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Japanese paper Industry after the Meiji Restoration: How technology helped its growth
Part 5: Integrated mills and Wood resource exploitation

Kiyoaki Iida, Former Executive Director, JAPAN TAPPI

Preface

Paper industry has one critical problem. It is how to secure and feed enough raw materials. The report by Nishi on paper industries in the world at 1925 in Chapter 4 clearly demonstrated that the future of the industry would depend on whether it had enough wood resource or not.

Then how was Japanese paper industry? The demand for paper and paperboard grew exponentially, and the paper industry supplied products, taking latest technologies into operation. Technological infrastructure in Japan was also developing and helped the industry grow. Equipment got larger and productive. As a result, the industry had to deal with the same problem which paper industries of other countries faced. That was to get enough wood resource, and the efforts in the industry will be reviewed.

6. Integrated mills and wood resource exploitation

6.1 Wood resource

While Heisaburo Ohkawa was struggling to manufacture sulfite pulp from softwood in Kiso forestry, Jhoichiro Majima was interested in softwood in Fuji area, produced groundwood pulp and expanded business with paper products containing groundwood pulp. He also tried to manufacture sulfite pulp and intended to have a mill of an integrated model with wood pulp, which means a mill operating paper machines with pulp produced in its own mil.

How did they secure wood resource? Historically, forest was carefully maintained and controlled by feudal lords as an important treasure. It was said in the Kiso area that he should be beheaded if he cut down and stole just one tree [1)]. After the Meiji Restoration (1868), the areas controlled by feudal lords were transferred to the Meiji government. When a paper company wanted to buy wood for manufacturing pulp, government-owned forest was a major resource and it had to deal with the government. For instance, Keta Mill in 1894 received three fourths of the volume of wood it consumed from the government forest and the rest from private one [2)].

As the government encouraged producing every commodity domestically in general, it permitted cooperatively the deals with paper companies. The deals were reviewed in detail by Yamaguchi [2)]. The area where the government particularly offered deals was Shizuoka. In the period from 1889 to 1912, twelve mills planning to manufacture wood pulp were constructed, eight of which located in the Shizuoka area [2)].

As the volume of pulp manufactured increased, wood resource there became scarce. Keta Mill, and Nakabe Mill, both in the Kiso area which were in Shizuoka, suffered from short of wood supply, and water wheels had lost their advantage. They were symbolically closed in the 1920s, as described in Part 4 of this series.

Then the industry looked for another forest area, and Hokkaido was exploited in its second move.

How vigorous was the paper consumption?

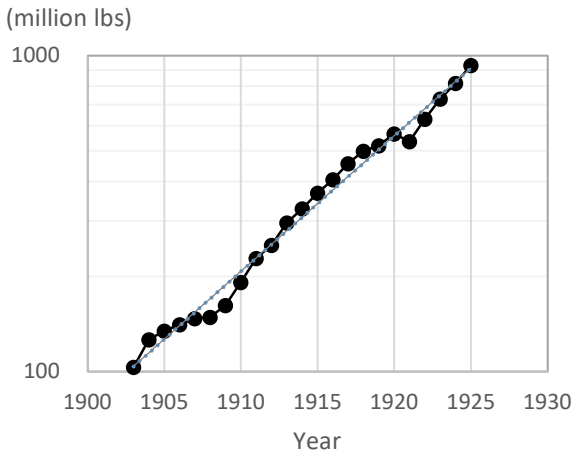

Fig. 1 Amount of Yoshi produced per year

Fig. 1 is cited from Chapter 1. It depicts the amount of paper, YOSHI, annually produced [2)]. Its y-axis is logarithmic. As the production volume increased almost linearly against years, it was suggested that it increased at the same rate per year, meaning exponentially. The rate was calculated to be about 10 % per year, equivalent to 10 times increase in 23

years. To supply enough wood for the demand, new forest had to be exploited one after another. The industry found it in Hokkaido and then in Sakhalin, which will be reviewed later. Wood supply has been a lifeline of Japanese paper industry, even after the World War II.

