Sawmill Engineering in New Zealand

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Abstract
This paper investigates the development of sawmill engineering in New Zealand's native sawmills from 1838 until their virtual end in the 1980s, which involved around 2000 mills. A broad description is provided of the design aspects of those sawmills. The role of engineers and others in technology improvement is investigated. A steer is provided for further detailed study of this topic.

1. Introduction

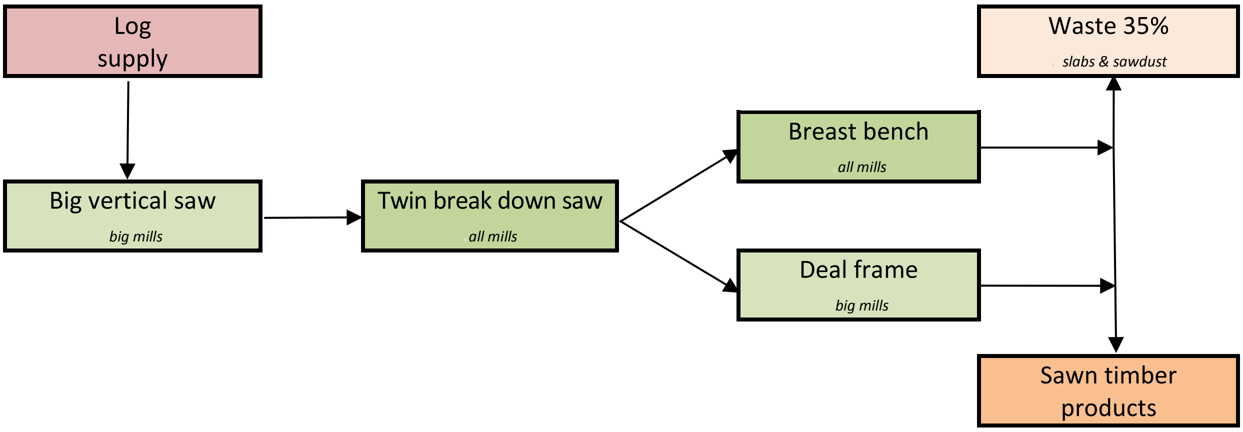

Figure 1: Schematic diagram showing process sequence of the principal saws typical of all native mills built after 1900 (breaking down saw plus breast bench saw) and the additional saws typically found in a large mill (add in a big vertical saw plus a deal frame). In some mills from the 1950s band saws replaced the big vertical and twin break down saws.

Addressing the theme of engineering and nature, this paper considers the engineering heritage of the production in New Zealand of timber, one of nature's most valuable, utilised, and renewable materials. The scope is sawmill engineering in the native timber industry, noting that plantation pine sawmills are an equally big story that is not touched on here. Much of the historic information is drawn from Mahoney's *Sawmill Technology in New Zealand: Our Native Mills* [1]. Colin Zeff, having had a professional career in the sawmilling industry, provides valuable design insights. An estimate of technology scale is that nearly 2000 native mills were built 1838–1980. This paper's objectives are:

1. To provide a broad description of the design aspects of sawmills
2. To investigate the role of engineers and others in sawmill technology improvement
3. To provide a steer for further more detailed study of this topic.

2. Chronology

An indicative outline of the era and technology:

1794 First round timber exports, Royal Navy spars, probably Kahikatea
1818 First pit sawn timber exports to Australia
1838 First sawmill: Mercury Bay, Coromandel; water powered; erected by a millwright
1841 First steam mill: Catchpool near Wellington; likely one saw
1842 First large mill: Cornwallis near Auckland; likely a frame saw plus circular bench
1880s Twin circular breakdown saws introduced
1887 First band saw: P. Bartholomew, Levin
1902 First Radiata pine milled commercially at Temuka
1959 Exotic timber output first exceeds native
1980 Last native mill built: J. B. Cowan, Haast
1993 Last classic native sawmill closes: D. Cadigan, Three Mile, near Hokitika
2014 Lindsay & Dixon Tuatapere mill: last major indigenous mill continues in production

3. Native Sawmilling Overview

Sawmilling was amongst New Zealand's first mechanised industrial enterprises. This section

briefly outlines the key elements of a typical native mill and its supporting infrastructure. This report will focus on engineering and operational aspects of the three principal sawing machines used.

The technical design of mills was done by four main groups of people: those with know-how gained from practical experience, engineering tradesmen, millwrights and professional engineers. Equipment manufacturers, both locally and overseas, did the design of most sawing machines.

