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Visualization of High-speed Interaction of Bodies in Water

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Abstract. The work presents opportunities of hydroballistic complex for studying the characteristics of movement supercavitation model (SCM) on the length of waterway to 10 m. Gunfire of SCM implemented by this complex allows to study movement and collision of the different masses of SCM with underwater obstacles at subsonic, transonic and supersonic velocities in water. During the movement of SCM different masses the behavior supercavity was investigated.

INTRODUCTION

The most important tasks for developers of new models of underwater technology are overcoming resistance to the body's movement in water and its sustainability. During the motion in the water, as in the air, the resistance force depends on the shape of the body. The one way to reduce the resistant force is to make the body is specially designed streamline shape. Another way of a significant reduction of resistant force is the movement in supercavitation mode. This is a mode of body motion in water, wherein around it using a special head cavitator a cavity filled with steam. This significantly reduces the contact area between the body and water, as a result is resistance drops [1, 2, 3, 4]. The most important for the study of the bodies' motion in the water is the visualization of the processes, identification of patterns and approaches to task solving. Different approaches to visualization of complex flows in liquids are considered in [5, 6, 7]. The history of the 50-year period of research on supercavitation in the United States is described in the article [3] as the author's personal recollections. The experimental setup, experimental methodology and the main results of the research of body movement in supercavitation mode are described in [4, 8]. This work aims to develop methods for researching high-speed movement of bodies in water on the hydroballistic complex.

CALCULATION-EXPERIMENTAL RESEARCH

The hydroballistic stand is a closed ballistic installation, consisting of: gunfire ballistic installation (1), the vacuum part of the track (2), the aerodynamic part of the track (3) and the hydrodynamic part of the track with the target complex (4) equipped with measuring, photo and video recording and auxiliary equipment. Figure 1 shows the hydroballistic general scheme of the complex. The projectile is consists of the impactor and the guiding device, accelerates in the ballistic installation barrel to the desired velocity. A cooling of the hot powder gases occurs in the vacuum part of the track. A separation the guiding device from the impactor occurs in the aerodynamic part of the track. Then the impactor enters in the hydrodynamic part of the track, the length of which can be up to 10 m. The body captures and registration of its deviation from the aiming point occurs in the target complex.

The projectile velocity recording occurs in the barrel by microwave Doppler sensor, in the output from the barrel using a muzzle velocity sensor (MVS) and in the trajectory before moment of contact with the target. After the pro-

