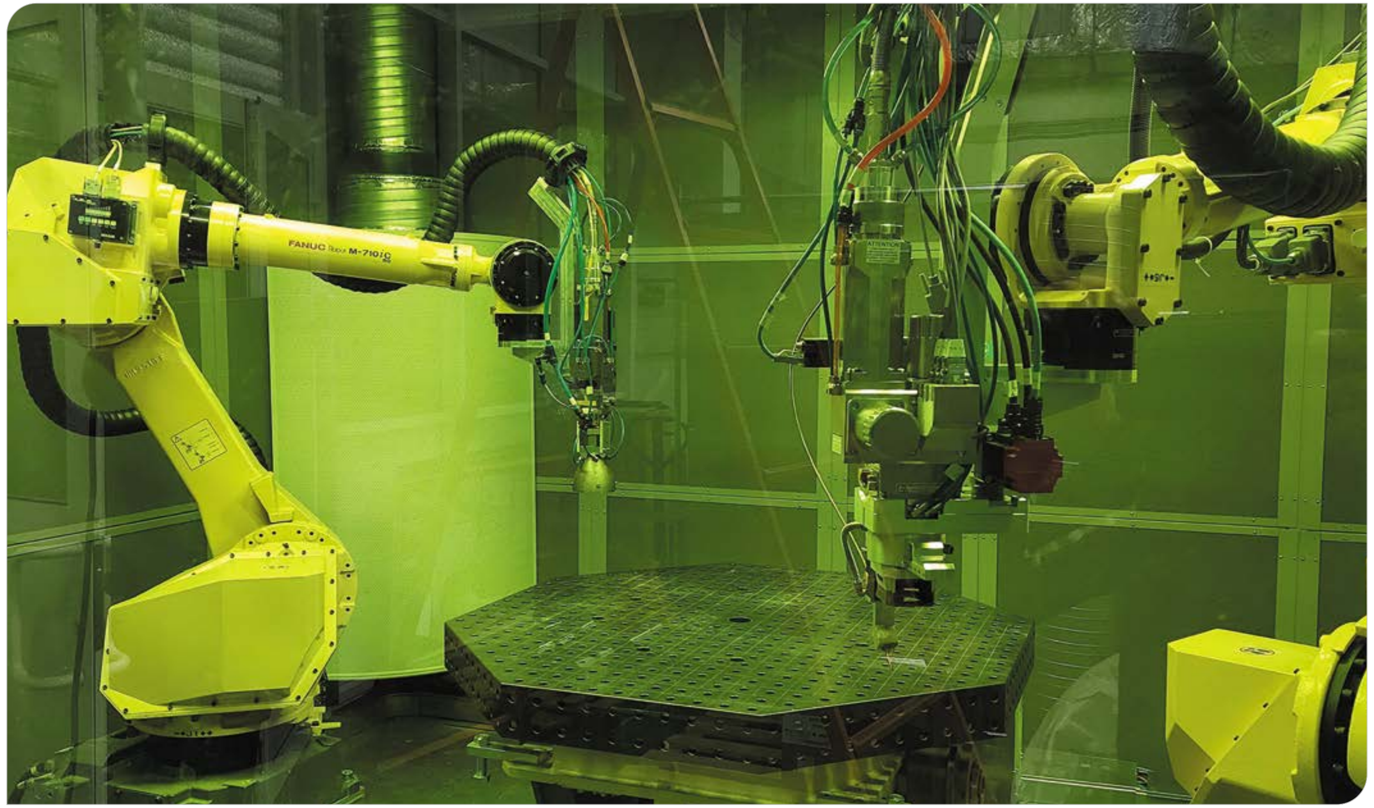
DEVELOPMENT OF A TECHNOLOGICAL TOOL

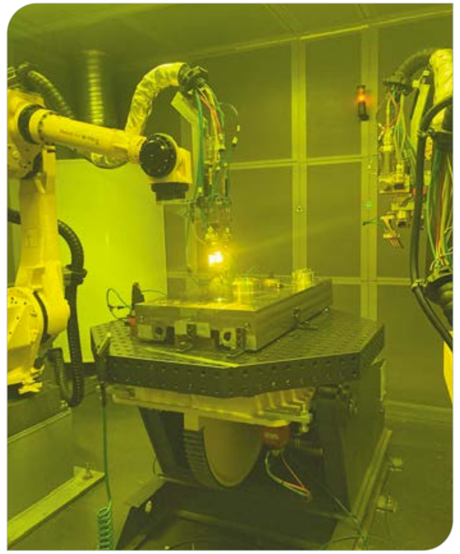
Development of technological complexes based on:

- self-propelled guideway carriages
- portal systems
- production lines
- anthropomorphic robots

Protection and commercialization of intellectual property in the field of laser and electrophysical technologies:

- analysis of global development trends
- patent researches
- marketing researches
- determination of patentability and patent purity

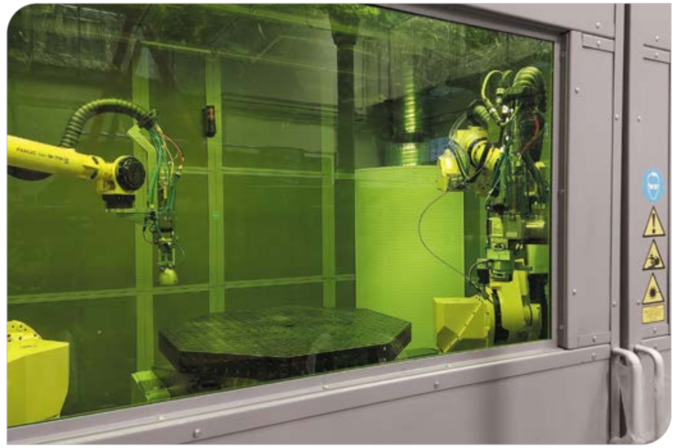




SPECIAL ROBOTIC LASER WELDING MACHINE "ILWT-20S-2"

MACHINE OPTIONS:

High power laser – 20 kW
Two industrial robots with two technological tools: for autogenous laser welding and laser welding with a filler wire
Cabinet protection with air handling unit
Thickness of the welded plates – up to 20 mm in one pass



INDUSTRIAL LASER AND ELECTROPHYSICAL TECHNOLOGIES

"ORBITA" HYBRID LASER ARC WELDING UNIT

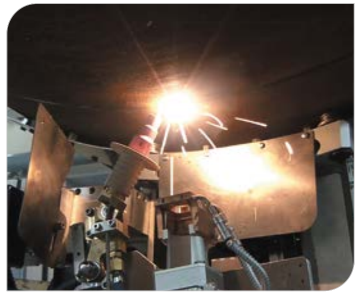
The system is intended for use at shipbuilding enterprises for manufacturing complex spatial hull structures of Arctic vessels and marine equipment for the development of offshore fields within minimum tolerances.

