11

Determination of principal dimensions of ACV/SES

11.1 The design process

Initial determination of principal dimensions and key design parameters is the core of overall craft design. We will introduce here a methodology for this using a number of relationships which have been arrived at by successful experience. Once these initial data have been defined, the vehicle general arrangement, initial performance estimation, power plant selection and design of lift systems, skirt, propulsor and hull structure can be started.

Hovercraft design is similar to that of conventional ships, as also is the process of progressive approximation, namely a sequence of initial concept design, preliminary design, detail design and preparation of production drawings and documents. This chapter aims at the first stage – identification of the basic concept.

The design requirements are dependent on the craft's role. It might be military, commercial, a special utility role, or recreation. The controlling parameters will also differ according to the performance requirements for stability, damage resistance, heavy weather performance, seaworthiness, manœuvrability, restrictions on engine selection and limitations on principal dimensions.

There is no one universal approach to vehicle design, but we recommend the following sequence:

1. Define the role parameters (including payload, performance, any special requirements).
2. Make initial weight estimate (using experience-based rules).
3. Select dimensions.
4. Estimate powering and performance.
5. Check standards, rules and regulations.
6. Compare to suitable existing craft.
7. Begin design optimization through detailed analysis.

11.2 Role parameters

To make a start, consider some key attributes for craft within the different major roles:

Commercial

An ACV or SES for commercial use will require to deliver a given quantity of passengers or cargo between two points at the highest possible transport efficiency (payload × speed / installed power). Since payload such as passengers is of low density, the space requirements are most important to define.

In addition, the craft should be able to deliver the payload with maximum efficiency throughout the year, i.e. performance degradation in heavy weather should be within acceptable limits for the particular route (if it can be better than the competition, so much the better). It is not sufficient to have high calm water speed; rather, performance must be matched to the route characteristics so that a regular timetable can be maintained.

Craft route length is another important parameter, since this will control the fuel load and requirements associated with passengers such as catering, shopping facilities for larger craft and both passenger and crew accomodation if the route is associated with overnight travel.

Finally, commercial craft may require aesthetic appeal in order to attract customers and retain them. This requires attention to quality of internal outfitting and to external styling. At the definition stage of an ACV or SES this means including a margin of weight.

Military

Military craft have similar requirements to commercial vehicles, except that a round trip may well be measured in days rather than hours and include periods of operation at different speeds. It is necessary therefore to define the mission profile rather than simply the cruise and maximum speed requirements as for a commercial craft. Some craft may have multiple missions, in which case each one needs to be defined and the controlling mission identified for initial dimensioning purposes.

The functional payload for a military craft is defined by its permanent outfit plus consumables required for a particular mission, and operating crew. Permanent outfit may include military 'hardening' in the form of shell proof panels, additional structural compartmentation, stealth adjustments to the structure etc. At the initial stage, a margin of weight should be identified.

Utility

Utility craft generally have a low utilization, so that transport efficiency is not so important as the ability to deliver the payload for the defined task or range of tasks in a reliable manner and to have lowest practical annual fixed operating cost. A simple craft needing little maintenance is desirable.

Utility craft will be used at times beyond normal design capacity, perhaps extreme weight (in lighter weather), more bulky load, or in extreme environmental conditions. At the initial stage of design it is therefore best to maintain a substantial margin for powering and to check the performance outside the normal envelope.

Such craft are also often used in the floating mode. Deck space, access to the deck edge, stability for lifting equipment on board and off-cushion manœuvring are all parameters which need specification at an early stage.

Recreation

Craft in this category are normally specified by the extreme performance within a particular role. A racing craft will require much higher installed power than a craft used for cruising or expeditionary purposes. On the other hand, the latter craft will have space, payload and stability requirements which a racing craft is not limited by.

Small craft are greatly affected by the mass introduced by enclosed cabins. At the same time it is likely to be difficult to provide full standing accommodation. Personnel access to such craft will normally be by climbing over the side deck structure. This may be the highest loading for that area. The designer will need to look at a number of alternatives to balance these requirements and obtain the most effective ACV design. At the initial stage, include a margin for unknowns, and refine at a later design stage. Experience-based guidelines are given in reference 201.

11.3 Initial weight estimate

In designing a craft, the first task is to identify all the relevant components of weight:

$$W = \sum_{i=1}^{n} W_i \tag{11.1}$$

where

$$W_i = f_i(L_c, B_c, H, N_e, R, p_c, \ldots)$$

where W is the all-up weight of the craft, W_i the weight of various subsystems, L_c, B_c, H the cushion length, beam and height of the craft and N_e, R, p_c the engine power, range of the craft and cushion pressure respectively.

Once the designer has listed out the key design parameters, it is possible to estimate these components with reference to previous practice. Example data are presented in the tables later in this chapter. It should be noted that since these data are based on earlier craft, they should be considered the starting point with which the actual design data will eventually be compared.

We begin by introducing a number of different classifications of weight components and data for craft which have been built which should serve as a benchmark to start a craft design. We will continue by showing a number of methods used by different design groups to prepare initial estimates using such historical data. Some expressions for predicting the weight of various groups and items obtained by the regression method in some references may be suitable for the Western world, but not in China or other countries. Care should therefore be taken in using this information. In addition the classifications of craft weight are different for various design groups in different countries. For this reason, at first one has to understand their different approaches to weight classification of ACV/SES in order to analyse and use the information obtained from them. So we summarize different weight categorisations below

The procedure to follow is first to check through the weight category listings and identify the major known components. Initial craft sizing will be based on a simple fraction of craft total weight, so at this stage it is a matter of checking the difference between the known weights and the weight fractions. The detailed item weights can gradually be added in as the design progresses. At the end of the preliminary design, a detailed list should be available and the first estimate of available weight margin prepared. If this is felt insufficient at this stage, it can be arbitrarily increased before optimization is carried out.

Weight classification of hovercraft in MARIC

The weight classification below is used by MARIC:

- $W1$ hull weight including main hull structure, superstructure, bow/stern ramp structure, landing pad, air propeller ducts and their mountings, engine mountings and their strengthened structure, various bearings and mountings, etc.;
- $W2$ outfit weight including anchoring equipment, rudder and their handling equipment, mast, ladder, etc., cover of windows and doors, retractable equipment for ramp, life-saving and fire-fighting system, cabin equipment, floor and isolation, painting, etc.;
- $W3$ power plant: including main engine, machinery equipment such as the main reduction gearboxes of the main engine, reduction gearbox for lift fan, radiator for lubrication oil system, air filter, remote control system, fuel supply tank, pipeline, hydraulic and propeller pitch controlling system, shaft system, propellers, lift fans, etc.;
- $W4$ electric system: including batteries, electric generators, electric transmission and distribution system, starting system for engine, illumination system, communication equipment, navigation equipment, rectification equipment, cables, etc.;
- $W5$ weight of skirt and joints;
- W' light weight of craft, where:

$$W' = W1 + W2 + W3 + W4 + W5 \tag{11.2}$$

- $W6$ weight of weapons, passengers and luggage in the payload:
- $W7$ weight of crew and luggage, provisions, fresh water, supplies, etc.;
- $W8$ weight of fuel, lubrication oil;
- $W9$ liquid load on the craft, such as bilge, fuel, oil and water in the pipelines and engines;
- $W10$ reserve displacement.
- W_{op} operating weight of craft, including disposable loads:

$$W_{op} = W' + W7 + W8 + W9 + W10 \tag{11.3}$$

Weight classification of hovercraft in USSR [52]

Since ACVs are made in aircraft manufacturers' plant and SES are made in shipyards in Russia, two different kinds of weight specification have developed.