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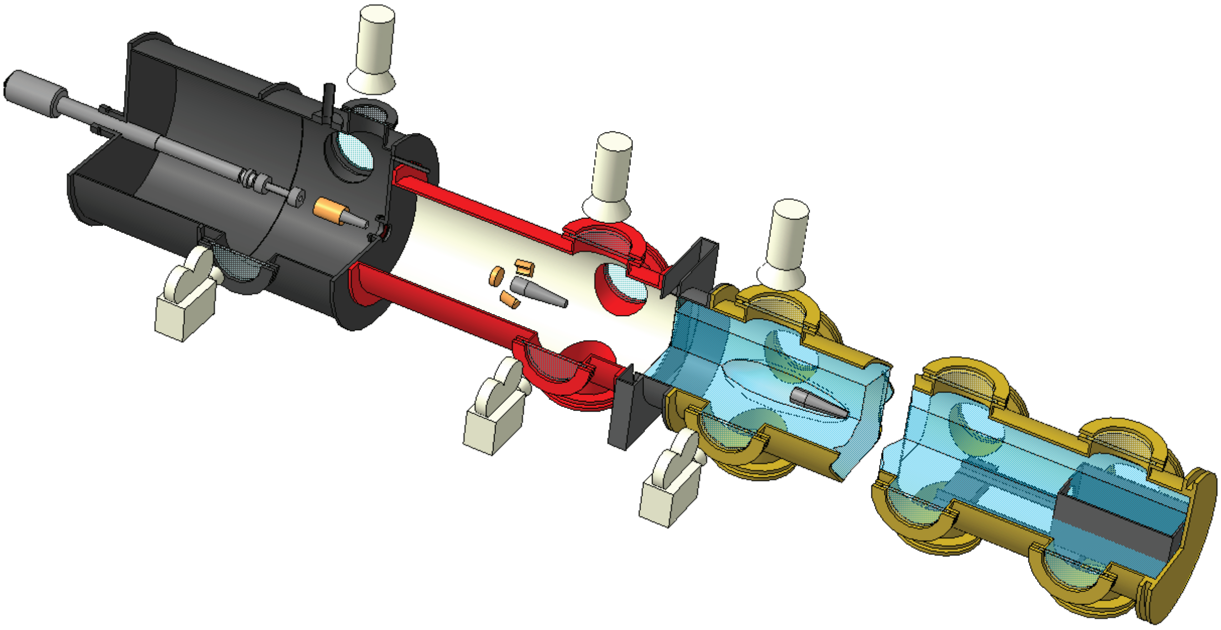
jectile flew from the barrel, on every part of the track the visual check of the body state and its location throughout the trajectory before reaching the target complex is possible through special windows. A significant amount of information is saved and processed by the measuring and recording facility by using various techniques of photo and video recording. Figure 1 shows one way the location of recording equipment. The video cameras are installed in this example in different parts of the track: the vacuum, the aerodynamic and the hydrodynamic parts. Direct observation of the bodies' movement on the aerodynamic part of the track by high-speed camera Phantom v711 and Cordin 530 allows developing the optimized design of the guiding device of different materials: textolite, polyethylene, cork, balsa. The studying the behavior of bodies in the hydrodynamic part of the track allows to evaluate the state of the impactor by the appearance, to correct of its shape or to choose construction material for implementation of strength and stability motion.



1 – powder ballistic installation, *2* – the vacuum part of the track, *3* – the aerodynamic part of the track, *4* – the hydrodynamic part of the track the target complex

FIGURE 1. The hydroballistic track

Features of cameras provide a good quality image of the object on the trajectory in investigated environment. Figure 2 shows video frames of the inseparable projectile movement on the vacuum part of the track. The continuity and no deformation of the projectile and the stable movement of the impactor on the trajectory from the MVS to reach places (node) the entrance to the aerodynamic part of the track are observed. The greatest interest for visual observation is the movement of projectiles with separation guiding device. For example, a research of the possible impact on the design by hurled body separation parts.

Separate designs projectile are used to hurl bodies with a diameter smaller than the barrel diameter, as well as applied to hurl bodies with a large prolongation. They include impactors by way of truncated cone with flat disc cavitator moving in water supercavitation mode. Figure 3 shows the appearance of typical samples supercavitation models (SCM) of the solid metal. Weights submitted SCM samples are in the range from 7 to 225 g.

Figure 4 shows video frames of the projectile movement on the vacuum part. Followed by the body, a separation of the pusher pallet parts occurs by the action of gas jets emerging from the barrel. Also there is the beginning of opening guiding device. By the time of the attainment locations (nodes) enter the aerodynamic part of the track by the projectile the pallet is completely taken away from the movement trajectory. The beginning of the separation of the centering device sectors of the hurled body also is seen.

