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Multidisciplinary Design Optimization of A Human Occupied Vehicle Based on Bi-Level Integrated System Collaborative Optimization*

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ABSTRACT

The design of Human Occupied Vehicle (HOV) is a typical multidisciplinary problem, but heavily dependent on the experience of naval architects at present engineering design. In order to relieve the experience dependence and improve the design, a new Multidisciplinary Design Optimization (MDO) method "Bi-Level Integrated System Collaborative Optimization (BLISCO)" is applied to the conceptual design of an HOV, which consists of hull module, resistance module, energy module, structure module, weight module, and the stability module. This design problem is defined by 21 design variables and 23 constraints, and its objective is to maximize the ratio of payload to weight. The results show that the general performance of the HOV can be greatly improved by BLISCO.

Key words: *Multidisciplinary Design Optimization* (*MDO*); *Human Occupied Vehicle* (*HOV*); *Bi-Level Integrated System Collaborative Optimization* (*BLISCO*); *general performance*

1. Introduction

The design of Human Occupied Vehicle (HOV) is a complex multidisciplinary problem, which involves hydrodynamics, structural mechanics, propulsion, energy, stability and other disciplines. Traditionally, the discipline specialists make use of local design methods and tools to perform optimization with respect to the unique aspect of its local discipline, and do not consider the influence from other disciplines. The chief designer is responsible for the coordination among different disciplines based on his experience. This spiral process will not be finished until the compatibility requirements among different disciplines are satisfied. Obviously, this traditional approach depends mainly on the experience of the chief designer and may result in a sub-optimal design. How to overcome this deficiency and obtain the global optimum is the main consideration of the chief designer. Liu and Cui (2004) made research about the theory of Multidisciplinary Design Optimization (MDO) and application in consideration of MDO in HOV design, and concluded that MDO is a

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promising tool for fulfilling this purpose.

MDO is a methodology for the design of complex engineering systems and subsystems that coherently exploits the synergism of mutually interacting phenomena (Korte *et al*., 1997). According to system decomposition, the system is divided into several subsystems, which are related to each other with coupled relationship. Based on this complex coupled relationship, MDO makes it possible to find the global optimum design. With the rapid development of MDO, it has been applied in many modern engineering applications like aircraft (Kroo *et al*., 1994; Zang and Green, 1999; Antoine and Kroo, 2005; Henderson *et al*., 2012), launch vehicle (Brown, 2004) and surface combatant (Peri and Campana, 2003; Kim and Vlahopoulos, 2012). During recent years, MDO has already been taken as an important method to design the underwater vehicles as well (McAllister *et al*., 2002; Kalavalapally *et al*., 2006; He *et al*., 2009; Martz and Neu, 2009; Alam *et al*., 2012). Therefore, as a typical MDO problem, it is meaningful to apply MDO in the design of HOV.

In the previous work, System Synthesis Model (SSM) (Zhao and Cui, 2009) is developed for a HOV. In order to further improve the general performance of this HOV, a new Multidisciplinary Design Optimization method "Bi-Level Integrated System Collaborative Optimization (BLISCO)" (Zhao and Cui, 2011) recently developed by the authors, is applied to the design of HOV.

2. Algorithm of BLISCO

BLISCO belongs to bi-level optimization with hierarchical structure, which is shown in Fig. 1. The original optimization problem is decomposed into system-level optimization and subsystem- level optimization. The subsystem-level optimization minimizes the synthetic influence of the coupled output response to the system objective, while the system-level optimization coordinates the difference between different subsystems. The key ideas of this method are to replace compatibility constraint with the sum of coupled output responses as an integrated objective of subsystem and to decompose design variables into system design variables and subsystem design variables.

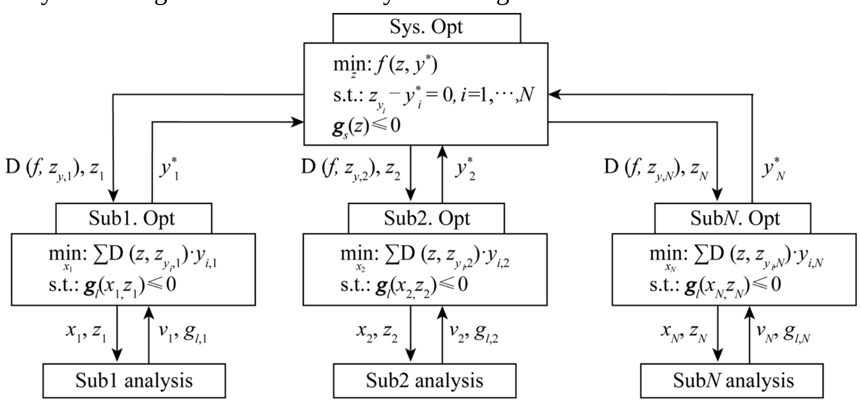

Fig. 1. Architecture of BLISCO.