6.2 Progress of pulping equipment

6.2.1 Sulfite process

Nishi reviewed the progress of sulfite process as follows [3].

"Digesters for sulfite pulping became larger and larger in size. One installed in Tomakomai Mill, Oji Paper in 1910 was 100 m^3, equivalent to 7.5 t of pulp. In 1939-1940, two mills installed digesters of 200 m^3, equivalent to 20 t of pulp. In 1940, Asahikawa Mill, Sanyo-Kokusaku Pulp installed digesters of 350 m^3 in volume [3]."

The process of preparing cooking liquor was also innovated. The process used in Keta Mall was just like one which had been introduced in Part 4 of this series as the Partington process. It was as follows. Several wooden vessels were connected with pipe lines downward in series. Slaked lime slurry was fed from the top of them. Sulfur dioxide gas generated by burning sulfur was injected in a counter current flow to the lime slurry. Sulfite process needed some knowledge of chemistry, and it took as long as ten years to master it in Keta Mill. It was different from copying a cylinder machine, which was mechanical in character and Japanese pioneers could do it well when the industry started. The review by Nishi continued [3].

"Ebetsu Mill, Fuji Seishi constructed in 1908 had an absorption tower by Barker. The bottom half of the tower was filled with lime stones. The upper half was divided to four sections with perforated plates, which were filled with slaked lime slurry. Gas was fed at the bottom and moved upward. Liquor moved downward through the plates. Ohtomari Mill, constructed in 1914, had five towers, still made of wood, which were filled with only limestones. Though limestones were less reactive, and took longer reaction time, it made equipment simpler and enabled easier operation. A tower filled with lime stones became a standard since then [3]"

"Sulfite cooking was a batch process under high pressure. When cooking finished, the gas was relieved. Latent heat and sulfur dioxide in the relieved gas had to be recovered. Initially, gas was reclaimed after cooled down. Then, the gas was reclaimed directly to a reclaiming tank, which was made of steel and of a closed type, and then was fed to cooking liquor in an acid tank. The revised flow made latent heat and residual sulfur be recovered with better rates. Fabricating a high-pressure vessel for gas was technically important [3]."

Nishi introduced an episode showing that though plants and equipment were imported, engineers were eager to modify them by themselves.

"Tomarioru Mill was constructed in 1918. The mill installed a plant for making sulfite liquor of its own design. Mr. Ohkawa had a look at a picture of an absorption tower, Jensen tower, in some journal published in the US. He designed a tower made of concrete by himself. It was successful and mills constructed since then had the same towers. To recover gas completely, mills had multiple towers of that kind [3]."

In the 1920s, the US and Sweden, a newcomer, innovated sulfite process instead of the UK.

6.2.2 Groundwood process

How was groundwood production? The production equipment had been mostly imported. Its history was reviewed by Nishi as follows [3]. For reference, Fug. 2 is a picture of a grinder that has three pockets.

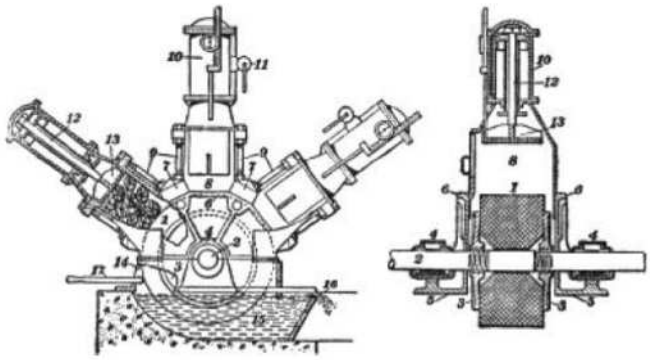

Fig. 2 A picture of pocket grinder

In 1890, two sets of pocket grinder were imported from the US to Fuji Seishi, first time in Japan. Its stone width was 12 inches. In 1894, Keta Mill imported grinders of three pocket-type from Olive Scott Co., Benington, New England. Their stones were 52-inch in diameter and 18-inch wide. They were powered by Pelton wheel of 140 HP. In 1899, Nakabe Mill imported grinders from Ontario Co., US.