Weight classification of hovercraft in shipbuilding industrial ministry of the former USSR

$$W = W1 + W2 + W3 + W4 + W5 + W7 + W9 + W11 + W12 + W13 + W14 + W15 + W16 \tag{11.4}$$

where

- $W1$ hull weight: metal hull, strengthening structure, mountings, deck equipment coating, painting, isolation and cabin furniture and equipment;
- $W2$ weight of ship equipment: rudder, anchor, mooring, life-saving and crane equipment, mast, rigging, flexible skirt, ramp, etc.;
- $W3$ weight of systems: bilge system, fire-fighting system, water supply system, sewage system, sanitary system, air conditioning, air duct system, heating system, hydraulic system;
- $W4$ machinery: main engine, transmission system, starting system, auxiliary engine, propulsor and other system for power plant;
- $W5$ electric system: internal communication system, handling system;
- $W7$ weight of communications equipment: radio technical equipment, telecomunication and navigation equipment;
- $W9$ weight of spare parts carried on board;
- $W11$ reserve weight for displacement and stability;
- $W12$ fixed weight of liquid: residual liquid in hull, fuel oil tanks and in engines as well as in the pipes of various systems;
- $W13$ weight of provisions;
- $W14$ weight of crew, provisions, fresh water and other consumables;
- $W15$ weight of cargo or passengers;
- $W16$ weight of fuel, oil and fresh water.

Weight classification of hovercraft in aviation industrial ministry of the former USSR

$$W = W1 + W2 + W3 + W4 + W5 + W6 \tag{11.5}$$

where

- $W1$ weight of hull structure: wing, fuselage, landing gear, coating;
- $W2$ power plant: engine, propeller, pylon, engine system, exhausts and silencers, air intake, drive system;
- $W3$ weight of equipment and handling systems: electric apparatus, hydraulic system, pneumatic system, aviation navigation equipment, telecommunication equipment, control system of aircraft, safety system, ice and fire-protection system, oxygen system, air conditioning, noise and heat isolation facilities and cabin furnishing;
- $W4$ equipment weight and working load: crew, fresh water, provisions, life-saving

equipment used in *W*2; the fuel weight includes residual fuel oil and working liquid, i.e. *W*8 and *W*9 from classification 1 are considered together and payload includes spare parts and tools, giving the simplified definitions. Items *W*1 to *W*4 are the same as used at MARIC.

*W*5 fuel weight including operational and supplying fuel;
*W*6 payload including passengers, luggage and cargo (≡ MARIC *W*6, *W*7, *W*10).

Weight classification of high-speed marine vehicles in Western countries

Hovercraft weight terms [4]

*W*1 hull (or structure): base structure, plate, frame, stringers scantling, decks, foundations, fittings, superstructure, doors and closures (*W*1);
*W*2a auxiliary systems: fuel, heating, ventilation, fresh water, ship's controls, rudder, cushion seals, plumbing, oil, fire extinguishing, drainage, ballast, mooring/anchoring (*W*2);
*W*2b armament: weapons, mounts, ammunition stowage, handling system, special plating (part of *W*2 for a military craft);
*W*3 propulsion and lifting systems: engines, turbines, propeller fans, gearboxes, shafting, drive systems, associated controls, nuclear plant, associated fluid (*W*3);
*W*4a electric: power generator, switching, lighting, load centres, panels, cables (*W*4);
*W*4b communication and control: communication (internal, external) and navigation equipment, military electronic computers, displays (*W*4);
*W*2/5 outfit and furnishing: hull fittings including skirt system, marine hardware, ladders, furnishing, boats and rafts, life jackets, storages, lockers, painting, deck covering, hull isolation, insulation, commissioning equipment, radiation shielding (*W*2 + *W*5).

The total of these items is equal to the light displacement or 'empty' weight of the craft including all fixed equipment (*W*′).

*W*6/10 variable load or useful load: operating personnel and effects, cargo, freight, fuel, passengers, luggage, water, ammunition, aircraft, stores, troop provisions (*W*6 to *W*10).

Full load displacement or load displacement or gross weight or all-up weight are the sum of empty weight plus the useful load.

This breakdown is very similar to the MARIC listing (see item numbers in brackets), splitting items in more detail which relate to military equipment, while combining the skirts with outfitting and not breaking down the payload.

Weight classification used for high-speed boats

This may be defined as follows:

standard bare weight + customer equipment weight	=	basic weight
+ variable loads + expendable loads + payload	=	operating load
+ usable fuel	=	all-up weight

The detailed breakdown of these items, which need to be defined, are as listed below:

1. *Standard bare weight (equivalent to hovercraft terms W1 + W5 part of W2, W3, W4)*
   Weight of structure, power plant and systems
   Oil (turbine engine only)
   Full hydraulic/pneumatic/cooling systems, etc.
   Essential standard equipment common to all customer requirements
   Unusable fuel and other non-consumable liquids (ullage)
   (assume includes all items under MARIC *W*1, identified items under *W*2, *W*3, *W*4 and the skirt systems, *W*5)
2. *Customer equipment weight (part of W2, W3 and W4)*
   Flight crew seats
   Flight crew emergency equipment
   Soundproofing, trim, partitions, floor, covering, etc. in payload areas
   Passenger seats, tables, lockers and other furnishings
   Heating, ventilating and air conditioning
   Toilet and washing facilities
   Galley facilities
   Domestic water supply (in toilet)
   Fire precautions in payload areas
   Marine equipment
   Life rafts and containers stowage, life-jackets and stowage
   Radio, radar and navaids
   Intercommunication and internal broadcasting
   Electrical racking
   Signalling equipment
   Weapons
   Environmental equipment
   Long range tankage and system
3. *Variable load (W7)*
   Crew
   Crew baggage and equipment, purser's equipment, role equipment
   Non-consumable liquid ballast, oil (piston engines only)
4. *Expendable load (other than usable fuel) (W9)*
   Domestic, humidifying, windscreen water
   Other liquid or gaseous consumables
   Ammunition
   Food, drink, bonded stores, etc.
   Boarding parties and their equipment
5. *Payload (W6)*
   Passengers, vehicles, freight
6. *Usable fuel (W8)*
   Main fuel, reserve fuel, long-range fuel

This breakdown distributes the components of the light weight differently and since it is derived from fast boat practice, does not define the skirts specifically. The payload components are defined in a very similar way to MARIC.

The weight distribution of some British ACV/SES and US SES are shown in Tables 11.1–11.3. Principal dimensions and features of some Western ACVs are shown in Table 11.4. The weight breakdown of a Chinese SES and ACV are listed in Table 11.5. All of these can be referred to and analysed by readers during preliminary design, to obtain estimates for the various weight components identified above. It is recommended that where a component is known to be needed, if relevant reference data are not available, then a simple estimate should be made. To aid this process a checklist is included at the end of this chapter, based on the MARIC weight breakdown (see Table 11.7).

11.4 First approximation of ACV displacement (all-up weight), and estimation of weight in various groups

The first approximate calculation of craft all-up weight (displacement) is carried out by determining the payload and relating this as a percentage of the all-up weight. The logic illustrated in Table 11.6 may then be used to develop the design. Where possible, the relationships presented below are referenced to the weight breakdown descriptions in section 11.3.

Payload fraction ($W6$ and $W7$ combined)

At the initial stage of hovercraft design, it is difficult to separate the components of $W6$ and $W7$ and so a combined estimate is given here. The designer will usually prepare a more refined estimate at the detailed design stage.

$$W6 = K14 \times \text{AUW} \tag{11.6}$$

where $K14$ is a coefficient. Typical values are

0.15	for small ACV	(AUW < 10 000 kg)
0.16	for medium ACV	(AUW < 30 000 kg)
0.20	for large ACV	
0.20	for small SES	(AUW < 60 000 kg)
0.25	for large SES	

An initial cross-check can be made here against the designer's desired payload. For passenger craft it is reasonable to use 200 kg per passenger including luggage. Other payloads should be directly defined, for example cars, trucks or container masses. For fuel payload, initially use $0.25W6$ for craft with limited range, $0.5W6$ for long-range craft. This can be refined once the first estimate of power has been made and based on mission profile.

