The Steam Driven Sugar Mills of Java Preserving the Skills

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SUMMARY: The island of Java has had a sugar industry since colonial times and about thirty mills, built during the late nineteenth and early twentieth-century, driven by reciprocating steam engines, remain in operation. These contain machinery, much of which has remained largely as it was originally built.

These mills are being operated, maintained and managed by local personnel, trained within the mills. The great age of the machinery makes its maintenance intensive, especially as very few spare parts are obtainable.

The skill levels observed in these mills are very high. Breakdowns are attended to quickly by well-coordinated teams with parts being repaired or made form scratch in extensive workshops.

The Indonesian sugar industry produces a large proportion the nation's sugar requirements. The industry employs a large number of people with the benefits this brings to local communities. There is considerable pride in being involved in this sustainable industry.

1 INTRODUCTION

The old sugar mills in Java contain a mixture of technology. The earliest machinery still in service dates back to the last decades of the nineteenth-century although some of the buildings in which this machinery is housed are much older. Many of the mills were built during the period 1912 to 1930 and many older mills were completely rebuilt with new machinery during this period. Since 1930 the industry has struggled to obtain capital and other resources for modernisation. What resources were available for the industry have tended to be invested in new mills, often on other islands where land for sugar growing is more readily available.

Clearly much has changed in the old sugar mills. Some new machinery has been installed. Some machinery which has failed, has been replaced with other old machinery, scavenged from mills already closed down. Some modernisation has indeed occurred. For instance some mills have a mixture of prime movers driving their mill trains with some mill stands driven by modern steam turbines whilst adjacent mill stands are still driven by steam engines which have been in service for 80 years or more.

Many small loads are now powered by electric motors and there has been a corresponding increase in the capacity of the Power-Houses in the mills to generate more electricity to meet this load.

This has made the range of machinery to be maintained and operated very wide. In some mills the same mechanics will be working on the latest state-of-the-art hydraulic drives on the same day that they work on a steam engine built in the 1880's.

Furthermore, spare parts are not common in the old mills, the materials which are available are often second hand and most of the repair work has to be carried out without the aid of instructions and documentation from manufacturers – many of whom have not been in business for a century or more.

What is most remarkable about the remaining sugar mills in Java which still have reciprocating steam engines, thought to be about 30 in number, is that more than a century after many would have considered that the reciprocating steam engine was a superseded technology there are so many steam engines still hard at work making sugar for the people of Indonesia.

2 THE SKILLS

The key trade skill which is required in these old mills is the mechanical tradesman. These tradesmen, who we might call fitters, mechanics, machinists or other terms have a need for somewhat the same basic set of skills now that they might have needed a century ago. Documentation from the era in which the antique machinery was built is rare in the mills and the text books seen were much more modern with many contained no information at all about steam engines.

It is not clear how the tradesmen obtain their knowledge specific to the steam engine. Probably most of it has been passed down verbally from generation to generation. It was clear from the high levels of skill demonstrated by quite young men that they were being taught their trades with considerable care by older men who were master-craftsmen.

The sheer audacity of some of the work carried out suggests training and ongoing transfer of knowledge of a very high order. I would venture that a young mechanic in Australia today, faced with the need to repair a connecting rod from a large mill engine (a steel forging 4 metres long and weighing several tonnes) would not immediately conclude that it was practical to weld it with a simple arc welding machine which might be bought at a local hardware store for a few hundred dollars.

Skills which have almost disappeared from the modern factory are present and being used in the Java sugar mills. There include blacksmiths, riveters, boiler brick-layers, (steam) engine drivers and firemen. The tools of these trades are in the workshops and tool boxes of the men who maintain the sugar mills. They apparently don't need instructions or drawings - they just fix things.

3 THE STUDY TOUR

The material used to prepare this paper was collected during a tour of Java sugar mills in mid 2006 by members of the International Stationary Steam Engine Society (ISSES). The tour lasted two weeks with up to three mills being visited on some days. The tour provided the opportunity to visit 27 mills between Cirebon 200km east of Jakarta and Situbondo 850km east of Jakarta, in the far east of Java[1].

The mills visited are listed in Table 1 in the order visited. The location of the mills, major towns and cities in eastern Java and the route taken by the study trip are shown at Figure 1.