The two sets each were driven by one water wheel, 550 HP, at 200 rpm. Their stones were 52-inch in diameter and 27-inch wide [3].

In 1909, Tomakomai Mill was constructed. It had ten grinders of three pocket-type. Their stones were 54-inch in diameter, and 27-inch wide. One induction motor of 750 HP drove two grinders, one grinder on each side. It was a first case of using an electric motor. In 1914, the motors were replaced to synchronous motors of 850 HP [4]. In the other reference [3], Ishikawajima delivered grinders to Tomakomai Mill in 1910. Domestic suppliers took part in the grinder business.

The first grinder of four-pocket type delivered by Bagley in the US was used in 1909 at Tokai Pulp. Since then, the four-pocket type became popular. Grinder itself became bigger and was 62-inch in diameter and 32-inch wide. It was powered with 600 HP and operated at 256 rpm [3].

In 1913, Voith in Germany invented a grinder of a magazine type. Woods stored above a stone dropped into pockets facing to each side of the stone, and were ground under hydraulic pressure. Those grinders were used in Canada to produce groundwood pulp for newsprint. Their production capacity was 30-40 t/h [3].

In about 1924, Voith modified it to a caterpillar type. Almost at the same time, John Warren in the US was developing a similar machine in Black River Mill of St. Regis Co. Takata of Oji Paper had a chance of looking at the machine, was interested in it and immediately placed an order for it. Then, dispute on the patent right occurred between Voith and Warren. The delivery was delayed and Oji got it in 1930. The stone was 62-inc in diameter, and 54-inch wide. Two sets were connected to one synchronous motor of 2,600 HP [3].

It is an episode showing that a top engineer like Takata was curious of technical developments and eager to take risks of operating new equipment. The dispute also showed that a patent right was functioning among countries concerned.

Voith further made a four-pocket grinder of which diameter was 60-inch and which was equipped with an automatic pressure control device to maintain a constant load to an electric motor [3]. Grinder was progressing in its size and quality, and latest models were imported one after another.

Followings are from the memoirs by Katayama [4]. It is interesting that technical staff as well as operators in mills elaborated to improve operation.

"In 1895, three grinders of 3 pocket-type were imported from the US to Nakabe Mill. They were connected in series to a water wheel. The water wheel did not have a governor so that its rotating speed changed when its load varied. It was terrible indeed.

A foreign instructor insisted to make pulp in a cold-water process by cooling a stone in water. Majima and Kamiyama, operators at the grinder, wanted to do it in a hot-water process to get longer fiber. They did it after the foreign instructor went back home. It was a tough job to increase the ratio of their longer groundwood pulp to 20-30 percent of the whole stock.

Naoki Takata was a chief engineer when Tomakomai Mill was constructed. A grinder stone was connected to a drive motor. The stone should be replaced at some interval, as it was worn down. It usually took long time to align its center to that of the motor. Takata devised a way to do it with ease as follows. He made a space between the coupling of the stone shaft and that of the rotor shaft, and inserted a kind of plate in between and screwed them all with bolts.

Ryousaku Takata worked as an operator in a mill in the US to learn operation. He became a foreman of pulp manufacturing in Tomakomai Mill, and manufactured groundwood pulp of high quality. He also improved pulp yield by recovering whole white water. As a result, newsprint quality was greatly improved.

Grinding at high temperature with low consistency was put into operation. The temperature at a pit was maintained at 75°C by recycling white water and the pulp consistency was controlled to about 3%. Resulting pulp was very strong. There had been some claims of being burned from operators during the operation."

Examples of such efforts were frequently described in JAPAN TAPPI Journal. Those efforts made technologies in Japan progress and made Japanese industries in general competitive in the world. The characteristics have been inherited even after the World War II.

As the more grinders were installed, the more

grinder stones were needed. Supplying grinder stones domestically was looked for just as happened in cases of wire, felt and canvas of paper machine [5].