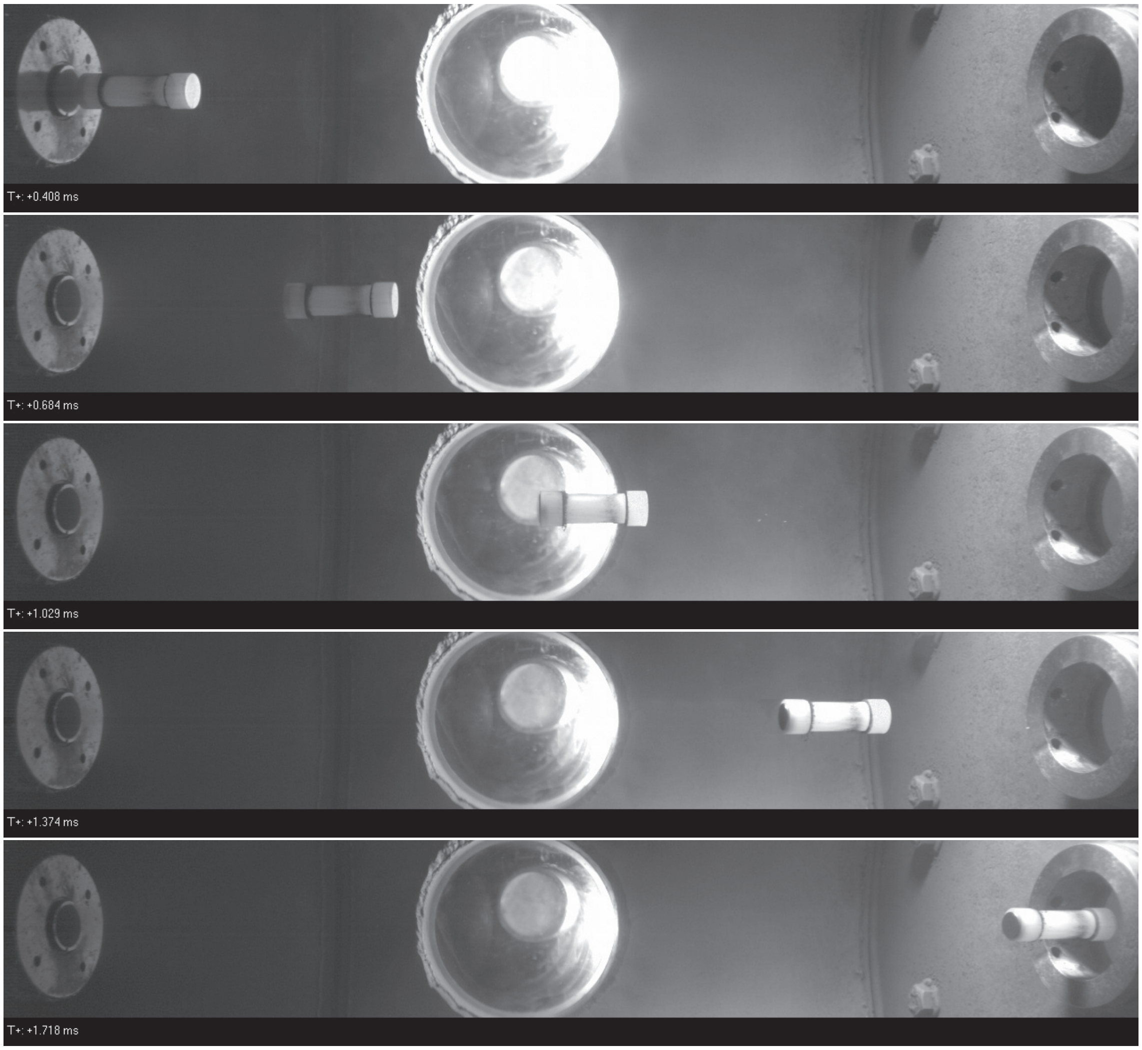


FIGURE 2. Video frames of the unshared projectile movement on the vacuum part of the track

