General Arrangement and Naval Architectural Aspects in Midget Submarines

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Abstract

This paper represents architectural aspects and general arrangement of systems in midget submarines. Because of limitations of displacement, dimensions and single deck arrangement of midget submarines special aspects must be regarded that is not similar to large naval submarines. Main limitation is single deck arrangement and small pressure hull diameter. Midget submarine in this paper are introduce as submarines less than 300 ton displacement.

This paper introduce some naval architectural aspects of systems arrangement in midget submarines such as general arrangement, optimum diameter and L/D, volume and weight distribution inboard the midget submarines and comparison to the large naval submarines. Arrangement of systems in several parts inboard the midget submarine, has special requirements in operationally, ergonomically, repair and maintenance aspects that can't be found in any naval vessels. This points, needs adequate experiments and sciences of designers and builders of naval submarines. In midget submarines there are not watertight bulkheads and compartments but there are several partitions and parts. Some parts combined such as torpedo room and accommodation. Main parts are torpedo room, control room, motor room and battery room.

Key Words: *midget, submarine, general arrangement, volume, architecture*

Introduction

In World War I and II, midget submarine had told to submarines less than 30 ton displacement and had extensive applications for Japanese and Germany Navy. This submarine was operationally defined for small ranges and speeds. Their propulsion had only an electric motor without diesel electric. Weapons consist of two outboard torpedoes. Inboard arrangement of these submarines was so simple that a large number of them could be produced and transported in minimum time and cost [1]. These submarines were very suitable for shallow water, channels, lake and coast guard of islands.

After WWII design and construction of midgets less than 30 ton were sharply decreased because of main limitation in operational range, speed and seaworthiness. Therefore after WWII, midget submarines are told to the submarines less than 300 ton displacement. Displacement 300 – 700 ton are classified in small submarines. In comparison to large naval submarines with displacement about 40000 ton, these names, midget and small submarines can be meaningful. In midget submarines there are not watertight bulkheads and compartments but there are several partitions and parts.

The new midget submarines may have diesel–generator thus would have more operational range. Most of midget submarines are single hull, not double hull. Therefore outer hull (hydrodynamic hull) there are only in the bow and stern of pressure hull [1].

According to Iranian Defense Standard (IDS-643) in midget submarine at least one place must be regarded for person upright standing. It is vital in human health point of view [3].

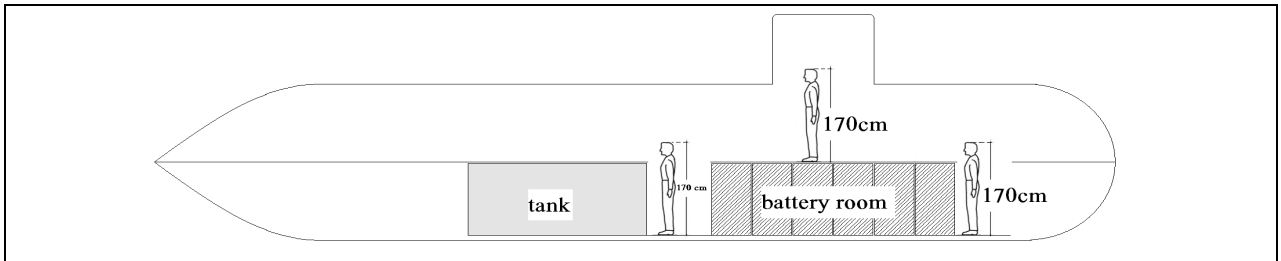

Figure 1- Some Suggested Places for Upright Standing in Midget Submarines (IDS-643)

General arrangement

General arrangement as shown in figure 2 has two main section inboard and outboard of pressure hull.