"In the beginning, natural stones were imported from the US and then from the UK and Germany. Meanwhile, natural stones of good quality were searched domestically. As the war starting 1914 made it difficult to import them, a first domestic stone cut out from Matsushima area was delivered to Sakamoto Mill, Kyushu Seishi in 1917. Since 1920, artificial stones made by Hercules in Germany were replacing natural ones. Then, domestic one became as good as the imported in 1931 with efforts of Banji Yamada of Nakatsugawa Mill, Karafuto Kogyo, and rapidly increased its share in the market. Then, natural stones were regaining the market, as the stone of good quality was found in Hirashima, and the war made importing difficult."

6.3 Construction of Integrated mills and new wood resource in Hokkaido

Ten years later since Oji Paper built Keta Mill in 1888, mills designed to use wood pulp were constructed one after another, most of which were of an integrated type, had paper machines, and manufactured sulfite pulp and groundwood pulp. They were introduced as follows [6].

1897 Omiya Mill, Fuji Seishi (Shizuoka)

1898 Sakamoto Mill, Touhi Seishi (Kumamoto)

1898 Shibakawa Mill, Yokkaichi Seishi (Shizuoka)

- Buildings were made of brick
- Two grinders of 250 HP
- Three digesters for sulfite pulp of 43.5 m^3
- One 98-inch Fourdrinier machine
- Driven by water wheel

1899 Nakabe Mill, Oji Paper (Shizuoka)

Nakabe Mill was constructed by Oji paper, based on the experience of 10 years at Keta Mill. Oji Paper prepared for the construction and installed the equipments as follows.

- 1896 Ohkawa visited the US to purchase equipment for Nakabe Mill.
- 1899 Naoki Takata was dispatched to the US to study paper making.
- One 98-inch Fourdrinier machine (max. speed: 440 ft/min)
- One 72-inch cylinder machine (max. speed: 300 ft/min)
- Three digesters (22,000 lb/d)
- Four grinders (75 logs/d)
- Six Francis water wheels (1,850 HP in total)

"As a price and a term of contract was different for each news printer, sales business was a really tough job. Though an American instructor, named Fuller, was invited, newsprint rolls were frequently less weighted and some discounts had to be done to compensate. The business rules for delivering newsprint were different between Japan and the US, and troubles frequently happened [7]."

1908 Nakatsu Mill, Chuo Itagami Seishi (Gifu) [8]

Power supply by water wheels on Nakaktsu River was important for selecting the mill site. The total power was 1,400 HP.

Main buildings were made of brick, and warehouses were of wood.

- Two digesters (39.6 m^3 each)
- Three grinders (300 HP each)
- One 98-inch Fourdrinier machine for tissue
- One 100-inch Fourdrinier-Yankee machine
- One 102-inch Fourdrinier machine for newsprint

1908 Ebetsu Mill, Fuji Seishi (Hokkaido) [9]

The mill was a flag-ship one of Fuji Seishi in Hokkaido.

- Three 100-inch Fourdrinier machines
- One 184-inch Fourdrinier machine installed in 1920. It was the widest in East Asia at that time.
- Total production: about 7000 tons per month. The details of its equipment were missing.

1910 Tomakomai Mill, Oji Paper (Hokkaido) [10]

Oji Paper constructed a monumental mill in Hokkaido like Fuji Seishi did.

- Ten grinders (stone: 54-inch in diameter and 27-inch wide)
- Four digesters (7.5 tons each)
- Two 142-inch newsprint machines by Bargley
- Three 100-inch fine paper machines by Bargley
- One 100-inch cylinder machine for wrapping paper by Z.H. Horn Co. (?)
- Four hydraulic power generators (2,500kW each) by Escher-Weiss

The investment was far bigger than that of Nakabe Mill. Ebetsu Mill and Tomakomai Mill were game changers in the history of Japanese paper industry. Shinomiya described them as follows [11].

