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RESEARCH OF DEFORMATION QUALITIES OF POROUS MATERIALS ENHANCING COMPUTER DESING OF WETSUIT

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Abstract. *The article presents the research in order to create a new level of computer tools for effective design of clothing for underwater kinds of activity. This report covers the consideration, sub-stantiation, and proposals relating to the ways for improving the mathematical models built into integrated CAD systems to be used in creation of underwater outfits. In order to ensure precise solutions for stocking the outfit object with materials with respect to the underwater conditions selected, the experimental studies of deformation of modern expanded polymer materials under the action of external pressure and local stretching have been performed in this research. Such multiaxial deformations lead to redistribution of the thickness of clothing being under investigation over the complicated surface of the man's body. A method of autonomous fixing the deformation of expanded material thickness has been developed for conduction of such investigations. Basing on the method proposed, the authors have developed a fundamental solution for a special device for autonomous measurements of the deformation characteristics of expanded polymer materials, in particular, in the conditions of direct hydrostatic pressure on the clothing. The results of experimental studies obtained have allowed to derive relations for the behaviour of deformation characteristics of expanded materials.*

1 INTRODUCTION

Rapid development of modern CAD/CAM technologies in clothing industry is increasingly using mathematical models of various type and purpose. Clothing design for underwater environments is based on conventional computer-aided-design (CAD) systems basis of which consists of mathematical models for obtaining construction parts and surface development, which are adequate to the external shape of the man's body under static and dynamic conditions [1]. In doing so, such clothing is a sophisticated system of work of expanded polymer materials aimed at ensuring heat and mechanical protection of the man's body [2].

In the manufacture of wetsuits, 3 types of design are noted:

- "Dry" — these wetsuits almost never pass the water inside. This effect is achieved by the use of packing seals at the hands and neck, and waterproof zippers. Such suits can be made of trilaminate or neoprene.
- "Wet" — these wetsuits are made of neoprene (foam rubber). Thermal insulation is provided by the suit material itself due to the presence of air bubbles. Water trapped under the wetsuit cannot be a heat insulator, therefore, the closer suit is fitting, the less is a circulation of water under it, and the less a heat is spent for heating of new cold-water portion.
- "Semi-dry" is an intermediate type of wetsuits. Despite the presence of seals, a water can penetrate to under-suit space (if air penetrates into it), but to a lesser extent, and, in close suit's fitting, a water does ingress practically, due to which the heat insulating properties is increased.

For wet type suits, a porous neoprene is used. For the manufacture of dry type wetsuits, a pressed neoprene is most commonly used (neoprene, which pores are partially or completely crushed), which increases reliability and reduces the buoyancy of the wetsuit. For spearfishing, an ordinary neoprene is used, but with the cut pore (there are unclosed pores on inside, due to which the material is snag against the body, a water circulation inside the suit is reduced, the man is getting warmer).

Neoprene can be used at -55 °C to + 90 °C temperatures, but the actual temperature range depends on the particular chemical composition of the material. Neoprene is resistant to the sunlight influence and chemically active oil products [3].

The average thickness of the material can range from water temperature and diving purposes (Table.1).

Table 1: Dependence of average thickness of the suit material on the water temperature

Material thickness, mm	Water temperature, °C	Intended use
9-10	4—12	diving operations
7	10—18	spearfishing, diving
5	17—23	surfing, diving
3	24 и выше	surfing, wind-kite surfing, other sports

The thickness of diving suits depends on the structure of set of individual layers of materials. These materials have a feature of compression deformation under external loads. A particular importance is the change in thickness of such materials at the hydrostatic pressure. At that, the presented data of material thickness for underwater clothes lose their effectiveness because of change of thermal resistance of clothes and overall heat loss by the man. These changes must be taken into account at the stage of engineering analysis in the CAD. This paper presents the engineering developments that allow determining the experimental changes in the geometric characteristics of the foam material under the influence of external pressure. The parts of the diving suits are exposed to the most pressure under the influence of the foot. Therefore, the integration of the results of experimental studies of foam materials for clothing is considered by the example of the design of support structures of the diving suit.

