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Japanese paper Industry after the Meiji Restoration: How technology helped its growth
Part 4: Wood pulp and integrated mill model

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Preface

Since around 1900, the paper and paperboard production grew exponentially at a high rate, 10% per year, as shown in figure 2 in chapter 1. An enough volume of wood pulp domestically supplied enabled it. The history of pulp production in Japan is reviewed in Chapter 5 and Chapter 6.

5. History of pulp production

5.1 Pulp made from rags

After the Meiji Restoration (1868), lifestyle in Europe and America was introduced into Japan and types of paper used in their systems were wanted and imported. They were called "YOSHI" which meant "Western paper" in Japanese. As European paper making had been based on linen rags, YOSHI making in Japan started with manufacturing pulp from rags. How was pulp manufactured? Seki explained its details, quoting from a manual published by Oji Paper Co. in 1877 [1].

"Rag, 37.5 kg, (probably cotton rags, not linen rags) is cooked in a vessel with caustic soda (2.5 kg) for 20 hours. After being washed several times, it is transferred to a bleaching bath. Bleaching powder (9.4 kg) and a small amount of sulfuric acid are added, and the rag is left until the chemical is consumed. Then, it is pounded well enough. Alum and rosin powder, and some other pigments being added, the stock is transferred to a vat for hand sheeting."

Nishi mentioned as follows [2].

"When Oji Paper Co. founded Oji mill in 1875, a cooking vessel was imported from England. It shaped like a cylinder. After cooking finished, it could rotate around its center to discharge its content."

Fig. 1 is a sketch of it. Even such a simple vessel as that was imported at the beginning. The mystery is that in several years after that, an imported cylinder machine was copied nicely, suggesting that Japan was capable enough in mechanical engineering. It may be said that importing equipment first would be a necessary step for developing technology. A second cooking vessel if Oji wanted might be self-made.

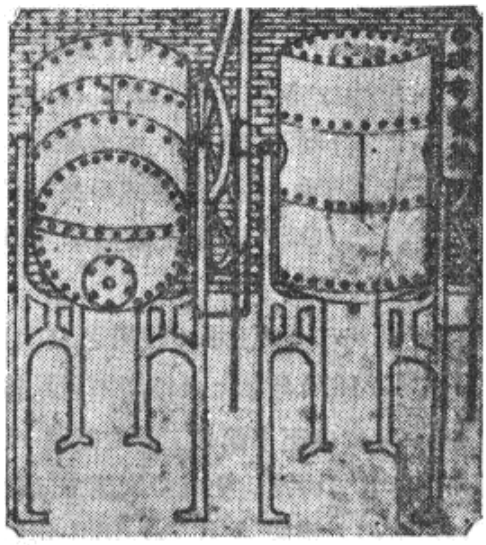

Fig. 1 Cooker for rags, imported from the UK (1875) [2]

As for chemicals, caustic soda and bleaching powder, probably sodium hypochlorite, were used. The dosage of sodium hydroxide was 6.3% and was not a small amount though it is less than that needed for cooking wood. Anyway, soda industry had to exist then. History of the soda industry in Japan is excerpted from Wikipedia as follows [3].

"In 1881, Mint, Ministry of Finance, began to produce sulfuric acid and sodium carbonate. In the same year, Printing Bureau, Ministry of Finance also started to produce sodium carbonate and calcium hypochlorite which they used in making paper for bank notes. In 1885, it constructed a new mill for paper making in Oji, and expanded its chemical production. Then, the chemical business was transferred to a private enterprise in 1895. Its process was Leblanc process, and was already outdated."

In the history of the soda industry, it is said that it began with paper making at Printing Bureau, but the manual for Oji Paper's rag pulp production cited by Seki was published in 1877, which was earlier than the start of the soda industry in Japan. For this reason, Oji Paper might use imported chemicals. Its effluent, rich with alkali, might be discharge as it was.

The process of cooking cotton rags with alkali was definitely introduced from Europe or America. They, however, did not cook linen rags, their major resource, with alkali. To get linen, flax had already been treated with alkali several times. To make linen rags to pulp, alkali cooking was not needed, and beating or pounding was enough so that technological development was to do the job efficiently by stamper and Hollander beater.