Figure 2: Typical early small sawmill ~1882. The outdoor structure on the left is the vertical frame saw used to break down logs. Under cover, the steam engine is located centrally and a breast bench to the left.

Early mills as above were built close to the log source because of the difficulty of moving large logs. Sawing machinery was mounted on large logs set in the ground. Mills were dismantled and moved to a new site after five to ten years as the log supply distance increased or was exhausted. The capacity of mills progressively grew as supply increased because of low cost transport systems, like log floating and bush trams. The typical economic life of these mills extended to 20–25 years. From this progression there emerged a skilled group of sawmill engineers who learned about materials handling, logistics, log geometry and timber yield, and most important of all, sawing technology.

From the information and images available New Zealand's early sawmills from the 1840s to 1880s were a varied lot! In addition to adapting imported machinery to conditions here, our early millers had to learn the capabilities and limitations of a totally new range of wood species. For example, some woods like Puriri and Maire are very hard to saw, Rewarewa and Pukatea collapse while seasoning, and Tawa and Kahikatea are prone to decay in use.

Many early sawmills seem to be poorly laid out, labour intensive, and with small output capacity. The key saw for log break down work was the frame saw with its vertical blade. It was basically a mechanised pit saw. Frame saws were the ones that started the industrial revolution for wood back in the 1600s but they were painfully slow. Over time much thought went into improving the productivity of mills.

By 1900 New Zealand native sawmills had evolved into a typical design (see Figure 3), with two key sawing machines: twin circular break down saws and a breast bench circular saw, all powered by steam. Such mills are described in Malfroy [2] and Stewart [3]. Larger mills varied this basic scheme. They had additional machines to boost production: typically a vertical breaking down saw, second breast bench, deal frame and docking saw. The band saw for breaking down was adopted later.

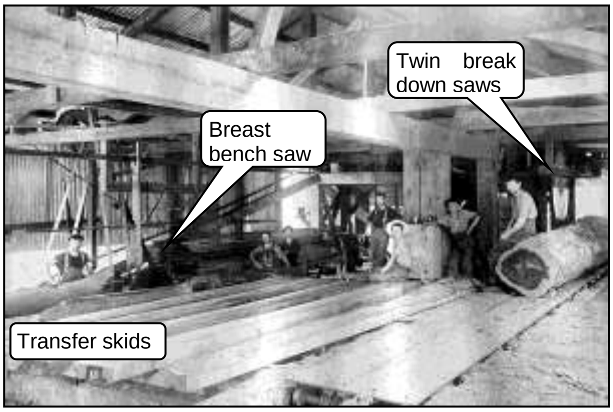

Figure 3: Typical native sawmill layout ~1910. Key technology elements are: the twin break down saws, flitch transfer skids and breast bench.

A typical mill building, as in Figure 3, was say 23 metres (m) long and 5 m wide, built of timber with an iron clad roof. Columns supporting wooden roof trusses were tree trunk sections set in the ground. Saw machinery foundations were whole logs set into trenches in the ground. Mass concrete was used as a foundation for the steam engines driving the larger mills. Some mills built from the late 1940s had concrete machinery foundations.

Material handling systems at mills were important but typically were primitive and labour intensive. Key elements were: log skids sufficient to hold several days cutting, timber transfers between saws, sawdust disposal, wood waste and sawn timber yards to hold up to six months production which was sufficient time for air-drying. Drying sheds and dry kilns were uncommon. The fork lift and straddle carrier were adopted late at such yards. There was no native timber by-products industry. Sawdust and off cuts, typically 35% of the log volume, was largely discarded as waste, creating problems.

The range of power sources used in mills was the same as those used in many other industries of the era. They evolved through water, steam, and internal combustion to electricity. No specialised power engineering was required. A notable feature was the complex mechanical power distribution systems adopted because mills were powered from a single source. Many mills were underpowered so not all the saws could work at once. The most distinctive power technology item

was the Dutch Oven, which very efficiently burned sawdust waste to raise steam in mill boilers.

Wood processing at mills was not common and at best typically just planers and moulders. The development of the industry relied firstly on coastal shipping and railways to transport the rough sawn timber to the fast-growing towns and cities and to the export ports. Rough-sawn timber was re-sawn, dried or 'seasoned', and planed and moulded as required in processing plants set up in the centres of population. Preservation was largely limited to tawa timber. The only engineered timber product was the output of three plywood plants.

Five trade skills were found at sawmills and four of these were distinctive to mills: millwright, saw doctor, timber classer and benchman. The fifth, engine driver certification, was cross-industry. Working conditions were very basic with hours ruled by the mill whistle. A five and a half day week was common, and much of the work was arduous, noisy, done in low light and hazardous to eyes, fingers, even limbs. Accidents and fatalities were far too frequent and for too long inquests ruled grisly mill deaths as unavoidable.