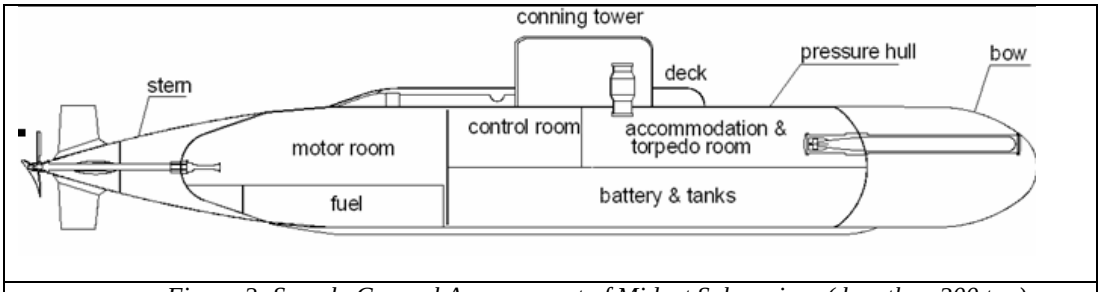

Figure 2- Sample General Arrangement of Midget Submarines (less than 300 ton)

The main parts inside the pressure hull are [2, 3]:

- *Torpedo room and accommodation room: these two spaces combined in a space in the front of pressure hull. These submarines usually have two torpedo tubes for 324 mm torpedoes (light torpedo) and in some cases they use 533 mm torpedoes (heavy torpedo). Heavy torpedo may cause some problems in stability after torpedo firing. Tube for light torpedo is about 3 meter long. If the torpedo can be intake to the pressure hull the length of torpedo room must be at least 5 meters. This space after torpedo loading and storing is vacant. This space is suitable for accommodation and resting the crew. Weapon percentage (payload) in midget submarines can be up to 2.5 percent but in large submarines is less than 1.2 percent. Length of this part is about 25-40 percent of pressure hull length.*
- *Control room: are located beneath the conning tower and middle of pressure hull for easy access to the navigation masts and periscope. This space in midgets is very tight and compressed because of several navigation panels, computers and valves. The height in control room is usually more than 1.7 meter for upright standing and deck in this room is lower than the centre of pressure hull. There are always 2 people in this space and total navigation and control activities in these submarines are defined for 2 person. The length of this space is 10-20 percent of pressure hull length.*
- *Motor and auxiliary room: in midget submarine these two spaces are integrated in a single space. Electric motor, diesel – generator (if exist), shaft system (bearings, thrust bearing, clutch) and auxiliary machineries such as hydraulic, pneumatic, fresh and sea water systems are located in this space. Motor room is situated at the end of pressure hull. The height of motor room deck is definitely lower than the center of pressure hull because the motor shaft must be aligned to the centre of propeller shaft. This length to the pressure hull length is 35-45 percent.*
- *Fuel tank: if the submarine has diesel–generator, it needs a lot of fuel. In midget submarine entire space under motor room are dedicated to the fuel tank. Approximate volume of fuel volume is 4-7 percent of displacement volume and in large submarines is the same.*
- *Battery room: battery room is usually a single part beneath the middle deck of control room and torpedo room. The usual voltage level is 220 volts that needs two groups of 110 cells in battery wells. In midgets less than 100 ton usually there is only one group of batteries and one battery well. The deck above battery well cannot be watertight and welded to pressure hull because of survey and maintenance of batteries. In midget submarines there are not enough diameters for installation of battery survey carriage under the middle deck and so there are some moveable plates (usually fiberglass) that are situated on the deck stiffeners and are not watertight. It may causes some problem in water spillage on the batteries and spreading of the battery hydrogen gas and dangerous of explosion.*

The arrangements outboard of pressure hull are:

- *Bow and stern ballast tank*
- *Anchor system: anchor, cable or chain, hydraulic Winch, cutter and stopper.*
- *Sonar: all sonar must be located in the sea water because of acoustic transfer of sonar waves. All snares such as passive and active snares are situated in the extreme front of the bow.*
- *Shaft and propeller in the extreme aft of the hull.*

Length to diameter ratio (L/D):

Cylindrical shape of hull is defined with length and diameter. Length is the same overall or total length. For hydrodynamic and optimum resistance, optimum L/D for

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tear drop shape is 6-7. For submarines with parallel middle body shape (cylindrical middle shape), optimum L/D in midgets is 9-12. In large naval submarine, for tear drop, L/D is the same but for parallel middle body, optimum L/D is 10-11.