In Japan, however, mulberry was historically cooked with wood ash, and Chinese also cooked mulberry and bamboo with wood ash and lime. As they were accustomed to cook with alkali, they might be ready to use caustic soda to make pulp from rags if available.

Then, how did Europe and America come to use alkali for making pulp? It started in order to use straw as an alternative to linen rags.

5.2 Straw pulp: cooking with alkali

In the history book of Oji Paper Co., published in 2001, Heisaburo Ohkawa was introduced as follows [4)].

"He went to the US and leaned paper making in 1879, who was 20 years old at that time. After returning to Japan, he succeeded in big cost saving by changing pulp stock from rag to straw." What did Ohkawa learned there?

Europe began to use esparto, a fibrous plant, in the early 1800s. Regarding straw, it was famous that Koops tried to use it in a large scale and failed [5)]. His process was not clear even in his document. According to the chronicle by Munsell [6)], two cases in France, in 1820 and 1824 respectively, were listed. Their processes were explained as a process of fabrication or reducing straw to pulp, which suggested mechanical treatment, not alkaline cooking. Then, Musell listed a following case. In 1827, Magaw, Meadville got a patent of manufacturing pulp from agricultural products including straw, though the process was not specified in the Munsell's chronicle. Munsell listed another case in which Magaw made an appeal to a patent of manufacturing pulp from aspen shavings with lime in 1830, saying that using alkali infringed his patent in 1827. Straw might be treated with alkali for the first time in Magaw's patent in 1827.

The paper industry in the US started with importing technologies from the UK, and grew rapidly with increasing demand, which definitely more than doubled in the period of 100 years from 1750 to 1850, estimated from the fact that its GDP grew by twice in the same period. At around 1830, it had already considerable technical skills. Valente summarized how the US started to use straw pulp as follows [7)].

Valente pointed out that one of causes of rapid production growth was that the US made cylinder machines by itself, not importing them from the UK. In those days, cotton fabric became common and its rags were easy to get at cheaper prices. As its fiber was shorter and thinner than linen rags, traditional hand sheeting could not handle cotton rags. Cylinder machine, however, made it possible to form them to sheets of paper. So, printing paper made of mixed linen and cotton rags was widespread. In such days, a farmer in Meadville, PA found accidentally that straw could be pulped by cooking with potash and brought it to John Shyrock in 1827. This corresponded to the description by Munsell on a patent by Magaw. Potash was prepared from wood ash, and consisted mostly of potassium carbonate. It was a first case in which alkali was used in cooking and straw was pulped in the US.

Shyrock found that straw pulp could be formed to sheets on cylinder machines by using finer mesh wires, and got a patent. This rag-straw paper was used as wrapping paper and was widespread. He received a lot of royalty. As more and more paper machines got in operation, rags became in short supply and panic ensued. Then, wastes of products made of jute and hemp such as ropes, sails and canvases were cooked in a rag boiler, and their pulp, physically strong, was blended with straw pulp to make manila-colored paper.

A rag boiler was a spherical vessel. After being filled with rags or manila stock, it rotated for about 4 hours, steam being injected. Rags became soft and whitish, as they were purified. So, it was also called a bleach boiler. A boiler is an equipment that generates steam. In the 1800s, however, a boiler was exactly for boiling or cooking something. Using alkali instead of steam led to alkaline cooking of wood.

Fig. 2 is a rag boiler once used in Nakagawa mill, Mitsubishi Paper Mills, and is in a park in Katsushika Ward, Tokyo. Its center shaft for rotation is missing.

It was very popular in the 1850s not only in the US but also in Europe. It was imported into Japan after the Meiji Restoration and was a standard one for cooking straw.

Fig.2 Rag boiler

With help of rag boiler or bleach boiler, straw-manila paper was widely produced in the 1850s. How was the demand for paper then? At around 1800, a literacy rate in the US was small. Then, "Spelling book" became common in the 1830s and publications such as books and newspapers that had been for the privileged were widely read in the 1850s. Printing was also innovated and a rotary printing press was invented in the 1860s. Per capita GDP increased by 2.1 times in the period of 50 years from 1850, and the demand for paper definitely more than doubled in the same period. As a matter of course, pulp resource got scarce and substitutes were eagerly looked for.