An alternative to using the above relationship is to set up a list of the expected total weight components, fill in the weights of the known components and generate the AUW by determining the expected remaining value, using data from the tables as a

Table 11.1 The weight distribution of a number of British ACVs [52]

Weight item (t)	Description	SR.N5	SR.N6 Mk1	SR.N2	SR.N3	SR.N4 Mk1
Hull structure	Riveted aluminium	2.3	2.7	6.3	9.2	57.5
Flexible skirt	Bag and finger	0.4	0.5	0.8	1.6	3.5
Power plant	Gas turbine	0.8	0.8	3.8	4.0	23.7
Equipment	Passenger ferry outfit	1.2	1.6	5.5	8.3	21.9
Dry weight		4.3	5.1	15.6	21.5	103.1
Crew		0.1	0.2	0.2	0.2	0.5
Fuel		0.9	0.9	4.1	3.8	12.2
Payload		1.5	3.05	7.5	12.2	51.6
Full displacement		6.8	9.25	27.2	37.5	167.4
Payload and fuel % of displacement		35	42	42.5	43	38.5

Table 11.2 Typical weight distribution of British SES [52]

Weight item	% all-up weight
Hull (including equipment and bow/stern seals)	30–33
Public systems of craft	2–3
Power plant	8–10
Electric system, communication, navigation	3–4
Liquid load	2–6
Crew and provisions	2–4
Fuel	20–30
Freight (inc. passengers and luggage)	10–23
Reserve displacement	5–6

Table 11.3 The weight distribution of US SES-100 A and B and 2KSES

Weight item	2KSES		SES-100A		SES-100B	
	Weight (t)	% AUW	Weight (t)	% AUW	Weight (t)	% AUW
Metal hull structure	617	28.04	34.50	30.16	31.7	33.44
Power plant	168	7.64	22.30	19.49	12.69	13.38
Propulsion system			14.70	12.85	7.37	7.77
Lift system			7.60	6.64	5.32	5.61
Electric system	48	2.18	1.74	1.52	0.65	0.63
Control system	54	2.45				
Auxiliary equipment	211	9.59	5.81	5.08	3.07	3.24
Public systems			4.21	3.68	1.41	1.49
Weapons	12	0.54				
Reserve displacement	147	6.68				
Provision	111	5.04				
Empty displacement	1368	62.18	68.56	59.95	49.52	52.24
Crew			0.42	0.37	0.49	0.52
Provisions			0.25	0.22	inc. crew	inc. crew
Liquid payload			0.05	0.04		
Payload inc. experimental facilities			9.06	7.92	10.30	10.86
Ammunition	50	2.68				
Fuel	773	35.14	35.16	31.60	34.50	36.69
Undefined	9	0.41				
Full displacement	2200	100	114	100	98.4	100

Table 11.4 Principal dimensions and features of available and planned ACV [81]

	Name	Country	Weight (t)	Length (m)	Beam (m)	L/B	p_c (kg/m^2)	p_c/L (kg/m^3)	S_c (m^2)	q_v/p_c	Power (shp)	Speed (knots)	$M_t = WV/P$
1	SR.N4 Mk 3	UK	300	56.4	23.2	2.43	257	4.56	1168	0.272	18 000	65	7.43
2	N500	France	265	50.0	23.0	2.17	315	6.3	840	0.257	17 000	70	7.48
3	Aist	Russia	260	47.8	17.5	2.73	360	7.53	725	0.225	26 000	70	4.80
4	SR.N4 Mk 2	UK	200	39.7	23.2	1.71	257	6.47	780	0.315	17 000	70	5.65
5	SR.N4 Mk 1	UK	180	39.7	23.2	1.71	230	5.79	780	0.351	17 000	70	5.08
6	JEFF (A)	USA	157	28.0	13.4	2.09	469	16.75	335	0.127	22 500	60	2.87
7	JEFF (B)	USA	150	24.2	13.1	1.86	484	19.84	310	0.131	22 500	62	2.84
8	VT-2	UK	100	30.2	13.3	2.27	305	10.10	328	0.229	7 600	63	5.87
9	Lebed	Russia	90	23.3	10.2	2.27	390	16.81	230	0.128	7 200	55	4.72
10	BH.7 Mk5A	UK	55	23.1	11.2	2.04	268	11.60	205	0.208	3 800	58	5.76
11	Bell AL30	USA	52	23.0	10.0	2.30	267	11.61	195	0.155	3 600	50	4.95
12	BH.7	UK	50	23.1	11.3	2.04	244	10.56	205	0.244	3 800	60	5.42
13	MV.PP15	Japan	50	25.1	11.1	2.26	217	8.65	230	0.322	4 400	65	5.07
14	Voyageur	Canada	35	20.0	10.0	2.00	213	10.65	166	0.171	2 600	47	4.39
15	AP1-88	UK	29	21.5	10.1	2.13	200	9.30	145	0.250	1 500	55	7.29
16	N300	France	27	24.0	10.5	2.29	169	7.04	160	0.367	3 000	62	3.83
17	Gus	Russia	27	21.3	7.3	2.92	193	9.06	140	0.214	2 340	50	3.95
18	Vosper 18m ACV	UK	25	18.4	9.3	1.98	185	10.05	135	0.322	2 500	60	4.12
19	MV.PP5MkII	Japan	19.3	17.6	7.6	2.32	186	10.60	104	0.240	1 050	52	6.56
20	Viking 7505	Canada	19	16.5	6.7	2.16	193	11.70	90	0.220	1 700	50	3.89
21	SR.N4 Mk 6	UK	17	17.1	6.6	2.59	155	9.06	110	0.267	1 125	50	5.18
22	MV.PP5	Japan	16.3	15.4	7.6	2.03	185	12.10	88	0.270	1 050	55	5.86
23	Viking 7501	Canada	14.7	13.2	6.7	1.97	193	14.62	76.3	0.214	1 700	50	2.97
24	SR.N6	UK	10	14.8	6.6	2.47	128	8.65	78	0.350	900	52	3.96
25	SR.N5	UK	6.7	11.8	6.6	1.97	129	10.93	52	0.462	900	60	3.06
26	SH2-4	UK	3.1	8.0	4.4	1.82	110	13.75	28.3	0.265	200	42	4.46
27	SH2	UK	1.8	5.9	4.4	1.34	90	15.25	20	0.372	200	45	2.80
28a	Skima 12 (12)	UK	1.9	7.2	2.8	2.57	101	14.03	18.8	0.120	250	27	1.41
28b	Skima 12 (9)	UK	1.675	7.2	2.8	2.57	89	12.36	18.8	0.164	250	30	1.37
28c	Skima 12 (6)	UK	1.45	7.2	2.8	2.57	77	10.69	18.8	0.225	250	32	1.29
28d	Skima 12 (3)	UK	1.225	7.2	2.8	2.57	65	9.03	18.8	0.363	260	38	1.27

Table 11.4 (continued)

	Name	Country	Weight (t)	Length (m)	Beam (m)	L/B	p_c (kg/m^2)	p_c/L (kg/m^3)	S_c (m^2)	q_v/p_c	Power (shp)	Speed (knots)	$M_t = WV/P$
29a	Skima 4 (4)	UK	0.475	4.0	2.0	2.0	95	23.75	5.0	0.081	25	22	2.82
29b	Skima 4 (3)	UK	0.40	4.0	2.0	2.0	80	20.00	5.0	0.150	25	27	2.96
29c	Skima 4 (2)	UK	0.325	4.0	2.0	2.0	65	16.25	5.0	0.224	25	30	2.65
29d	Skima 4 (1)	UK	0.250	4.0	2.0	2.0	50	12.50	5.0	0.292	25	30	2.04
30a	Skima 4 Mk 2	UK	0.550	5.03	2.08	2.42	78	15.51	7.0	0.085	40	20	1.89
30b	Skima 4 Mk 3	UK	0.330	5.03	2.08	2.42	47	9.24	7.0	0.310	40	30	1.68

Notes:
1. M_t is a non-dimensional coefficient, therefore the physical units in this expression are: W in N; v in m/s; P in Nm/s.
2. $q = 0.5\, \rho_a\, V_s^2$ has units of m/s.