The main derivation procedure is as follows.

The system objective f can be expressed as a function of system design variables $\boldsymbol{z}$ by the linear part of the Taylor series:

$$\begin{aligned} f &\approx f_0 + \mathrm{D}\left(f, \boldsymbol{z}_{\text{share}}\right)^{\mathrm{T}} \Delta\boldsymbol{z}_{\text{share}} + \mathrm{D}\left(f, \boldsymbol{z}_y\right)^{\mathrm{T}} \Delta\boldsymbol{z}_y \\ &\approx f_0 + \mathrm{D}\left(f, \boldsymbol{z}_{\text{share}}\right)^{\mathrm{T}} \Delta\boldsymbol{z}_{\text{share}} + \mathrm{D}\left(f, \boldsymbol{z}_y\right)^{\mathrm{T}} \boldsymbol{z}_y - \mathrm{D}\left(f, \boldsymbol{z}_y\right)^{\mathrm{T}} \boldsymbol{z}_y^0, \end{aligned} \quad (1)$$

where $\mathrm{D}\left(f, \boldsymbol{z}\right)$ is the derivative of f with respect to the system design variables $\boldsymbol{z}$.

Since the output-input equalities ensure that the system design variable $\boldsymbol{z}_y$ equal to the corresponding $\boldsymbol{y}^*$, the third term in the right side of Eq. (1) can be rewritten as:

$$\mathrm{D}\left(f, \boldsymbol{z}_y\right)^{\mathrm{T}} \boldsymbol{z}_y = \mathrm{D}\left(f, \boldsymbol{z}_y\right)^{\mathrm{T}} \boldsymbol{y}^*, \quad (2)$$

which is used as the subsystem objective. This formulation reflects a “synthetic” influence of the subsystem on the entire system objective. Particularly, if system objective f is one output response from subsystem, the corresponding subsystem objective will be f, because it reflects the total influence of the subsystem on the entire system objective.

The calculation of $\mathrm{D}\left(f, \boldsymbol{z}_y\right)$ is very important for the successful application of BLISCO. There are two methods about its calculation. The first one is to obtain $\mathrm{D}\left(f, \boldsymbol{z}_y\right)$ by analytical derivation or finite difference before subsystem-level optimization, so the subsystem-level optimization will not be influenced by the calculation of $\mathrm{D}\left(f, \boldsymbol{z}_y\right)$, and can be performed in the distributed and concurrent process. The other is to obtain $\mathrm{D}\left(f, \boldsymbol{z}_y\right)$ by optimal sensitivity analysis (Nystrom, 1863) after subsystem optimization.

After the development of BLISCO, approximation model is used to improve the efficiency for cost simulation problem (Jiang *et al*., 2012), and BLISCO-SORA is developed for multidisciplinary design optimization under hybrid uncertainty of randomness and fuzziness (Li *et al*., 2013). Besides, BLISCO method is also cited in international journals of multidisciplinary design optimization (Yao *et al*., 2012; Ciucci *et al*., 2012; Lin and Gea, 2013).

3. Multidisciplinary Design Optimization of An HOV

The system synthesis model (Zhao and Cui, 2009) is a primarily semi-empirical model for an HOV in the conceptual design stage. It includes six modules: hull module, resistance module, energy module, structure module, weight module, and the stability module.

Hull module is based on Nystrom’s model (Allmendinger, 1990) and the bare hull shape of the HOV is composed of a teardrop shape and parallel midbody, which provides more arrangement areas. This module calculates the hull characteristics, such as the envelop volume and the wetted surface area.