In 1850, Jordan was invented a revolutionary machine in beating pulp. It made beating operation continuous and saved much labor and time. In 1867, the first grinder was imported into the US, and produced groundwood pulp from esparto and then from wood. In the 1850s, Henry Lowe imported equipment and tried to cook bark of spruce and fir. He, nowever, could not get enough volume and, instead, cooked other fibrous resources such as straw, flax and hemp. This trial led to alkaline cooking of wood.

In summary, in the middle of the 19th century, the paper industry in the US was actively developing technologies. Rag boilers made other resources such as straw, and jute and hemp wastes available for paper making. More and more cylinder machines were installed, and a volume of paper manufactured kept increasing. Manila-straw paper, a new product, became common in the market.

Then, in a couple of decades later, wood could be pulped in several processes. In the 1860s, Burgess developed a process of pulping wood with alkali, and Philadelphia where his venture located became a center of alkali pulping. His process adopted a stationary digester, not a rag boiler, and the cooking was carried out under pressure. In a decade, the process was refined with structural modifications and a basic design of stationary digester was completed. Right around that time (1866-1869), Tilghmam applied a patent of sulfite process for pulping wood. His digester was cylindrical, was laid horizontally and rotated. Its inside was covered with lead lining. He, however, could not overcome leakage troubles caused by corrosion. It was later in Europe that the process became practicable. Groundwood pulp was increasing its volume of production. Those kinds of pulp, however, still had not replaced linen pulp yet.

Right at that time in 1879, Ohkawa visited the US. He probably watched that mills were cooking straw with alkali. He had already learned to operate a paper machine in Japan and might be conscious to production cost.

The history book of Oji Paper Co. (2001 version) described as follows [4].

"Ohkawa knew that wheat straw was used as a stock for paper making while staying in the US. He tried and found that paper could be manufactured from a stock which consisted of rag pulp and rice straw pulp at a ratio of 4 to 6. He succeeded in making newsprint in trial. Then, reconstructing the mill started. It finished in February, 1883, costing 20,049 yen for a building and auxiliary installations. In August of the same year, two dryer drums were added to the paper machine, 12 drums in total, to make the best use of a new alkaline cooker at its full capacity. It enabled to produce paper at the output of 10 thousand lbs. per day. The project was great and revolutionary at that time. "

Ohkawa might be influenced with the atmosphere of the US, young and dynamic. This experience led him to his next venture of manufacturing sulfite pulp in Japan.

5.3 Sulfite pulp production

Followings are described in the history book of Oji Paper Co. (2001 version) [4].

"In 1883, when our company began to produce rice straw pulp in a large scale, a surprising news arrived saying that European succeeded in producing pulp from wood. As the company was very sensitive to new technology and new products, sulfite pulp was imported in 1884. It was blended with rag pulp and was tested for paper making."

The company moved rapidly. It dispatched Heisaburo Ohkawa, 25 years old, there to get information in the same year. Ohkawa went to Europe by way of America, visited Partington Mill in the UK and Ritter Mill in Germany, study the process and concluded that the process would be applicable to domestic wood. In October 1886, A year and a month after his returning to Japan, he set up a pulp plant in Oji Mill, and started test production. Though he could manufacture pulp, he failed to do it in a large scale.

In the chronology in the history book of Oji Paper Co. (1959 version) [10], followings are listed.

"December 1884, 425 UK pounds were paid to Ohkawa, staying in the UK, as a fee for disclosing technology."

Ohkawa's visit was not free of charge. How expensive was it? An engineer invited to Japan as a consultant was paid by about 60 pounds a month at that time, which was not a small money and would be equivalent to a couple of million yen in today's money. The sum Ohkawa paid was seven times of it. As Oji Paper was in its start-up, it might be really expensive. Acting quickly to the news was a something and Ohkawa himself might be an initiator.

"October 1886, Pulp manufactured from wood was blended in pulp stock for the first time. It worked fine."

Ohkawa remembered as follows [11].