Table 1 – List of Mills and Key Data

Mill Name (Modern Indonesian spelling)	Closest Large Town	Year Mill Opened
Karangsuwung	Cirebon	1850-67 ▲
Sindanglaut	Cirebon	By 1856
Tersana Baru	Cirebon	By 1856
Jatibarang	Tegal	1842
Pangka	Tegal	1831-32
Sumberharjo	Pemalang	1913
Gondang Baru	Klaten	1860
Tasikmadu	Solo	1871
Sudhono	Madiun	1889
Purwodadi	Madiun	1832
Redjosarie	Madiun	By 1854
Pagottan	Madiun	1884
Kanigoro	Madiun	1884
Redjoagung	Madiun	1894▲
Meritjan	Kediri	1884
Cukir	Jombong	1884
Jombang Baru	Jombong	1836
Watutulis	Krian	1839
Candi Baru	Sidoarjo	1832
Tulangan	Sidoarjo	1876
Kremboong	Sidoarjo	1847
Padjarakan	Probolinggo	1813-34 ▲
Olean	Situbondo	1846
Pandjie	Situbondo	By 1854
Wringinanom	Situbondo	1839-45 ▲
Gending	Probolinggo	1834-44 ▲
Wonolangan	Probolinggo	1831-32

NOTE: ▲ Exact date uncertain

[1] There were nine participants in the tour, from the United Kingdom (6), Netherlands (1), Germany (1) and Australia (1). All these could be described as steam enthusiasts. The leader was an Englishman living in China accompanied by his wife and son.

4 THE INDONESIAN SUGAR INDUSTRY

Indonesia is a country of 1.9 million square kilometres consisting of over 13,000 islands located in the tropics between the mainland of south-east Asia and Australia. The country has a population of approximately 231 million and is predominantly Moslem. The central island of Java is only 132,000 square kilometres but is home to 140 million people. It is volcanic and extremely fertile making it ideally suited to intensive agriculture.

The economic development of Indonesia has been described as a history of "missed opportunities". Despite rich natural resources, rich land, favourable climate, and a large, industrious population, the Indonesian economy has under-performed for long periods in its history.

In the nineteenth-century a process of intense colonization started, predominantly in Java, where the Cultivation System (1830 – 1870) was based. This was a state-governed system for the production of agricultural products such as sugar and coffee. In return for fixed compensation (planting wage), the Javanese were forced to cultivate export crops. The export products were consigned to a Dutch state-owned trading firm and sold profitably abroad. After 1870, private enterprise was promoted and the export of raw materials gained decisive momentum after 1900. Sugar, coffee, pepper and tobacco, the old export products, were supplemented by highly profitable exports of petroleum, rubber, copra, palm oil and fibres. Economic expansion, including the sugar industry, was very rapid during the period 1870 to 1930. Sugar represented about 28% of these exports fairly consistently during this period but declined more rapidly than other commodities during and after the Great Depression.

This growth period was followed by a series of economic disasters in Indonesia. The post-Depression recovery was very weak; this was followed by occupation and economic stagnation during World War II and the period referred to as the “Old Order” from independence up until 1965. The “New Order”, under President Suharto from 1966 to 1997, brought about a period of rapid economic development which had not been seen since 1931.

The sugar industry prospered during the late nineteenth-century and up until 1928. Most of the steam driven sugar mills we see today were built during this period and their old machinery, state-of-the-art at the time it was commissioned, is a testament to the optimistic economic outlook of those times. The colonial masters “built to last”.

Current sugar production in Indonesia is a matter of some dispute. Government estimates of production for 2006 are in the vicinity of 2.5 million tonnes and the government contends that production is sufficient for domestic use without significant importation. This claim is at variance with several international sources which place 2006 production at closer to 1.8 million tonnes; consumption at around 3.7 million tonnes and the import requirement at 1.8 million tonnes. At least part of the discrepancy appear to be accounted for by a sugar “black market”.

According to the Indonesian Sugar Association (AGI), there are now 69 sugar mills in Indonesia located predominantly on Java and Sumatra. By comparison there were 185 mills in Java alone in 1925.