2. EXPERIMENTAL STADIES

2.1 Justification of special materials for the research

Support structures of diving suits can be made from several types of materials that are part of information provision in CAD-designing of underwater clothes (Fig.1):

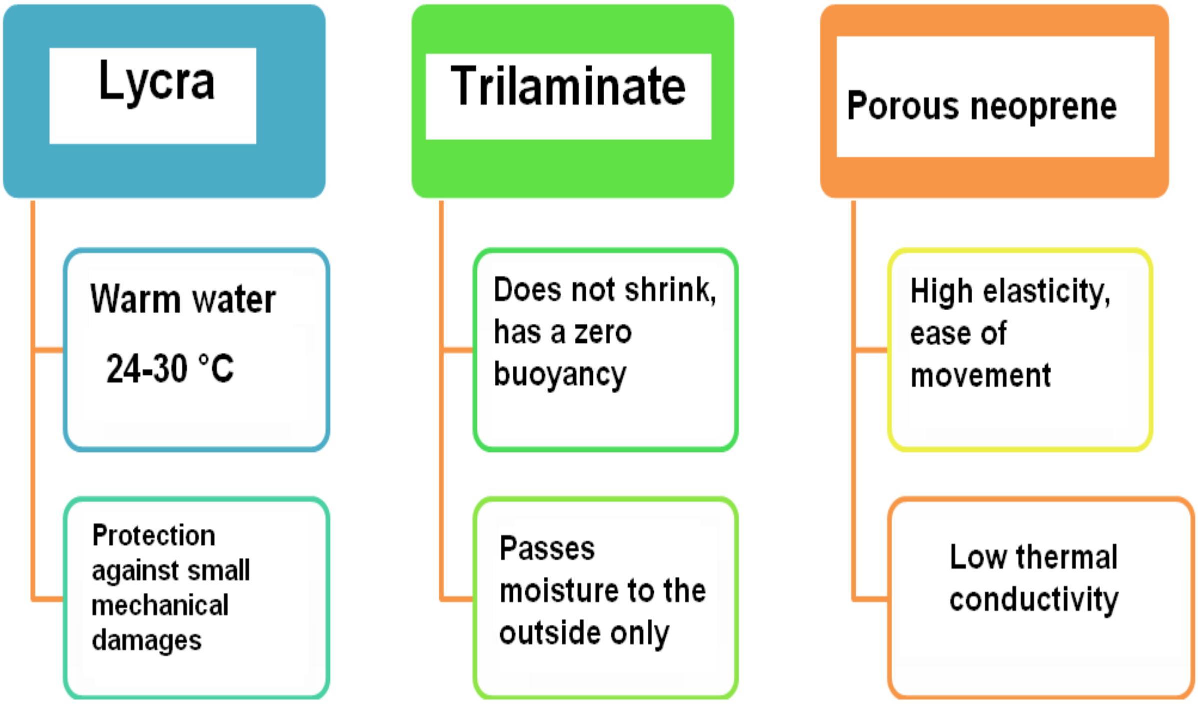

Figure 1: Main types of materials for the supporting structures of diving suits

2.2. Features of structure of "sandwich-type" material sets.

To determine the source data required in the automated calculation of clothing, the information registry of necessary materials for the supporting structures of diving suits has been established [4] (Table 2).

Table 2: Features of materials for wetsuits

New materials	Manufacturing country	Composition	Benefits
Radially covered neoprene	Korea	super stretch (latex), neoprene, nano-titanium alpha, jersey nylon	High strength, durability
Nano-zirconium lycra	Japan	lycra-nylon, neoprene, nano-titanium alpha and aero-zirconium	Convenience, flexibility. Technology of transmission of solar heat to the human body. Allows to compare the heat of 5 mm fabric with 8 mm one.
Nano-super stretch	Japan	super stretch, neoprene, nano-titanium alpha, super stretch	Super stretch material increases the elasticity of neoprene in 2 times. Nano-titanium alpha is used for maximum heating
Nano-aqua block, neoprene	Japan	aqua block, neoprene, nano-titanium alpha, aqua block	“Aqua block" is a material that blocks the water from stagnation. Nano-titanium alpha provides maximum heating.
Nano-SCS Silver	Japan	super stretch, neoprene, nano-titanium silver	It retains 30 % more heat.
Nano-SCS Gold	Japan	super stretch, neoprene, nano-titanium gold	Retains 35 % more heat
Breathable fabric	Japan	cordura, polyurethane, polyurethane film, a net-like layer	Removes a moisture, the weight of suit is 3 kg. Suitable for all-season dry suits
Butyl-rubber fabric	United Kingdom	lycra nylon, neoprene, nylon	Suitable for light dry suits. More durability and less volume

As can be seen from the above analysis of materials used for the manufacture of wetsuits, neoprene is the basic material from which the wetsuits are made. The main part of “sandwich structures” is neoprene (more precisely, chloroprene),(Fig.2).