Table 11.5 Weight distribution of a Chinese ACV and SES

	Key	Craft version			
		7313		7202	
		Design weights (kg)	%	Final weights (kg)	%
Type		SES		ACV	
Date completed		September 1969		October 1980	
Manufacturer		Wu Dong shipyard		MARIC	
			$\%W'$		$\%W'$
Hull structure	$W1$	7 796	39.6	641	31.2
Outfit	$W2$	2 605	13.3	289	14.1
Power plant	$W3$	8 540	43.4	734	35.8
Electric system	$W4$	735	3.7	117	5.7
Skirts	$W5$	Included in 'Hull'		270	13.2
			% AUW		% AUW
Empty weight	W'	19 676	73.2	2 051	78.2
Passengers and crew (including luggage)	$W6,7$	6 400	23.8	520	19.8
Liquid load (water, oil, etc.)	$W9$	Included in 'Hull'		32	1.2
Fuel	$W8$	800	3.0	20	0.8
All-up weight	AUW	26 876	100	2 623	100

guide. Remember that this is simply an initial step, all the data will need to be refined at a later stage.

With this as a starting point, it is useful to determine a number of the basic dimensions for the craft such as l_c, B_c, S_c, p_c, Q', H_{sk}, H_{sw} and B_{sw} as in section 11.4 and Table 11.6. Start with:

$$p_c = K_p \, W^{0.333} \tag{11.7}$$

$$K_p = 50 \text{ kg/m}^2 \quad \text{(low-density craft)}$$
$$\quad\; 100 \text{ kg/m}^2 \quad \text{(high-density craft)}$$

then

$$S_c = W/p_c \tag{11.8}$$
$$l_c = p_c/(p_c/l_c)$$

where

$$p_c/l_c = 10\text{–}15 \quad \text{(low-density craft)}$$
$$\quad 15\text{–}20 \quad \text{(high-density craft)}$$

then

$$B_c = l_c \, B_c/l_c \tag{11.9}$$

where

$$B_c/l_c \quad 2.0\text{–}2.8 \quad \text{(amphibious ACV)}$$
$$\quad 3.0\text{–}3.5 \quad \text{(SES)}$$

Table 11.6 Determination of principal dimensions and weight of ACV (taking the given engine type as the constraint, as this is the normal situation)

Item	Dimensioning value	Calculation method	Remarks
1	W	W	Initial starting estimate
2	B_c	$B_c = (W/[(p_c/L_c)\,(L_c/B_c)^2])^{0.333}$	L_c/B_c ratio and p_c/L_c initially chosen from Table 11.4
3	L_c	$L_c = B_c/(B_c/L_c)$	According to given L_c/B_c ratio chosen from Table 11.4
4	p_c	$p_c = W/(L_c\,B_c)$	According to given L_c/B_c ratio chosen from Table 11.4
5	H_{sk}	$H_{sk} = (H_{sk}/B_c)\,B_c$	According to given H_{sk}/B_c from Chapter 10 (requirements for stability)
6	The various weights can be calculated as follows:		Coefficient in weight calculation from this chapter
	I. Hull weight		
	1. Metalic structure	$W_s = K_s\,S_c$	
	2. Deck equipment and paint	$W2\text{-}2 = K2\text{-}2\,W$	
	3. Ship equipment	$W2\text{-}4 = K2\text{-}4\,W^{0.666}$	
	4. Life-saving equipment	$W2\text{-}5 = K2\text{-}5\,S_n$	S_n – passenger numbers determined by role
	5. Other items in hull group	According to prototype	
	II. Power plant	$W3 = K3 \,.\, N$ N = designer choice	Lift and propulsion engines can be obtained according to the AUW of craft in the first approximation, craft speed and some coefficients. Then designers can select the type of lift and propulsion engines and thus determine the power plant weight
	III. Fuel weight	$W8 = q_e\,\Sigma\,N\,R/V_s\,K8$	
	IV. Electric equipment weight	$W4 = K4\,W^{0.666}$	
	V. Skirt weight	$W5 = K5\,B_c\,h_s\,p_c$ $W5 = K5\,(L_c + B_c)\,h_{sk}\,p_c$	SES or ACV
	VI. Provision weight	$W10 = K10\,W$	
	VII. Passenger weight	$W6 = K6\,P_n$	S_n is number of passengers or seats. $K6$ will vary a little in different parts of the world
		$K6$ = 140 kg passenger only 200 kg with luggage	
7	Calculation of craft weight	$W_c = \Sigma\,W_i$	If this relation does not hold, then the process should be iterated until the difference is small enough to be ignored (say less than 5% at estimating stage)
8	Calculation of speed	V_s	Iteration. See Chapters 10 and 3, Fig. 12.5
	I. Wave-making drag	$R_w = f\,(L_c/B_c, P_c/L_c, W, F_r \ldots)$	Use method in Chapter 3
	II. Air momentum drag	$R_m = f\,(Q, Fr, W \ldots)$	
	III. Air profile drag	$R_a = f\,(S_a, Fr, \ldots)$	S_a is frontal area of craft
	IV. Skirt drag	$R_{sk} = f\,(Q, Fr, \ldots)$	
	V. Trim drag	$R_\psi = f\,(\ldots)$	

Table 11.6 (continued)

Item	Dimensioning value	Calculation method	Remarks
9	Estimation of lift power	$N_l = Q\,H/(\eta_F\,\eta_M)$ where $Q = Q' S_c\,(2p_c/\rho_a)^{0.5}$ $H = p_t/\zeta_h,\ p_t = \bar{p}_t\,p_c$ $\bar{p}_t$ = bag/cushion pressure ratio	H is fan overall pressure head ζ_h is the coefficient due to loss of head in ducts, obtained from prototype
10	Estimation of engine power propulsion power	$N_p = V_s\,\Sigma\,R_i/(\eta_p\,n_m)$	η_p is efficiency of air propeller
	Total power	$N = N_l + N_p \leqslant \varepsilon$	If this expression is not satisfied it has to be revised and repeated until it is
11	Estimation of transverse stability	$h_\theta/B_c = f(H_{sk}/B_c, L_c/B_c, \ldots)$	Determined as in Chapter 5. During this initial estimate, skirt responsiveness is not considered
12	Estimation of speed of craft in wind and waves		Note: head wind and oncoming waves
	I. R_{wmax} (drag peak in calm water)	$R_{wmax} = f(L_c/B_c, p_c/L_c, Fr \ldots)$	Use Chapters 3 and 8
	II. R_m **III. R_a** **IV. R_{sk}** **V. R_ψ** **VI. Thrust reserve**	$R_m = f(\ldots$ $R_a = f(\ldots$ $R_{sk} = f(\ldots$ $R_\psi = f(\ldots$ $\bar{T} = (T - R'_{wmax})/R'_{wmax}$ where $T = f(N, [V_w + V_s]/V_s, Fr \ldots)$	The wind speed has to be taken into account for calculation of II–V then ... $R'_{wmax} = \Sigma R$ V_w is wind speed
13	Seaworthiness		
	I. Maximum vertical acceleration at CG, $\ddot{\zeta}_{gmax}$	$\ddot{\zeta}_{gmax} = f_g\,(Fr_l, \bar{Q}, L_c/B_c, p_c/L_c, h_w/H_{sk}, L_w/L_c \ldots)$ where h_w = wave height L_w = wavelength	For Passenger craft, the main check targets are the vertical acceleration in a wave, which can be calculated by the method in Chapter 8 and according to the seaworthiness requirements for craft given in Chapter 10
	II. Maximum vertical acceleration at bow	$\ddot{\zeta}_{bmax} = f_b\,(Fr_l, \bar{Q}, L_c/B_c, p_c/L_c, h_w/H_{sk}, L_w/L_c \ldots)$	
14	Area of passenger cabin S_{ca}	$S_{ca} = L_{ca}\,B_{ca}$	L_{ca} and B_{ca} denote cabin length and width respectively, which are related to L_c, B_c and the relation between them can be determined

It is also helpful to estimate the installed power at this point, which can be found from

$$N_e = K_n\,W^{7/8} \quad \text{kW} \tag{11.10}$$

where

$$K_n = 135$$
$$W = \text{AUW in tonnes}$$

This expression is representative of efficient craft of all sizes through the late 1980s assuming speed and size follow existing norms. High-speed craft would require additional power, low-speed craft less. This also applies to SES as well as ACVs.