L/D in midgets less than 30 ton have a wide range between 5 and 22. Length to diameter ratio in submarines is approximately independent from tonnage. Table 1 shows the L/D in several midgets less than 30 ton and table 2 is for midgets less than 300 ton.

L/D	D	L	Displacement	Submarine
15.2	0.5	7.6	2.7	Neger
16.6	0.5	8.3	3	Marder
22.0	0.5	11	3.5	Hai
6.0	1.8	10.8	11	Molch
5.6	1.6	9	6.3	Biber
4.7	2.5	11.8	12	Biber III
6.1	1.7	10.4	11.8	Hecht
6.2	1.7	10.6	15.6	XXVIIB
11.2	1	11.2	9.2	XXVIIF
8.2	1.7	13.9	17.3	XXVIIK
7.0	1.7	11.9	14.9	Seehund
8.0	1.7	13.6	17	227
4.7	2.4	11.3	11.3	Chwertwal
4.8	2.8	13.5	20	Seeteufel
5.5	1	5.5	2.8	Delphin I
6.7	1.3	8.7	7.5	Delphin II

Table 1- Dimensions of Submarines Less than 30 ton

L/D	D	L	Displacement	Submarine
8.78	3.2	28.1	127	UBI
8.20	4.4	36.1	263	UBII
10.63	3.2	34	168	UCI
10.00	4.1	41	254	IIA
10.41	4.1	42.7	279	IIB
10.71	4.1	43.9	291	IIC
10.00	3.2	32	300	V
10.48	2.1	22	73	V80
11.82	3.3	39	277	Wa201
10.18	3.4	34.6	236	WK202
11.97	3.4	40.7	301	XVIIK
0.03	3	27.1	155	XXII
11.57	3	34.7	234	XXIII
9.33	3	28	160	XXV
9.20	2.5	23	90	XXXIV

Table 2- Dimensions of Submarines Less than 300 ton

Important note is that variation of diameter has step changes and has not continuous variation, for example, submarine between 100 and 170 ton displacement have diameters 3 or 3.2 meters and submarines 250-300 ton have 4.1 meters diameter.

In dynamic stability aspect of view, the more L/D is equal to more dynamic stability and less maneuverability. Dynamic stability and maneuverability have antonym behavior. The final optimum L/D must provide suitable for all three parameters: resistance, dynamic stability and maneuverability.

Because of limitation of diameter, midget submarines have only a single deck. This deck is middle deck. The space above deck is usually used for crew activities and the space under the deck is used for tanks arrangement and battery room. Thus the height above the deck must be suitable for a crew moving by crawling. Ideal height above deck is 1.7 meter that is usually impossible in tonnages less than 150 ton. For providing this height the middle deck can be arranged lower than centre of pressure hull but the main limitation is height of battery beneath the deck.

In midget submarines less than 150 ton, middle deck can be 0.1 D under the centre of hull. In ergonomically aspect of view, ideal condition is that crew can move vertically but is not usually practicable in midget submarine because the maximum diameter of a 350 ton submarine is 3.5 meter and the height above middle deck is 1.75 meter in best condition and largest midget submarine. The suggested condition in figure 1 is usually best conditions.

In architecture of submarine, at least, one small space must be provided for vertical standing of one crew for some times. In midget submarines, this condition can be sustainable because of short duration or period of operation that is less than 7 days at maximum and usually 3 days. The number of crew is dependent on the displacement of submarine. For example a 70 tons submarine has 4 crews and a 150 tons submarine has 6 crews and a 300 tons submarine has 9 crews. The number of crew of midget is very important because of limitation of inboard spaces.

Single deck arrangement causes minimum volume efficiency. Volume efficiency is ratio of useable volume to the total volume. Curvature of circular cross section is the main parameter.

