Growth and Technological Development of the Korean Shipbuilding Industry

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1. INTRODUCTION

The shipbuilding industry is considered the representative success case in the history of the Korean industry. The country's shipbuilding tonnage was only 15,000 GT in 1972, but grew to 1.4 million GT in 1982 and surpassed 10 million GT in 2000. Based on ship orders, the country's shipbuilding industry ranked first in the world from 1999 to 2008 (excluding 2001). Korea surpassed Japan, which had long led the global shipbuilding industry, and emerged as a new shipbuilding power. However, it is also undeniably true that China, which has fostered its shipbuilding industry by establishing a large shipbuilding complex at the national level, is rapidly catching up with Korea and threatens the country's status as the world's leading shipbuilder.

TABLE 1 Global Market Share of Major Shipbuilding Countries

Unit: 1,000 CGT, %

Classification	1997	1999	2001	2003	2005	2007
Size of global market	36,480	28,940	36,667	74,041	161,331	167,522
Korea(share)	6,764(29.2)	6,325(33.3)	6,990(29.6)	18,810(42.9)	13,571(32.4)	32,861(37.7)
Japan(share)	8,790(37.9)	4,934(26.0)	7,932(33.5)	12,335(28.1)	9,446(22.6)	10,017(11.5)
China(share)	1,211(5.2)	1,924(10.1)	2,802(11.8)	6,107(13.9)	6,606(15.8)	31,382(36.0)

Note: These statistics include only ships of over 100 GT and are based on commissioned orders.
Source: Lloyd's World Shipbuilding Statistics

The global status of the Korean shipbuilding industry is recognized in the ranks of the world's shipbuilders. Among the global top-10 shipbuilders based on the order backlog of September 2006 there are as many as seven Korean shipbuilders: Hyundai Heavy Industries, Samsung Heavy Industries, Daewoo Shipbuilding & Marine Engineering, Hyundai Mipo Dockyard, Hyundai Samho Heavy Industries, STX Offshore & Shipbuilding, and Hanjin Heavy Industries & Construction. Hyundai Heavy Industries ranks first with unrivalled capacity for all ship types, while Samsung

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Heavy Industries and Daewoo Shipbuilding & Marine Engineering are competing for the 2nd place, mainly with LNG ships and very large crude carriers (VLCC) (Chun, 2008: 17).

The growth of the Korean shipbuilding industry has not been limited to the production capacity. Rather, it has led to the improvement of productivity and technology. This is clearly revealed in the fact that Korea takes up a large share of the building of most ship types (excluding bulk carriers). Container ships, tankers, and LNG ships are the main ship types built in Korea and attract a high demand from the global market due to a high added-value benefit. Korea's shipbuilding technology has improved via three stages of development: the technology acquisition stage until the early 1980s, the technological catch-up stage after the mid-1980s, and the technology creation stage after the mid-1990s. In the 1970s and the early 1980s, the industry learned production technology and design technology from developed countries; however, after the mid-1980s, it established an R&D system to independently develop new technologies. Since the mid-1990s, technological development was carried out on high value-added ships using new construction methods.

2. CONSTRUCTION OF LARGE SHIPYARDS AND TECHNOLOGY ACQUISITION

The Korean shipbuilders (including Hyundai) aimed to build super-large shipyards from the beginning to target the global market. Hyundai originally planned to construct a shipyard of 150,000–200,000 tons, but it revised the plan several times to expand the capacity to 1 million tons in 1973 (HHI, 1992: 338-342). Hyundai's challenge was evaluated as very ambitious considering that the annual capacity of Daehan Shipbuilding (currently Hanjin Heavy Industries & Construction), the country's representative shipyard at that time, was only 100,300 tons.