Table 11.7 Weight Estimate Checklist

Item	Sub-items	Check comments
*W*1	*Hull weight* including: Main hull structure, including basic raft or hull structure plate, frames, stringers and other scantling,decks, sandwich panels Superstructure Bow/stern ramp structure Doors and hatches Landing pads Air propeller ducts and mountings Engine mountings and their strengthened structure Bearings and mountings, etc. Integral tankage Fins (vertical or angled stabilizers) Horizontal fixed aerodynamic stabilizers	The hull includes the primary structure (buoyancy tank area for ACV, sidehulls and central buoyant connecting structure for SES) superstructure and all main secondary structures
*W*2a	*Basic Outfit weight* including: Rudder and their handling equipment Mast Ladders Windows and doors Retractable equipment for ramp Floors and coverings Isolation, insulation, sound proofing, trim, partitions, etc. Painting Flight crew seats Flight crew emergency equipment Passenger seats Fire precautions in payload areas Marine equipment, including anchoring Life-saving and fire-fighting system Life-rafts and containers stowage Life-jackets and stowage	The items included here will be very dependent on the craft mission and safety regulations for the area of operation
*W*2b	*Customer-specified equipment* which may be considered optional, including: Passenger tables, lockers and other furnishings and cabin equipment Heating, ventilating and air conditioning Toilet and washing facilities Galley facilities Domestic water supply (in toilet) Long-range tankage and system	These items should be checked individually, since most of them will not normally be installed Do not assume they are included in the historical reference data, unless clearly identified
*W*3	*Power plant* including: Main engine(s) Machinery equipment such as: Main reduction gear boxes of main engine Reduction gearbox(es) for lift fan(s) Radiator(s) for lubrication oil system Air filters Hydraulic and propeller pitch controlling system Transmission shaft system Remote control systems	
*W*3a	Lift and propulsion equipment and auxiliaries, including: Propellers Lift fans Fuel supply tanks (if not integral with hull) Pipelines	

Table 11.7 (continued)

Item	Sub-items	Check comments
$W4a$	*Basic Electric system* including: Batteries Electric generators Electric transmission and distribution system Engine starting system Illumination system Voltage rectification equipment Cabling and cable trays Navigation equipment, inc. radio, radar, Navaids	
$W4b$	*Cockpit communications equipment* Intercommunication and internal broadcasting Electronic enclosures and racking Signalling equipment Environmental equipment	These items should be checked individually, since most of them will not normally be installed. Do not assume they are included in the historical reference data, unless clearly identified
$W5$	Weight of skirt and joints including Loop or bag Bag stabilizer diaphragms Segments or fingers or jupes Rear double segments or anti scoop flap Rear multi loop skirt (SES) Longitudinal stabilizer skirt Athwartships stabilizer skirt Skirt shift mechanism Segment ties Loop attachments	 Estimate loop surface area Estimate one finger and total number off Estimate loop surface area Estimate loop surface and individual cones × number
$W6$	*Weight of payload* including: Weapons, passengers and luggage, vehicles, freight	Define as unit weights, number and distribution
$W7$	Weight of crew and luggage, Provisions Bonded stores and sales stores Fresh water supplies Boarding parties and their equipment Spares carried on board	
$W8$	Weight of fuel, Main fuel, reserve fuel, long-range fuel Lubrication oil	
$W9$	*Liquid load on the craft* such as: Bilge, water in the pipelines and engines	
$W10$	*Reserve displacement* This item should include : Project weight estimating reserve	 Do not start with less than 15%

An alternative to this expression is to use installed power/tonne knot :

$$N_e = K_n\, W\, V_s \tag{11.11}$$

where V_s is the design craft service speed, W the weight (t) and

$$K_n = \begin{array}{ll} 0.7 & \text{(light large craft)} \\ 0.9 & \text{(light small craft > 5 t)} \end{array}$$

2.0 (dense large craft)
3.0 (recreational and small utility craft)

We can now move on to develop further estimates for the craft weight components and begin to refine the parameters.

Weight of hull structure

According to ref. 4, the weight of the hull structure for an ACV, W_s can be written as

$$\frac{W_s}{W} = 0.29\,(W^{0.33}/p_c)^{0.60} \tag{11.12a}$$

or

$$\frac{W_s}{W} = 0.6/p_c\ W^{0.33} + 0.015\ W^{0.33} \tag{11.12b}$$

where W_s is the weight of the hull stucture (t), W the weight of craft (t) and p_c the cushion pressure (lb/ft^2). (*Note*: 1 Pa = 0.02 lb/ft^2 = 1 N/m^2.) This expression can be seen plotted in Fig. 11.1 and the structural weight of some hovercraft is shown in Fig. 11.2.

Based on data from some SES designed and built in China, the weight of the hull structure can be estimated by the following equation [11]:

$$W_s = 8.8\,K\,[1 + 0.045(V_s/L)^{0.666}]\,[L\,(H + B_c)/100]^{1.25} \tag{11.13}$$

where W_s is the weight of the hull structure (kg), L the length of the hull structure (m), V_s the design speed (knots), B_s the cushion beam (m), H the cushion depth (m) and K a coefficient, which can be taken as

K = 750–800	for welded aluminium alloy structure
= 900–950	for GRP structure
= 830–860	for the combined structure of GRP and aluminium (GRP sidewalls)
= 1100–1500	for combined structure of steel and aluminium (aluminium superstructure)
= 1200	for whole steel structure

Weight of metallic structure for an ACV, W_s (or $W1$)

$$W_s = K'_s\,S_c \tag{11.14}$$

where S_c is the cushion area (m^2) and K'_s a coefficient (taken from the prototype or reference craft, see Tables 11.1 and 11.4).

Weight of deck equipment and painting $W2$-1

$$W2\text{-}1 = W\,K2\text{-}1 \tag{11.15}$$

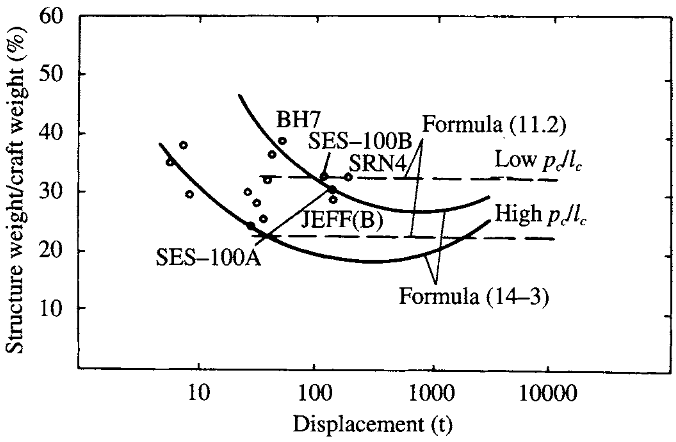

Fig. 11.1 Weight trends for ACV/SES structures with displacement.