5 THE SUGAR MAKING PROCESS

The first stage of sugar manufacture is the extraction of sugar juice from the cane. It is necessary to break the cells in the cane stem to allow the mills to squeeze the juice out during milling. To achieve this the cane from the sugar fields is first passed through “cane knives” and “shredders” which cut it into small pieces. These are “attrition” devices which operate by impact rather than by grinding between two surfaces. In some of the oldest Java mills the cane is “crushed” in older steam-powered two-roll mills termed “crushers” without first cutting it into small pieces.

The cane then passes through a series of “mills”, each consisting of three slowly rotating rollers in a triangular format, which squeeze the juice from the cane, at the same time reducing the cane to a pulp. Water is added in a counter-flow process so that the most dilute juice is obtained from the last mill and it becomes progressively stronger as it moves towards the first mill. There are typically, but not always, four mills in the mill line.

The cane residue is called “bagasse” and is primarily used as boiler fuel. It has quite high moisture content when is leaves the mills and the boilers are of special design to deal with the damp bagasse. The steam produced is used for process heat, and to drive steam engines and turbines for process power and electricity generation. The bagasse also has other uses such as paper-making and as animal food when mixed with molasses.

The raw juice first undergoes clarification to remove impurities. The clarified juice is then thickened into a syrup by evaporation in steam-heated multiple-effect evaporators by boiling off the water under partial vacuum. The thickened syrup is subjected to bleaching with sulphur dioxide and placed into a series of vacuum pans where even more water is boiled off until conditions are right for sugar crystals to grow. Sugar dust may be added to initiate crystal formation. Once the crystals have grown the resulting mixture of crystals and syrup called "massecuite" is dropped into a receiving tank called a crystalliser where it is cooled down and the crystals continue to grow before being spun in centrifuges to separate the crystals and syrup. The crystals are then dried with hot air before being bagged. The remaining heavy syrup is called molasses. It contains useful energy value and is usually sold to make animal food or for fermentation into industrial alcohol and other chemicals. In Indonesia the bulk of the off-white sugar is sold in local markets without further purification.

The various liquids from the centrifuges (washings and syrup) still contain valuable sugar so the liquors are re-boiled and crystallisation (and centrifugation) is repeated several times, the impure sugar so produced being recirculated for further purification.

6 STEAM DRIVEN MACHINERY

There are many types of steam engines in the sugar mills. There are very large mill engines, mostly of the single cylinder horizontal type, made by makers of high repute such as Stork and Werkspoor from the Netherlands; there are large vacuum pumps and compressors, predominantly single cylinder horizontals with the vacuum cylinders driven from the tail rods of the steam cylinders; there are conventional mill engines of all types and sizes, vertical and horizontal, driving various ancient machinery through miles of line shafting and flat belts; there are hundreds of non-rotative pumps, vertical and horizontal, often hidden away in dark, dirty corners pumping various process fluids and there are engines driving electrical generators in Power-Houses[2].

[2] As Indonesia was a Dutch colony the machinery came largely from Holland. However there are steam engines from Germany, the United Kingdom, France and even a few from the United States of America.

The total number of engines observed during the recent Java Inspection Tour is shown in Table 2. Most of the engines listed in Table 2 were seen in operation however some filled standby roles, some were broken down and a few had clearly been derelict for a long time.

Table 2 – Total Number of Engines

Engine Category	Number of Engines
Mill Engines (driving mills and crushers)	88
Vacuum Pumps and Compressors	96
Engines driving Line Shafting, engines driving by individual Belt Drive and some miscellaneous types	64
Pumping Engines	260
Power-House Generators (reciprocating steam engines only)	9
TOTAL	**517**

7 OPERATION OF THE MILLS

Observation of the operation of the mills at close quarters was of great interest. The crushing season was well under way and was expected to last for several more months[3]. The mills were operating on a twenty-four hour per day basis with no regular shutdowns during the season.

There were a large number of operators, mechanics and other employees in the mills by Australian standards. Most of the operation appeared to be fairly leisurely although on careful analysis some of the operational tasks were quite demanding. For instance an operator providing manual control of the speed (and hence frequency) of a steam turbine driving a 2 megawatt generator needed his whits about him. He sat on a chair in a most relaxed position with a control button station in his lap with a raise and lower button and a trailing cable to the turbine governor. He responded to changes observed on a panel-mounted frequency meter. His relaxed attitude bellied the importance of the work he was carrying out and the need for constant vigilance. Operational skills of this type are no longer used in developed countries where the risks of inattention, coupled with the difficulty of maintaining concentration, has ensured that automatic devices have replaced human operators for this type of work.