FIGURE 3. The typical SCM appearance

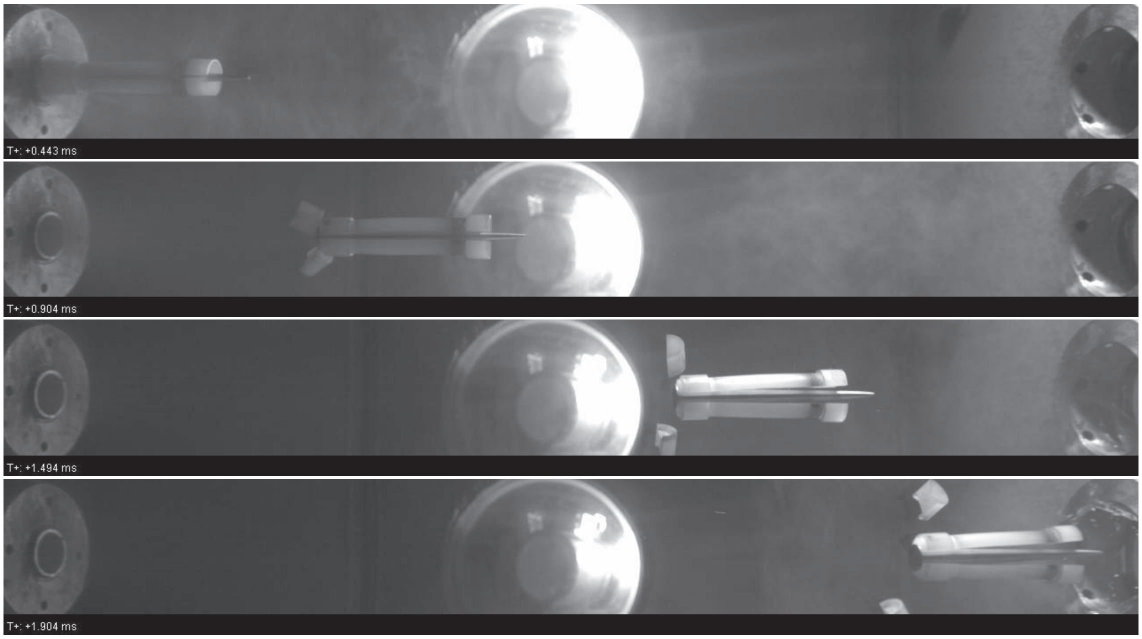


FIGURE 4. Videos frame of the projectile movement on the vacuum part of the track

Figure 5 shows video frames of projectile movement after passing distance of 2.0 m on air part of the track at a speed of 970 m/s. There is a complete separation the guiding device from SCM, moving without deviating from the trajectory axis. Then SCM enters on hydrodynamic part of the track, without outside influences from the centering device sectors and the pusher pallet. Used visualization systems also allow measuring the geometric characteristics of the body: length, width, angle of alternation from the axis of movement, as well as possible to determine the projectile velocity or its other parts.

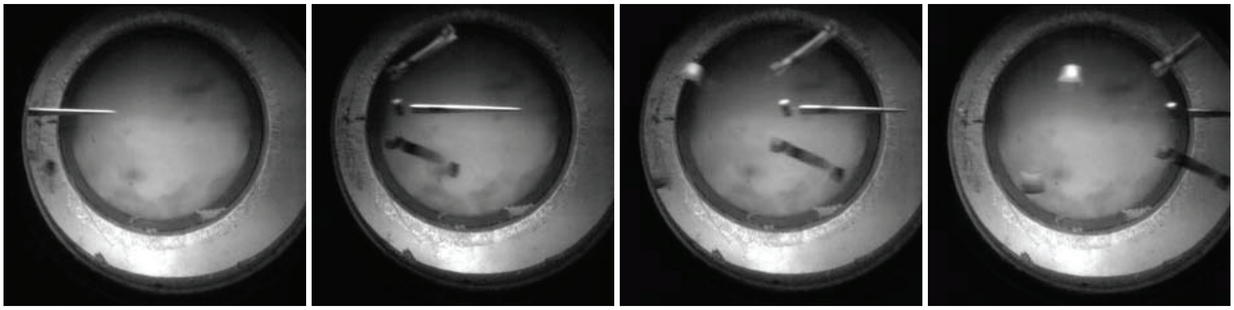


FIGURE 5. Video frames of SCM movement on air part of the track

Figure 6 shows video frames of movement of the SCM weighing 58 g in the water, at a velocity of 954 m/s at a distance of 3.2 meters from the entrance to the water part of the track. There is the steady movement of the projectile in the center of the cavity, so SCM contact with the water surface is only by plane forebody part. Figure 7 shows the movement of the same body through the 5 m, a velocity of the body was 857 m/s on this section. It can be seen that the afterbody briefly touches the inside of the cavity and repels from its walls thereby stabilizing in the cavity. Initially SCM movement in water the duration of body contact with the surface of the cavity can be much greater, depending on the initial entry angle of the body in water, velocity and body weight [9]. The more the weight, the higher the inertial properties of the body by glissade in the cavity. Figure 8 shows the movement of SCM weighting 225 g, at a velocity of 801 m/s at a distance of 3.2 m from the entrance of water.

