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Layout optimization of landing gears for an underwater glider based on particle swarm algorithm

Baoshou Zhang [a,*], Baowei Song [a], Zhaoyong Mao [a], Boyang Li [b,c]

[a] School of Marine Science and Technology, Northwestern Polytechnical University, Shaanxi, China
[b] College of Electromechanical Engineering, Qingdao University of Science and Technology, Shandong, China
[c] Marine Engineering Department, Qingdao Ocean Shipping Mariners College, Shandong, China

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ABSTRACT

A novel optimization process is proposed to find the optimal layout of landing gears for an underwater glider, based on which the comprehensive performance of the underwater landing platform is significantly improved. The performance of the platform is defined by 4 sub optimization objectives. The weights of the sub objectives are determined according to the degree of importance. 2 kinds of instability states of the platform are defined. Numerical investigations are carried out to analyze the hydrodynamic performance of the platform using Ansys CFX. Then, response surface models of the optimization objectives are established using 30 sample points (design schemes). The response surface models describe the relationship between the optimization objectives and layout parameters of the landing gears. Particle swarm optimization (PSO) is applied to search for the optimal solution accompanied with the response surface models. Finally, the value of the global optimization objective is enhanced from −0.1601 to −0.1147.

1. Introduction

Various unmanned underwater vehicles (UUV) have been developed to complete ocean exploitation tasks. Underwater gliders are a type of practical underwater vehicles. Underwater gliders use small changes in their buoyancy in conjunction with wings to convert vertical motion to horizontal motion, and thereby propel themselves forward with very low power consumption [1]. Compared with traditional underwater vehicle with a slender body of revolution, the gliders have the advantages of low-noise, long range and long duration [2]. Many underwater gliders have been used in underwater inspection and detection technology [3–5].

When an underwater glider has to collect data from a prearranged position on the seabed, the ability of landing or mooring on the seabed is necessary. At present, the design of landing or mooring method for an underwater vehicle has become an essential issue. As for mooring platforms, 3D interaction and numerical differential models between anchor chain and seabed has been studied [6–8]. The influence of external disturbance factors on mooring line should be taken into account. This type platform has the advantages of simple structure design, but it is difficult to keep stable gesture. Thus, the platforms are easily affected by ocean currents. As for bottom resting platforms, hydrodynamic characteristics and stability of the platforms have been analyzed [9,10]. Furthermore, the control principle of these autonomous underwater robots has been studied [11]. But the flat seabed is necessary for the bottom resting platforms, and disturbance factors from seabed have significant negative effect on the performance of the landing platforms.

In this paper, the design scheme using landing gears will make UUV staying away from disturbance factors from seabed. But the optimal layout of landing gears is always hard to resolve. The layout of the landing gears will influence the performance of the landing platform, such as fluid drag, fluid torque and glider attitude. Therefore, considering multiple objectives, a synthesis optimization process is proposed. A highly effective optimization method must be selected for the optimization process. In recent years, many optimization algorithms have been used in engineering applications. Inspired by observing the natural swarming behavior of bird flocking, the stochastic optimization technique called particle swarm optimization (PSO) had been proposed [12]. PSO algorithm is simple in concept, easy to implement and computationally inexpensive. PSO has been successfully applied to a wide range of application areas [13–15].

Compared with the traditional design method for the layout of landing gears for an underwater platform, the layout design procedure using PSO algorithm accompanied with the response surface models is more efficient. The optimal design scheme could be accurately found in the feasible scheme, so that synthetic properties of

* Corresponding author.
E-mail address: 1262034751@qq.com (B. Zhang).

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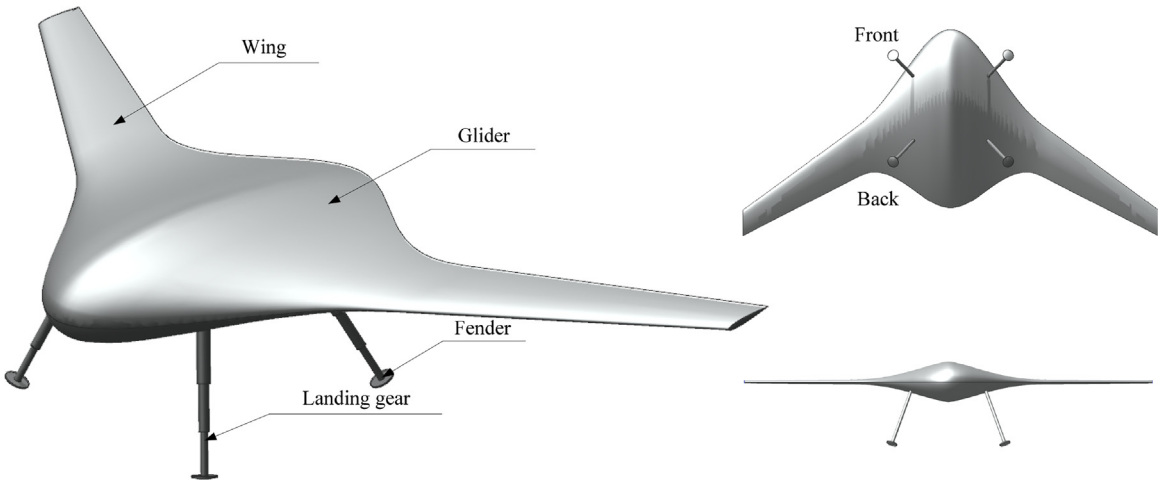