Resistance module is to predict the HOV resistance, and is based on two assumptions (Burcher and Rydill, 1994; Fidler and Smith, 1978): (1) the steady-state condition in level flight without maneuvering; (2) the drag of the streamline vehicle which can be decomposed with individual drag components, permitting an analysis using empirical relationships. Towing Tank Conference (ITTC) 1957 formula is adopted to predict the frictional resistance, while the shape and appendage resistance coefficient are adopted with references (Jackson, 1983; Barthelemy and Sobieszczanski-Sobieski, 1983). Except for the resistance prediction, this module also estimates the input power, weight and volume of the propulsion system.

Energy module is to calculate the power of HOV. This module considers different batteries, such as Lead-Acid, Nickel-Cadmium, Silver-Zinc, and Lithium-Ion. With the power-energy profile of the specific mission for HOV, the total energy can be easily calculated.

Structure module is mainly concerned about the mechanics of pressure hull. Three different topological structures, which are sphere, stiffened cylindrical shell, and Multiple Intersecting Spheres (MIS), are considered about the collapse of sphere, interframe yield, interframe buckling, general instability, frame yield, frame instability, and head instability.

Weight module calculates the total weight, longitudinal coordinates of gravity center and buoyant center, metacentric height, and the trim angle of HOV. Under the consideration of reserve buoyancy and positive buoyancy, the total buoyancy is designed to exceed the total weight with a margin during the conceptual design stage.

Stability module mainly considers the dynamic stability of HOV. Based on semi-empirical approach DATCOM, the hydrodynamic coefficients in horizontal plane and vertical plane can be obtained with the sum of the hydrodynamic coefficients of bare hull and appendages. With the eight hydrodynamic coefficients, the stability indices in the horizontal plane and vertical plane can be obtained to evaluate the dynamic stability in the horizontal plane and vertical plane, respectively.

According to Design Structure Matrix (DSM), a reasonable design sequence is established as shown in Fig. 2, where the black dots mean that the left upper module passes input variables to right lower module. The objective in this design problem is to maximize the ratio of payload to the weight of HOV. The design is subject to constraints on structural strength, stability, energy and so on.

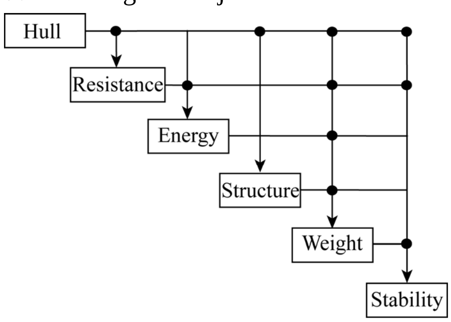

Fig. 2. Design Structure Matrix (DSM) of system synthesis model for HOV.

It is found that there is only feed forward from the left upper module passing input variable to the right lower module and no feedback from the right lower module to the left upper module in the data flow. Therefore, the relationships between different disciplines are loosely coupled, and the multidisciplinary analysis does not need to perform iterative computations between different disciplines.

The traditional optimization model of HOV has 15 design variables and 20 constraints. The model is specified as follows:

$$\min_{x} f = W_{\text{effec}}; \tag{3a}$$

s.t. $$g_1 = 600 - E_{\text{bat}} \le 0\,;\; g_2 = 0 - V \le 0\,;\; g_3 = V - 55 \le 0\,; \tag{3b–3d}$$

$$g_4 = \sigma_{\text{c}} - \sigma_{\text{s}} \le 0\,;\; g_5 = P_1 / P_{\text{m}} \le 1\,;\; g_6 = P_2 / P_{\text{n}} \le 1\,; \tag{3e–3g}$$

$$g_7 = \sigma_{\text{t,f}} - \sigma_{\text{s}} \le 0\,; g_8 = P_3 / P_{\text{cf}} \le 1\,; g_9 = P_4 / P_{\text{cs}} \le 1\,; \tag{3h–3j}$$

$$g_{10} = P_5 / P_{\text{cr}} \le 1\,;\; g_{11} = \sigma_{\text{sphere}} - 0.85\sigma_{\text{s}} \le 0\,; \tag{3k–3l}$$

$$g_{12} = \frac{w_{\text{f}}}{t_{\text{f}}} - 0.3\sqrt{\frac{E}{\sigma_{\text{s}}}} \le 0\,;\; g_{13} = \frac{h_{\text{w}}}{t_{\text{w}}} - 0.9\sqrt{\frac{E}{\sigma_{\text{s}}}} \le 0\,; \tag{3m–3n}$$

