J. Chosun Natural Sci.
Vol. 13, No. 2 (2020) pp. 63 – 68
https://doi.org/10.13160/ricns.2020.13.2.63

Study of Yeongjocheok and Industry-Academic Calculation Methods Using Scale and Circumference of Jaseungcha Dohae

Kwang-Cheol Rim†

Abstract

Different units of metrology were used in the Joseon Dynasty, such as Yeongjocheok, Pobaekcheok, Jolegicheok, and Jucheok. In many cases, Yeongjocheok and Pobaekcheok were of different dimensions depending on the region. Therefore, this study analyzed Jaseungcha Dohae of Ha BaeckWon to restore the scale of Hwasun Dongbok area in which Seokdang Na GyeongJeokyung and Gyunam Ha BaeckWon lived and made practical devices. The results of the analysis show that a universal Yeongjocheok of 30.6 cm was used.

Keywords : Ha BaeckWon, Jasengcha, Cheok, Silkhak, Honam Silhak.

1. Introduction

The problem of achieving uniform length and volume has been addressed by all human civilizations. In most civilizations, lengths taken from the human body, such as the length of a hand, the length of an arm, the length of a foot, and the length of a body, were used as direct measures and units of scale. This phenomenon was common to ancient cultural activities in different countries and regions.[1]

In the Joseon Dynasty, the scale used in the private sector was represented by Yeongjocheok, Jucheok, and Pobaekcheok. Yeongjocheok, which was also called Mokcheok, was used mainly for woodworking and construction purposes. Pobaekcheok was used primarily in the fabric trade, and tended to be shorter than the standard in order to prevent losses from occurring in the sale of fabrics.

In the late Joseon Dynasty, metrology was established by law, and was used in connection with the maintenance and production of “Ye” (courtesy) and “Ak” (pleasure), the basis of the standard philosophy of Neo-Confucianism, which formed the foundation of Joseon’s rule. In addition, metrology existed in a dual manner as the standard for tax collection in the government sector, as well as the standard for commercial and economic life in the private sector. Of course, there was an organic connection between the two, but the legal metrology in the government sector tended to unify the metrology in the private sector. However, due to the intrinsic conditions of Joseon society, the metrologies of the government and the private sector differed in reality.

In Gyeongguk Daejeon (National Code), metrology for the government sector was provided by Gongjo (Ministry of Commerce). In the provinces, it was tested and branded under the responsibility of a provincial governor. Metrology for the private sector was set every year in autumn by Pyeongsiseo (Marketing Control Office) in Seoul and was used for the levying of taxes in the provinces.

Naturally, this dual system became disorderly. Civilians were allowed to make and use metrology, inspection agencies were decentralized, and there were no punishment criteria. Therefore, in the Daejeon Sillok (Annals) during the reign of King Seongjong, metrology was delegated from Seoul’s Pyeongsiseo to the Inspector of Saheonbu for inspection and approval. In the provinces, it was entrusted to those who ruled the Gunhyeon (prefectures). Further, there was a regulation for punishment if the government official was unclear and did not adhere to the law.

In Sokdaejeon, during the reign of King Yeongjo in the late Joseon Dynasty, “dugok,” the unit for the mea-

Department of mathematics, Chosun University, Gwangju

†Corresponding author : rim1201@hanmail.net
(Received : June 11, 2020, Revised : June 14, 2020, Accepted : June 17, 2020)

surement of grain, had no distinction in the government and private sector, with Gongjo in Seoul and Yeongjin in the provinces serving as managing inspection agencies. Those who violated regulations were punished with 60 floggings of the Daemyungyul, the criminal code of Joseon.[2,3]

The scale used to measure the height of soldiers recorded in Sokogunjeok in the 16th and 17th centuries is unknown. By examining data related to the "hopae" (identity tags) and verifying its relevance, it was found that the scale of the height of soldiers in the Joseon Dynasty did not exist on the five scales of Jucheok, Yeongjocheok, Joyegicheok, Whangjongcheok, and Pobaekcheok, as had originally been believed by the community. Instead, a sixth scale—the Sokogun Sinjangcheok—existed. In addition, it was confirmed that Whangchongcheok and Shinjojucheok coexisted in the era.[2]

In this study, the length of the Yeongjocheok at the time was calculated by measuring the drawing with modern figures, after examining basic data related to the scale using the proportions shown in the Jaseungcha of Gyunam Ha BaeckWon in Hwasun Dongbok area.