"Oji Paper was deeply concerned with the future of its mills, Nakabe and Keta, as the performance of

Nakabe Mill was three fourths of the target and its operating balance was in a bad condition. It came to a conclusion that the business should be reconstructed by having a new big mill. It started to investigate Hokkaido as a candidate. Fuji Seishi was also interested in Hokkaido and built Ebetsu Mill in 1908. The investment on Tomakomai Mill was successful and Oji took back a leading position in the industry. Its share in the total output of paper in 1911 became 23 %."

How was forest in Hokkaido exploited? Yamaguchi reviewed as follows[13].

"In the history of Hokkaido exploitation, a decade from 1900 was a turning point. A law which promoted to exploit Hokkaido was enacted in 1897. Vast state-owned land was disposed of and industrial capital was initiatively invited to invest there. To secure financial resources for the development, a law allowing to sell land and forest which the government owned as a special provision was enacted in 1902. Wood there could be sold to businesses such as match stick, rail road sleeper, and paper making in private contracts of long term. The contract guaranteed a fixed volume of logging for 10 years at most. The revenue was used to put the infrastructure of Hokkaido in order. The contracts with paper companies promised steady revenue for the local government. Forest area owned by the government shared more than 50% of the total forest area in Hokkaido. The volume of logging by long term contracts was 30-60% of the total volume logged in government owned forest, 30-60% of which was sold to paper companies."

That wood supply made it possible to construct mills in Hokkaido such as Tomakomai Mill, Oji Paper (1910) and Ebetsu Mill, Fuji Seishi (1908).

Then, how was the market going? Shinomiya described newsprint market as follows [11].

"The newspaper business grew steadily as news on a war and politics attracted readers. In 1883, Osaka Asahi issued 20 thousand copies in circulation a day. At the beginning, the market was dominated by the imported. Domestic newsprint suppliers gradually increased its share, replacing imported products. Then, Tomakomai Mill began to manufacture a lot of newsprint and domestic suppliers occupied most of the market."

To take the market, a product had to be competitive not only in price but also in quality. How did Japanese improve their skills? Kikutaro Shiono left memoirs as follows [15].

He was a graduate of Kyoto University, prestigious in Japan and majored in industrial chemistry. He spent 18 years at Ebetsu Mill, Fuji Seishi

"In mill operation, experience was more esteemed than science, and scientific approach on operation was not interested. Fortunately, however, Ebetsu Mill was different, and journals and books on pulp and paper technology published overseas were mostly on shelves. They were very helpful for learning advanced technologies as we were eager to catch up them."

"In about 1937, a message came from our head office saying that they were manufacturing groundwood pulp at a consistency of 2% at a pit with good result in foreign countries, while we were operating at 7-8% consistency. We tried to do in their way. At a low consistency, pulp stock, that was very hot, popped up from a pit with which operators got burned. The operating efficiency got worse. Then, there was found a report by Dr. Brecht in Wochenblatt fur Papierfabrikation entitled "Depth of immersion of grinder stone in a pit on pulp quality and operating efficiency". Following the report, the depth was lowered down to 2 inches. It was very successful and from that time on the low consistency grinding became a routine."

This episode tells that in the early 20th century, a mill in Hokkaido, far from Tokyo, had a collection of journals and books, which helped solve problems. Brecht（Walter Brecht）(1900-1986) was a professor, Darmstadt University of Technology, and contributed to progress of paper science and technology. This kind of approach to advanced technologies was not particular but characteristic in Japan those days.

Integrated mills were constructed in the mainland as well [16]. One of them were introduced as an example as below.

1916 Niigata Mill, Hokuetsu Paper Co. (Niigata)

- Sulfite pulp: 450 tons per month
- Groundwood pulp: four grinders
- One 86-inch Fourdrinier machine
- One 67-inch Fourdrinier machine
- One tissue machine
- Output: 20 million lbs.

6.4 Further to Sakhalin

Sakhalin was exploited after Hokkaido. First projects were to construct pulp mills. Pioneers' efforts were introduced as follows [17]. Sakhalin was transferred from Russia to Japan after the Russo-Japanese war ended at 1905.

