# Solid Fuel Making from Oil Palm Trunk
## ～To Reform Pellet Quality for Expanding the Application～

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## Abstract
Recently, biomass power generation has come to attract attention to prevent global warming as renewable energy. In Japan, demand of biomass solid fuel has increased in association with increasing its consumption in biomass-fired power plant and supply of biomass solid fuel has partially depended on the supply from foreign countries. On the other hand, the whole biomass fuel consumption in the world also tends to increase for obligation to the Paris Agreement. As the result, securing long-term stable supply for biomass energy becomes important. To solve this problem about long-term stable supply for biomass energy, Nippon Steel & Sumikin Engineering has focused on the old oil palm trunk cultivated in Malaysia and Indonesia as unutilized biomass resources, and developed conversion process to product biomass solid fuel from oil palm trunk and squeezer as the key technology for this process. This paper describes essence of process to enable oil palm trunk pellet to be applied for mono-fuel combustion in biomass-fired power plant and for high mixed combustion in coal-fired power plant.

## 1 Introduction

In recent years, along with the introduction of the Feed-in Tariff (FIT) scheme for renewable energy into Japan as a measure against global warming, woody biomass has been attracting attention for its stable usage regardless of environmental conditions, acquiring an upward demand pushed by an increase of dedicated biomass power plants and a popularization of biomass co-firing in coal-fired power plants. In this situation, the ratio of biomass power in the energy mix in Japan is expected to increase from 2% in 2016 to 4 or 5% in 2030, for which dependence on imports of woody biomass will likely increase to meet the demand[1)]. In the meantime, increase in the demand is also expected on a global basis in an effort to meet the Paris Agreement targets, making it an issue to secure a long-term stable supply of woody biomass[2)].

Under such circumstances, Nippon Steel & Sumikin Engineering focused on old oil palm trunks (hereinafter called OPT) as unutilized biomass. Oil palms are cultivated for the purpose of producing palm oil and replanted in the 25-year cycle due to a decrease in productivity, suggesting an estimation that more than 30 million tons of OPT is cut down every year in Southeast Asia and other regions around the world. For the abundance of the felled OPT, the palm oil industry has been seeking for an effective utilization, however, due to the moisture content as high as approximately 70wet% and the fragility of the plant tissue, old OPT is currently filled back in the plantations as a fertilizer. For this reason, there have been problems such as a generation of methane gas by anaerobic fermentation, or diseases and pests that could cause damage to the surrounding palm trees.

Focusing on the OPT's situation stated above, in order to make a contribution to security of the long-term, stable supply of woody biomass and to improvement of the plantation's sustainability, which will lead to the prevention of methane gas generation and insect damage due to the backfilling, Nippon Steel & Sumikin Engineering has devised a business model. That is to locally produce fuel pellets from OPT in Indonesia and use them in Japan based on the FIT scheme, by which a higher profitability is expected than the typical model on the basis of "local production for local consumption." Furthermore, as a result of the above, Nippon Steel & Sumikin Engineering has developed a production process for OPT fuel pellets as well as a new-type Squeezer, which is the key technology of the process.

This paper will introduce the issues attributed to raw material OPT used in producing pellets having enough quality for mono-combustion in dedicated biomass-fired power plants or co-combustion with a high ratio of biomass in biomass-coal co-firing power plants in Japan, and describe the features and effects of the process developed for solving the issues.

## 2 Features of OPT-to-Fuel Pellet Process

Shown in Figure 1 is a comparison between typical wood pellet production process and newly developed palm trunk pellet production process of Nippon Steel & Sumikin Engineering, and shown in Figure 2 is a photograph of the palm trunk pellets produced by the newly developed process. A typical wood pellet production process is comprised of four steps: crushing, drying, grinding and pelletizing steps. The raw materials such as logs and wood waste are first crushed into fragments by a crusher, then subject to a control of moisture content by use of a dryer until it falls within the range of 10 to 20wet% so as to be suitable for pelletizing. After drying, dried materials are ground down with a hammer mill to a suitable size for entering the die having small holes with diameter of 6 to 10mm, then finally formed into pellets by being compressed into the die holes. On the other hand, newly developed pellet production process of Nippon Steel & Sumikin Engineering incorporated additional two steps after the crushing step: one is a water-washing step and the other is a squeezing step with our newly developed key technology, Squeezer, by which the ash content in raw materials such as potassium can be reduced to the degree enough to satisfy the quality level for use for mono-combustion in dedicated biomass-fired power plants, or co-combustion with a high ratio of biomass in coal-fired power plants in Japan, and at the same time, it is made possible to reduce the drying heat quantity required in the drying step and to eliminate the grinding step.