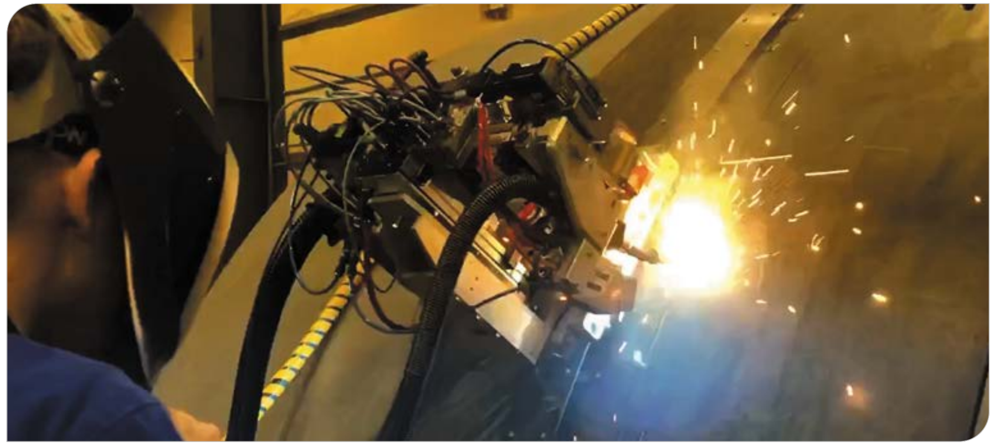
TECHNOLOGICAL SPECIFICATIONS:

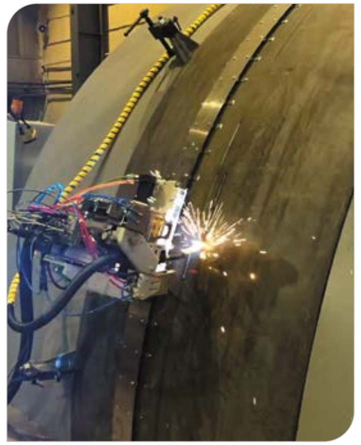
Materials – high-strength and special steels
Technological operations – laser and laser-arc welding
Processing speed – up to 3,5 m/min
Thickness range of processed materials – from 4 to 50 mm

TECHNICAL SPECIFICATIONS:

Laser power – at least 15 kW
Type of laser used – fiber laser
Welding current – up to 400 A
Working tool motion system – welding carriage







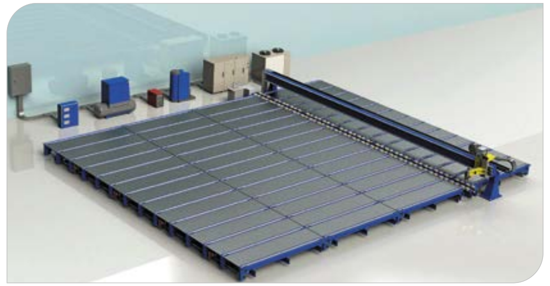
INDUSTRIAL LASER AND ELECTROPHYSICAL TECHNOLOGIES

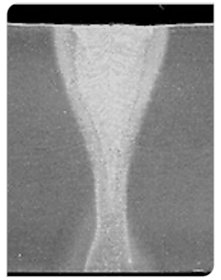
PORTAL UNIT HYBRID LASER ARC WELDING

Designed for serial construction of new generation inland waterway and multimodal vessels and provides the ability to perform hybrid laser-arc welding of butt joints in the lower spatial position as part of an automated flat section assembly and welding line at the web consolidation section.

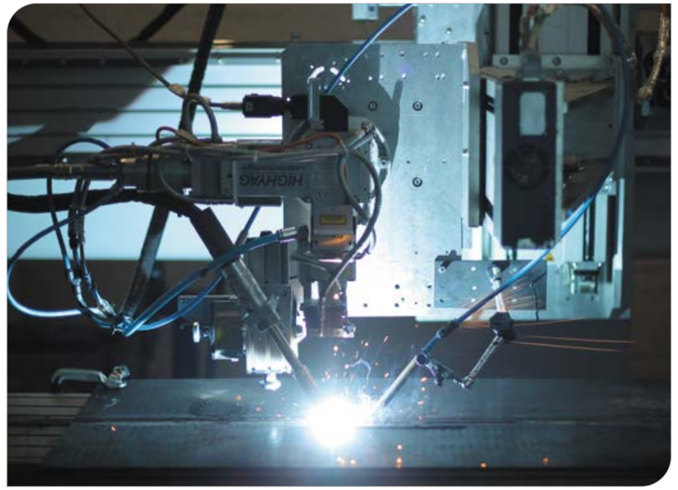
MACHINE OPTIONS:

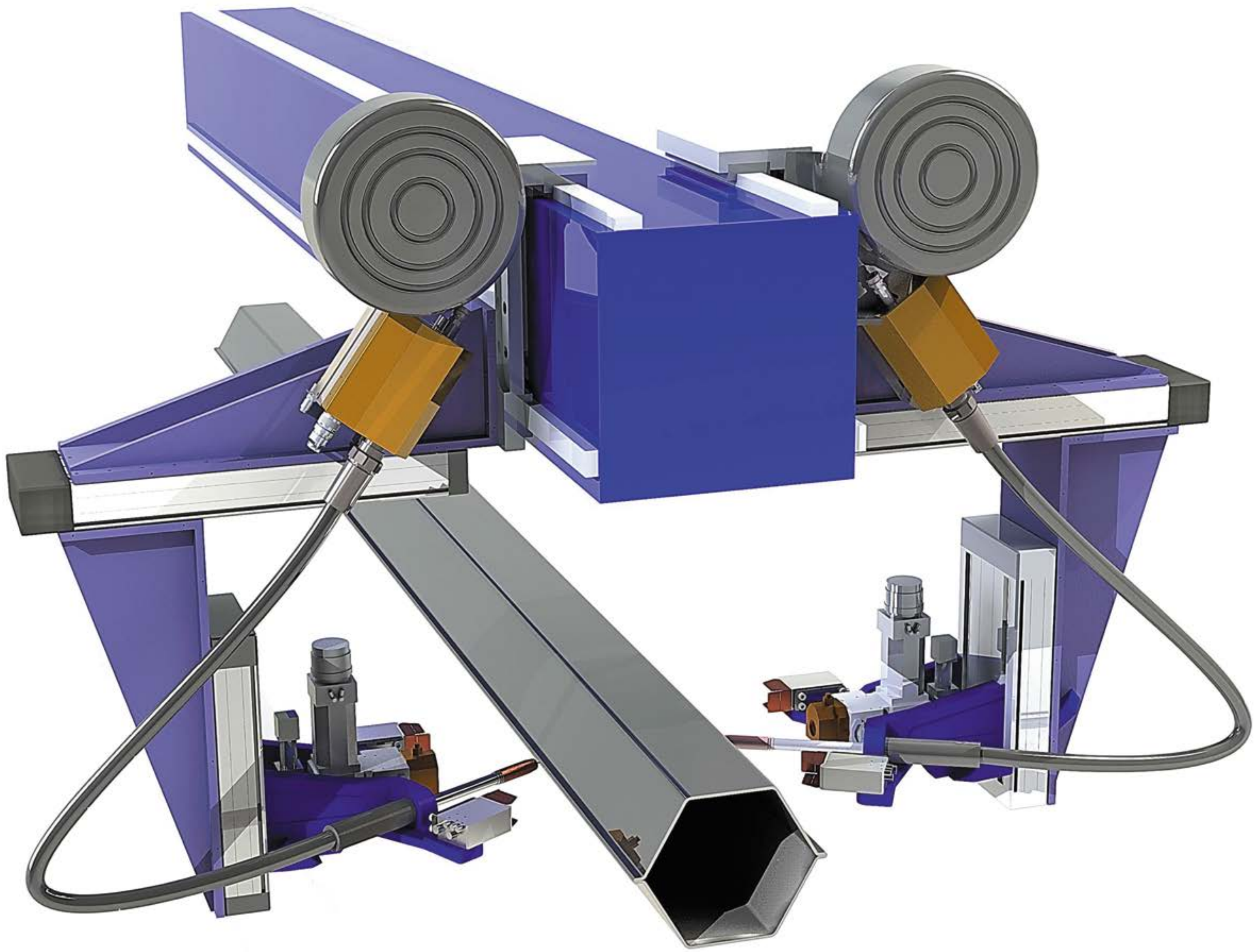
Maximum size of welded plates – 12 × 3200 × 12 000 mm
Laser power – up to 16 kW
Welding current – from 50 to 500 A
Arc voltage – 15 to 40 V
Wire feed rate – 2 to 18 m/min
Diameter of welding wire – 1 to 1.6 mm
The thickness of welded plates – up to 15 mm in one pass
Max. operating speed – 4 m/min
Max. idle speed – 10 m/min
Max. deviation from straightness when moving – 0.5 mm





Welded joint, thickness – 15 mm



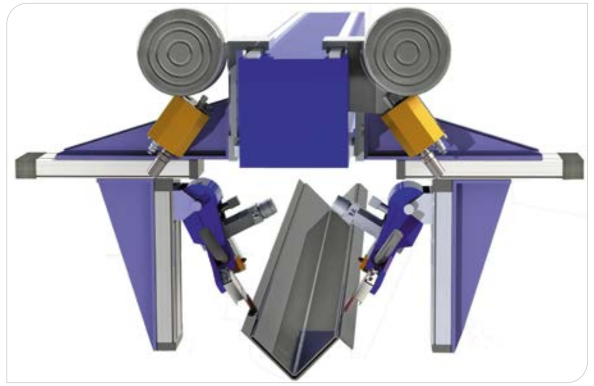


SPECIALIZED UNIT FOR HYBRID LASER-ARC WELDING OF EXTENDED LINEAR WELDS

The unit is designed for hybrid laser-arc welding of flat sections (welding the main direction set to the web) and pipe manufacturing.