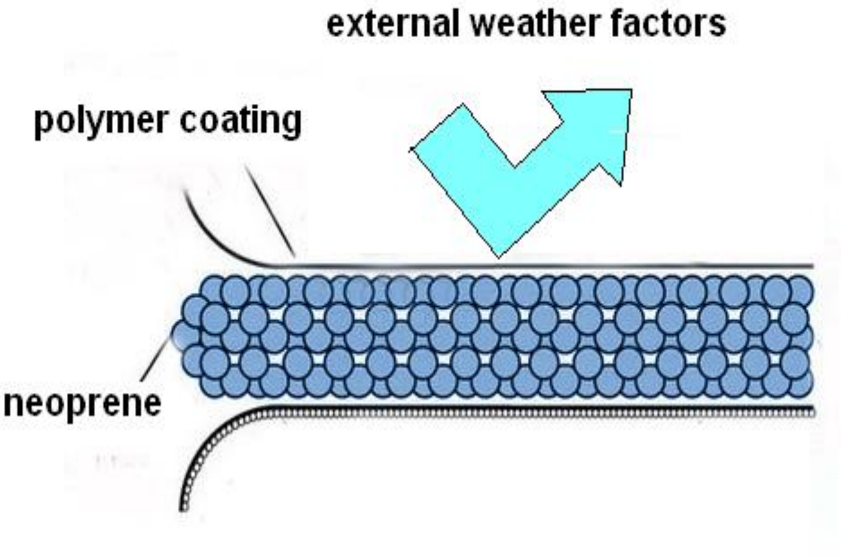

Figure 2: Neoprene

2.3 Basic properties of chloroprene materials for information database of CAD-system for designing the wetsuits.

Table 3: Properties of rubbers based on chloroprene rubbers

Index	Unfilled rubbers		Filled rubbers	
	regulator		regulator	
	sulfur	thiol	sulfur	Thiol
Elongation tension 300 %, MPa	1,0-1,5	1,9-2,3	8,5-9,5	17-18
Relative elongation, %	880-11000	780-900	450-550	450-550
Tear resistance, kN/m (20 °C)	30-45	25-35	55-70	55-65
Rebound elasticity, %	40-42	40-42	32-35	38-40
Brittleness temperature, °C	-37	-37	-37	-37
Compression set 20% (120 t, 100 °C), %	80-90	35-40	80-85	45-53

The properties of such materials are determined by the characteristics of composite layers combined into the “sandwich type” general construction of the material. Mechanical and thermophysical properties of clothing from expanded sandwich type materials are greatly dependent upon the conditions of hydrostatic pressure and deformation with respect to the man’s body surface as well as upon dynamic deformations during operational service of the suit [2,3]

2.4. Study the effect of pressure on the deformation of neoprene.

Material of clothes in service suffers loads and deformation that in general do not exceed rupture stress. At thus, when examining mechanical properties of materials, total strain and components thereof at single loadings below rupture stress are measured besides strength and rupture elongation characteristics.

A method of autonomous fixing the deformation of expanded material thickness has been developed for conduction of such investigations. Basing on the method proposed, the authors have developed a fundamental solution for a special device for autonomous measurements of the deformation characteristics of expanded polymer materials, in particular, in the conditions of direct hydrostatic pressure on the clothing (Fig.3).