Living conditions at sawmill settlements also merit study. Many mills were set in remote locations at the end of rudimentary access roads. Services like electricity and phone were rare. Mill houses were so primitive that the government got involved in a Sawmill Worker's Housing Scheme 1946–50. Single men were accommodated very basically with a cookhouse and huts. Schooling was also an issue if married men were to be retained.

Sawmilling became progressively bound by legislative requirements that impacted on design. In approximate order of introduction these include: coroner's investigations 1858, company registration 1860, boiler inspections 1874, boiler attendants 1894, machinery inspections, sawdust in waterways 1908, rural fires (affecting waste wood disposal) 1921, sawmill registration 1944, and timber stacking 1948. Major sawmilling organisations of the era were the Timber Workers Union, Sawmillers Federation, and Forest Service, founded in 1900, 1917 and 1919 respectively.

4. Twin Break Down Saws

Twin break down (breaking down) circular saws were the first stage of sawing in a typical indigenous mill, like the example in Figure 4 at Oio, in the central North Island. They cut heavy logs into flitches for the breast bench. Figure 4 shows twin circular saws and a heavy flat wooden bench drawn along a bed of rollers. Visible right of centre, twin saws of around 1800 millimetre (mm) diameter are mounted one above the other. Their size and momentum, whizzing around at 300 revolutions per minute (rpm), made them frightening to be near. They are stopped for the photo. Visible to the right is the pulley and belt drive to the upper saw. The heavy wooden bench has a slot along most of its length to allow passage of the lower saw.

Figure 4: Typical twin circular break down saws, 1930s. The log is positioned laboriously on a flat top bench. The belt and pulley drive system is evident.

The circular saw blade is not just a disc of steel plate with teeth cut into it. It is necessary for a saw doctor to hammer the plate to tension the saw so when it is running at speed the saw is stiff and cuts a true straight line. The saw doctor was also needed to shape and swage the teeth to provide a sharp cutting edge and clearance for the saw in the cut. After the mill manager, the saw doctor was the most important man on site, with the possible exception of the cookhouse cook.

The earliest known New Zealand example of this type of saw was in 1871 at Guthrie and Larnach's mill at Owaka, in the Catlins, Southland. Twin circular saws were latest technology. They superseded vertical reciprocating frame saws, boosting productivity tenfold. Twin 1800 mm diameter saws enabled logs of around 1600 mm diameter to be readily broken down. This technology was largely unchanged when native mills ended a century later. A challenger to the twin saw was the band saw. However, it had limited acceptance until the 1950s despite being introduced in New Zealand in 1887.

The main engineering improvement to boost twin saw productivity was the log carriage which replaced the flat bench. Unlike the labour intensive flat benches they replaced, log carriages were a greatly improved method of holding, turning, and aligning logs during the break down process. The key improvements were spiked arms that gripped the logs, uprights (called the set works) that the log was held against, and kickers that turned the log. With the log securely gripped, the speed of cutting could be increased which required more power delivered to the saws and to the log carriage drive system. The speed of returning the carriage after each cut was also greatly increased. Log carriage technology significantly reduced labour demands and greatly increased production. Despite this,

relatively few mills had log carriages. A popular design was the Pacific Carriage, the name indicating its United States of America (USA) origins from the 1890s.

The twin break down saw went out with the indigenous sawmill and has no role in the sawmilling industry of today. In 2014, remaining New Zealand examples exist in three sawmill museums.

5. Breast Bench Saws

The breast bench was the second stage of sawing in a typical indigenous sawmill. Its role was to cut the heavy flitches into final sizes for retail sale. The benchman was a key and skilled job in mills, shown in Figure 5. He is pushing a heavy 250 mm thick flitch into the 1050 mm diameter circular saw blade, whizzing around at 450 rpm. The flitch will be passed repeatedly through the saw until it is completely cut into saleable boards. Working at the other end of the breast bench is the tailer out. At the completion of each cut, he sends the final sawn sizes to the load-out trolley and directs the flitch back to the benchman. Productivity was increased by employing a third man, often called the pin boy, to set the gauge (also called the fence) determining the width sawn on each pass. The mill manager will have advised the benchman what sizes were needed to meet customer demand.

Figure 5: Typical breast bench saw. These saws were labour intensive. The introduction of powered feed rollers reduced effort and increased productivity.