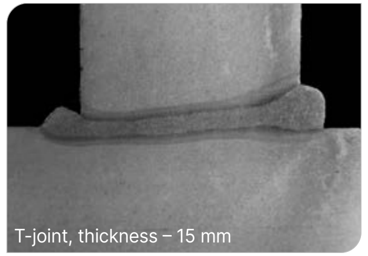
TECHNOLOGICAL CHARACTERISTICS:

Thickness of processed materials – 1–16 mm
Processing speed – up to 6 m/min
Scalable working zone length – 3, 6, 12, ... m

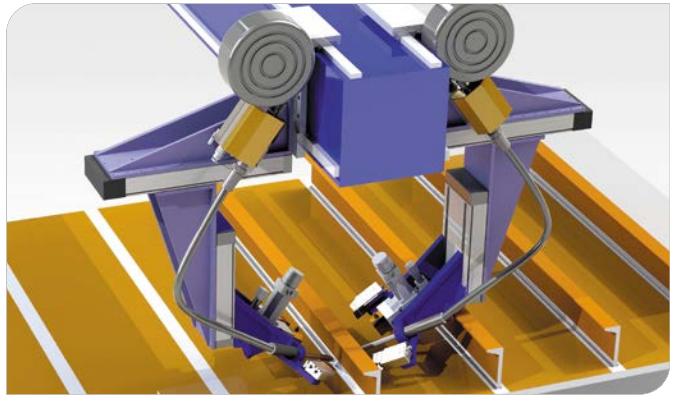


TECHNICAL SPECIFICATIONS:

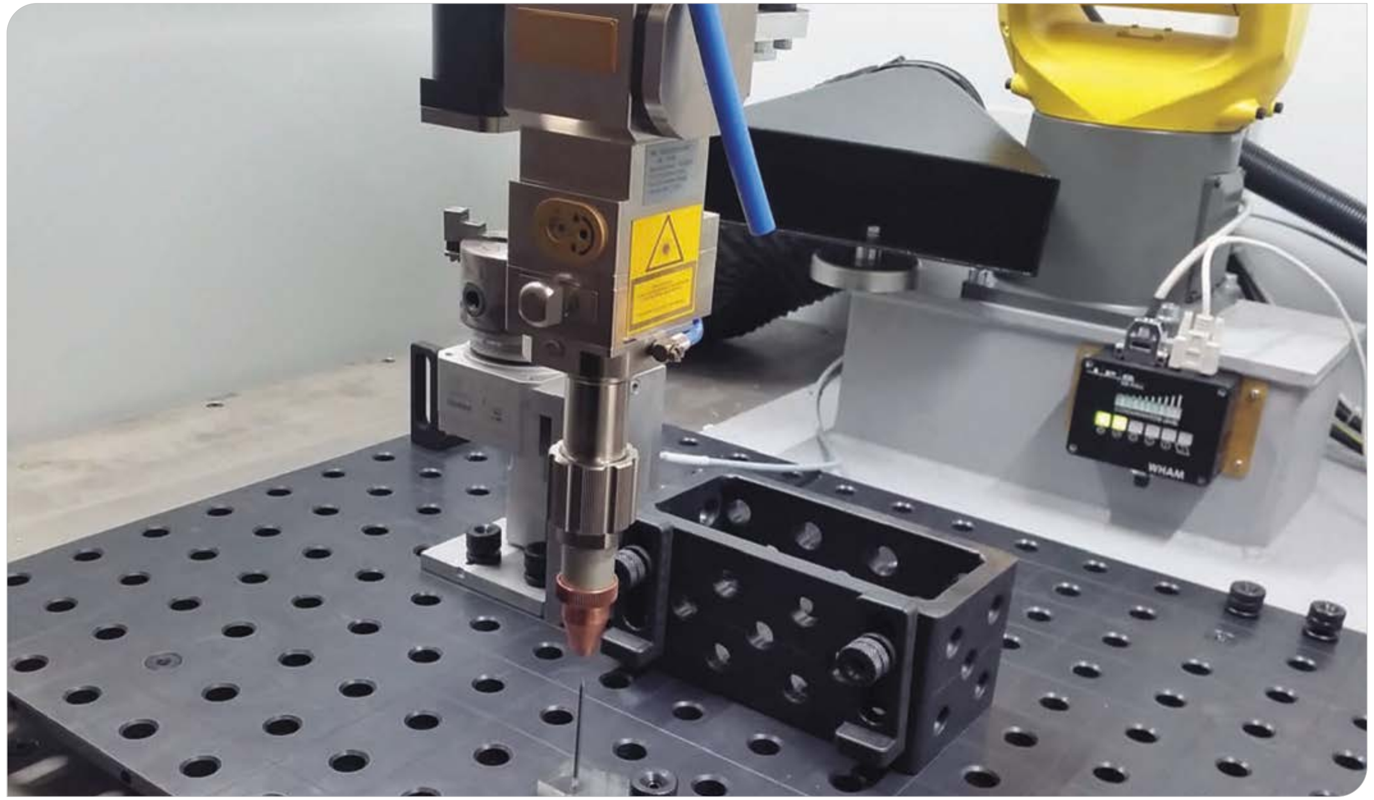
Laser power – 20 kW (10 + 10 kW)
Max. welding current – up to 500 A
Wire diameter – 1,2–2 mm
Wire feed rate – 3–20 m/min



T-joint, thickness – 15 mm



SMALL-SIZED ROBOTIC LASER WELDING MACHINE



MACHINE OPTIONS:

Size of items to be welded – up to 800 × 500 × 500 mm	Protective gas nozzle set
Maximum part weight – 100 kg	Cabinet protection
Fiber laser with power up to 5 kW	Filter ventilating unit
Thickness of items to be welded in one pass – up to 5 mm	
Local gas shielding	
6 synchronously controlled axes	

OPTIONAL:

Increased part height – up to 1500 mm

TECHNOLOGICAL TOOL

LASER-ARC WELDING CARRIAGE

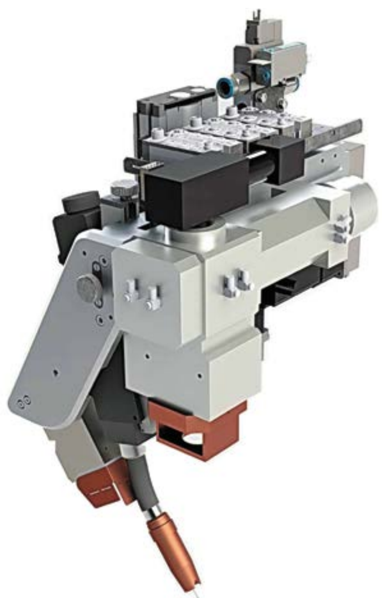
TECHNOLOGICAL SPECIFICATIONS:

Materials to be machined – metals and their alloys
Thickness of processed materials – 3–50 mm
Processing speed – up to 6 m/min