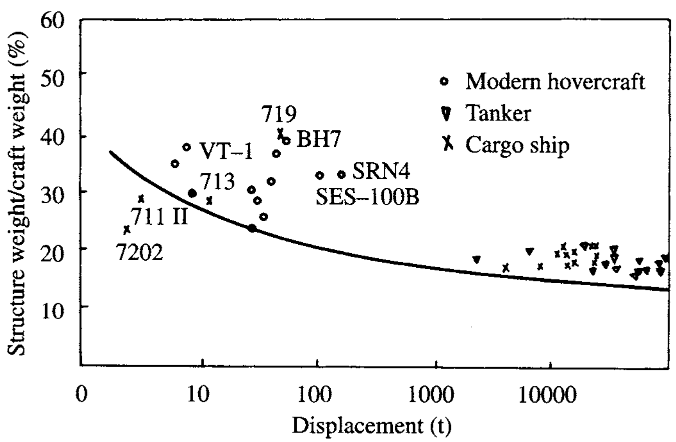

Fig. 11.2 Hovercraft and ships' structure weight statistics with displacement.

where W is the craft weight (t) and $K2\text{-}1$ a coefficient. Typical values are 0.12 for an ACV and 0.1 for an SES.

Weight of ship's equipment $W2\text{-}2$ (rudders, anchors, mooring, towing, lifting equipment, etc.)

$$W2\text{-}2 = K2\text{-}2\ W^{0.666} \tag{11.16}$$

where $K2\text{-}2$ is a coefficient. Typical values are 0.08 for an ACV and 0.1 for an SES.

Life-saving equipment $W2\text{-}3$

In the case where the weight of the craft is similar to that of a prototype, then W2–3 is

$$W2\text{-}3 = K2\text{-}3\ S_n \tag{11.17}$$

where S_n is the number of passenger seats (should also be the same as the number of passengers) and $K2\text{-}3$ a coefficient. Typical values are 3.0 (kg) for an ACV or an SES, covering life vest and weight component of life-raft and fittings installed.

Weight of ship's systems $W2\text{-}4$

$$W2\text{-}4 = K2\text{-}4\ W \tag{11.18}$$

where $K2\text{-}4$ is a coefficient. Typical values are

0.05	for small ACV	(AUW < 2000 kg)
0.05	for medium ACV	(AUW < 20 000 kg)
0.02	for large ACV	
0.02	for small SES	(AUW < 20 000 kg)
0.01	for large SES	

Weight of power plant $W3$

$$W3 = K'\ K3 \sum N \tag{11.19}$$

where $K3$ is a coefficient according to the specific weight of the given power plant. Typical values, in kg/kW, are

0.5	Gas turbine engines
2.5	High speed diesels
5.0	Medium speed diesels

and $\sum N$ is the total installed power (lift, thrust and auxiliaries) (kW). For engine weight, with respect to the total weight of the power plant, the coefficient K' has to be found in this equation; for example for gas turbines $K' = 2$–3, while for high-speed diesels $K' = 1.5$–2.5. This is to account for gearbox weights, etc.

Note: Cooling systems additional outfit weights (in addition to K')

0	for air cooled (though maybe there will be an oil cooling system)
0.1	for water cooled diesels
0.2	for recirculated cooling water

It should be noted at this point that it may be best to check the available power plants to provide the power. A number of design choices may have to be taken at this point, since if it is decided to use separate power systems for lift and propulsion, an estimate of the required cushion system power is needed. This will mean making a preliminary cushion system design (Chapters 2, 6 and 12) and then revisit the engine selection, before going on. Power system selection has a strong influence on the whole craft layout, so it is worth while spending some time on this aspect. Since engines are only available in discrete sizes, some flexibility in design is required in order to avoid underpowering or overpowering a given design.

Weight of electrical equipment *W4*

$$W4 = K4\ W^{0.666} \quad \text{(based on dry weight)} \tag{11.20}$$

where $K4$ is a coefficient (non-dimensional). Typical values are

0.10	SES
0.14	ACV
0.10	additional component for military craft

Skirt system weight of ACV *W5*

$$W5 = K5\ (L_c + B_c)\ h_{sk}\ p_c \tag{11.21}$$

where h_{sk} is the skirt height (m), p_c the cushion pressure (Pa) and $K5$ a coefficient. Typical values are 0.02 for an ACV depending on cushion depth.

Skirt system weight of SES *W5*

$$W5 = K5\ B_c\ h_s\ p_c \tag{11.22}$$

where h_s is the height of sidewalls (m), B_c the cushion beam and $K5$ a coefficient. Typical values are 0.023 for an SES.

Weight of fuel and oil *W8*

$$W8 = q_e\ \Sigma\ N\ R/V_s\ K8 \tag{11.23}$$

where R is the range (nautical miles), V_s the craft speed (knots), $\Sigma\ N$ the total power (kW), q_e the specific fuel consumption of main and auxiliary engines (kg/kwh) and $K8$ the additional oil and water consumption coefficient (approx 1.07).

Liquid Load *W9*

This will vary somewhat, dependent on whether a static ballasting system is used rather than a skirt shift system (a), and whether water (b) or fuel (c) is used for the trimming ballast.

$$W9 = K9\ W \tag{11.24}$$

where $K9$ is a coefficient. Typical values (a/b/c) are

0.05 / 0.1 / n.a.	for small ACV	(AUW < 2000 kg)
0.06 / 0.12 / 0.08	for medium ACV	(AUW < 20 000 kg)
0.07 / 0.12 / 0.10	for large ACV	
0.05 / 0.10 / 0.08	for small SES	(AUW < 20 000 kg)
0.05 / 0.10 / 0.08	for large SES	

Estimating margin for hull weight *W*10

$$W10 = K10\ W \tag{11.25}$$

where $K10$ is a coefficient. At the initial design stage, use 0.15, reduce to 0.05 once the structure is designed, and fabrication drawings are available for a detailed weight take-off.

11.5 Parameter checks for ACV/SES during design

Role requirements

The tactical and technical/economic validation for military and civil hovercraft designs for specific routes or roles is often commercially confidential, or the subject of defence secrecy laws. From data publicly available it is possible to identify the key parameters which control the economy of these vehicles. Here we introduce some commonly used criteria.

Transport efficiency η_1

$$\eta_1 = \frac{\text{payload} \times \text{speed}}{\text{total power}} = \frac{\text{payload}}{\text{AUW}}\ \frac{\text{AUW}}{\text{overall equivalent drag}} \times \frac{\text{overall equivalent drag} \times \text{speed}}{\text{total power}}$$

$$= \text{payload factor} \times \text{equivalent lift/drag ratio} \times \text{propulsor efficiency} \tag{11.26}$$

where overall equivalent drag is the sum of various hydrodynamic drag, aerodynamic drag and equivalent drag due to the lift power; therefore the transport efficiency not only denotes the hydrodynamic characteristic of the craft, but is also related to the payload factor and propulsor efficiency.

Payload factor η_2 [= K14]

$$\eta_2 = \frac{W_6}{\text{AUW}} \tag{11.27}$$

Payload is related to the structure, material, power plant and outfit which not only affect the cost, but also the operational cost.

Fuel consumption per unit passenger and unit nautical mile η_3

$$\eta_3 = \frac{\text{fuel consumption} \times \text{block route time}}{S_n \times \text{route length}} \tag{11.28}$$

where fuel consumption is in litres or kg/h, route length is in nautical miles, S_n is number of seats/passengers and block route time is in hours.

Total construction cost per unit seat η_4

$$\eta_4 = \frac{\text{total construction cost}}{S_n} \tag{11.29}$$

η_4, quoted in $US here, denotes the cost of craft per unit seat, which characterizes the first investment of the craft, at delivery from manufacturer. It must be noted that for larger craft, the cost of delivery to site, initial training of crew, investment in terminal and maintenance facilities and spares inventory, can add significantly to the craft's construction investment. It is suggested that in evaluating different sizes and types of craft for a given service or role, the effect of the different craft on these other investments should be evaluated in parallel, to identify the most economic overall solution to the transportation project.

It should also be noted that the construction costs can vary widely between different countries. The data given as example below are representative for Europe or Japan, while in China the costs are between a quarter and a half of these values (1995 data).