2. Ha BaeckWon's Silhak in Hwasun Dongbok

In the Dongbok area of Hwasun-gun, Jeollanam-do, where Ha BaeckWon was active, knowledge about waterwheels had already spread to the extent that Na GyungJeok could make the Jajeon Soocha (self-rotating waterwheel). After the death of Na GyungJeok, his studies appear to have been passed onto his great-grandson, Na SangGeun (1777–1850) through Na SimJwa (1710–1770) and Na DeukMun. [Daedongbo] As there is an excerpt in Na SangGeun's record that reads, "I received recognition from my seniors for the continuous study of the alarm clock and self-rotating waterwheel," it is believed that Na GyungJeok's academic tradition was passed on to his family for a period, in addition to his disciples Ahn CheoIn and Yeom YoungSeo. Ha BaeckWon, who lived in the same village as Na SangGeun, was the great-grandson of Na GyungJeok's friend, Ha YoungCheong, and grew up with interest in automatic devices. Ha BaeckWon included not only agriculture, manufacturing, and commerce, which were disdained based on the consciousness of the four classes during the Joseon Dynasty (i.e., the nobles, farmers, artisans, and merchants), in the academic domain of the Confucian scholars. He also paid attention to Section 47 of Zhuziyulei (Book 17), stating that money, agriculture, and the military are all part of the learning necessary to become a sage and accepted the issues regarding these as practical elements of learning. This is notable because it is in line with the arguments of Silkhak scholars—Hong DaeYong and ParkJiWon—who propounded the theory of the Thoughts for learning Qing Culture and the spirit of the promotion of public welfare. However, previous studies on Ha BaeckWon had primarily focused on the location and ideological flow of Ha BaeckWon's Honam Silkhak and the contents of books and maps in Ha BaeckWon's poetry collections. Research on the restoration and operation of Jaseungcha Dohae (illustration) focuses on its hydrodynamic mechanisms. Of course, the study of Ha BaeckWon's Silkhak spirit and his poetry collection is important. However, Ha BaeckWon's Jaseungcha Dohae is also significant because it reveals the principles and calculations used to draft blueprints at the time through the design drawings of mechanical devices and buildings in the Joseon Dynasty.

2.1. Ha BaeckWon's Silhak

Ha BaeckWon was approximately 30 years old when he made Jaseungcha Dohae and Jaseungcha Dohaesul and attached the preface "While recently going through several books in my spare time, and learning it after thinking a thousand times, I have devised a way to complete it, and named it 'Jaseungcha,' which makes it possible for people to profit without being laborious. The nature of water is to fill in the middle, so it can move on to empty space. But water cannot move if something is blocked. 'Water moves down' does not mean that water is divided into the top and bottom but that it only flows along the empty space. When you see the spring water rise from the bottom and overflow, you realize that people can lead the water into a frenzy to provoke anger, get drunk by absorbing it, and drive water so that it goes up." This implies that Ha BaeckWon was influenced by his avid reading of approximately 1,000 books handed down in the family of Ha BaeckWon and Silhak's academic traditions of practical learning.

The structural form of the Jaseungcha is largely composed of three parts: the cylinder, the gear, and the frame. At the operating principle's core is the spinning of the turbine using the flow rate of the river, and the rotation of the turbine, which lifts the piston and pumps the water up. The production of a sample Jaseungcha showed that this device requires a high level of technology and can only be made with good knowledge of hydromechanics and mathematics. In this regard, it can be perceived that it was a product of science and technology that was incomparable to China's keel, traditional, "bun," or "dap" waterwheels.

2.2. Jaseungcha

Ha BaeckWon was about 30 years old when he made <Jaseungcha Dohae> and <Jaseungcha Dohaesul>, and attached the preface "While recently going through several books in my spare time, and learning it after thinking a thousand times, I have devised a way to complete it, and named it 'Jaseungcha', which makes it possible for people to profit without being laborious. The nature of water is to fill in the middle, so it can move on to empty space. But water cannot move if something is blocked. 'Water moves down' does not mean that water is divided into the top and bottom, but that it only flows along empty space. When you see the spring water rise from the bottom and overflow, you realize that people can lead the water into a frenzy to provoke anger, can get drunk by absorbing it, and can drive water so that it goes up." This is a part to imply that Ha BaeckWon was influenced by the avid reading of about 1,000 books handed down in the family of Ha BaeckWon and by Silhak's academic traditions of practical learning.