The large mill engines require constant speed adjustment to regulate the speed of the cane through the mills. The operating spindles of control valves are extended many metres so that the operator had a good view of the mills involved whilst still maintaining quick control of the engine. Tasks such as this were long-ago automated in developed countries.

The operators controlling the feed of cane into the mills did not always maintain a steady flow of cane onto the cane carriers. This process was invariably manually controlled (with mechanical assistance) resulting in considerable variation in loading on the constant-speed cane carriers. Although the various stages of crushing and milling tended to smooth out the flow of cane/bagasse there was constant change of load on the mill engines. Periodically we observed overload and stalling of the mills. Sometimes this led to reversing the mill, decongesting the load, restarting and carrying on. On rare occasions the overload caused breakage in the mill machinery and we saw two mills broken down, possibly from overload, during the time we were in Java. The mill operators depended on their quick reflexes to minimise such breakdowns.

The mechanics in the mills seemed very relaxed. They spent much of the day lounging around doing very little work. However when there was a problem needing their attention they moved with lightning speed and attacked the problem until the offending machinery was running again[4]. These mechanics apparently did very little preventative maintenance, however it must be kept in mind that the operation of sugar mills is based on a short “campaign” with maintenance and repair being done in the “off season”[5].

Operators were responsible for lubrication and in general this appeared to be well attended to with numerous oil cans, tins and bottles to get into hard-to-reach places. I did, however, observe a few cases of very dry crosshead guides despite the presence of an operator with an oil can.

The overall impression of maintenance quality varied greatly from mill to mill. Whilst small faults such as steam leaks understandably went un-attended-to more major faults such as heavy knocking in the engines and unsecured foundation bolts were sometimes also left. The general condition of engines varied from “sweet” to “downright dangerous” depending on the mill but machinery condition was generally consistent within a particular mill.

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[3] In Java the crushing season usually starts in June and lasts 3 to 4 months. In Queensland the crushing season starts at the same time but can last up to six months.

[4] The sugar mills have very little spare capacity. In most cases if something breaks the whole process stops. Hence there is a lot of pressure on the mechanics to keep the mill running.

[5] The mechanics would not expect to be fully employed during the “off season” however this might vary from year to year as the magnitude of repairs and modifications will vary from year to year in each mill.

There is little emphasis on steam efficiency. Massive steam leaks are frequent, and prolonged operation of boiler safety valves was observed.

8 MILL ENGINEERING OFFICES

During our visits to the mills we usually made the engineering office of the mill our base for inspections. We came back to these offices frequently to change photographic gear, write up notes and just to have a break from the noise, heat and dust out in the plant.

We seldom found more than one or two people working in these offices, the occupants appeared to spend most of their days out in the plant. There were piles of papers on desks, text books, typewriters and a few computers. The evidence in these offices was that the engineers and technicians who worked in the mills used very basic engineering tools. In some offices there were pieces of broken machinery and samples of new products. The offices had the look of Australian engineering offices in the 1950's and 1960's. It was impressive that in most cases these offices were located close to the key mill process plant. Chief Engineers long ago had decided that they needed to have their people close to the action.

9 SPARE PARTS, STORES, WORKSHOPS

There was little evidence of spare parts stores or tool stores. Sometimes we saw spare parts for a particular machine tied with string to a column near the machine, liberally coated with bagasse dust. Basic materials such as sheet steel and steel sections were laying about the mills in strategic locations. Every mill had large piles of scrap steel which showed clear evidence of having been chopped up for something useful in the recent past. Gas cutting sets were readily available as were electric welding machines of the simplest type. No MIG or TIG welders were seen in any of the mills.

The machine shops were extensive and equipped with the basic tools which one would expect for medium to heavy engineering activity. The average machine shop contained five or six lathes of various sizes and ages, at least one large drilling machine, typically a couple of shapers, a hydraulic press and many had a small casting facility and/or blacksmiths forge. Milling machines were rare but several of the mills had planing machines of considerable size which could accomplish much of the work of a milling machine. There were no grinding machines of any configuration in evidence apart from grinding wheels. Almost all of the machine tools were old and came from all over the world[6]. The few newer machines (primarily lathes) were made in Taiwan or China.