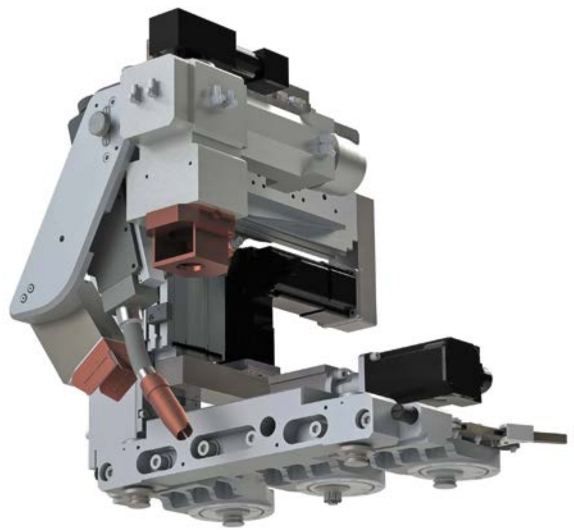
TECHNICAL SPECIFICATIONS:

Permissible power of laser beam – up to 20 kW
Permissible welding current – 500 A
Length of beam wave ~ 1 μm
Joint tracking system – available

LASER ARC MODULE



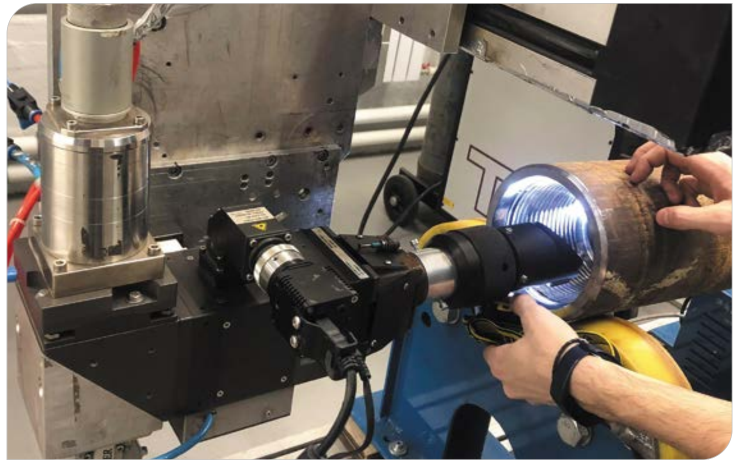
LASER ARC WELDING CARRIAGE



INDUSTRIAL LASER AND ELECTROPHYSICAL TECHNOLOGIES

TECHNOLOGICAL TOOL

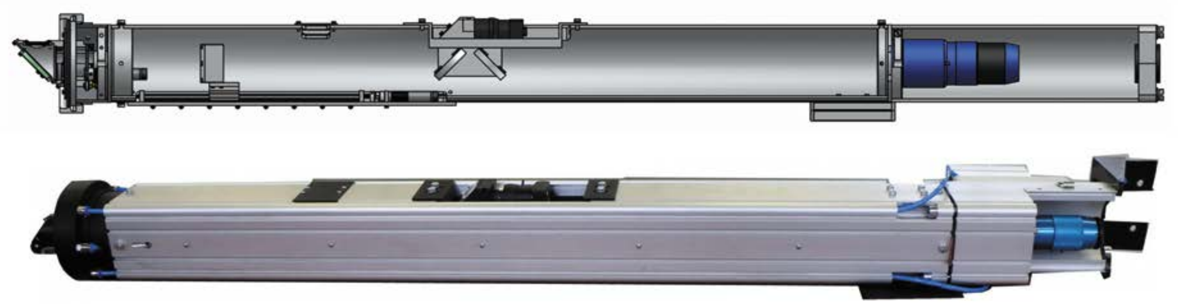
LASER HEAD FOR MACHINING THE INNER SURFACES OF BODIES OF ROTATION



TECHNOLOGICAL SPECIFICATIONS:

Min. diameter of the inner surface to be treated – 150 mm
Permissible power of laser beam – up to 3 kW

LASER HEAD FOR MACHINING INTERNAL SURFACES



TECHNOLOGICAL SPECIFICATIONS:

Range of workable diameters – 150–650 mm
Reach depth – 1000 mm
Welding speed – 0.5–6 m/min
Thickness of materials to be welded – 0.5–2 mm

TECHNICAL SPECIFICATIONS:

Optical input – optoconnector
Emission wavelength – 1 μm
Focal length – from 250 to 500 mm
Input aperture – not less than 30 mm

"ILWT-MF" MULTIFUNCTIONAL MACHINE

MACHINE OPTIONS:

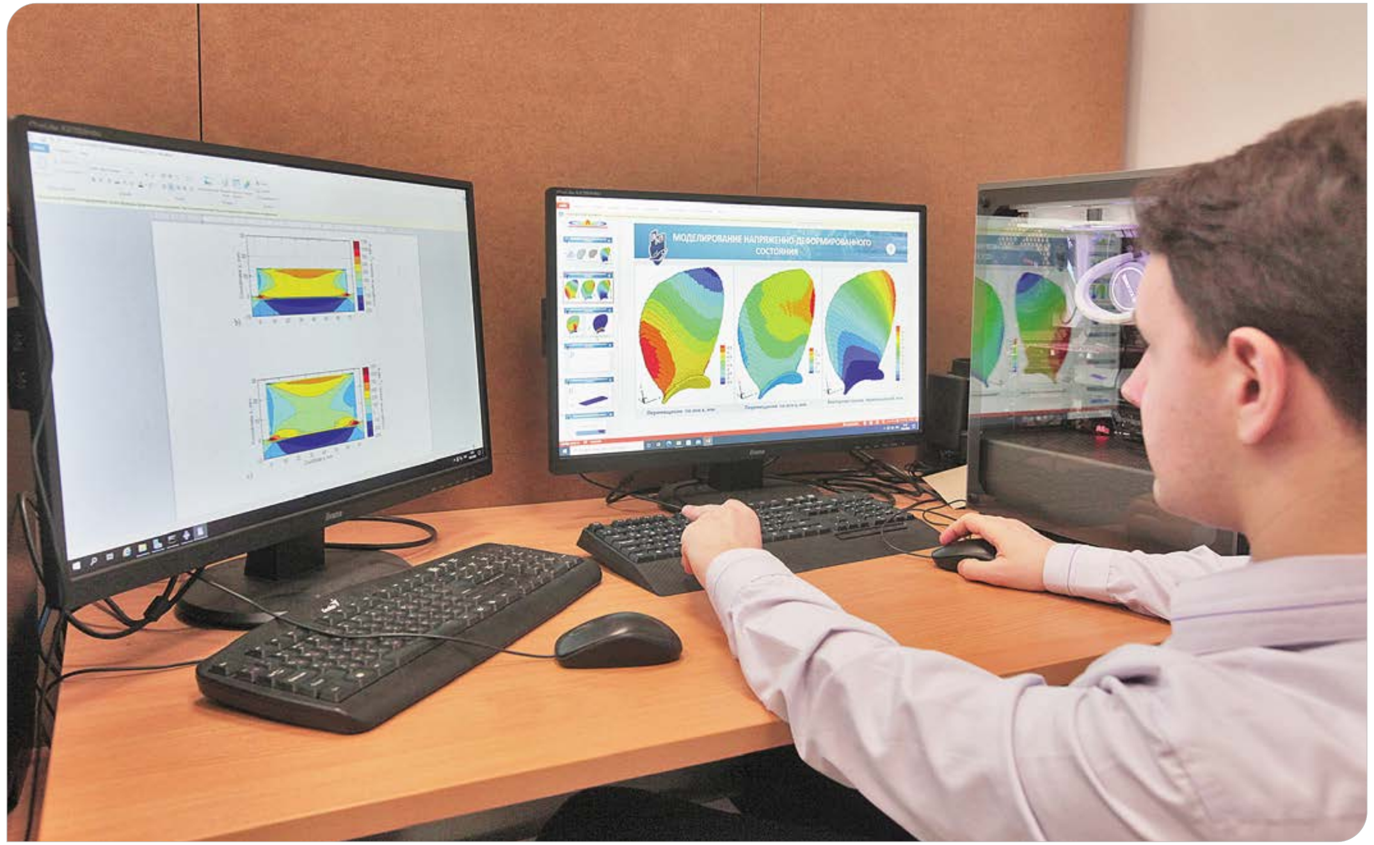
- Build part size – up to 2000 × 2000 × 1000 mm
- Max. build part weight – up to 2000 kg
- Fiber laser up to 4 kW
- 8 synchronously controlled axes
- Powder feeder for two hoppers
- Filter ventilation unit