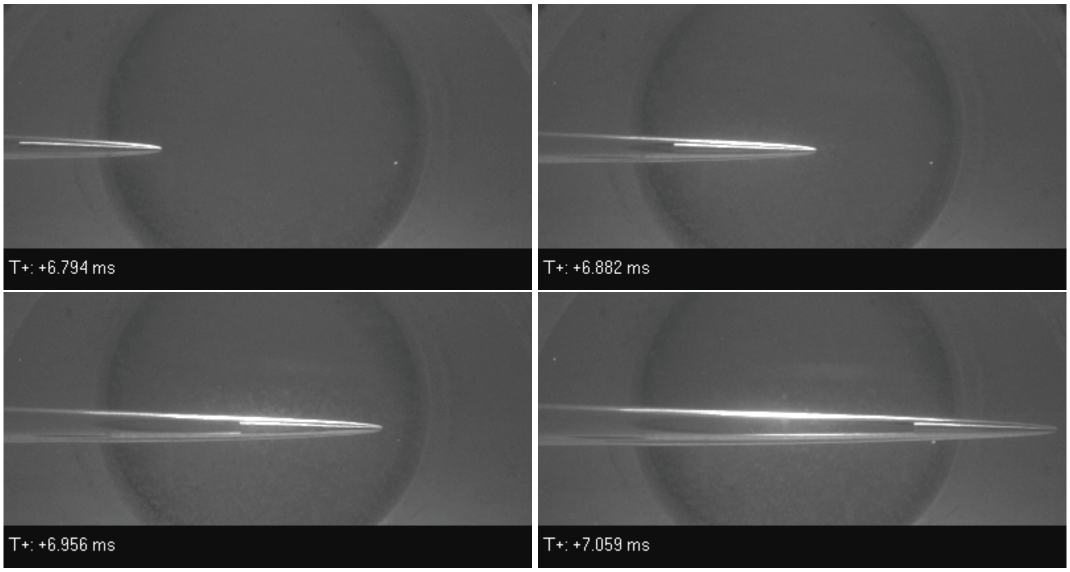


FIGURE 6. Video frames of movement of the SCM weighing 58 g, at a velocity of 954 m/s at a distance of 3.2 meters from the entrance to the water part of the track