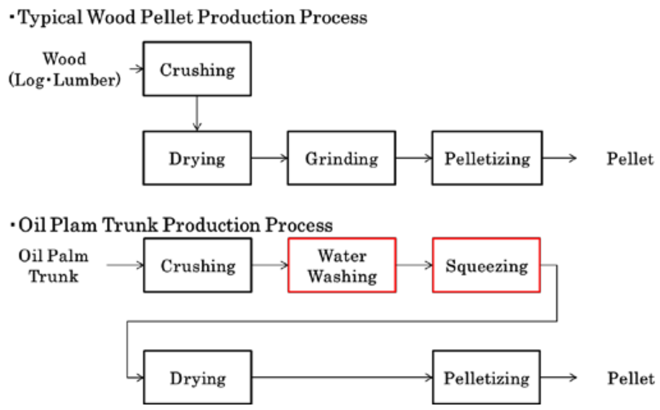


Figure 1 Comparison of Pellet Production Process

Figure 2 Palm Trunk Pellet (Photo)

## 3 Technical Challenges

There are two technical challenges in developing the process of solid fuel making from OPT. The first challenge is to reduce the ash content such as potassium in the pellets. The ash content is non-combustible mineral substances consisting of CaO, $SiO_2$ and $K_2O$, which remain after coal or charcoal is burned. When materials with high content of ash such as potassium are burned, the amount of noncombustible ash content becomes high, which not only makes an adverse effect on the calorific value of combustion, but also causes adhesion of ash content to the inside of the combustion furnace or to the superheater tubes or reheater tubes which, after fusion and solidification, forms lumps called clinkers, resulting in slagging or fouling which generates a negative impact on the boiler. For this reason, acceptance criteria with regard to the content percentages of the elements of ash content in the fuel pellets are established independently by each of the users, and the survey of such criteria resulted in that the requirement for the potassium concentration in fuels to be used for both mono- combustion in dedicated biomass-fired power plants or co-combustion with a high ratio of biomass in coal-fired power plants overall is up to 0.20dry% to 0.25dry%. Figure 3 shows the biomass generated in the production of palm oil from oil palms includes not only OPT (Trunk) but also 3 to 5-meter long pruned leaves (Frond), empty fruit bunches (EFB) which are the remainder left after taking out the flesh from palm fruit bunches, palm kernel shells (PKS) which are the remainder left after extraction of kernel oil from the seeds of palm fruit and mesocarp fibers (MF) which are the fibrous form mesocarps. As shown in Table 1, the above-stated types of biomass, other than PKS that are already circulating as the fuel for mono-combustion in dedicated biomass-fired power plants and MF that are used as the fuel in local oil extraction factories where generation of clinker is allowed by alternately operating a plural number of boilers, show higher potassium concentration than that of users' acceptance criteria and are, in fact, left unutilized or limited to particular usages.

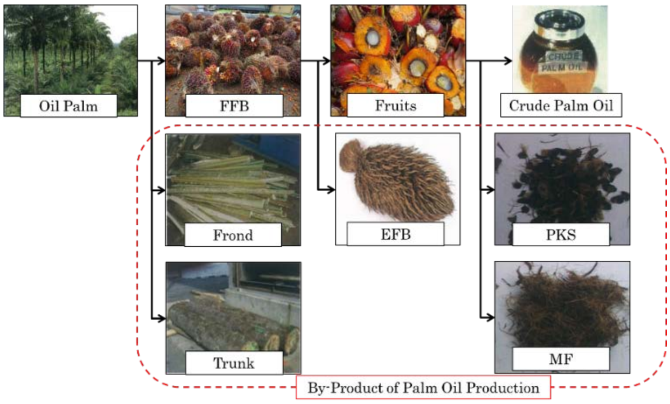


Figure 3 Biomass derived from Oil Palm [3) 4) 5)]