In March 1972, Hyundai held a historic groundbreaking ceremony for shipyard construction in Ulsan, and it concluded a contract with Livanos of Greece to supply two 260,000- ton VLCCs on April 10. Hyundai adopted a strategy to build these crude carriers and a shipyard at the same time. Simultaneously constructing a shipyard and large-scale crude carriers was an epochal method to shorten the construction period. With the 1974 launch of two VLCCs and completion of the shipyard, Hyundai entered the global market in earnest (HHI, 1992: 257-269). In 1975, Hyundai established the Hyundai Mipo Dockyard, a ship repair company.

The Korean government provided active assistance to the development of the shipbuilding industry through the establishment of a long-term shipbuilding industry promotion plan in 1973 and the implementation a comprehensive plan to foster the marine and shipbuilding industry in 1976. Against this backdrop, Hyundai steadily broadened its shipyards to secure seven docks by 1970, and Samsung took over Woojin Shipyard in 1977 and completed the first dock in 1979. In 1978, Daewoo took over the first dock completed by Daehan Shipbuilding in Okpo and entered the shipbuilding industry. As Daewoo's 2nd dock and Samsung's 2nd dock were both finished in 1983, shipyard construction that had been ongoing was temporally concluded. In 1983, the Korean shipbuilding industry became the world's second leading shipbuilder in terms of production capacity and Hyundai emerged as the world's largest with 10.3% of global shipbuilding market orders.

Based on such expansion of the production capacity, Korea's shipbuilding companies (including Hyundai) made active efforts to introduce and absorb advanced technologies. Hyundai owned neither element technology nor design and production technology when it entered the shipbuilding industry and it was forced to import all the technology from advanced shipbuilding countries, such as Britain and Japan; in addition, the company had to import most shipbuilding materials from abroad. It is said that at that time, few Korean technicians could read the design plans introduced from abroad (Bae, 2002: 142-143).

While advancing into the shipbuilding industry, Hyundai tried to desperately secure technicians as it tried to secure funding. That was because recruiting highly skilled domestic and foreign human resources alone was not enough to satisfy the requirements for the large number of technicians needed. In September 1972, Hyundai invited Director Robert L. Wilson from A&P Appledore and established an in-house training center to independently nurture technicians. The training process lasted for six months, and 11 subjects were taught, including gas cutting, piping, sheet metal, electricity, mechanical engineering, drawing, and management. Thanks to this effort, the shipbuilder could educate 3,636 technicians (including 2,172 regular trainees) by late 1975. By training these technicians, Hyundai could smoothly proceed with shipyard construction and ship production (HHI, 1992: 344-345).

Hyundai recruited technicians from developed countries and provided technical training in advanced companies to secure shipbuilding technology. At that time, Britain's Scott Lithgow Ltd. was building the same type and grade of ships that Hyundai had received as orders, and it considerably assisted Hyundai to learn the techniques of shipbuilding within such a short period. As for Japan, Hyundai received technical training on overall shipbuilding technology in accordance with a technical agreement with Kawasaki Heavy Industries and (in particular) technology transfer on shipyard construction and ship design took place at shipyards sites (Amsden, 1989: 276-279; Bae, 2011).

It was not always easy to repeat the knowledge obtained through technical training on-site. Although the company acquired technology from advanced countries through technology introduction or human resource training, it was another job to apply this technological know-how to production sites. One person concerned said that there were as many as 104 cases of large and small on-site experiments before the first and second ships were built (HHI, 1992: 358). While repeatedly experiencing vicissitudes on the way to eventual success, the shipbuilder continued to repeat tasks frequently and obtained the expertise necessary for production. As a result, Hyundai's pass rate in ship inspection (38.1% in 1973) increased to 84.1 percent in 1976, a figure close to those of developed countries. In 1983, Hyundai was recognized by Lloyd's Register of Shipping (LR) and Det Norske Veritas (DNV) for its ship quality (Bae, 2002: 143-144).