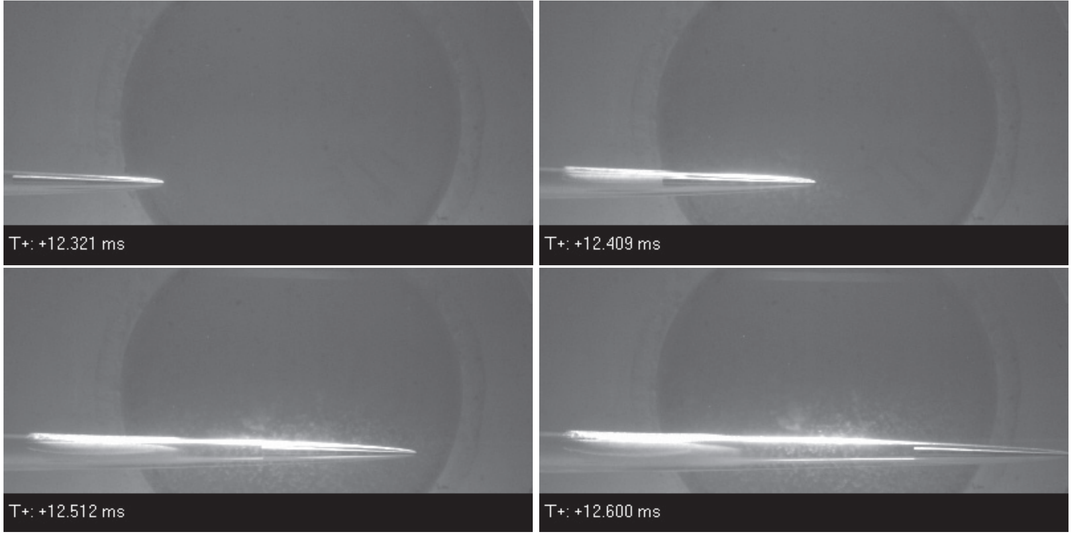


FIGURE 7. Video frames of movement of the SCM weighing 58 g, at a velocity of 857 m/s at a distance of 8.2 meters from the entrance to the water part of the track

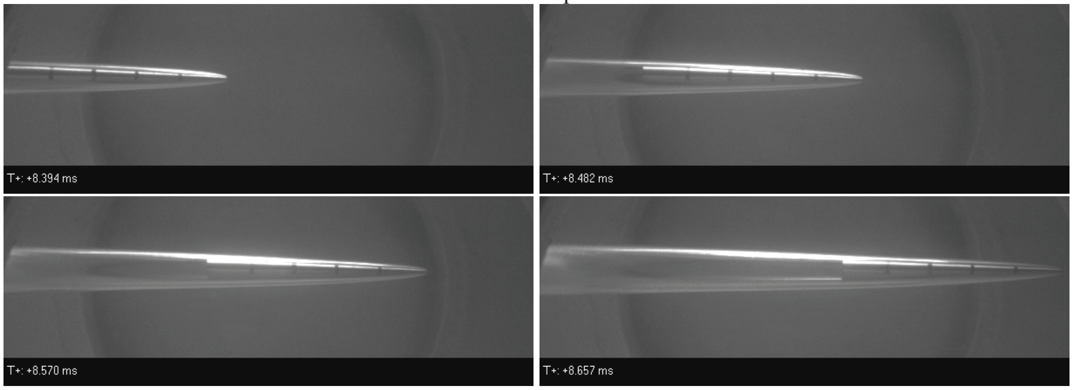


FIGURE 8. Video frames of movement of the SCM weighing 225 g, at a velocity of 801 m/s at a distance of 3.2 meters from the entrance to the water part of the track

It is also possible geometrical holding of body measurements and determining its velocity in water. In addition to state of the body in the cavity the relating much recording time allows to observe the behavior of the cavity, as well as to perform measurements of its geometric characteristics. The motion of the well stabilized body in the water is characterized by transparent walls of the cavity. Figure 9 shows video frames of the motion of SCM weighing 150 g and formed cavity at a velocity of 628 m/s and a distance of 3.2 m from the entrance of water. The diameter of the cavity in the projectile afterbody is 31 mm. The maximum diameter of the cavity was reached by about 8 ms after the vault of the body and was 105 mm. Time before closing the cavity at this part of the trajectory was about 15.5 ms. The cavity has the shape of an elongated ellipse (oval) with a maximum diameter approximately in the middle.