Breast bench technology is likely as old as circular saws and may date to the 1830s. New Zealand's earliest mills probably included a breast bench. When new it was latest technology boosting productivity up to tenfold compared to the early frame saws it replaced. It was an arduous job for early benchman to spend all day pushing heavy flitches into a circular saw. Improvement was required to raise productivity. Research suggests that by the 1890s manual feed rollers were commonly fitted to breast benches. Initially these rollers were powered by a third person called a leverman, who wound a crank. By 1910 engineering had improved and the rollers were powered, making leverman obsolete. In time powered return rollers were fitted to ease the work of the tailer out too. In this final engineered form the breast bench was a modestly sophisticated machine. It still had very low productivity compared to the saws of today. The main challenger to the breast bench's role was the deal frame, a highly engineered high speed multi-blade frame saw.

The breast bench was a dangerous machine that maimed and claimed lives. Machinery regulations eventually demanded that a safety guard, called the fin, be added. This followed tragedies where the whirring saw blade picked up flitches, hurling them back and killing benchmen. The curved fin is seen on the left in Figure 5. The benchman's badge of trade was the loss of at least a few fingers. The number of breast bench injuries and deaths is not recorded but Henry Hoyle's tale is tragic. Hoyle owned a Thames sawmill. In 1916 Holye lost his right arm clearing a chip from the saw blade and 17 years later he was killed in an accident using the same breast bench.

6. Band Saws

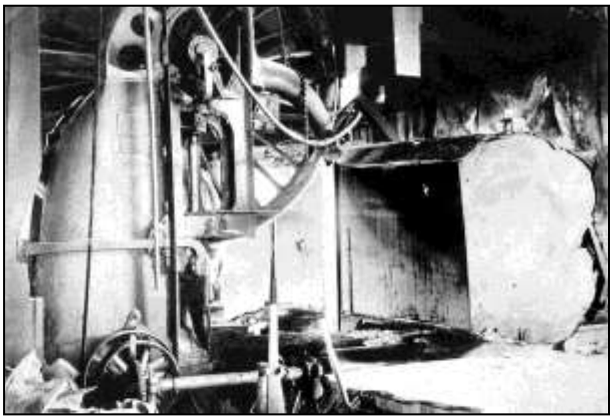

Figure 6: Typical band saw. This early example was used to break down large kauri logs in Northland. A carriage was required to hold logs firmly during cutting.

Band saw technology for large diameter logs was successfully introduced in the USA by Allis Chalmers in 1885. Two key advantages they offered were higher speed and lower sawdust waste. They soon spread globally and 1887 saw the first successful New Zealand use. While band saws had also been developed in Europe, New Zealand looked to the USA's West Coast for machines that could cut the relatively large log species harvested here.

Band saws were a great leap forward technologically. However, there were impediments to their introduction. [5, 6] Firstly, they were much more expensive to buy and install than locally made breaking down saws and breast benches. Secondly, they not only needed a whole new range of saw-keeping machines, but also a whole new

skill set to operate them. Thus in the early days of the band saw's introduction in New Zealand their speed and conversion advantages were often not fully realised. Only larger mills with access to high value resource could afford the capital investment required, the powerful engine to drive it, and training staff in the new way of handling logs and cutting flitches. Therefore, many mills that cut large girth logs retained the vertical break down saw. This old technology was developed in New Zealand to an exceptional size, a topic that demands further study.

Band saw blades lasted only half a shift before having to be removed for re-sharpening, swaging and benching. They were cumbersome and dangerous to handle. [7] Colin Zeff vividly recalls two band saw incidents in the late 1960s. At Stuart and Chapman's mill at Ross, West Coast of the South Island, the bandsaw blade came off at full speed because the saw guides failed, punched through the mill wall and bounced out into the yard, causing a general scatter. A few years later Colin was nearly killed. A bandsaw blade was folded awaiting sharpening in the saw shop at Henderson and Pollard's mill, Auckland. It broke loose from its restraints, breaking through the door to the next room, and cut Colin's wrist in the process. Just a few centimetres more and …

The flat-top carriage was not adequate for a band saw and a whole new family of powered log carriages were developed that could turn logs and flitches and set the dimension to be cut. The operator of the log carriage would ride on the carriage, controlling the cut pattern and the feed speed as the saw passed through the log, and manually turning down the cut slabs and flitches to pass on to the re-saws.[8]

Early bandsaws were not rated a success here because, allegedly, they did not cut our timber straight. This prejudice delayed their earnest adoption until the 1950s when the Forest Service insisted on their installation. From professional experience gained at the end of this era, Colin Zeff considers many of the supposed shortcomings of band saws simply related to a lack of skills and knowledge, meaning they were not being adjusted appropriately or operated and maintained for optimum results.