Each mechanic had at least one large tool box. We saw into very few of these (they were kept carefully and heavily padlocked) but the few we did see into were full of not only hand tools but the kind of odd bits and pieces which all of us who run workshops tend to collect in jam jars and fruit tins over a lifetime. Clearly these mechanics did not expect to be able to go to a tool store to obtain a sheet of emery paper, a length of gland packing or a few bits of sheet metal to make shims. It was all in their tool boxes. They were much better prepared than we had expected. Clearly the mechanics had been trained by tradesmen who knew their business.

10 MAJOR REPAIRS OBSERVED

At many of the sites worn out rolls from the mills showed signs of bearing failures. Broken gears from the mill drives were littered around. This highlights the very heavy loads encountered by the mills used in the sugar making process.

At Padjarakan Mill we saw repairs under way on the engine of Mill 2 which had suffered a serious failure a couple of days before. Apparently the connecting rod fractured in service close to the "big end". The cause of the failure was not clear. The result was that the piston drove through the cast iron cylinder cover on the outboard end fracturing it into a number of pieces. The crosshead was also damaged and had been repaired at the time of our visit by welding on "doublers".

The connecting rod was being repaired in situ by welding after extensive preparation with an angle grinder. When we were there layers of weld metal were being placed in the break with a very simple arc welder and rods. Whilst this method of repair would never be attempted in the developed world today the Indonesian mechanics used the resources they had available. They have highly developed mechanical skills, honed by working with many breakdowns of antique machinery being worked hard. Money and time are scarce and there are no spare parts.

Meanwhile, in the machine shop, work was under way on fabrication of a new cylinder cover. Steel plate (about 40mm thickness) was being built up in several layers, welded together and turned to shape. The engine is fitted with a tail rod so a new tail rod gland would also be required, attached to the cylinder cover. Measurements were being taken from the broken fragments of the original cylinder cover which were laid out on the floor of the machine shop and we saw no drawings.

Whilst all this was going on the sugar mill was in full operation with Mill 2 bypassed. This was a very major failure but there was an attitude of total confidence that

[6] At the time that these mills were built (late nineteenth and early twentieth-century) the major machine tool manufacturing countries were the United Kingdom, Central Europe and the United States of America.

the repair would soon be completed and would be entirely satisfactory. This audacious repair demonstrates the skills of engineers and mechanics in Indonesian sugar mills today.

At Sudhono Mill we saw the final stages of the repair of the primary reduction gearbox on Mill 4. This mill is driven by a steam turbine. A gear wheel from the gearbox had broken teeth at three locations around the periphery. These had already been repaired by welding and the process of grinding the gear teeth to final shape was in progress as we arrived. This was being done with a hand-held electric angle grinder. Later in our visit the mechanics were satisfied with the finish on the gear after a lot of discussion and a few more final swipes with the angle grinder. The gear was then slung and lifted with the mill line gantry crane. As we were leaving the gear was back in its place and the gearbox was being reassembled. It would have been nice to have seen this machine back in service. Whilst it might not have been as quiet as before the crash it was clear that the mechanics expected it to be OK and were pleased with their handiwork.

A third problem was observed at Kremboong Mill where the whole mill line was shut down when we arrived. There had just been a failure in Mill 4, driven by a Stork steam engine built in 1920. The stoppage must have occurred very shortly before our arrival as boiler safety valves were still blowing off and continued to do so for a considerable time.

The first action was to hastily weld bypass chutes onto the mill so that the whole plant could be restarted without Mill 4. This took about an hour and we were able to watch the engines being restarted. This was the first time we had seen one of the big mill engines started. It took a team of four men to manhandle the barring lever of the Werkspoor engine driving Mills 1 and 2 to get it into the correct position to start. Then it was away and cane soon began to flow through the mill train and over the top of Mill 4.

Meantime the mechanics had started to remove the top roll of Mill 4 which was apparently damaged. This was extracted towards the drive end and had to be carefully manoeuvred amongst the gear wheels of the drive train. We had to leave at this stage and were not able to get close enough to the mill roll to see what had caused it to be removed. The handling of the cranes to carry out this operation was expert. One can imagine that they get a lot of practice but the team worked well with very adequate hand signals and close co-operation between the men.