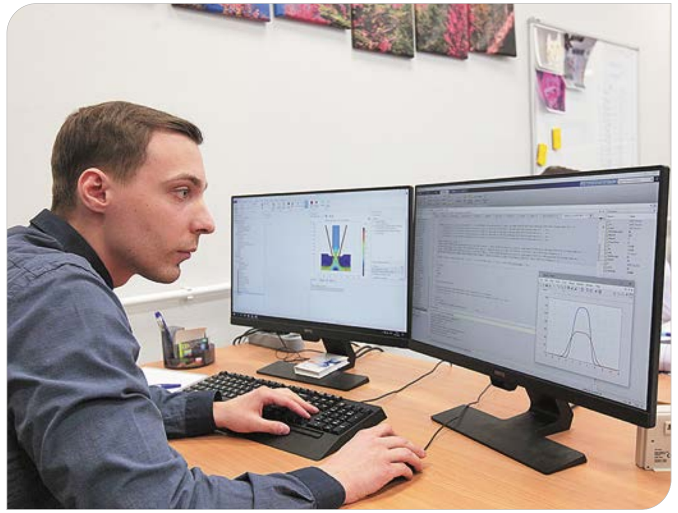
REPLACEABLE TECHNOLOGICAL TOOLS:

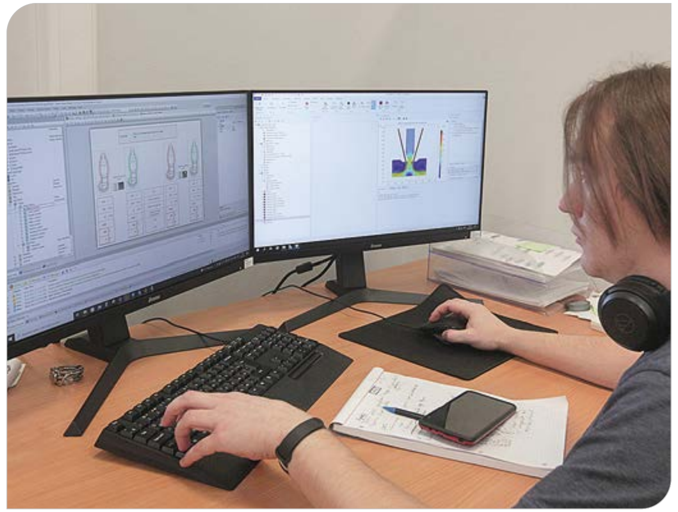
- Laser head for laser welding and surfacing
- Scanning laser welding head
- Inner tube surfacing head

OPTIONAL:

- Fiber laser up to 20 kW
- Arc source for hybrid laser arc welding
- Feeder for wire surfacing







NUMERICAL SIMULATION

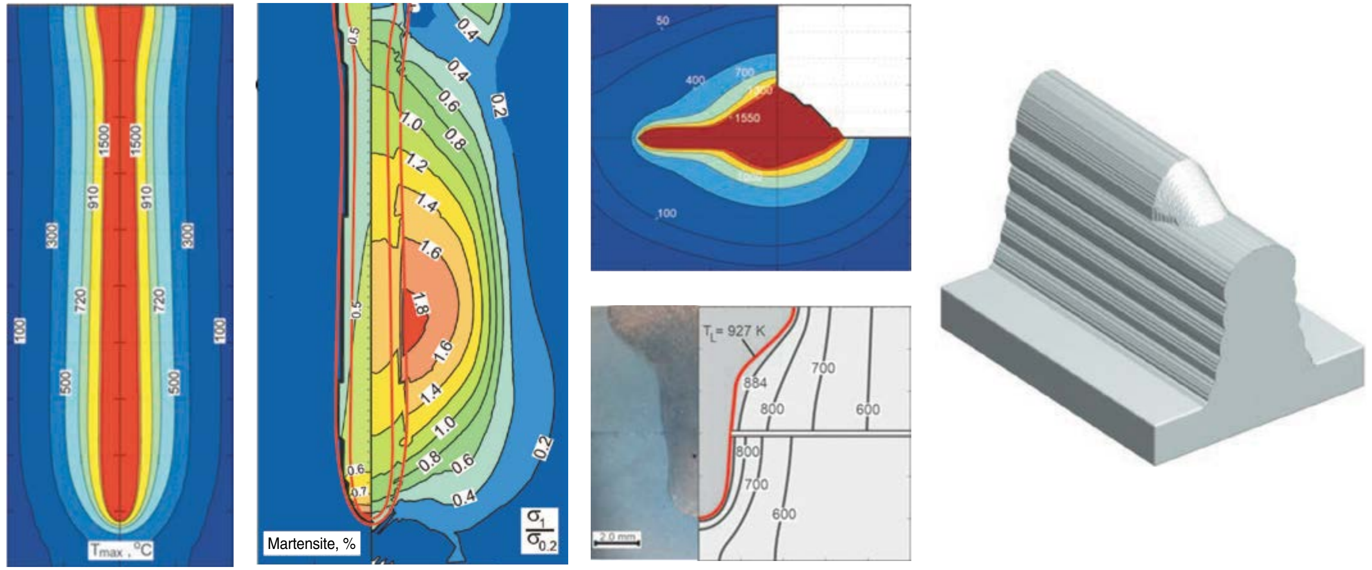
For more than 30 years ILWT has been working on theoretical research and modeling in the field of physical processes and phenomena accompanying laser processing and additive manufacturing technologies.

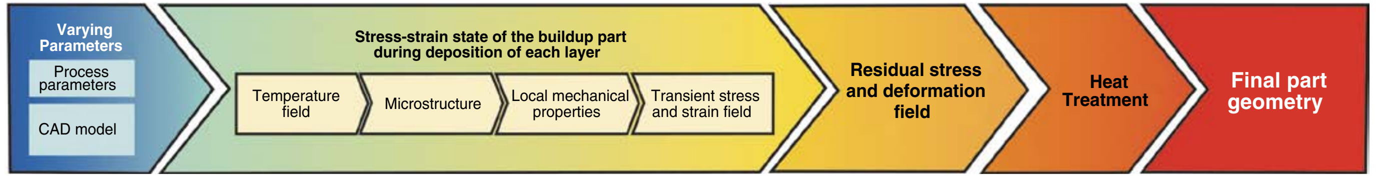
The results of many years' research of the beam treatment processes are reflected in the LaserCAD software developed under the guidance of Prof. G. Turichin. LaserCAD provides a comprehensive virtual assessment of the quality of welded joints produced by a wide range of beam and hybrid welding technologies.

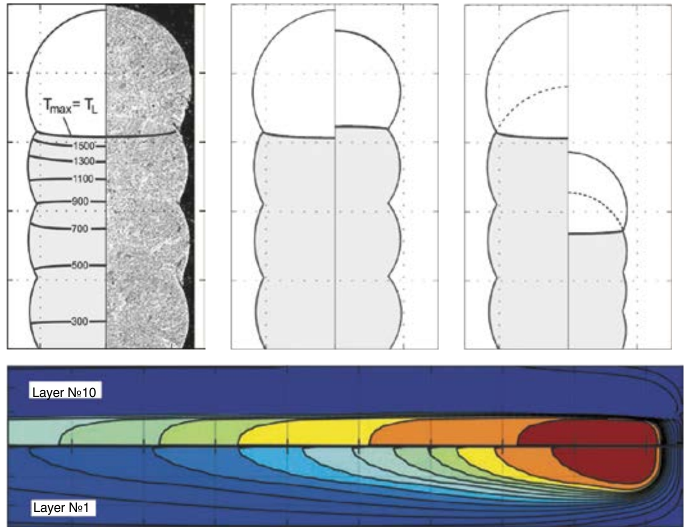
Digital twins for laser processing and additive manufacturing technologies, computer vision systems, and algorithms for big data processing are being actively pursued.