$$g_{14} = \frac{w_{\text{f}}}{F_{\text{spacing}}} - 1 \le 0\,;\; g_{15} = \frac{h_{\text{w}}}{R - 0.5t_{\text{s}}} - \frac{1}{6} \le 0\,; \tag{3o–3p}$$

$$g_{16} = 0.3 - h_{\text{BG}} \le 0\,;\;\; g_{17} = 0 - \varphi_0 \le 0\,;\; g_{18} = \varphi_0 - 1.5 \le 0\,; \tag{3q–3s}$$

$$g_{19} = -G_{\text{H}} \le 0\,; g_{20} = -G_{\text{V}} \le 0\,; \tag{3t–3u}$$

where W_{effec} is the ratio of payload to weight, E_{bat} is the total energy, V is the total volume of displacement, σ_{c} is the maximum von Mises stress of interframe shell, σ_{s} is the yield stress of material, $\sigma_{\text{t,f}}$ is the total stress of frame, σ_{sphere} is the sphere stress, w_{f} is the width of flange plate, t_{f} is the thickness of flange plate, E is the modulus of elasticity, h_{w} is the width of web plate, t_{w} is the thickness of web plate, F_{spacing} is the frame spacing, R is the outer radius of pressure hull, h_{BG} is the outer radius of pressure hull, and φ_0 is the trim angle. Eq. (3b) is the energy constraint, Eqs. (3c) and (3d) are dimension constraints, all required by the design indices. Eqs. (3e)–(3p) are structural constraints, $\{P_1, P_2, P_3, P_4, P_5\}$ are the allowable pressure load in lobar buckling, general instability, frame instability, demo instability and sphere instability, respectively; $\{P_{\text{m}}, P_{\text{n}}, P_{\text{cf}}, P_{\text{cs}}, P_{\text{cr}}\}$ are the critical pressure of interframe buckling, general instability, frame instability, spherical head and sphere, respectively; Eqs. (3q)–(3s) are equilibrium constraints, and submersible design criteria require that the metacentric height is not smaller than 0.3 m and the absolute value of trim angle is not smaller than 1.5°; Eqs. (3t) and (3u) are dynamic stability constraints in the horizontal plane and vertical plane, the submersible design criteria require that the stability index (G_{H} & G_{V}) should be positive number. Fifteen design variables of overall conceptual MDO model for HOV are summarized in Table 1.

Optimization procedure with decomposition is one of the main contents for MDO (Sobieszczanski-Sobieski and Haftka, 1998). Decomposition through distributed architectures allows individual design groups to work in isolation, which leads to optimization that will proceed and concurrently reduces the wall-clock time (Martins and Lambe, 2013). In order to apply BLISCO to multidisciplinary design optimization of the HOV and reduce the optimization dimensionality, a special decomposition scheme is adopted. Some disciplines are integrated as a new subsystem for decomposition of system design variables and subsystem design variables. Therefore, the hull module, resistance module and stability module are integrated as the hydrodynamics subsystem; the energy module and the weight module are integrated as the weight subsystem; the structure module is remained as the structure subsystem. The relationship among three subsystems is shown in Fig. 3.

Table 1 Design variables of overall conceptual MDO model for HOV

Parameters	Symbols	Initial design	Lower bound	Upper bound
Vehicle diameter (m)	D	3.4	3.3	3.6
Overall length (m)	L_{oa}	15	14	16
Radius of pressure hull (m)	R	1.2	1.15	1.4
Length of parallel midbody (m)	L_{pmb}	5.5	5.0	6.0
Length of forebody (m)	L_f	3.4	3.2	3.7
Fullness factor of forebody	n_f	2.5	2.0	3.5
Fullness factor of aftbody	n_a	2.5	2.5	4.0
Cruise speed (m/s)	V_e	1.0288	1.0288	1.5432
Thickness of flange plate (m)	t_f	0.015	0.001	0.0575
Width of flange plate (m)	w_f	0.07	0.001	0.014
Thickness of web plate (m)	t_w	0.01	0.001	0.0575
Height of web plate (m)	h_w	0.12	0.001	0.2
Shell thickness (m)	t_s	0.021	0.001	0.025
Frame spacing (m)	$F_{spacing}$	0.3	0.25	0.35
Payload (kg)	W_{pl}	1500	1500	2000

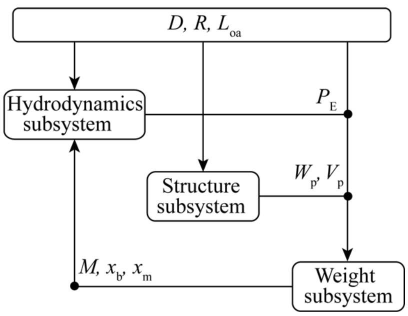

Fig. 3. The coupling relationship diagram of BLISCO framework for HOV.