"I visited the UK and Germany, studied there and manufactured sulfite pulp first in Japan in 1884. Sulfite pulp was not manufactured in the US yet at that year, and my trial was earlier than theirs. Unfortunately, my work was not successful. So, I visited the US in 1887, and collected information on the process. Then, I set up a mill in a mountain area in Enshu and started to manufacture sulfite pulp."

Partington and Ritter are key persons in developing sulfite pulping. Partington was interested in sulfite pulp and bought a pulp mill in 1874. He was attentive to technological developments. His venture was successful and employed 1000 persons. He was granted Baron Doverdale by the success. He used a rotating rag boiler, having lead lining inside [9].

Ritter was Baron Hector Von Ritter-Zahony, helped Kellner and yielded the Ritter-Kellner process, one of sulfite pulping processes. The digester was stationary and vertical, had a lining of lead plates, and was heated up by injecting steam. The cooking time was greatly shortened [9].

Ohkawa visited two of the most advanced mills in Europe, one using a rag boiler and the other having a stationary and vertical digester. As cooking liquor is acidic, a key technology was a lining inside the vessel, and lead plate was used at that time. The difference in heat expansion between iron and lead causes heat stress during cooking. A rag boiler released the stress by rotating the vessel. A stationary one did not solve the problem yet at that time, and brick lining developed later made it.

What was sulfite pulping process like in those days? It is introduced in Reference [9]. A case of one venture project in Canada was interesting. Halifax Wood Fibre Co. was established in 1885 in Quebec in Canada to manufacture sulfite pulp. The project was carried out under the license from England. Equipment was imported from England. As maintaining lead liner of a rag boiler was a key know-how, a professional was invited from England and stay at the mill (some complains for his not disclosing the know-how). It imported lime from Scotland, and sulfur from Spain. It exported pulp to the US, and paid royalty to England. Amazingly, information, technology and commodities were exchanged between Europe and America. The patent system was also functioning between them. Its circumstance was quite different from that Ohkawa encountered in Japan.

Though Ohkawa had visited two mills, he failed to make the process practicable. So, he visited the US for the second times.

Oji Paper recorded as follows.

"In September 1887, Heisaburo Ohkawa along with Shaku Hoshino visited the US to study pulping."

In a period of a few years between his two visits, one to Europe and the other to the US, a

revolutionary change in sulfite pulping occurred in the US, not in Europe. Acid-roof lining using bricks was investigated and tried since around 1870, and was established by a patent by Russell in 1890 [12]. Ohkawa visited the US exactly at that time. He probably knew the brick lining there. Then, he set up a sulfite mill in 1889 at Keta, and its digester was called an Ohkawa model. It is not certain how he modified a digester.

Keta Mill was described as follows [13].

"It started production in 1889. Cooking liquor was prepared as follows. A wooden bath was filled with lime slurry into which sulfur dioxide gas generated by burning sulfur in an iron bath was absorbed. The digester was 24 feet and 6 inches in height, 2500 lbs. in capacity and made of iron with brick lining inside."

One literature described a typical sulfite pulping process in the 1920s in North America [14]. It said that a vertical digester was from 10 to 18 feet in diameter inside the shell and from 25 to 65 feet in height.

There was another description as follows [15].

"The digester, Wheelwright type, was imported from America. Rings made of iron, of which diameter was 6 feet and of which height was 2 feet, were piled up and screwed each other by bolts. Its height was 24 feet and 6 inches, and its capacity was 25000 lbs as pulp. It had lead lining. It was popular in the US."

There is difference on lining between the two descriptions. It may be guessed that the imported digester had lead lining, and Ohkawa modified it with brick lining, and called it an Ohkawa model.

In 1899, 10 years after Keta Mill got in operation, Oji paper set up a new mill at Nakabe, near Keta. Its digester was made of steel and its lining was brick on lead plates.

In the year of 1889, sulfite pulp was quite rare even in the US. A report estimated that the volume of wood pulp produced in 1891 was about 700 thousand tons a year and most of it was groundwood and the rest was soda pulp [16]. In 1888, Tamaoki visited over ten paper mills in the US in order to buy paper machines, and left memoir on equipment in each mill. Only one mill seemed to have sulfite digester and the rest operated grinders and rag digesters (stationary as well as rotary). In such days, Ohkawa was interested in sulfite pulp and selected a stationary digester which was still in development, not a rotary digester technically established in the UK. His sense for technology was admirable.