"In 1910, Mitsui & Co. made a feasibility study on forest all over the island, found it promising and asked the government to sell woods. It was permitted under a condition that a pulp mill should be constructed within 5 years. Heisaburo Ohkawa also got the same kind of permission in the same year. They had to study if pulp from native wood spices, spruce and pine, was acceptable enough and how the project was profitable."

Mitsu & Co, sent native logs to Germany and Sweden and dispatched its employees to study feasibility. Then, Mitsui started to construct a mill at Ohtomari in 1913, and Ohkawa at Tomarioru in the same year. These were the start of exploitation in Sakhalin.

How much was the price of wood government sold? Yamaguchi wrote as follows [13].

"The local government of Sakhalin needed money to promote development and intended to invite investment by paper companies. Its revenue from forest was about 10% of the total revenue in the early 1910s, and was 15-55% in the late 1920s. The volume of logs sold to paper companies was 60-95 % of the total volume. As the revenue from paper companies was very important, it offered terms favorable to them."

"The price of wood logged from government forest in Sakhalin was determined at a half of that in Hokkaido. In actual fact, however, the price was as low as one third or one fourth of that in Hokkaido. In 1916, the government raised the price fourfold to squeeze money for carrying out its port preparation program."

Wood supplied by the government, however, was indispensable for the industry.

In 1914, Ohtomari Mill started operation. Nishi commented on the mill [8].

"Mitsui & Co. dispatched staffs to Sweden to have information on pulp production. Ohtomari Mill was the first in Sakhalin.

- Digesters: 150 m^3 x 2
- One 118-inch pulp machine

The mill was transferred to Oji Paper at 1915. Following the case, many pulp mills were constructed in Sakhalin."

In 1915, Tomarioru Mill, Karafuto Kogyou started [10]. Buildings were made of wood as in other mills. They were lost by fire, and the new one was made of reinforced concrete.

- Digesters: 156 m^3 x 4
- Pulp machines; two 118-inch Fourdrinier machines by Karl Stadt
- Generators: two 1,000 kW condense turbines by G.E.

Nishi commented on power generation in Sakhalin as follows [18].

"There were no rivers suitable for hydro-power generation in Sakhalin. As it had rich coal mines, thermal power generation was common. The first one was built in Ohtomari Mill. Its steam pressure was only 160 lb. The capacities of successive new turbines, however, grew one after the other, and one built in Esutori Mill in 1929 was 400 lb. of pressure and 5,000 k of capacity."

In 1919, a fine paper mill was constructed in Maoka [8]. Buildings were made of wood.

- One digester: 140 m^3
- One 108-inch Fourdrinier machine by Beloit
- One 108-inch Fourdrinier machine by Japanese supplier
- One 500 kW condense turbo generator by Esher-Weiss

In 1925, Fuji Seishi constructed a first kraft pulp mill in Sakhalin. How it was managed was introduced as follows [19].

"Fuji Seishi dispatched Shinji Shimada, an engineer, to Sweden who had studied kraft process beforehand. The construction started in 1924 at Ochiai. It continued even in winter, in which temperature was down to 30°C below zero. Equipment became ready and was tested with water by July, 1925. Then, Seegerfelt (?) was invited from Sweden to instruct pulping operation in June, 1925. He had studied kraft process under Klason and was well experienced in practical pulping operation. He was an excellent leader and could deal with various troubles. He stayed for a half year and left to Czech Republic for his next job in January, 1926."

The description on him reminds of Rogers who instructed paper machine operation in the early days

Who was Shinji Shimada?

"He was a graduate of Applied Chemistry, Tokyo Institute of Technology, and joined Fuji Seishi. He was selected as one of overseas training members by the Ministry of Agriculture and Commerce, and studied paper technology for four years in various countries [20]. He was interested in kraft process, and advised the president to build a kraft pulp mill. He was dispatched to Sweden and ordered main equipment to Karlstad in 1923. Then, the construction started in 1924. The business of kraft paper was very successful as Fuji Seishi was an only one supplier and it got good profit. Oji Paper, the other big company, monopolized rice paper business and got also good profit. The two companies agreed each other not to invade the other business."