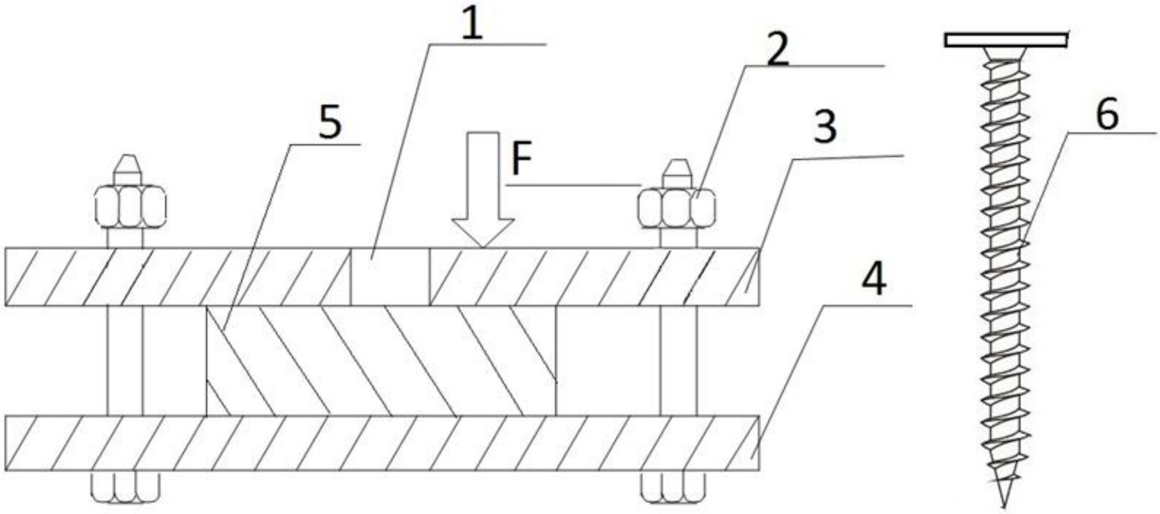

Figure 3: Device for compression of porous materials research (1-axis neoprene fixation; 2 - screw connection; 3 - the top support plate; 4 - a lower base plate; 5 - neoprene; 6 - screw clamp for a porous material).

The results of experimental studies obtained have allowed to derive relations for the behaviour of deformation characteristics of expanded materials. The examination resulted in derived dependency for further use in automated calculation of correlations of the diving dress' parts dimensional parameters:

$$\delta = -0,0002P + 0.0098$$

$$R^2 = 0.9943 \quad (1)$$

where: δ - Thickness, m.; R^2 - credibility factor.

2.5. Results for CAD wetsuit

The thicker the neoprene sample is, the less it is affected with strain changes. As to the plastic strain, the experiment had show that plastic strain depends upon both thickness of the sample and the coating of it.

Accounting derived results there was an algorithm for further integration in CAD systems elaborated [5] (Fig.4).

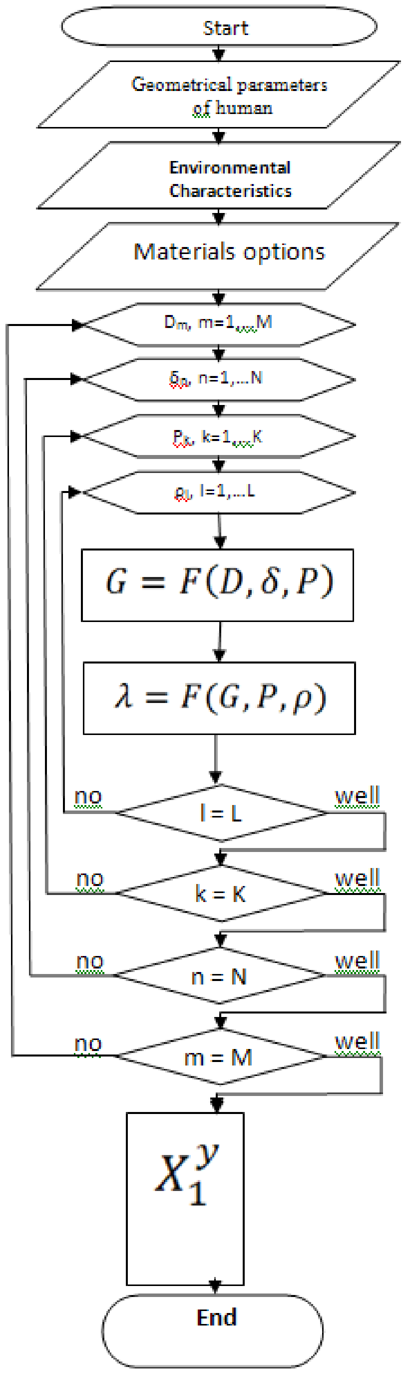

Figure 4: Algorithm CAD-Design wetsuits (D- deformation; δ - thickness, P - pressure, ρ - density, G- geometric index,λ - thermal conductivity, X_1^y - design factors).

3. CONCLUSIONS

The results allow enlarging of modern capabilities of diving dress' design using computer-aided methods, accounting for stress-strain behavior of materials, being complex physico-chemical systems, thus facilitating development of science and technology.

On the basis of the new relations for the behaviour of material properties in the elements of clothing construction, the authors have proposed a mathematical model and a basic algorithm of the program module for extending and improving the functional life cycle of modern CAD systems for functional clothing design.

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