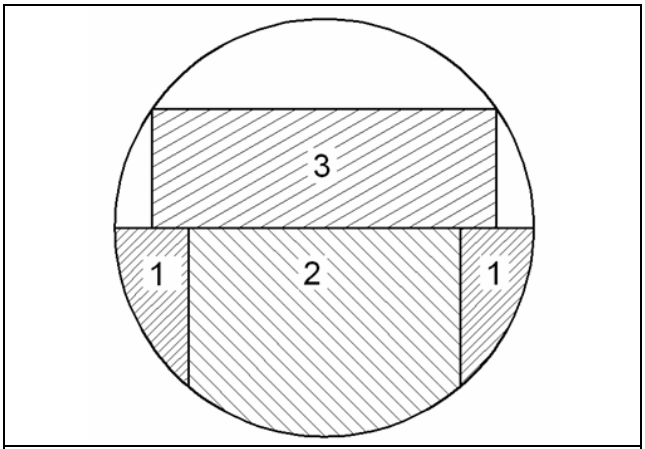

Figure 3- Volume Efficiency in Single Deck Arrangement

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As shown in figure 3 the space 1 is usually used for tanks and space 2 is for battery cells. Thus the volume under deck is approximately totally applicable. Space 3 above the deck is arranged for other part that has little volume efficiency. White spaces in figure 2 are not useable because of hull curvature. Devices and apparatuses cannot be installed. Volume efficiency in single deck arrangement is 70 percent that is minimum efficiency and is 77 percent in two deck and 82 percent in three deck arrangement. Thus midget submarine has minimum volume efficiency [1].

Volume and weight distribution

Volume and weight distribution between several part and systems are very important in general arrangement of submarine. This quotation is different to large naval submarines. Figure 4 shows volume quotation for midget and large submarines. Figure 5 shows weight quotation for midget and large submarines. Weight and volume distribution are vital for providing neutral buoyancy in submerged condition and preventing excess weight problems. Structural bending moment is very dependent on the volume and weight distribution.