Some constraints in weight subsystem depend mainly on system design variables, which leads to the constraints that may not be satisfied for weight subsystem optimization because their values do not change or change slightly. Therefore, these constraints are handled at the system-level optimization instead of subsystem-level optimization.

The mathematical model of BLISCO for this HOV is as follows.

System-level optimization

$$\min_{z} f = -W_{\text{effec}}^{*}; \tag{4a}$$

$$\text{s.t.} \quad g_1 = \left(\frac{P_E^{*} - z_{P_E}}{z_{P_E}}\right)^2 \le \varepsilon; \tag{4b}$$

$$g_2 = \left(\frac{W_p^{*} - z_{W_p}}{z_{W_p}}\right)^2 + \left(\frac{V_p^{*} - z_{V_p}}{z_{V_p}}\right)^2 \le \varepsilon; \tag{4c}$$

$$g_3=\left(\frac{M^*-z_M}{z_M}\right)^2+\left(\frac{x_{\mathrm{m}}^*-z_{x_{\mathrm{m}}}}{z_{x_{\mathrm{m}}}}\right)^2+\left(\frac{x_{\mathrm{b}}^*-z_{x_{\mathrm{b}}}}{z_{x_{\mathrm{b}}}}\right)^2\le\varepsilon\,; \tag{4d}$$

$$g_i(x)\le 0,\qquad i=1,\ 16,\ 17,\ 18\,; \tag{4e}$$

$$\boldsymbol{z}=\left\{z_D,z_{L_{\mathrm{oa}}},z_R,z_{P_{\mathrm{E}}},z_{W_{\mathrm{p}}},z_{V_{\mathrm{p}}},z_M,z_{x_{\mathrm{b}}},z_{x_{\mathrm{m}}}\right\}$$

where the ratio of payload to weight W_{effec}^* and constraint $g_i(x)$ are passed from the weight subsystem. ε is a small tolerance used to relax the system constraints and to accelerate convergence, which is specified as 1E–5 here. $z_{W_{\mathrm{p}}}$ and $z_{V_{\mathrm{p}}}$ are the weight and displacement volume of the pressure hull, M^* is the optimal weight of HOV feedback from subsystem-level optimization to system-level optimization, z_M is the weight of HOV, $z_{x_{\mathrm{b}}}$ and $z_{x_{\mathrm{m}}}$ are longitudinal coordinates of the buoyant center and gravity center, z_D is the vehicle diameter, z_R is the radius of pressure hull, $z_{P_{\mathrm{E}}}$ is the effective horsepower, and $z_{L_{\mathrm{oa}}}$ is the overall length of HOV. Besides, since the dimensions of system design variables are much different from each other, the normalization method is used in system design variables and compatibility constraints for a better convergence of system-level optimization.

Hydrodynamics subsystem optimization

$$\min_{\boldsymbol{x}_{l1}} f=\mathrm{D}\left(f,z_{P_{\mathrm{E}}}\right)*P_{\mathrm{E}}\,; \tag{5a}$$

$$\text{s.t.}\quad g_i(x)\le 0,\qquad i=19,\ 20\,; \tag{5b}$$

$$\boldsymbol{x}_{l1}=\left\{L_{\mathrm{pmb}},L_{\mathrm{f}},n_{\mathrm{f}},n_{\mathrm{a}},V_{\mathrm{e}}\right\},$$

where $\boldsymbol{g}(x)$ is the stability constraint, which requires that HOV should be stable in the horizontal and vertical plane. The calculation of $\mathrm{D}\left(f,z_{P_{\mathrm{E}}}\right)$ is based on the optimal sensitivity analysis. L_{pmb} and L_{f} are the length of parallel midbody and forebody; n_{f} and n_{a} are the fullness factors of forebody and aftbody; and V_{e} is the cruise speed.