Although Hyundai accumulated production technologies, it was not easy to acquire design technology. Five years passed after the establishment of its first shipyard without the company independently designing a ship; instead, it imported all its design drawings from foreign shipyards or consultants. It adopted a Japanese-style production design in 1974; subsequently, the shipbuilder made enormous efforts to achieve its own production design. After setting up a basic design studio in 1978, Hyundai established the notion of hull form design and began a detailed design on the hull structure based on the mother ship of a foreign shipping company. Between 1979 and 1983, Hyundai introduced additional design technologies from Germany, Denmark, and Canada to improve its own design capability. The company then began to design and independently develop standard ships at about half to two-thirds cheaper than what a standard ship then cost (KOSHIPA, 2005: 89-90).

Like Hyundai, Daewoo and Samsung also absorbed shipbuilding technologies from advanced countries through technology introduction or human resources training. Noteworthy is that Korean shipbuilders introduced technologies mainly from European countries; Daewoo introduced Britain's A&P Appledore and T. F. Burns and Samsung introduced Denmark's Burmeister & Wain (B&W). Japan intended to continue to dominate the global shipbuilding market and was reluctant to transfer shipbuilding technology to Korea because it was concerned about a possible boomerang effect from the Korean shipbuilding industry; however, the European shipbuilding industry had already entered a phase of decline and was therefore relatively open toward technological transfer (Kim, 2008: 260-264).

3. STREAMLINING OF THE SHIPBUILDING INDUSTRY AND TECHNOLOGY CATCH-UP

As the global economy entered a slowdown phase in the 1980s, new orders tended to decrease worldwide. In response, the Korean shipbuilders had to conduct aggressive business activities (such as accepting orders at low prices) to raise the operation rates of large facilities with high fixed costs. As a result, they could receive an annual average of 2.5 million GT from 1980 to 1987, thereby securing about 60% of their shipbuilding capacities. However, in the mid-1980s the ship price per ton dropped to below 50% of what it was in the late 1970s and this worsened the financial structure of the Korean shipbuilding industry. In addition, the appreciation of the Korean currency and labor-management disputes (which began in 1987) caused the Korean shipbuilding industry to face somewhat of a crisis (Kim, et al., 2006: 74-76).

Against this backdrop, the Korean government took action to streamline the shipbuilding industry in 1989, which amounted to a massive restructuring of the industry. Judging that poor management of the industry was caused by excessive facility investments, the government prohibited new entries or facility expansions until 1993. Daewoo Shipbuilding, Inchon Shipbuilding, and Daehan Shipbuilding asked the government to streamline them to improve their financial structure. In 1990, the Hanjin Group acquired Daehan Shipbuilding and started anew as Hanjin Heavy Industries and successively merged Donghae Shipbuilding, Pusan Repair Shipbuilding and Korea Tacoma. The Halla Group took over Inchon Shipbuilding and renamed it Halla Heavy Industries (currently Hyundai Samho Heavy Industries). As for Daewoo Shipbuilding, the government imposed a moratorium on debt repayment and provided new loans, under the premise that the shipbuilder would make efforts to rescue itself (such as the integration of some affiliates). Hanjin Heavy Industries and Halla Heavy Industries received tax benefits in return for the acquisition of the insolvent companies (KOSHIPA, 2005: 180-182).

In response to the government's actions, the Korean shipbuilding industry endeavored to improve its structure. It replaced some facilities to increase productivity and perform automation without building new facilities, and conducted a massive reduction of employees. Also, the industry enthusiastically adopted management diversification strategies to flexibly cope with the ups and downs of the shipbuilding market conditions. The industry applied shipbuilding technologies to actively enter other sectors, such as industrial machinery, ocean plants, and steel structures.

Amid rapid changes in the management environment, Korean shipbuilding companies were also keen on technological development. The industry was aware that it desperately required the ability to self-develop higher technology to compete with advanced countries. This perception led a series of Korean shipbuilders to improve R&D systems through the 1980s (KOSHIPA, 2005: 87-89). Hyundai Heavy Industries established a welding technology institute in 1983 and a shipbuilding and marine research institute in 1984. Daewoo Shipbuilding set up a shipbuilding and marine technology institute, and Samsung Heavy Industries established a shipbuilding research institute under its advanced institute of technology in 1984 and expanded it into a shipbuilding and marine institute in 1986. An important background factor to all these efforts was that the Korean government had strengthened assistance polices on finance, taxation, and human resources in order to facilitate private sector R&D activities since the 1980s.