It is interesting that a kind of minor product like kraft paper and rice paper contributed to the profit of each company.

Investment in Sakhalin was summarized as follows [21].

The total pulp capacity was 421 thousand tons per year in 1942, and sulfite pulp was a main one (Table 1). The total capacity of paper machine was 213 thousand tons in 1940 (Table 2). Roughly speaking, a half of the pulp output was converted to paper within mills and the other half was delivered to the mainland.

With those efforts of exploiting enough wood resource, the industry could supply paper products to domestic market. Due to strong demand, the industry installed the latest models of paper machines successively, refined technologies, improved productivity and could be competitive to imported products. The industry, as Shinomiya said, could stand on its own.

Table 1 Pulp capacity in Sakhalin (1942)

	Sulfite pulp		Rayon pulp		Kraft pulp		Groundwood pulp		Pulp machine	
	No. of digesters	Annual production capacity (tons)	No. of digesters	Annual production capacity (tons)	No. of digesters	Annual production capacity (tons)	No. of digesters	Annual production capacity (tons)	No. of digesters	Wire width (inches)
Oji Paper										
Ootomari	2	17,340							1	118
Toyohara	5	51,240							2	198
Ochiai	4	36,200			7	26,000			2	236
Chitori	5	45,220					3	24,800	2	236
Maoka	4	36,350								
Noda			2	53,200					1	118
Tomarioru			5						2	236
Esutori	4	37,100					4	32,400		
Subtotal	24	223,750	7	53,200		26,000	7	57,200	10	1,142
Nippon Rayon Pulp										
Shitoka			4	40,000	3	21,000			2	238
Total	24	223,750	11	93,200	10	47,000	7	57,200	12	1,380

Table 2 Paper machine capacity in Sakhalin (1940)

	Fourdrinier machine		Cylinder machine		Total		Daily production capacity	Annual production capacity
	No. of mahcines	Wire width (inches)	No. of mahcines	Wire width (inches)	No. of machines	Wire width (inches)	(lbs)	(1000 lbs)
Oji Paper								
Ootomari								
Toyohara	1	98			1	98	28,500	9,690
Ochiai	6	636			6	636	239,600	81,464
Chitori	2	284	1	102	3	386	277,200	94,248
Maoka	7	683			7	683	226,800	77,112
Noda]	1	142			1	142	60,000	20,400
Tomariori	1	86			1	86	19,700	3,298
Esutori	5	924			5	924	38,400	131,546
Subtotal	27	2,853	1	102	28	2,955	1,238,700	417,758
Nippon Rayon Pulp								
Shitoka	1	175			1	175	150,000	51,000
Total	28	3,028	1	102	29	3,130	1,388,700	468,758