Table1 Potassium of Oil Palm Biomass [3) 6) 7)]

| Item | Potassium (dry%) | Use State |
|---|---|---|
| Trunk | 0.70 % – 1.21 % | × : Unattended in Plantation |
| Frond | 1.34 % – 2,00 % | × : Unattended in Plantation |
| EFB | 1.59 % – 2.28 % | △ : Fuel or Compost (Partially Used) |
| PKS | Approx. 0.09 % | ○ : Fuel (Partially Used in Japan) |
| MF | 0.47 % - 0.50 % | ○ : Fuel for Local Consumption |

The result shown above is assumed to be attributable to the use of fertilizers containing potassium as one of the nutrient elements for cultivation of oil palms in the process of palm oil production. Although the potassium concentration of OPT (Trunk) is approximately half that of Frond or EFB, the application of OPT (Trunk) as a raw material in untreated condition seems to be limited to the fuel pellets for co-combustion with a low biomass ratio in coal-fired power plants. Therefore, in order to use OPT as a raw material of fuel pellets for mono-combustion in dedicated biomass-fired power plants or co-combustion in coal-fired power plants, the potassium concentration must be reduced to 1/5 to 1/6 that of original state.

The second challenge is to reduce the energy consumption throughout the process of pellet production. In a typical wood pellet production process, the drying step and the grinding step are the ones with large energy consumption. In the drying step, commonly used raw materials for wood pellets have a moisture content of 30 to 50wet% and are heated to reduce the moisture content to 10 to 20wet%, which is the optimal moisture content for pelletizing. On the other hand, as OPT has the moisture content as high as 70wet%, the amount of water that must be removed for the moisture content to become 10wet% would be four times that of the commonly used raw materials having moisture content of 40wet% as shown in Table 2, which suggests a problem that adoption of the same process as typical wood pellet production process would largely increase the cost of heat source for drying. Therefore, for reducing the production cost, the moisture content must be lowered before the drying step. Further, raw materials are ground down in the grinding step with a hammer mill or the like to the size capable of entering the die holes as a pretreatment before the pelletizing step, and the electric power consumption for that purpose accounts for approximately 20% of the whole consumption of the wood pellet production process [8]. Therefore, if the raw materials are coarsely ground down to the size suitable for the pelletizing step simultaneously with the reduction of moisture content before the drying step, it will be possible to eliminate the grinding step and largely reduce the electric power consumption for production.

Table2 Moisture Content Comparison between Before and After Drying Process

| Item | Before Drying | | After Drying | |
|---|---|---|---|---|
| | Moisture Content wet% | Water Amount | Moisture Content wet% | Water Amount |
| Typical Wood | 40% | 60 | 10% | 10 |
| OPT | 70% | 210 | 10% | 10 |

## 4 Embodiment of technical challenges

As an embodiment of technical challenges, Nippon Steel & Sumikin Engineering, focusing on the fact that potassium contained in OPT or other plants exists in a state dissolved in water in a plant body, has developed a fuel pellet production process that can largely reduce the energy consumption in the whole process, achieving reduction of both potassium concentration and moisture content, while optimizing the production process with elimination of the grinding step. This innovation was accomplished by employing a water washing step to dilute potassium dissolved in water within a plant body as well as by introducing the Squeezer, which is newly developed as an application of Nippon Steel & Sumikin Engineering's original rolling mill technology for high-efficiency squeezing, in order to reduce potassium concentration and moisture content and, at the same time, to optimize the whole process perform coarse grinding in the squeezing step and allows elimination of the grinding step.

### 4.1 Development of a new type-squeezer

Shown in Figure 4 is a schematic sketch of the Squeezer developed by Nippon Steel & Sumikin Engineering. The rolling mill technology, which is one of the steel-making technologies, is applied to the Squeezer, which consists of three rolls i.e. upper roll, lower roll and ring roll. The three rolls are arranged so that the ring roll works together with the upper roll installed inside the ring roll, and the ring roll works together with the lower roll installed beneath the ring roll. By applying hydraulic screw-up to the local area where rolls come into contact with each other, a high pressure can be given to the material to be ground. When the material is fed into the ring roll, the material is compressed and coarsely ground with a high pressure while passing through the contact point between the upper and ring rolls and is separated into a solid and a liquid. The amount of liquid to be squeezed from plants with the method of compression is dependent on the decreased amount of volume of the plants responding to the forced pressure. This newly developed Squeezer is capable to squeeze a significantly larger amount of water out of raw materials than any conventional technologies, such as screw, press could by applying a higher pressure to increase the amount of compression.