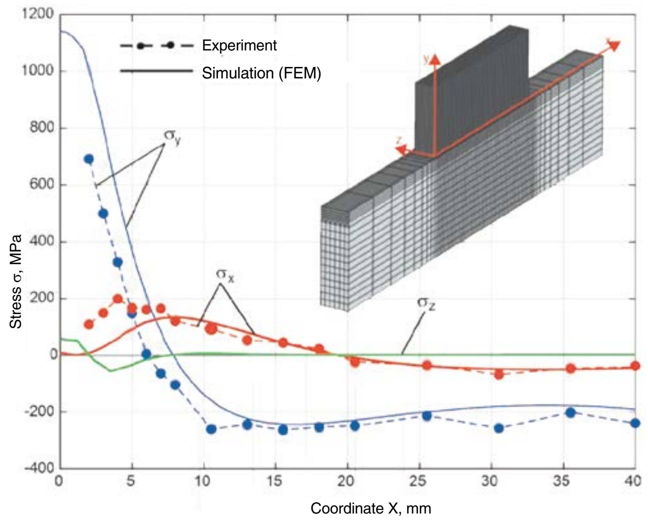
MAJOR DIRECTIONS:

- Numerical simulation of nonstationary heat and mass transfer processes in beam and electrophysical treatment of materials
- Prediction of the stress-strain state of welded joints and additively manufactured parts
- Topological optimization of parts produced by additive manufacturing methods
- Development of specialized software for computer engineering analysis of technological processes
- Development of methods and algorithms for big data processing as part of the intelligent control and monitoring system based on artificial intelligence

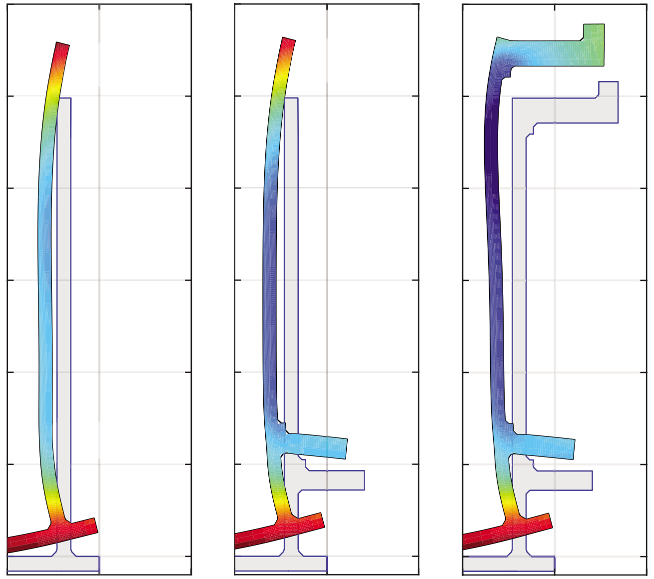




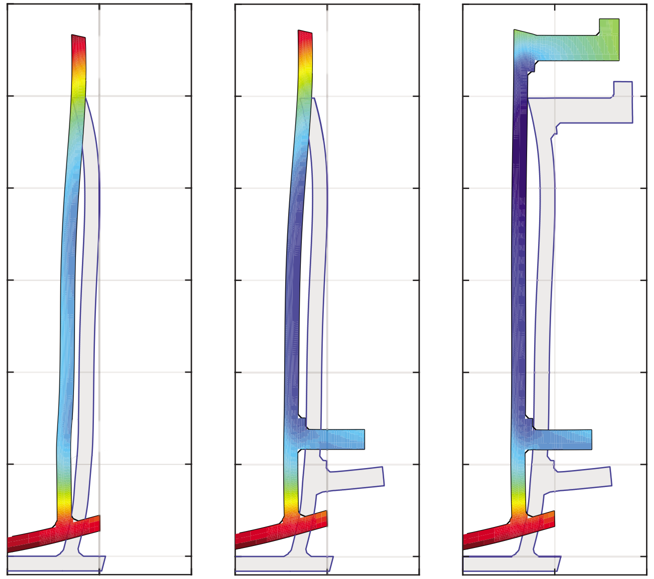


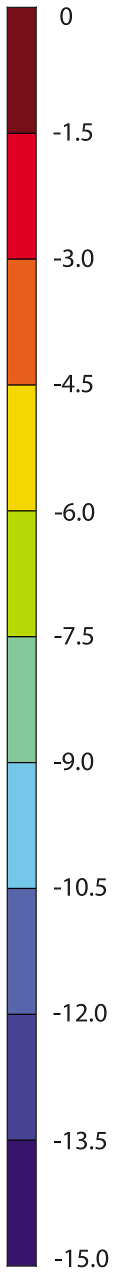


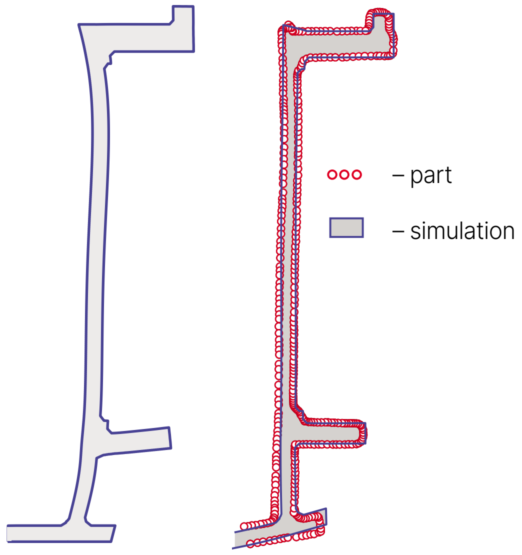
Without deformation compensation (numerical simulation)



Deformation compensation (numerical simulation)