In particular, it is noteworthy that Hyundai constructed a towing tank and two small tanks with the 1984 establishment of the shipbuilding and marine research institute. To build an optimum ship type, it is necessary to conduct various tests on a model shipas reduced in size (at an appropriate ratio) in a tank under conditions similar to actual maritime conditions. Such model tests were previously commissioned to foreign organizations with serious material and time losses as well as leakages of expertise. However, Hyundai began to conduct model tests on its own in 1984 so it could save test costs, reflect test results to design in time, and accumulate relevant data. The database greatly helped to develop similar or new ship types and worked as an important basis to enhance its reputation for reliability abroad.

Based on the improved R&D systems, Korean shipbuilders began to close the technological gap with advanced countries through active technological innovations (KOSHIPA, 2005: 86-87). As to design technology, they could independently design ordinary merchant ships (including bulk carriers); however, they had no design technology for high value-added ships (including LNG carriers). Korean shipbuilding companies (such as Hyundai) steadily prepared for their entry into the high added-value ship market with the introduction of LNG carrier technology and test-manufacturing mock-ups of key parts to of Cain international certification. One of its research accomplishments was the development of a Surface Effect Ship (SES) with a hull floated by air pressure.

The industry has used various technologies since the 1980s to improve the efficiency of ship production in the production process. CAD/CAM technologies were used to design and produce computer-utilized ships; in addition, laser-cutting equipment was adopted to enhance cutting accuracy and speed. Carbon dioxide welding techniques and flux-cored wire welding techniques were distributed to greatly increase welding efficiency. A panel line device that assembled hulls by moving panel blocks was installed and a method was applied complete hull blocks before painting the entire blocks inside a factory. In addition, hull-fitting jobs (such as piping or device installations) were mostly performed before hull blocks were loaded at the docks. To improve production management technology, the shipbuilders invited Japanese experts to introduce theoretical planned management techniques that were computerized to improve and complement the circumstances of each shipyard.

Through these technology innovations, Korean shipbuilders began to rapidly catch up with the leading the world shipbuilding industry of Japan. The technology levels of the Korean shipbuilding industry remained at about 40% of those of Japan in the early 1980s; however, they increased to around 70% in the early 1990s. A survey (based on 1992 figures) shows that if Japan was 100, the design technology of Korea was 71, production technology was 75, and management technology was 68. The survey also found that the ratio of R&D investment (compared to revenue) was below 1% in major Korean shipbuilding companies, while it was 2–3% for their Japanese counterparts (Korea Development Bank, 1993: 461-463).

4. LEAPFROGGING INTO THE WORLD FRONTIER AND TECHNOLOGY CREATION

New and additional construction occurred as the world shipbuilding economy showed an upturn that centered on alternative shipbuilding demand in the 1990s. In particular, the new and additional facility constructions temporarily contained by the government streamline measures were allowed in 1993; subsequently, Samsung, Hyundai and Halla Heavy Industries and Daedong Shipbuilding (today's STX Shipbuilding) were able to build new or additional docks. This facility expansion stemmed from the expectations that the global shipbuilding demand would increase in the late 1990s and that the Korean shipbuilding industry would secure a high international competitiveness. With the value of the yen rising, Korea received ship orders of 9.5 million tons in 1993 (a sharp increase from 5 to 6 million tons in the past) and surpassed Japan to emerge as the world's biggest ship order-receiving country (KOSHIPA, 2005: 51).