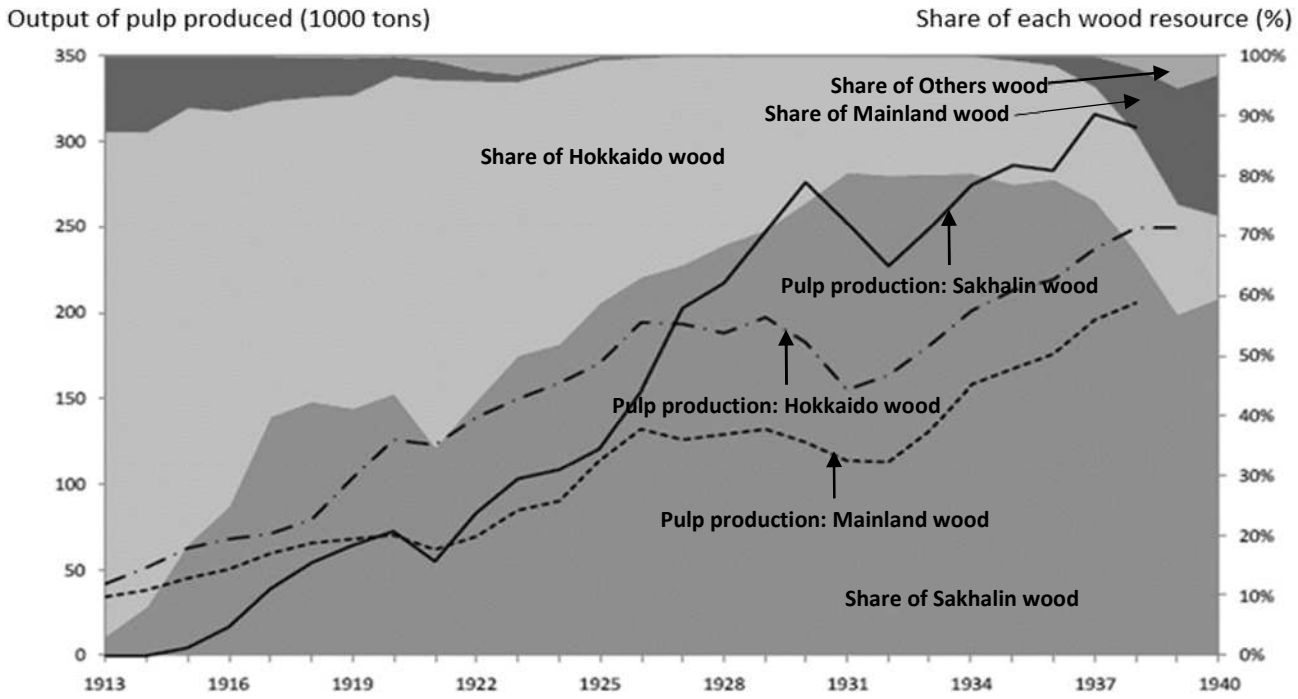

Fig. 3 An amount of pulp produced in each district and a share of pulp wood consumed in each district

Fig. 3 is an elaborated work by Yamaguchi [13]. It definitely demonstrates that wood resource in Hokkaido and then in Sakhalin was a lifeline for the industry. Yamaguchi commented that in the 1930s, Sakhalin wood was, furthermore, delivered to mills in the mainland and met almost of their demand, as the then Sakhalin government permitted wood export.

As the demand for wood in other industries increased, it became difficult for the paper industry to get enough volume of wood even in Sakhalin. It looked for new resource and started ventures in Korea and Manchuria. Since the latter half of the 1930s, the share of wood supplied from the mainland increased as in Fig. 3. The mainland had a lot volume of red pine. It, however, could not have been used due to pitch troubles it caused on paper machines. As wood supply became in short, counter measures were developed and red pine became acceptable.

The paper industry lost Sakhalin after the World War II. Securing pulp resource to satisfy growing demand has been a topic of the most concern in Japan.

6.5 Technological strength

What kind of technological strength have Japanese paper industry had? It has been a topic of my concern [22]. Once, Japan was the second largest paper producer in the world after the US in the 1990s. It meant that Japan could manufacture products internationally competitive, and technological strength or advantage Japan had made it possible.

The definition of technological strength is not so clear. Everyone may have a different definition. Those who work in production may say that the ability of improving productivity is the most important part of technological strength. Those who work in new product development regard the ability of doing it as technological strength. So, the technological strength should be evaluated based on subcategories the technology consists of. Each industry has a list of subcategories fundamental to its own.

My understanding is that planning corporate strategy is as important a subcategory as productivity improvement or new product development. In paper industry, wood resource exploitation has been the most important and has been a fundamental subject of corporate strategy. The history until the 1940s exactly proved it.

It has been important even after the World War II. The demand for paper kept increasing after the war,

and Japanese paper industry developed new pulp resources. They were hardwood chips, wood chips imported from overseas, and recycled fiber. As demand was growing and pulp resource had been secured, the industry could improve productivity and product performance, and could be competitive against the imported. Its history looks like a replica of one in the early half of the 1900s, which was reviewed in this series.

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