Fig. 1. schematic of the landing platform.

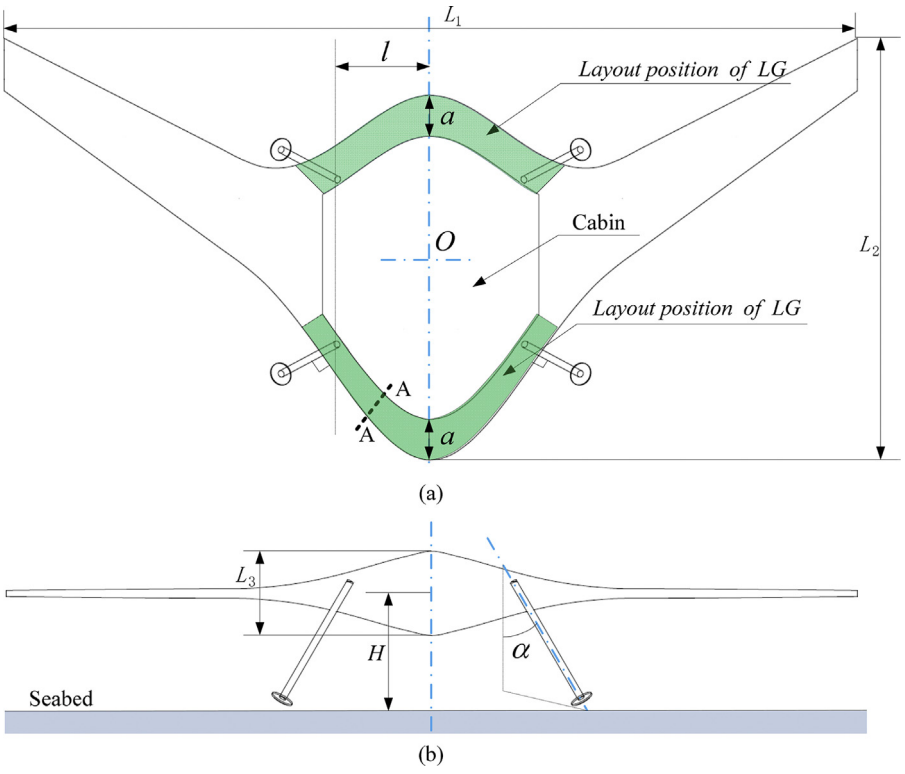

Fig. 2. (a) plan view and (b) front view of landing platform.

the landing gears will be excellent. The global optimization objective is significantly improved changing from −0.1601 to −0.1147. Moreover, it will enrich the modeling method and optimization ideology for future research about landing platforms.

2. Geometry configuration

2.1. Physical model

At present, the design of the glider has been completed. The landing platform consists of an underwater glider and landing gears. Fig. 1 shows the schematic of the landing platform.

Several parameters should be taken into consideration for the design of the landing platform, for example, the shape of the glider, hydraulic supports, the seabed conditions, environmental conditions. Fig. 2 shows the main parameters of the landing platform. L_1 represents the maximum width of the glider. L_2 represents the maximum length. L_3 represents the maximum height. H represents the height of the center of buoyancy. Four landing gears are divided into two groups (front and back). The front landing gears are perpendicular to the profile of the glider. The front landing gears are placed in *Layout position of LG (Landing Gear)*. The back landing gears are buoyance-symmetric with the front landing gears. According to the known geometry of glider's pressure hull, the landing gear could be defined by two parameters (the distance from the center l and the inclination angle α). Since the present study focuses on the optimal layout of the landing gears, the internal structure of the glider has been omitted.