If you look at the structural form of the Jaseungcha, it is largely composed of 3 parts: the cylinder, the gear, and the frame. The core of operating principle is the spinning of a turbine by using the flow rate of river, and the rotation of the turbine lifts the piston and pumps the water up. It has been proved through the fabrication of a sample Jaseungcha, that the device requires a high level of technology, which is possible only with a good knowledge of hydromechanics and mathematics. In this regard, it can be seen that it was a product of science and technology that was incomparable to China's keel waterwheel, traditional waterwheel, "bun" waterwheel, "dap" waterwheel, etc.

Ha BaeckWon added in the Tonga and Eonjo sections of Jaseungcha Dohae that "1 of 15 'bun cheok' was used in the Tonga drawing, while 1 of 10 'bun cheok' was used in the Eonjo drawing." This means that the actual size of each part in Jaseungcha was reduced to 1/15 and 1/10 in the drawings. Currently, the criteria for the known, commonly used Yeongjocheok are 1 cheok = 30.6 cm, 1 chon = 3.06 cm, and 1 pun = 0.3 cm. Therefore, this study attempts to calculate the actual size of the parts appearing as the Tonga section of Ha BaeckWon's Jaseungcha Dohae, which is shown in Figure 1, and analyze the proportionality of the actual size of the parts explained in Jaseungcha Dohaesul using the industry-academic method of the times.

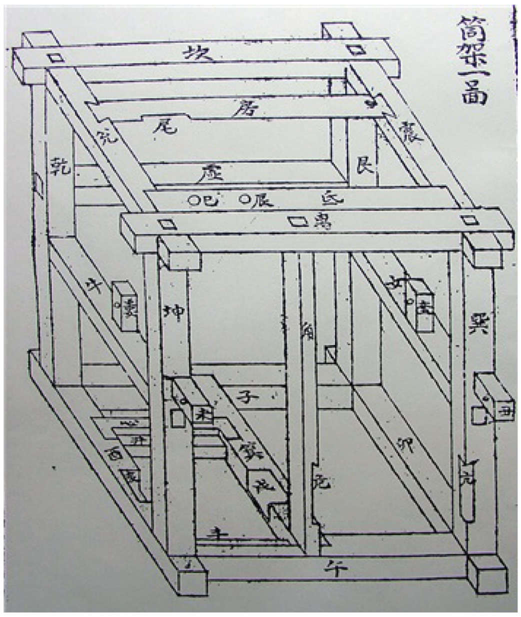

Fig. 1. Jaseungcha Dohae Tonga.

Figure 1 is the Tonga blueprint in Ha BaeckWon's Jaseungcha Dohae drawing. Figure 2 is a representation of the fabrication dimensions for the Tonga blueprint in Ha BaeckWon's Jaseungcha Dohaesul. As shown in figure 2, the length of one column on the base plate of Tonga is expressed as 42 cheok by Ha BaeckWon.

If this is calculated in the current known Yeongjocheok, the figure is 42×3.06 = 128.52 cm, which is 8.568 cm when reduced by 1/15.

In other words, if the length of one column on the base side of Tonga in the original <Jaseungcha Dohae> stored at Ha BaeckWon Memorial Hall measures 8.568 cm, it means that Ha BaeckWon's drawing was drawn up on a scale of 1/15 according to the standards of Yeongjocheok. In addition, considering the fact that the rep-

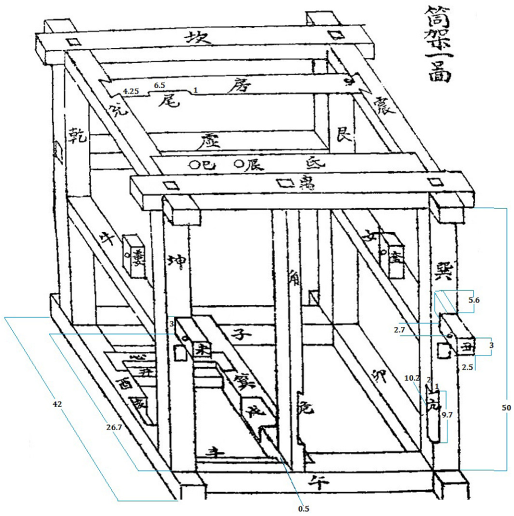

Fig. 2. Jaseungcha Dohae Tonga using cheok.

resentation of the drawing is based on a three-dimensional plan, the reduction in the dimensions of the frontal view and the dimensions of the sides and the top surface are considered.