Structure subsystem optimization

$$\min_{\boldsymbol{x}_{l2}} f=\mathrm{D}\left(f,z_{W_{\mathrm{p}}}\right)*W_{\mathrm{p}}+\mathrm{D}\left(f,z_{V_{\mathrm{p}}}\right)*V_{\mathrm{p}}\,; \tag{6a}$$

$$\text{s.t.}\quad g_i(x)\le 0,\qquad i=4,5,\cdots,15\,; \tag{6b}$$

$$\boldsymbol{x}_{l2}=\left\{t_{\mathrm{f}},w_{\mathrm{f}},t_{\mathrm{w}},h_{\mathrm{w}},t_{\mathrm{s}},F_{\mathrm{spacing}}\right\},$$

where $\boldsymbol{g}(x)$ are the strength constraints with the consideration of interframe yield, interframe buckling, general instability, frame yield, frame instability, dome instability and geometrical requirement. The calculations of $\mathrm{D}\left(f,z_{W_{\mathrm{p}}}\right)$ and $\mathrm{D}\left(f,z_{V_{\mathrm{p}}}\right)$ are based on optimal sensitivity analysis.

Weight subsystem optimization

$$\min_{x_{l3}} f = -W_{\text{effec}}; \tag{7a}$$

$$\text{s.t.} \quad g_i(x) \le 0, \quad i = 2, 3; \tag{7b}$$

$$\boldsymbol{x}_{l2} = \{W_{\text{pl}}\},$$

where W_{pl} is the payload weight. Since W_{effec} is one of the output responses from the weight subsystem and passed to system-level optimization as the system objective, the objective of weight subsystem-level optimization is W_{effec}. This is because the minimization of system objective in the weight subsystem-level optimization reflects the total influence of the weight subsystem on the entire system objective. $g_2(x)$ and $g_3(x)$ are the constraints about the displacement volume. Besides, there are some constraints handled at the system-level optimization, which are the constraints about energy, trim angle, and metacentric height.

In summary, the multidisciplinary design optimization of HOV based on BLISCO involves 21 design variables and 23 constraints. The method used in system-level optimization and subsystem optimization is sequential quadratic programming. All the computation is performed in MATLAB.

Since the ratio of payload to weight W^*_{effec} is a small magnitude value, which has influence on the convergence and accuracy of the optimization based on gradient method, and leads to the local optimal solution. Therefore, a magnified factor of 1000 is adopted for system-level optimization objective. Besides, in order to improve the convergence efficiency, normalization is used in system-level design variables.

It is clearly seen that BLISCO can find the optimal solution with the satisfaction of three system-level compatibility constraints, as shown in Fig. 4. However, there is oscillation during the optimization process, as shown in Fig. 5. This is because the change of variables for finite differencing is too large for this optimization problem. Therefore, the change of variables for finite differencing is shrunk by 1000 times, and the improved optimization processes are shown in Figs. 6 and 7.

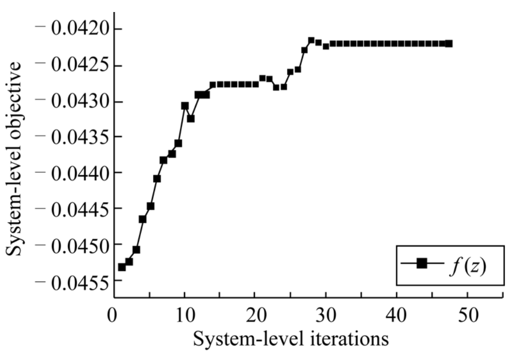

Fig. 4. Convergence history of system-level objective.

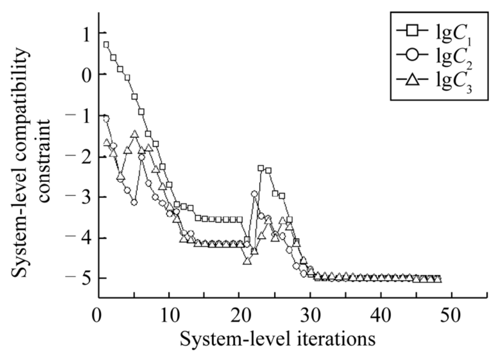

Fig. 5. Convergence histories of system-level compatibility constraints.