Paradoxically, the 1997 Financial Crisis provided an opportunity for Korea to dramatically raise the competitiveness of its shipbuilding industry. A big fall in the value of the won improved price competitiveness because the payments for the ships came in as dollars and generated foreign-exchange profit. The crisis nonetheless provided a good opportunity for the Korean shipbuilding industry as a whole although the financial crisis produced considerable debt issues (Halla Heavy Industries and Daedong Shipbuilding went bankrupt and the Daewoo Group crumbled). In addition, the world shipbuilding market continued to improve with annual ship orders reaching 22 to 37 million GT; this helped Korean shipbuilders quickly overcome the crisis (Kim, et al., 2006: 82).

Japan reduced shipbuilding facilities and human resources in anticipation that the shipbuilding industry would experience a recession at the end of the century. In this regard, some shipbuilding experts forecasted during the shipbuilding boom in the early 1990s, that the boom would go on for a decade before shipbuilding demand would fall. However, the ‘China Effect’ helped the shipbuilding industry thrive continually. Japan failed to cope with the continued boom and massive orders; subsequently, Korea benefitted by receiving these transferred orders and became the world's biggest shipbuilding power (Kim, 2008: 268-269).

Since the 2000s, the Korean shipbuilding industry rank first in the world through more ship orders and increased shipbuilding tonnage due to the global shipbuilding boom. In addition, the ratio of high value-added ships, such as LNG ships, floating production storage offloading (FPSO) vessels, ultra-large container ships, and super high-speed passenger ships, has gradually increased as part of its key ship type production base. This is because shipbuilding companies have steadily consolidated R&D (mainly on high value-added ship types) since the mid-1990s to receive qualitatively better orders than quantitative orders.

In May 1994, the Korea Shipbuilding Research Association (KSRA) was established by the big five shipyards (Hyundai, Daewoo, Samsung, Hanjin, and Halla) and the Ship and Ocean Engineering Research Center of the Korean Institute of Machines and Materials. The KSRA aims to break the common shipbuilding technology bottleneck and handle high-tech tasks by setting up a cooperative R&D system among industry, academia, and research institutes. In October 1996, the Korea Research Institute of Medium & Small Shipbuilding was established in Busan to improve the structure and enhance the technological competitiveness of small and medium-sized shipbuilders. In the past, shipbuilding companies individually and internally set up a research center to enhance technological competitiveness; however, they have worked together to develop technology through joint research associations since the mid-1990s (Kim, et al., 2006: 99-100).

Based on accumulated technologies and the new R&D system, Korean shipbuilders have secured the ability to design and competitively produce high value-added ships with good performance since the mid-1990s. Particularly, they came to dominate the world’s LNG ship market by building Moss and membrane type LNG carriers based on the LNG ship construction technology obtained in the 1980s (Chae, 2004). They have independently developed ultra-large container ships and super-high-speed passenger ships to cope with the trend toward larger and faster ships. In addition, a series of ships with complex functions have been built, such as the LNG-RV loaded with a device to convert liquefied gas that directly supplies gas to consumers, ice-breaking oil tankers to navigate the Arctic Ocean, FPSO vessels gathering and refining crude oil from under the sea, and wing-in-ground (WIG) craft flying near the water using the ground effect.

As shipbuilding was actively combined with information and technology, large shipyards led by the KSRA formed a consortium to advance a project to develop Computer Integrated Manufacturing System (CIMS) shipbuilding. As for production technologies, robots were widely used in the assembly and welding processes; in addition, technology to accurately measure large 3D blocks was developed that enabled no margin assembling. A production system for 2,500-ton ultra large blocks was established as a hull blocks enlarged; in addition, the industry acquired ISO 9000 certification for the entire process, including design, production, inspection, delivery, and post-management to secure a higher international reliability (KOSHIPA, 2005: 91).

Among the representative recent technology innovations of the Korean shipbuilding industry are new construction methods. Shipyards have often had to pass on receiving new ship orders because of fully occupied dock schedules; subsequently, Korean shipbuilders developed various new construction methods to overcome this problem. Representative examples included Hyundai's on-ground building method, Samsung's mega-block method, STX Shipbuilding's skid-launching system, and Hanjin's DAM construction method. By massively altering shipbuilding methods, Korean shipbuilding companies heralded a transformation of the shipbuilding paradigm (Song, 2008).