3. Scale Analysis in Jaseungcha

An examination of Ha BaeckWon's Jaseungcha Dohae drawing shows the following. The data were measured using an electronic Vernier caliper and transparent measuring instruments capable of measuring the thickness of the lines and the size of the type by copying the original Jaseungcha Dohae.

Table 1 shows the dimensions of the base forming the top and bottom of Tonga. The places that are represented by "cheok" are data recorded as "cheok, pun, ri" in Ha BaeckWon's Jaseungcha Dohae, based on which the converted cheok was calculated. First, each part of the drawing was measured with an electronic Vernier caliper, multiplied 15 times, and divided by recorded "cheok, pun, ri" data in order to obtain the size of one cheok. In general, the lengths of the eastern and western sides of the frontmost part of the drawing were measured with a small error rate and close to the measured Yeongjocheok scale.

Table 2 shows the measured and compared lengths of the columns. Although the data recorded in the Jaseungcha Dohae showed 5 cheoks and 7 chons, the length of the column was measured based on 5 cheoks, excluding the latched butterfly part for which the groove of the column was dug. Consequently, the front figure showed a ratio close to that of the Yeongjocheok scale, but the part where perspective was applied was measured to show some error.

Table 3 shows the dimensions of the Seungtong part, which connects the path of water that is pumped and raised. It was detailed in the drawing about the direction of flow in the Seungtongga, and the length of the drawing, which was somewhat larger, was similar to that of the Yeongjocheok scale. The remaining small dimen-

Table 1. Comparison of base side Dimensions

Cheok	Drawing (mm)	15x (mm)	Converted cheok (mm)
4.2	85.78	1286.7	306.36
4.2	86.61	1299.15	309.32
4.2	86.88	1303.2	310.29
0.4	7.68	115.2	288
0.4	6.33	94.95	237.38
0.4	7.93	118.95	297.38
0.4	8.58	128.7	321.75
4.2	86.10	1291.5	307.5
4.2	86.61	1299.15	309.32
4.2	86.28	1294.2	308.14
0.4	8.41	126.15	315.37
0.4	5.76	86.4	216
0.4	8.14	122.1	305.25
0.4	7.96	119.4	298.5
4.2	103.99	1559.85	371.39
4.2	104.53	1565.95	373.32
4.2	91.46	1371.9	326.64
4.2	103.40	1551	369.29
4.2	91.46	1371.9	326.64

Table 2. Comparison of Column Dimensions

Cheok	Drawing (mm)	15x (mm)	Converted cheok (mm)
5.7	101.97	1529.55	305.91
5.7	101.97	1529.55	305.91
0.4	8.53	127.95	319.88
0.4	8.53	127.95	319.88
0.3	7.25	108.75	362.5
0.3	7.25	108.75	362.5
0.3	5.9.	88.5	295
0.3	5.90	88.5	295

Table 3. Comparison of Seungtongga (Drainage line) Dimensions easure of stay

Cheok	Drawing (mm)	15x (mm)	Converted cheok (mm)
0.425	8.69	130.35	306.71
0.1	2.08	31.2	312
0.65	13.21	198.15	304.85
0.4	8.05	120.75	301.88
0.4	8.05	120.75	301.88
0.3	4.76	71.4	238
0.3	4.83	71.4	238
0.15	2.89	43.35	289
0.15	2.89	43.35	289

Table 4. Comparison of Pendulum Support Dimensions

Cheok	Drawing (mm)	15x (mm)	Converted cheok (mm)
2.67	54.11	811.65	303.99
2.67	54.11	811.65	303.99
0.25	4.88	73.2	292.8
0.25	4.88	73.2	292.8
0.3	6.30	94.5	315
0.3	6.30	94.5	315
0.27	5.48	82.2	304.44
0.27	5.48	82.2	304.44

Table 5. Comparison of Eonjo Support Dimensions

Cheok	Drawing (mm)	15x (mm)	Converted cheok (mm)
0.53	10.95	164.25	309.9
0.97	19.56	293.4	302.47
0.97	19.56	293.4	302.47
0.1	2.29	34.35	343.5
0.1	2.29	34.35	343.5
0.2	3.76	56.4	282
0.2	3.65	54.75	273.75

sions could be perceived to show errors depending on the size of the brush.