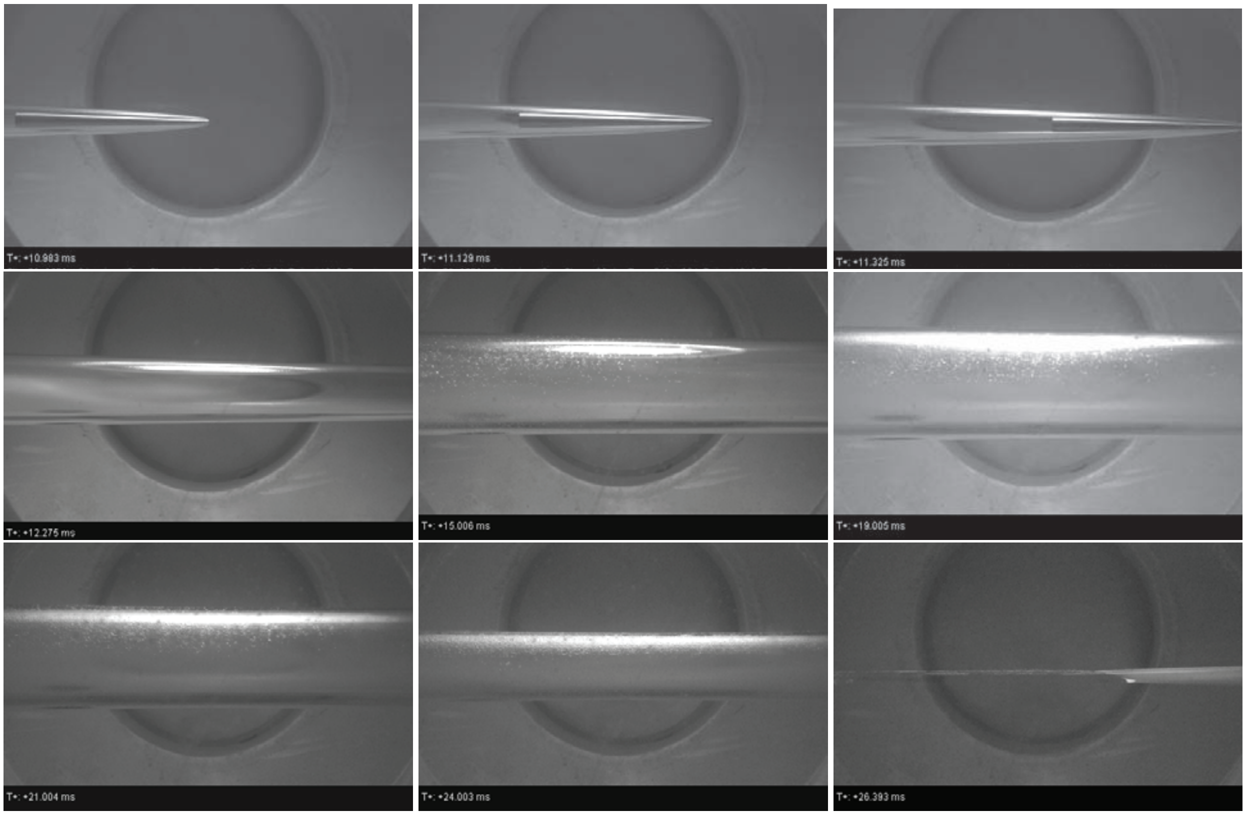


FIGURE 9. Video frames of the motion of SCM weighing 150 g and formed cavity at a velocity of 628 m / s and a distance of 3.2 m from the entrance of water

The visualization of the interaction of the SCM with various obstacles occurs in the target complex. Figure 10 shows video frames of the motion of the SCM weighting 55 g through the textolite obstacle 1 mm in thickness on the distance 3.2 m from the entrance in water. A velocity of the body at this part was 707 m/s. In this test, the obstacle was placed slightly at a different angle to the body, follow the point of impact. The aiming point on the obstacle is indicated by a small dot. The deviation from the aiming point was about 3.5 cm. On video frames can be seen that at a penetration obstacle the body saves its geometrical dimensions, but little touches the cavity by afterbody. Noteworthy is that the cavity behaves as if it does not interfere with the barrier.

Figure 11 shows results of the underwater interaction of SCM weighting about 150 g with steel obstacle of 8 mm in thickness at velocities about 500 m/s. Obstacle was located in the target complex at a distance about 10 m from the entrance in water.