Power per unit seat η_5

$$\eta_5 = \frac{\text{total installed power (kW)}}{S_n} \tag{11.30}$$

This is a simple coefficient for comparison of hovercraft with conventional transport vehicles.

Once an initial estimate has been made for craft dimensions, weight and powering,, it is useful to calculate the performance indicators above. Typical values which should be reached for craft designed for construction now (mid 1990s) are

η_2	= 20–30	for ACV	25–35	for SES	
η_3	= 0.1–0.15	for ACV	0.02–0.05	for SES	(diesel)
η_3	= 0.2–0.25	for ACV	0.15–0.25	for SES	(gas turbine)
η_4	= 4000–5000	for ACV	2000–4000	for SES	($ US)
η_5	= 25–30	for ACV	10–15	for SES	

If the initial estimate is far removed from these data, an unrealistic combination of design parameters may have been selected and so these should be reviewed. Once the initial design has been prepared, there should be some improvement in the factors compared with the initial estimate.

Other design checks

Based on the role requirement, operational region and use of the craft, design requirements may be specified which play an important role during the determination of principal dimensions of the craft, for example:

Required minimium craft speed

This can be determined according to the craft-specified block speed for ferries or role requirement by other users.

Required minimum range

This can be determined based on the route length and required minimum number of trips for ferries, or the role requirement for minimum endurance time for the craft by other users.

Power plant limitations (main engine)

The power plant selection may be determined according to the choice of main engines available to the constructor, considering the cost of delivery to the construction yard. Power plant selection is very important in practice since it influences many of the other craft design parameters.

Requirements for stability

Requirement for stability can be obtained from Chapter 10 to comply with the requirements of the IMO [215] or the rules for merchant ships. The simplest criterion for the stability is h/B_c (for an SES) or the percentage of shifting distance of C_p to cushion beam per degree of heeling angle (for an ACV).

Requirements for seaworthiness

Requirements for seaworthiness can be obtained from Chapter 10 to comply with the criteria specified by ISO 2638 and 2633 or the specifications from operators.

Accommodation space requirements

According to the number of passenger seats and the specific area for every passenger, the passenger cabin floor area can be determined. Typical space per passenger for seating and aisles for entry will be about 0.6 m^2 per passenger.

Limitations to principal dimensions

The limitation to craft beam due to transport requirements for the craft on a ship or road trailer, the limitation to draft due to port conditions and the limitation to the craft beam for getting into landing ship, dock, etc. may be required by users.

The designer should review each of the above possible restrictions on the craft design, as relaxation could enable improvements in other performance indicators. In general this would be done after the initial design has been completed as described below.

11.6 Determination of hovercraft principal dimensions

Determination of principal dimensions is begun by using the ratio of principal dimensions from past experience. In the first and second approximation of general design it is not possible to choose too many ratios of principal dimensions, because of the need to keep the design process simple. This then enables the designer to consider changes in some of the parameters to study possible improvements to the initial choices.

In such a case, it is possible to plot systematic changes in the parameters chosen to find the extreme value as a function of multiple variables. Since the functional relations between the parameters concerned with the craft performance and the ratio of principal dimensions have not been established analytically, and in addition, nowadays, it is straightforward to create a spreadsheet on a computer, such problems can be solved fairly simply and quickly. Therefore, the variation method may rapidly home in on an optimum craft design, based on the restrictive parameters and role functions above, using parameters such as those discussed below. The parameters that have the greatest effect on the performance of craft are as follows:

Cushion length-beam ratio (l_c/B_c)

The ratio l_c/B_c greatly affects the ship's speed, engine power and seaworthiness. In the case of low speed, increasing l_c/B_c will improve the seaworthiness, decrease the drag at medium speed, increase the range and decrease the drag peak. Therefore, during the 1980s, there was a general tendency to increase the cushion length/beam ratio. Clearly there is a trade-off to make it dependent on the desired operational speed for the craft.

A typical starting point for an ACV would be 2.0, assuming a basic rectangular plan-form with rounded or hexagonal corners. Craft as small as single seat ACVs up to medium size ferries stay close to this geometry. An l_c/B_c increasing to 2.5 is used on larger craft than this. SES normally have l_c/B_c in the range 3.0–5.0, though the most commonly used is 3.5–4.5.

Cushion pressure/length ratio (p_c/l_c)

In general, craft with large deck area and low load density are required for passenger craft; in contrast, craft with high load density are required for landing craft with tanks. There is a wide range in this ratio, as shown in Table 11.4, though for ACVs the starting point should be somewhere between 10 and 15 kg/m^3, or up to 20 if space constraints require high density such as for amphibious landing craft. The higher this parameter, the noisier the craft will be. SESs generally operate at values between 13 and 30 kg/m^3. Figure 11.3 shows this parameter plotted for a number of craft and some projected trends for reference. This parameter greatly influences the speed, seaworthiness, structural strength of the hull, craft weight and principal dimensions.

Sidewall depth ratio for an SES (H_{sw}/B_c)

The sidewall depth ratio affects the transverse stability, seaworthiness and hull weight, etc. Typical values of H_{sw}/B_c for an SES would be 0.25–0.333. Start with 0.25 and if stability is fine, try deepening the cushion a bit and check the stability parameters.

Skirt height ratio for an ACV (H_{sk}/B_c)

The effect of H_{sk}/B_c for an ACV is equivalent to that of H_{sk}/B_c for an SES. It should be noted that we are addressing the skirt height measured to the hull keel, not the upper loop attachment. The position of the upper loop attachment both vertically

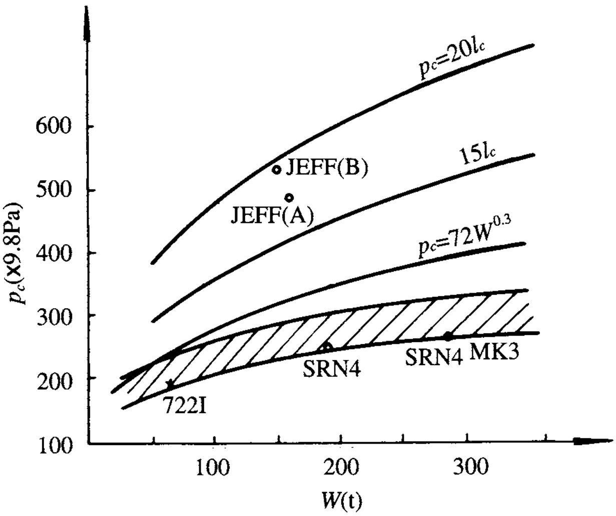

Fig. 11.3 Cushion pressure trends for hovercraft (hatched area for passenger hovercraft).

(hull depth) and horizontally (hull sidebody width) can be adjusted to tighten or loosen the loop tension and so stiffness. If the required underkeel clearance results in low stability, these skirt geometrical parameters should be varied first, together with the position of the skirt tip (toe-in or toe-out relative to the upper loop attachment) before reducing H_{sk}.

Typical values for H_{sk}/B_c for an ACV would be 0.11–0.18. Start with the higher value, as ACVs generally need all the clearance they can get.

Cushion flow coefficient $\bar{Q}$

$$\bar{Q} = Q / [S_c (2p_c/\rho_a)^{0.5}] \tag{11.30}$$

This coefficient influences the speed performance, seaworthiness and speed loss over different terrain. The higher the relative flow rate, the larger the air gap under the skirt. Choice of the base value, and thus the lift system requirements, is key to a successful hovercraft. It is best to start with a high number and if power requirements seem excessive, reduce the flow. Refer to Chapter 2 for guidance. Remember that if a reserve of cushion flow is available, the pilot can always operate at a 'cruising' level and if the sea state picks up, he can increase lift and so minimize speed loss.