Table 4 is the dimension that expresses the location of the pendulum support as a part that connects the turbine axis of rotation from the Eonjoro. The large data from the bottom showed similar results to that from the Yeongjocheok scale. The smaller the size, the greater the error due to the thickness of the brush. Table 5 is the binding part of the Eonjo, and is the part to be compared with the length of the Eonjo later.

The scale of each part described in the Jaseungcha Dohae was compared to the dimensions of the actual drawing. Measurements in the drawings were made with an electronic Vernier caliper, multiplied by 15 times to each of the measured dimensions, which were then divided by the recorded “cheock, pun, ri.” The measurement shows that the thickness of the line segment is approximately 1 mm, which is multiplied by 15 times and divided by the scale, resulting in an error of 15 mm. That is, if the error for the thickness of the brush is converted into “cheock, pun, ri,” the measurement error may occur within the range of 15 mm for each part. Accordingly, the mean through matching was calculated for the measurement dimensions of each part.

If the data for each part is a_i, then for 51 measurements:

$$\sum a_i \div 51 = 15635.79 \div 51 = 306.58 \quad (1)$$

This means that the measurement scale of the production device in Hwasun Dongbok area was approximately 306.58 mm. At the time, there was active flow of exchange between Hwasun Dongbok area and Najumok, so it can be seen that the Yeongjocheok Najumok and the length of the scale were not very different.

4. Conclusion

Ha BaeckWon carefully examined and identified the principles of water flow and developed a water pump. He had learned to apply the basic principles of natural science through various books, senior scholars' academic traditions, and various scientific instruments passed down to the villages.

Ha BaeckWon spun the turbine using the power of flowing water, changed the rotational motion of the turbine to an up-and-down motion, and subsequently completed the piston reciprocating motion with the use of that force. In addition, he created a blueprint for the production of these devices. Most blueprints described the name, size, and operation of each part. Each part was manufactured using the scales of Naju and Hwasun from Ha BaeckWon’s time in the early 1800s, and these scales need to be converted into modern metrology in centimeters.

Therefore, this study reviewed the Jaseungcha Dohae prepared by Ha BaeckWon in order to analyze metrology during Ha BaeckWon's lifetime. Among them, the length of each part in the drawing was measured using a measuring tool with an error of 0.1 mm for the Tonga part, which was prepared in 1/15 the size of the drawings. As a result of the measurements, the dimensions of the first frontal surface was measured from 30.3 cm to 30.9 cm. The remaining components included slight errors due to perspective. The drawing production method in the era of Ha BaeckWon was produced using a small brush and ink. Thus, the drawing was very sophisticated, given the very low manufacturing error of only 2 mm.

All the measured parts on the drawing were averaged considering this error rate, and the length of 1 cheok was calculated to be 30.6 cm. Given the studies analyzing Yeongjocheok of the times to be between 30.3cm and 30.8 cm, it was found that devices manufactured in the Hwasun Dongbok area were manufactured with a scale of approximately 30.6 cm.

Based on these results, further analysis of the rotating body in the Jaseungcha drawing is required. In addition, this is believed to be a step forward in analyzing the production process of Honcheon made by Hong DaeYong, who represents the next generation of Ha BaeckWon.

Acknowledgments

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2017S1A5B5A07064033).

References

[1] J. H. Kim, Y. S. Kang and H. K. Ko, "A Study on Historical and Cultural Viewpoints of Traditional Measuring Units Conversion," The Journal of Korean Medical History., vol. 23, No. 2, p. 15-22, 2010.

[2] K. K. Moon, "Taxation management of Impi-hyun, Jeolla-do and policies of Hyunryeong Cho Ji Myung in the middle stage of the 18th century," The Journal of Korean History., vol. 184, No. 0, p. 243-277, 2019.

[3] S. H. Yang, M. S. Kim, J. K. Kim and W. G. Sim, "A Research on the Alteration of Linear Scale in Chosun Reriod," The Journal of Korean Construction., vol. 15, No. 4, p. 155-162, 1999.