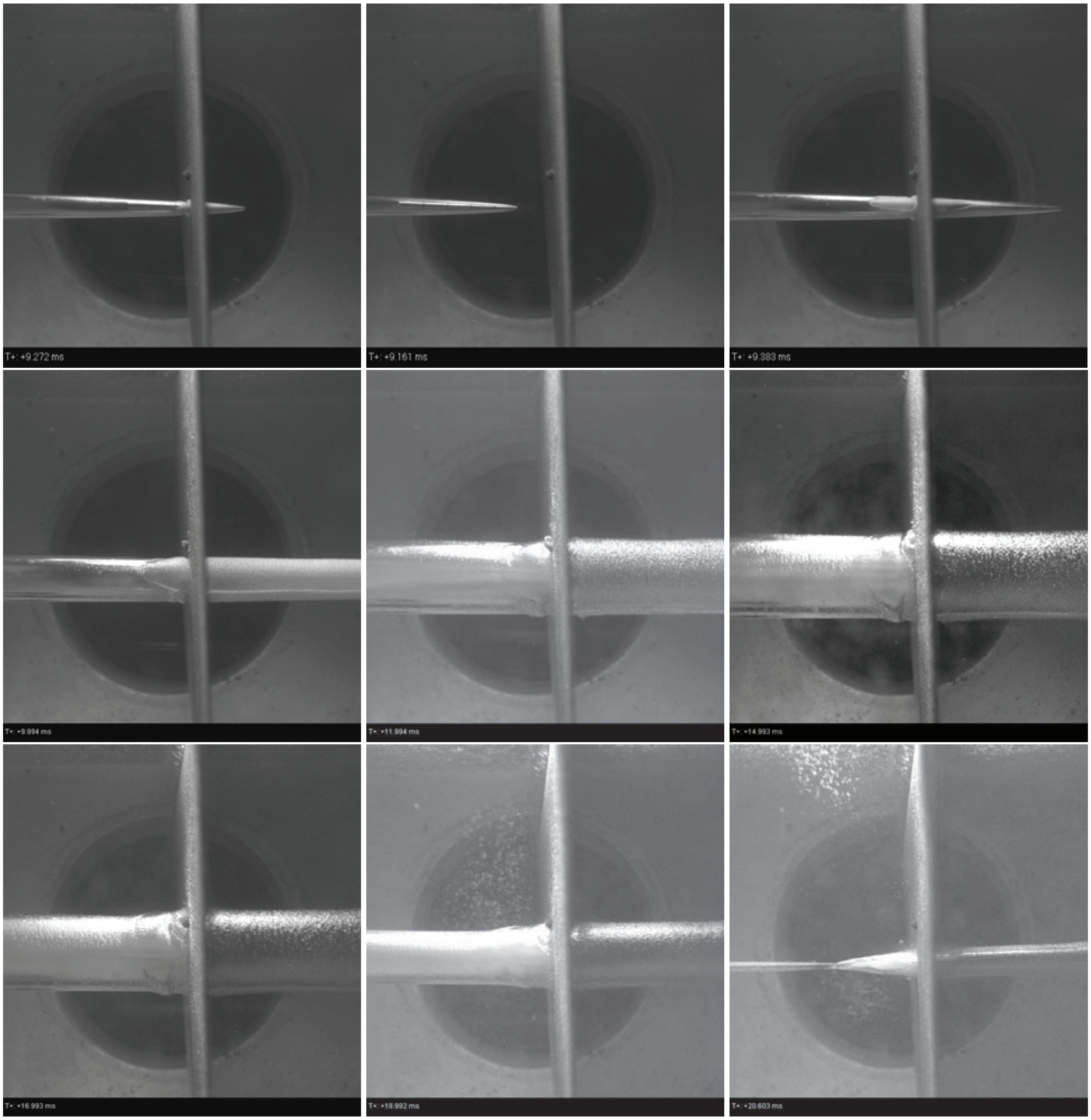


FIGURE 10. Video frames of the motion of the SCM weighting 20 g through the subtle obstacle on the distance 3.2 m from the entrance in water part of the track

FIGURE 11. Results of the underwater interaction of SCM weighting about 150 g with steel obstacle of 8 mm in thickness at velocities about 500 m/s

CONCLUSION

Features of the movement of developed SCM are investigated in the wide range of masses and velocities by using visual monitoring systems. The problems of SCM stabilization at the initial part of the trajectory in the water are investigated. It is shown that the SCM developed by gliding inside the cavity weights from 7 to 225 g and acquires resistance, saving until the defeat obstacle. The interaction of the SCM with the obstacles of various types and thicknesses is investigated. The maintenance and condition of cavity, as well as the impact of subtle obstacles to the formation of cavity are investigated.

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