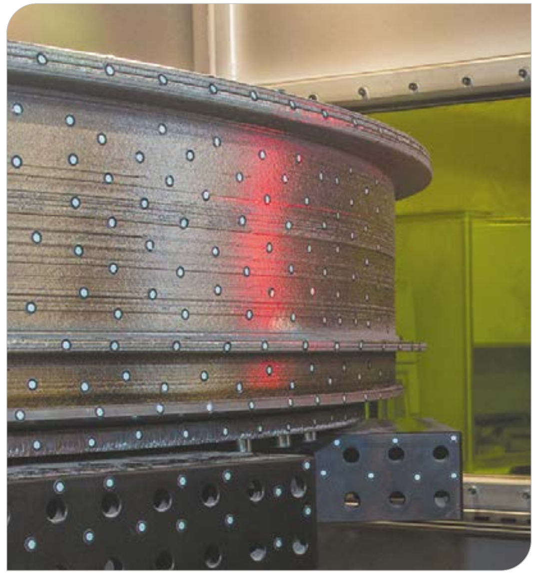


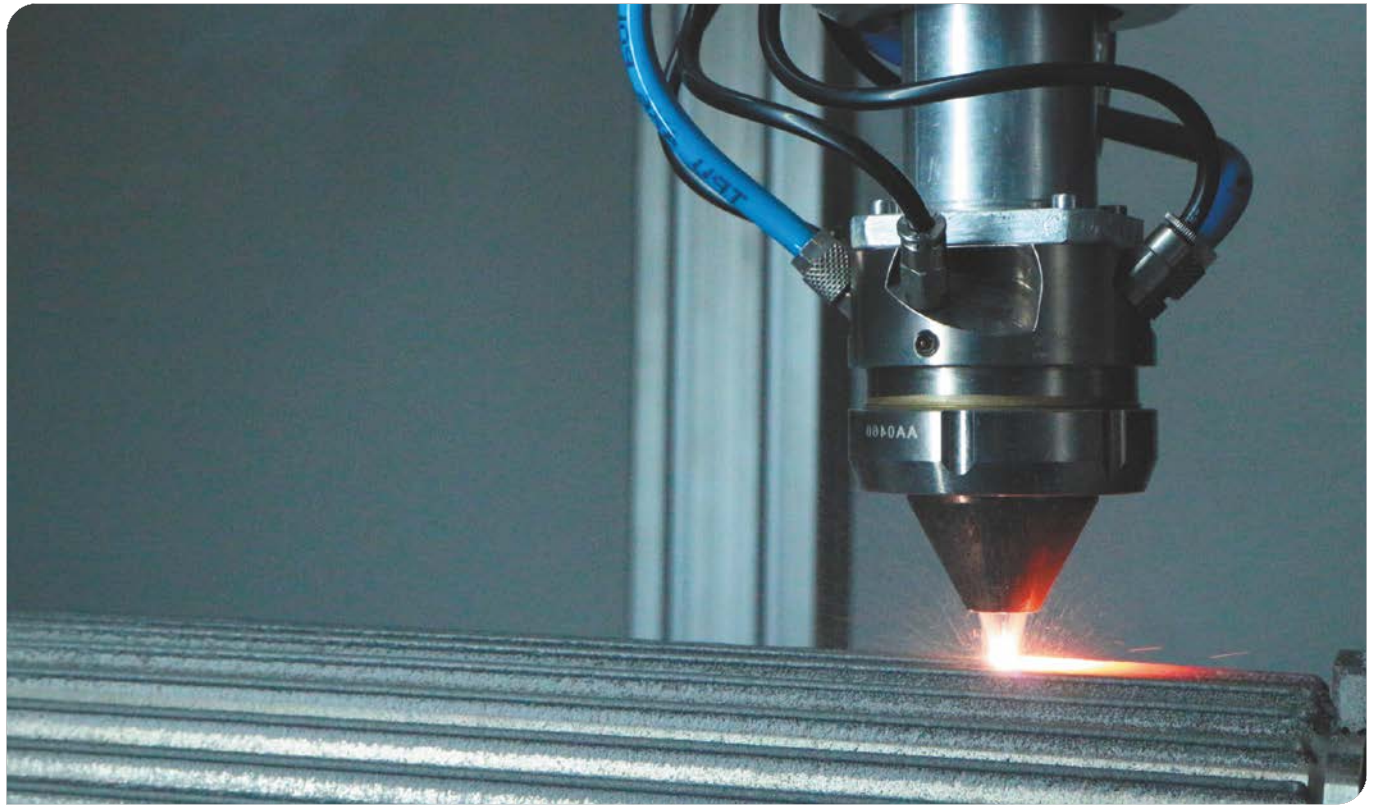


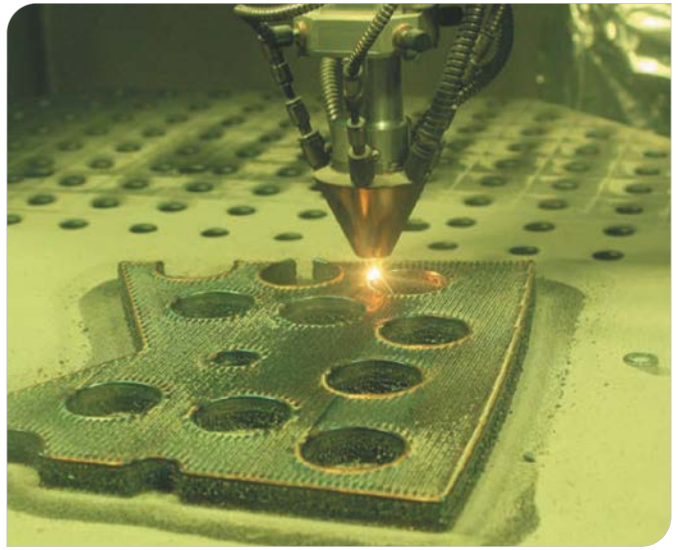


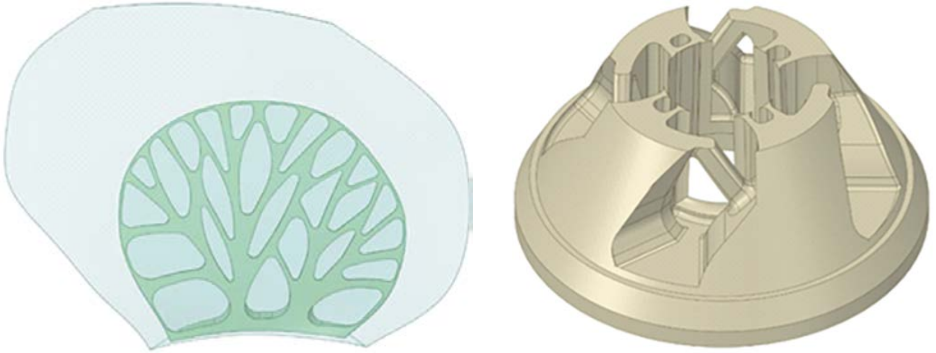
Manufacturing trajectory

Finished part

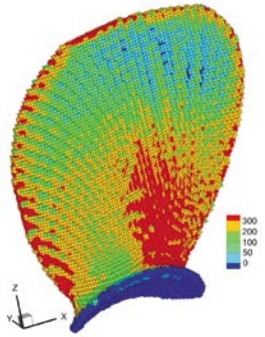




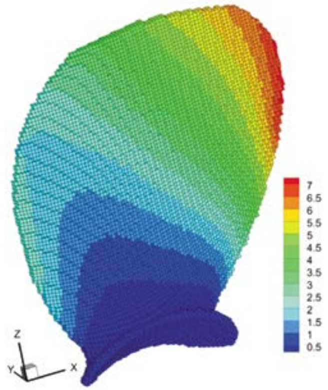




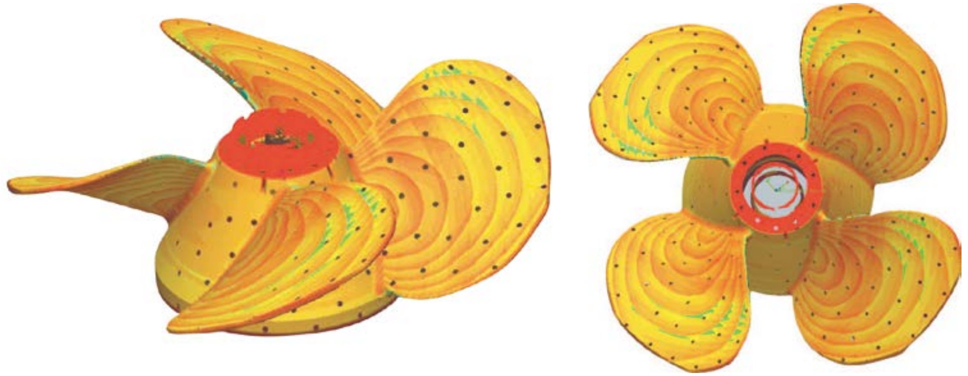
Topological optimization



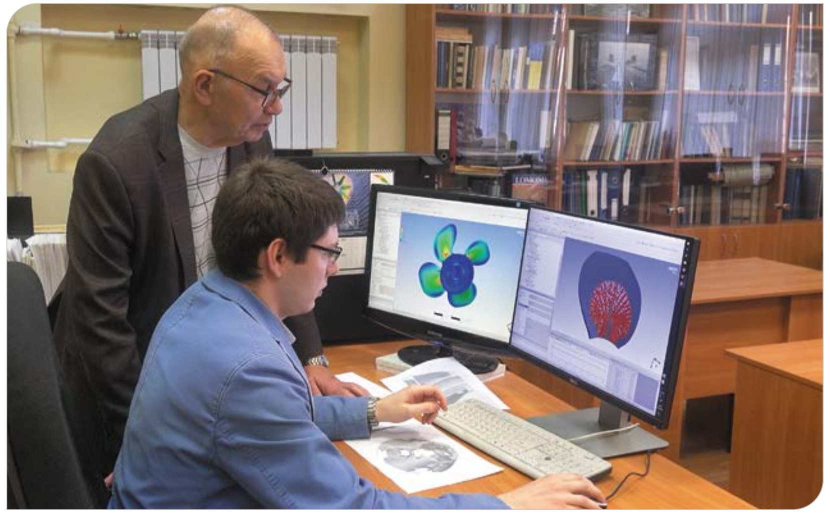
Residual stresses (simulation)