According to Fig. 6, the complete convergence process is better than before. However, there is still an oscillation from the 22nd iteration to the 23rd iteration. This is because the variation of system design variables leads to the decrease of constraint C_3, while constraint C_1 intensely rebounds due to the incompatibility of system-level design variables with subsystem-level design variables. After this oscillation, the optimization process gradually searches the optimal solution with satisfaction of compatibility constraint.

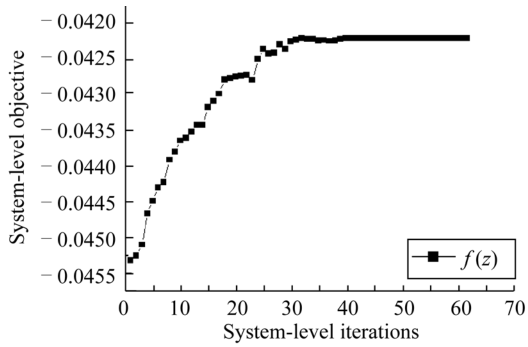

Fig. 6. Convergence history of system-level objective after finite differencing improved.

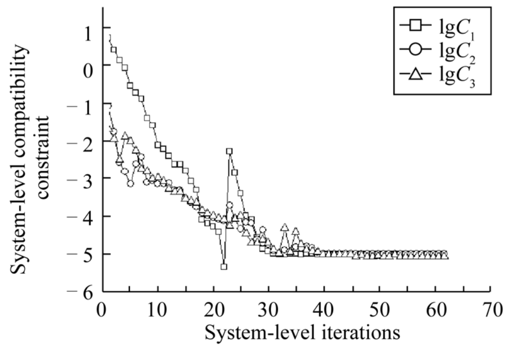

Fig. 7. Convergence histories of system-level compatibility constraints after finite differencing improved.

Table 2 HOV optimization results

Parameters	Initial design	Optimal design with finite differencing	
		Large change	Small change
D (m)	3.4	3.3	3.3
L_{oa} (m)	15	14.348	14.348
R (m)	1.2	1.15	1.15
P_E (kW)	1.5	1.011	1.011
W_p (kg)	15000	13856	13856
V_p (m^3)	32	30.225	30.225
M (kg)	50000	47477	47477
x_b (m)	7.5	8.359	8.359
x_m (m)	7.5	8.384	8.384
L_{pmb} (m)	5.5	5	5
L_f (m)	3.4	3.2	3.2
n_f	2.5	2	2
n_a	2.5	2.5	2.5
V_e (m/s)	1.0288	1.0288	1.0288
t_f (m)	0.015	0.0156	0.0156
w_f (m)	0.07	0.0745	0.0745
t_w (m)	0.01	0.0091	0.0091
h_w (m)	0.12	0.1301	0.1301
t_s (m)	0.021	0.0186	0.0186
$F_{spacing}$ (m)	0.30	0.25	0.25
W_{pl} (kg)	1500	2000	2000
W_{effec}	0.03	0.0422	0.0422

According to Table 2, the same optimal solution is found by BLISCO with large and small change in the value of finite differencing. Compared with the initial design, effective horsepower is saved from 1.5 kW to 1.011 kW, the ratio of payload to weight increases from 0.03 to 0.0422, and the weight is saved from 50 t to 47.477 t, which is up to 5.31%. It is obvious that the resistance and weight are reduced effectively with the requirement of the structure strength and stability index. Therefore, according to the multidisciplinary design based on BLISCO, the general performance of HOV is much more improved than the initial design.

4. Conclusions

In this paper, Bi-Level Integrated System Collaborative Optimization (BLISCO) is applied to the conceptual design of HOV, which consists of hull module, resistance module, energy module, structure module, weight module, and the stability module. This optimization problem aims to maximize the ratio of payload to weight, and involves 21 design variables and 23 constraints. Some constraints in weight subsystem depend mainly on the system design variables, these constraints are handled at the system-level optimization instead of subsystem-level optimization. The optimization with BLISCO reveals that: (1) decomposition with three subsystems for HOV is feasible; (2) BLISCO can be applied to the overall conceptual multidisciplinary design optimization of HOV efficiently. In conclusion, BLISCO is a promising MDO method worthy of further study and application in the field of ocean engineering. The next step will mainly focus on the introduction of approximation method to BLISCO.

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