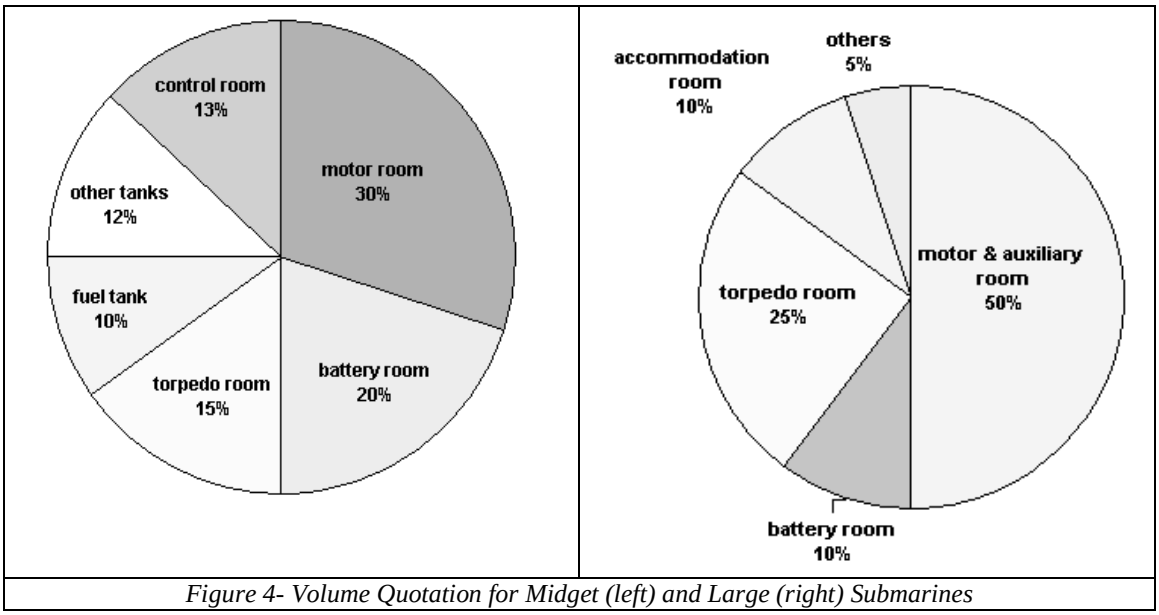

Figure 4- Volume Quotation for Midget (left) and Large (right) Submarines

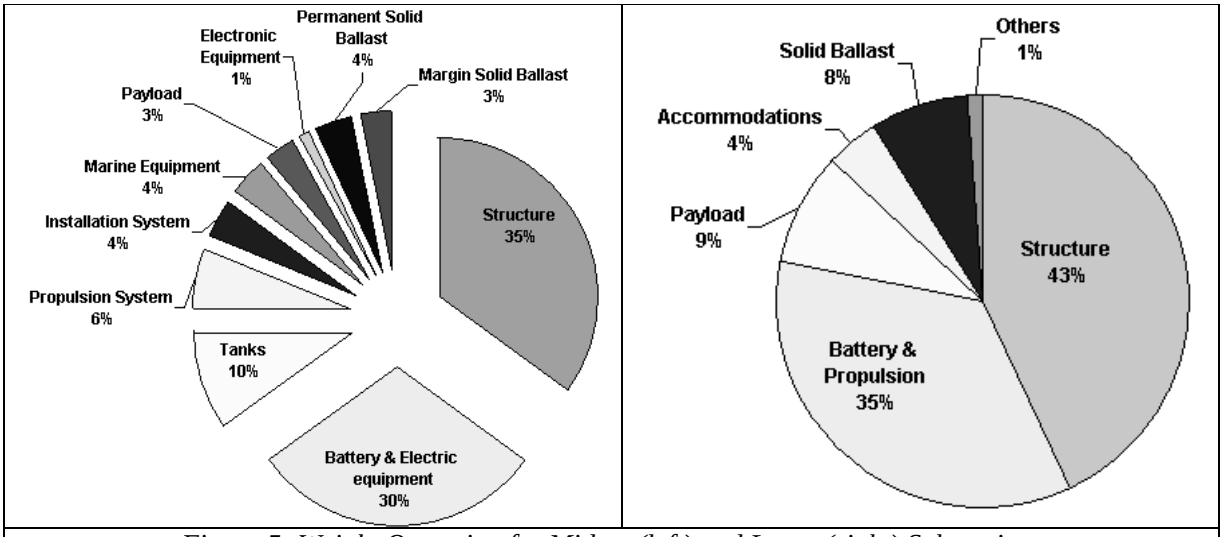

Figure 5- Weight Quotation for Midget (left) and Large (right) Submarines

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Stability condition

Stability condition is based on GZ curve specifications. This curve is very different from large submarines. The main parameters in GZ curve for midget are considered in figure 6 [3].

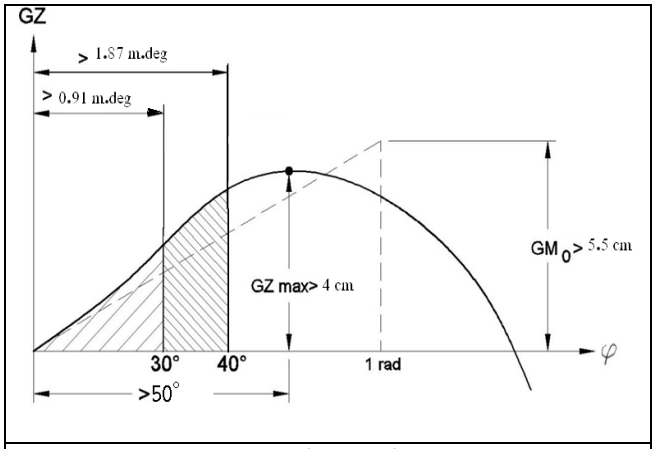

Figure 6- GZ Curve Specification for Midget Submarines (IDS-912)

Seaworthiness

Midget submarines are essentially designed for calm waters not oceans because of weak seakeeping behavior. They are designed for maximum sea state 3 and safe condition in sea state 2 while for large submarines, sustainable sea force can be up to 5 [4,5].

Conclusion

Midget submarines have special consideration for general arrangement, dimensions, weight and volume distribution and stability. The main parameters in naval architecture design between midget and large submarines were compared in this paper such as; displacement, payload, dimensions of torpedo room, control room, motor and auxiliary room, fuel tank, battery room, optimum L/D and usual diameter of pressure hull for midget were discussed and compared to the large submarines.

Volume and weigh quotation were given in polar diagrams for providing adequate balancing and stability. Stability of midget submarine is different from others especially in GZ curve.

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