Residual deformations (simulation)



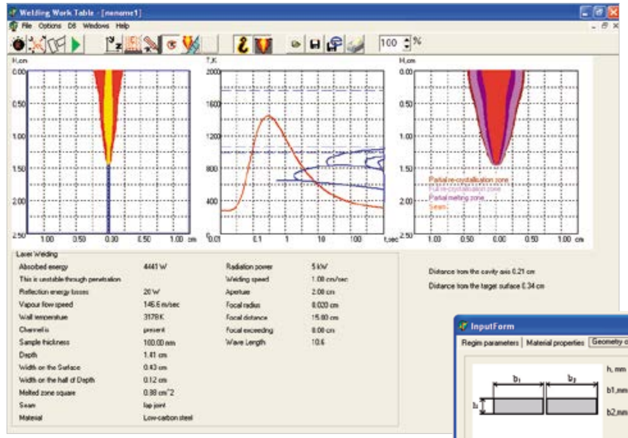
Finished part

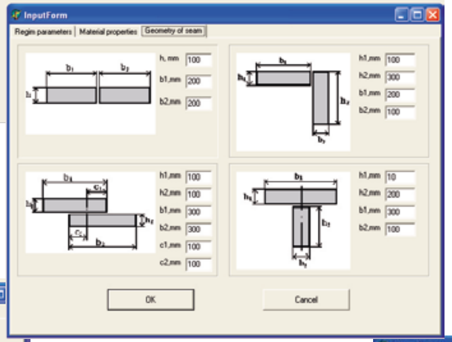


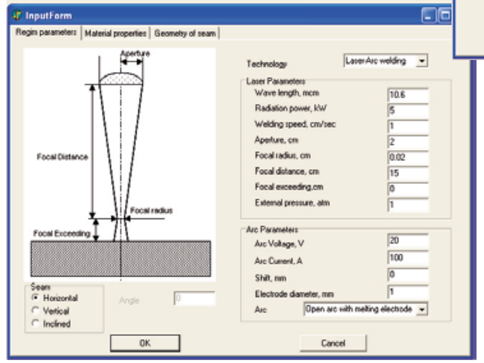
ENGINEERING ANALYSIS SYSTEM FOR BEAM TREATMENT PROCESSES

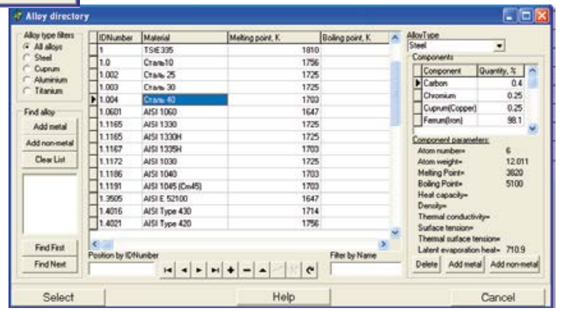
LaserCAD software is based on adequate models of coupled processes, extensive material properties database – steels, titanium and aluminum alloys. Database seeding is applicable.

The software allows you to find the best solution for a given joint type. Moreover it is possible to estimate the change in the chemical composition through the loss of volatile components.









AREAS OF APPLICATION:

- Shipbuilding
- Automotive
- Mechanical Engineering
- Tube manufacturing

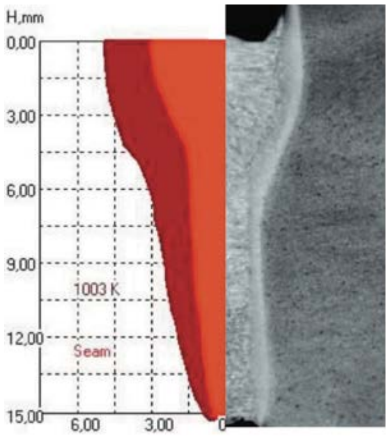
TECHNOLOGIES:

- Laser welding
- Laser-arc welding
- Electron beam welding

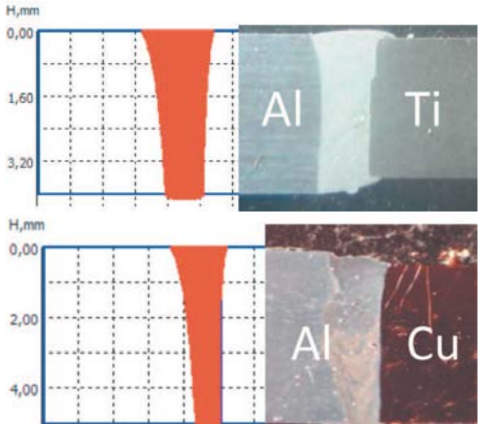
POSSIBILITIES:

- Selection of optimum process parameters
- Selection of the material with the desired properties
- Selection of equipment according to the obtained parameters

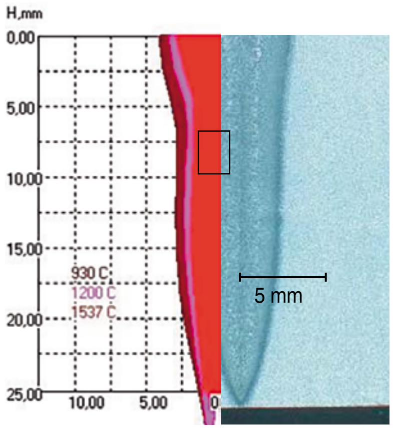
Laser arc welding of steels large thicknesses



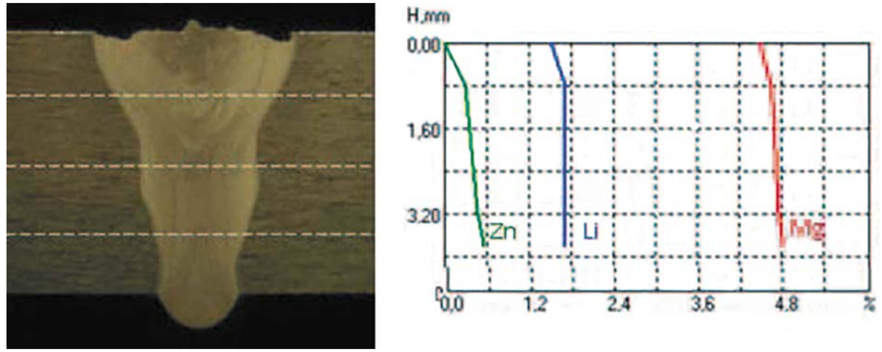
Laser welding of dissimilar materials



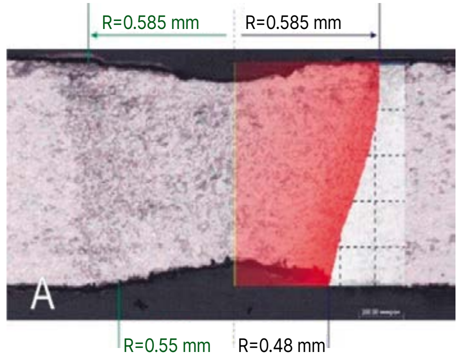
Electron beam welding



Changes in the concentration of volatile components

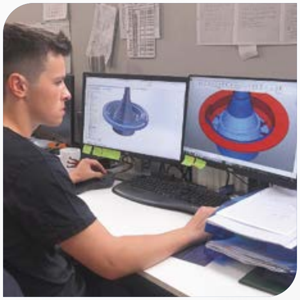


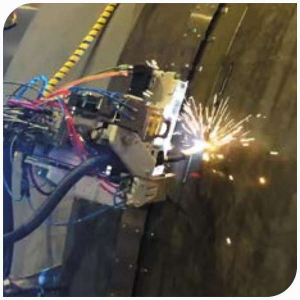
Welding of thin plates of light alloys



Institute of Laser and Welding Technologies

Saint Petersburg State
Marine Technical University





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