How was the mill operated? It was reported as follows [17].

"Oji paper constructed a small mill at Keta to manufacture wood pulp. As it was the first sulfite mill in Japan, its performance was not satisfactory. In 1894, Fourdrinier machine (78-inch wide) was installed along with grinders. With water wheels installed at Keta River, the mill became a model which used wood resource. With efforts by those concerned, its performance was gradually improved."

It is worth remembering. The mill site, Keta, was selected as its area was rich with forest. Keta Mill started to manufacture sulfite pulp. In five years after, it installed grinders to produce groundwood pulp and a paper machine to produce newsprint with those two types of pulp. The mill was driven by water wheel at a nearby river. Though the mill was small, the design of an integrated mill lasted in Japanese paper industry. In ten years after Keta Mill started, Oji Paper constructed a new mill, Nakabe Mill, near Keta with the same concept, but much larger in size.

One of key technologies of sulfite process was brick lining. It was established in Japan as know-how, and inherited in the industry even after World War II. Endo wrote in his memoir how the lining had been done when he engaged in constructing a digester in his early twenties, at around 1950. It was very laborious. Keeping know-how domestically in the industry helped expand sulfite pulp production in Japan.

5.4 Water wheels

Keta and Nakabe were chosen for abundant wood resource. Besides, water wheels installed at nearby rivers supplied power to mills. .

Nakajima wrote as follows [18].

"Oji Paper constructed the first sulfite mill in a mountain area in Shizuoka and began operation in 1889. Five water wheels of pelton type installed at Keta River supplied power, 612 HP in total, to the mill which consumed a lot for groundwood pulp production. Since then, for about 20 years, new mills which were designed to produce wood pulp had water wheels, turbine type or pelton type, for their power supply."

Nishi mentioned as follows [19].

"Paper mills having pulping plants were located in districts where wood resource as well as water power were available."

He listed seven mills constructed in the period of 20 years since Keta mill started, which had water wheels.

Water wheels had been only one power source before the Industrial Revolution. It was used to stamp rags to make them ready for sheet forming. After paper machine was invented, they drove them. Even after steam engines were common, they still did that job, because of cheap cost. When groundwood pulp was invented, they were indispensable for its production. When Tamaoki visited paper mills in the US in 1888, most of the mills got power from water wheels (water wheel: 7 mills, water wheel and steam engine: 1 mills, steam engine: 2 mills) [21].

Japan utilized water wheels relatively late, and they became common in the middle of the Edo period [20]. Early paper mills in Japan located in suburban area, and used steam engines, except one mill. For mills intending to produce wood pulp, on the other hand, whether water wheels were available or not was an important criterion for choosing their sites. Because of that, mills were frequently damaged by water floods.

Oji paper listed 11 cases damaged by flood in the period from July, 1887 to May, 1907 at two mills, Keta and Nakabe. Those two mills were discontinued shortly later.

Then, power supply for equipment changed from water wheels to electric motors. Nakajima described as follows [20].

"In 1892, a hydro power project started. It was not so successful until 1895 and supplied only lightening to limited districts. When power transmission in a short distance succeeded, hydro power projects popped up nationwide during eight years from 1900 to 1907"

Tomakomai Mill, Oji Paper founded in 1910 had a hydro power plant which supply all electricity the mill needed.

5.5 Rice straw pulp for paperboard

Although it was not so attractive in technology, rice straw remained as an important resource for paperboard manufacturing. The history of paperboard production in Japan was reviewed in details in references [23), 24)]. Different from softwood, rice straw was available everywhere in Japan. As paperboard business was local in nature, straw pulp production dispersed all over the country.

As reviewed in Chapter 2.2, paperboard was one of important products YOSHI intended to be from its beginning. The demand for paperboard grew steadily as commodities packaged with paperboard were distributed nationwide more than ever. Its growth was supported by pulp made from rice straw, using traditional rotary digesters. Then, in around the 1930s, waste paper reclaimed from household could be used as recycled fiber for paperboard and gradually replaced straw pulp.

The next issue will review further development in fiber resource exploitation.

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