11 CANE TRANSPORTATION

The mills can only use cane grown in their near vicinity. Since the nineteenth-century the cane has been brought in from the fields on the mill's own narrow gauge railway systems. In more recent times transportation of cane by motor trucks has become more common and the mill railway systems are in rapid decline.

Nevertheless many mills retain their railway systems and some still haul the trains with steam locomotives. The steam-driven railway systems require another set of skills which have all but disappeared in developed countries. The maintenance of the steam locomotives may not be much different to the maintenance of steam-driven machinery inside the mills however it seems that specialist crews are still used to carry out this work.

Furthermore the operation of the trains involves drivers and firemen who need significant skill. The permanent ways are very ad-hoc and derailments are frequent. Drivers know the fragility of the tracks and the limits of their locomotives and operate with great care. When the trains return to the mills in the afternoons they are heavily overloaded, requiring even greater care. Virtually all the machinery seen in the railway systems was ancient and maintenance-intensive. Whilst this probably accounts for the change from rail to road transport of cane the maintenance crews have the ever-increasing challenge of maintaining the ancient equipment.

12 THE FUTURE OF THE INDUSTRY AND THE STEAM DRIVEN MILLS

The future of the reciprocating steam engines in the Java sugar mills will not depend on the ability of the mill staff to maintain and operate the old machinery but on the policies of the Indonesian Government and the Indonesian Sugar Industry.

There are many pressures on both government and the industry. The government must consider its overseas balance of payments issues against the health of the domestic sugar industry, the retail price of sugar for all Indonesians and the employment issues which surround the sugar industry. The industry must balance capital availability against internal production costs and the shape of the market. Other issues which will involve both government and industry are the question of local production versus importation of sugar and land use priorities including the question of sugar production in Java versus other islands where there is less land-use pressure but also less supporting infrastructure.

It is simplistic to consider that domestic production is of paramount importance, that domestic production is preferable despite a cost premium as it provides many worthwhile jobs or that scarce capital could be better utilised in Indonesia rather than being spent to modernise sugar mills which have run satisfactorily for 80 years or more. It is likely that the old mills will gradually disappear but in the meantime the skills to support them must be maintained.

13 CONCLUSION

The sugar industry in Java has continued to operate ancient machinery long after it was extinct elsewhere. In doing so the managers of the mills have given adequate attention to the development of skills amongst their operational and maintenance workforce. All the evidence points to high levels of competence and pride of achievement amongst the workforce. The system of training and the handing down of information from generation to generation is clearly well developed and highly refined. This system is sustainable and makes very good use of the relatively simple resources available. Whilst it may not be the most economic way to make sugar in hard economic terms it has proven its durability over a very long time.

14 ACKNOWLEDGMENTS

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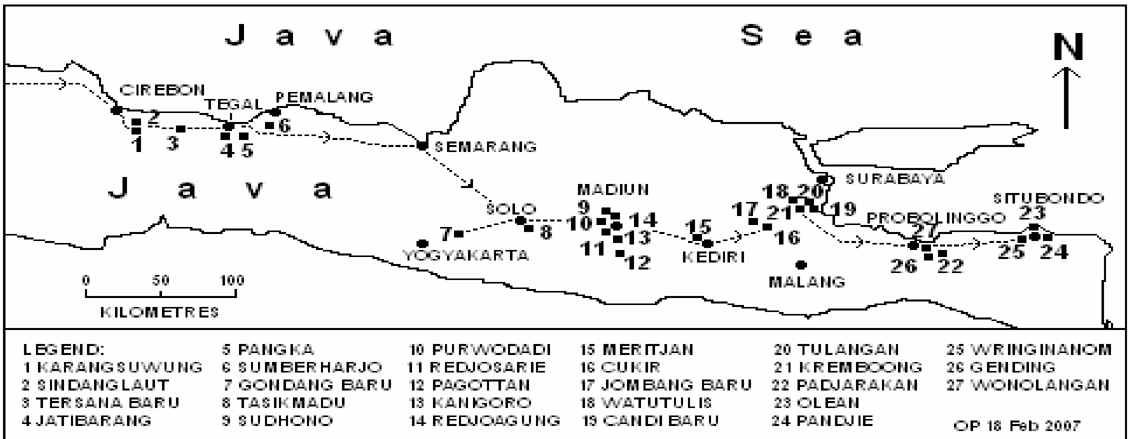

Figure 1 - Location of Mills Visited and Route Taken