7. Big Vertical Saws

Figure 7: Big vertical saws were an anachronism that New Zealand developed into very large machines, possibly the last and largest of their type in the world. This example is unusual having two saw blades.

One consequence of New Zealand reluctance to adopt band saws was the continuation of the use of vertical saws, or frame saws, as late as the 1980s. These saws had a saw blade held vertically under tension in a reciprocating frame. As the frame moved up and down the log was fed through it. This type of saw had started the industrial revolution for wood in the 1600s. However, there were limitations to how fast the reciprocating fame could move without inducing destructive vibrations. Globally, vertical saws were superseded from the 1820s by circular saws and then band saws.

With exceptionally large kauri logs to break down, New Zealand chose to develop frame saws into what we called 'big vertical saws' (see Figure 7). Balancing was improved, along with beefed-up foundations and bracing. They were confined to the central and upper North Island. It is not clear if any other country in the world followed this technology path. Therefore, it is possible that the vertical saw was developed into its final and finest form in New Zealand 300 years after it kicked-off the industrial revolution. While the other saw types used here could be found around the world, the big vertical saws could be distinctively Kiwi, and this warrants further investigation.

8. Sawmill Design and Construction

The technical design of sawmills shared four pathways; know-how, engineering tradesmen, millwrights and professional engineers. Research to date has uncovered little investigation of this topic. Case studies may be the best method to develop an insight into how sawmill design engineering happened.

Know-how and practical experience obtained on the job, seems to have been a significant contributor to routine sawmill engineering. There seem to be many examples of mills being erected

without the help of an engineering tradesmen or millwright.

Engineering tradesmen served a four year apprenticeship in an engineering workshop and studied at night school to pass theory examinations. They gained broad mechanical training and experience applicable to sawmill engineering. Many engineering workshops specialised in sawmill machinery which meant they, potentially, had the most proficient engineering tradesmen.

Millwrights specialised in design and erection of new mills and upgrading existing ones. They were also frequently involved in dismantling mills and re-erecting them on new sites. There was no millwright trade qualification, so more research is needed to understand the process of becoming a millwright, and also the relative roles of engineering tradesmen and on-the-job know-how.

Professional engineers seem to appear relatively late on the sawmill scene. Their role is obscured by their reluctance to publish professional papers. In 1873 English mechanical engineer, J Richards, complained that, worldwide, only two professional papers had been produced on sawmill technology to date [4]. This trend continued. Likely the first New Zealand professional sawmill engineer was Alex Entrican. He started with the Forest Service in 1921 as forest products engineer. His professional focus was to develop exotic timber processing and products, which is outside this paper's scope.

Initially sawmill equipment was imported. The Otago gold rush, starting in 1861, brought a huge demand for machinery. It was not long before there were a number of sizeable engineering shops able to build substantial machinery, including stationary steam engines. As shown in Table 1, these shops became involved in sawmill repairs and maintenance and worked out which equipment they could cost-effectively manufacture. Some machines were direct copies made without a licence agreement.

Equipment manufacturers were the main designers of sawmill technology. Machines were generally offered in standardised sizes but could also be customised. Manufacturers had the opportunity to continuously improve their technology in response to operational issues that arose.

Table 1: Sawmill Equipment Manufacturers.

Sawmill equipment item	Local production	Overseas production
Saw blades, *special steel*	-	☑
Band saw rig	some	☑
Pacific carriage	-	☑
Portable steam engine	-	☑
Stationery steam engine	some	☑
Internal combustion engine	-	☑
Deal frame	☑	☑
Big vertical breakdown saw	☑	-
Twin circular saws	☑	-
Table top carriage	☑	-
Breast bench - circular	☑	-
Underfired multitubular boiler	☑	-

In 2014, three museums preserve complete sawmill plants:

- Kauri Museum, Matakohe, Northland
- Timber Museum, Putaruru, Waikato
- Shantytown, near Greymouth, West Coast

In addition, two other significant complete sawmills (private property) survive at Waimiha, King Country and Marshlands, Marlborough.

9. Conclusion

Only a few highly selected engineering highlights can be included in the permissible size of this paper. The technology of the twin breaking down saws, the breast bench, the band saw and the big vertical saw were summarised. The role of engineers and others in technology improvement were outlined as well as possible given the readily available information. The overview section was structured to set a shape for a more comprehensive study that this major industry and its technology deserve. It is recommended that further study is done while the surviving specialists with the key knowledge can still participate.

10. References

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