It is important to remember that cushion air thrusters for ACVs, and cushion venting systems in the case of SES, absorb part of the cushion air flow or lift power if separate fans are used, and should be taken into account at the preliminary stage by adding a percentage to the cushion flow, power etc. Typically SES will use 30% for ride control systems, while ACVs will use 20–25% for rotating thrusters.

Sidewall thickness ratio B_{sw}/B_c

B_{sw}/B_c influences the transverse stability, seaworthiness, speed and general arrangement. Therefore, it is a very important parameter for an SES. In the case of craft with medium speed (Fr = 0.7–0.9), it is suggested thicker sidewalls are adopted. Start with B_{sw}/B_c at 0.08–0.125 as an average to start, assuming that the main engines will be housed in midships flared areas if diesel power is used.

The designer should concentrate on a few of these parameters at any one time. For ACVs, l_c/B_c, p_c/l_c and Q can be selected as the variables, while for SES, l_c/B_c, p_c/l_c and B_{sw}/B_c can be selected as the variables and H_{sk}/B_c, H_{sw}/B_c, etc. can be taken as the given values according to the requirement of stability and seaworthiness. More precise values for such parameters can be determined at the next design phase for determining the principal dimensions, namely in the preliminary design phase which follows the initial estimation of dimensions.

Thus, three variables for one parameter can be taken and in total there are 27 variants to be assessed. In the case of four variables for one parameter, then 81 total variants need assessment. This is not too much for computer analysis and such calculation can be undergone as in Table 11.6.

In this example, we take the general condition of design into account, namely the role stipulates not only the number of passengers, range, speed of craft, requirement

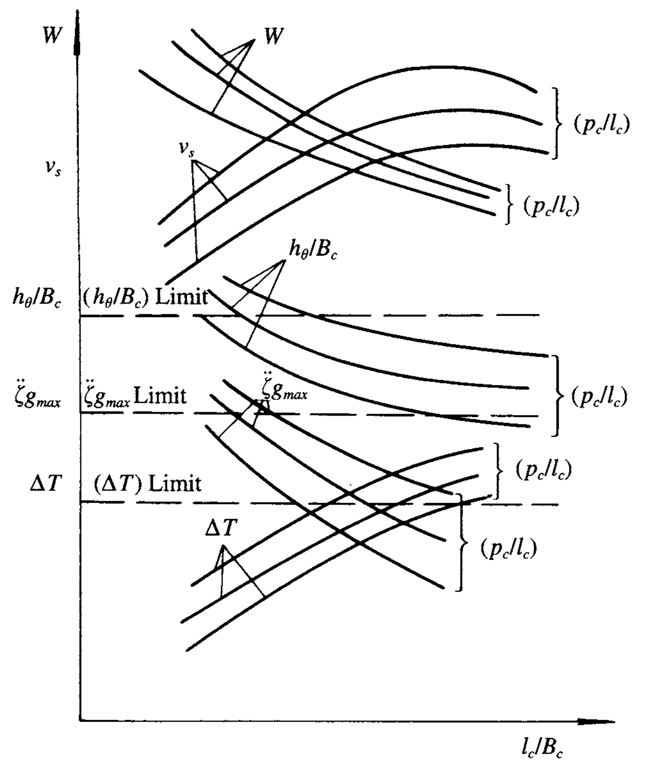

Fig. 11.4 Optimization plots of craft leading particulars selection prior to design.

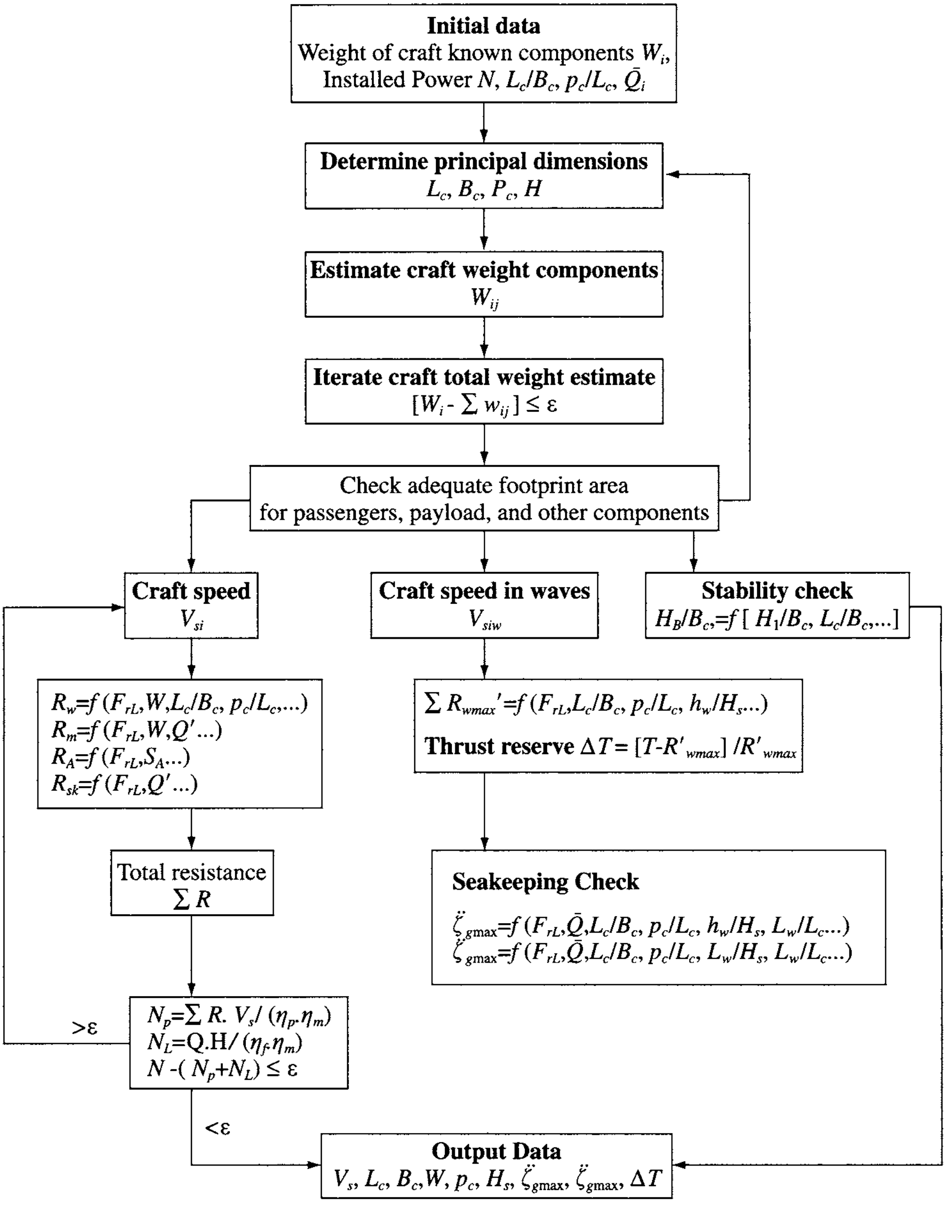

Fig. 11.5 Block diagram for determination of principal dimensions and weight of an ACV.

for seaworthiness, but also the type of engine which can be chosen in design. In this case, we take an integrated air propeller–lift system as the designing type of power systems, because this is the general case for ACVs, particularly for craft using gas turbine propulsion.

Once the data are gathered based on Table 11.6, varying the design parameters within a range, it is possible to construct a plot of the data such as shown in Fig. 11.4.

In the case of three parameters such as $\bar{Q}$, p_c/l_c, l_c/B_c, then three drawings can involve all of the data for the 27 groups of data. From the figure it can be seen that h_θ/B_c, ζ_{max} and ΔT are the limits for transverse stability, seaworthiness (according to the IMO requirements) and the thrust reserve of craft in waves respectively.

It is suggested to select the alternative which gives the maximum craft speed or minimum displacement and also meets these restrictions. The method expressed by Table 11.6 can also be illustrated by a block diagram as shown in Fig. 11.5.