Hyundai's on-ground building method assembles a ship on-land without using existing building docks, transfers the completed ship to a barge by pushing it on rails, and mounts it on an underwater barge to float the ship out to sea. Samsung's mega-block method assembles ultra large blocks (five to six times bigger than the existing blocks) outside a dock and then moves them into the dock using a floating crane. STX Shipbuilding's skid-launching system was developed to build the two halves of a ship on land and then connect them at sea. Hanjin's DAM construction method builds and launches only part of a ship (which could be loaded on a dock) and constructs the remaining blocks on the ground to weld and connect these parts at sea. Here, the dam refers to a watertight structure for underwater welding.

5. SUCCESS FACTORS

Among the factors contributing to the growth and technological development of the Korean shipbuilding industry are massive facility investment, a flexible response to demand, the procurement of highly skilled human resources, the competitive structure of Korean shipbuilders, and the active assistance policies of the Korean government.

First, the Korean shipbuilding industry has grown through massive investments in facilities. As Hyundai and Daewoo entered the shipbuilding industry in the 1970s, they secured a production capacity of over 1 million tons that equal the volume of a super large shipyard (by world standards) at that time. In the 1990s, Korean shipbuilders resolutely secured large-scale facilities in anticipation of a shipbuilding boom, while Japanese counterparts shrank their facilities in fear of oversupply. Such massive facility investment led to the growth of the shipbuilding industry and functioned to increase the breadth and depth of technology learning.

Second, Korean shipbuilding companies have developed by effectively satisfying the various needs and demands of ship owners. They first acquired the ability to design and build ordinary merchant ships and then gradually increased the ratio of high value-added vessels. While Japan focused on the construction of standard ships designed to build many vessels based on a single drawing, Korea flexibly responded to the demands for high value-added ships and now builds approximately 80% of large container ships, 80% of LNG ships, and 90% of FPSO vessels worldwide. Its capability design and build these high value-added vessels is evaluated as a base to widen the shipbuilding gap between Korean and Japan as well as compete with China.

Securing of excellent human resources has also worked as an important factor for the growth and technology development of the Korean shipbuilding industry. Korean shipyards have steadily cultivated technicians through internal training centers. These technicians possess excellent expertise accumulated while they worked long term in the shipbuilding field. In addition, shipbuilding-related departments in four-year-course universities in Korea produce about 700 graduates every year to meet the demands of Korean shipyards. It is hard to find a case worldwide where such a large number of highly educated people are provided to the shipbuilding sector. Korean shipbuilding companies have made more efforts to obtain distinguished R&D human resources than other countries. In the case of Hyundai Heavy Industries, R&D human resources represent a high a proportion of over 10% of its 26,000 employees.

The Korean shipbuilding industry is comprised of seven large shipbuilders, and the competition and cooperation among these companies generates an upward effects. Korean shipbuilders are accustomed to infinite competition because competition among domestic enterprises is tantamount to competition with world-class companies; however, they also fully cooperate with each other due to the unique national identity of Korea. An innovative case of a particular shipbuilder quickly spreads to the other shipbuilding companies because they are not afraid to work together and solve challenging tasks. Through the Korea Shipbuilders' Association and KSRA, they jointly develop cutting-edge technologies and effectively respond to trade disputes and patent litigations disputes with foreign countries.

The policies of the Korean government have significantly influenced the growth and technological development of the shipbuilding industry. The government has actively participated in laying the foundation for the early-stage growth and take-off of the shipbuilding industry with the formulation of a long-term shipbuilding industry promotion plan in 1973 and action to streamline the industry in 1989. Instead of directly assisting the industry, the government began to strengthen indirect assistance for technological innovations in the mid-1980s. In particular, the government continued to assist joint R&D projects through the KSRA, and representative projects include the next-generation shipbuilding production system, the establishment of a B2B network, and the construction of a joint research base for high value-added ships.

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