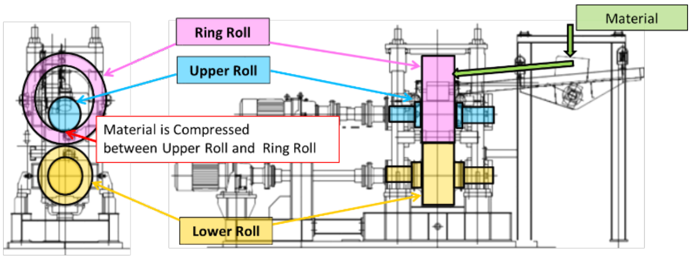


Figure 4 Component of Nippon Steel & Sumikin Engineering Squeezer

### 4.2 Potassium reduction by water washing step and squeezing step

Shown in Figure 5 is the potassium reduction model comparing reduction efficiency of potassium from the crushed chips in the water washing step and the squeezing step developed by Nippon Steel & Sumikin Engineering. The crushed chips (a) crushed in the crushing step absorb water until it reaches the saturated point when added with water in the water washing step and makes a shift from the initial state (a) to the state (b) with increased internal water content. In this transition process, the ratio of liquid portion in the crushed chips increases in response to the amount of added water, however, the absolute amount of potassium in the crushed chips does not change from the initial state. Therefore, soluble potassium in the crushed chips gets into a diluted state in response to the amount of water absorbed by the crushed chips. Subsequently, when water is further added from into the crushed chips with the saturated state (b), they cannot afford to absorb any more water and gets into the state (c) immersed in water. At this point, because a difference in potassium concentration is produced between crushed chips and immersing water, there arises a phenomenon that the potassium in crushed chips elutes to the immersing water. When the crushed chips in this state are subject to a solid-liquid separation by the squeezer, potassium in the crushed chips is discharged together with water as squeezed liquid, making it possible to reduce potassium in the after-squeezing material (squeezed residue) in response to the amount of discharge of the squeezed liquid.

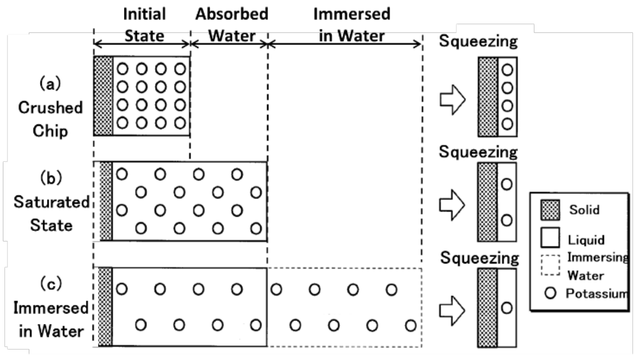


Figure 5 Potassium Reduction Model

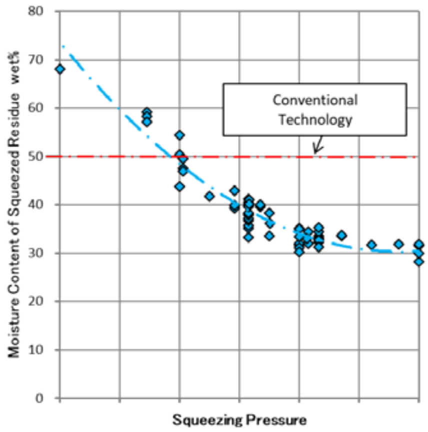


Figure 7 Relation between Squeezing Pressure and Moisture Content of Squeezed Residue

## 5 Test results and evaluation

### 5.1 Evaluation of saving effect of drying heat quantity by the new-type Squeezer

To evaluate the effect of saving the drying heat quantity by the newly developed Squeezer Nippon Steel & Sumikin Engineering developed, a squeezing test shown in Figure 6 was carried out, in which crushed palm trunk chips were squeezed by the Squeezer, and separated into squeezed residues and squeezed liquid, aiming to obtain the relation between squeezing pressure of the squeezer and moisture content of the squeezed residues.

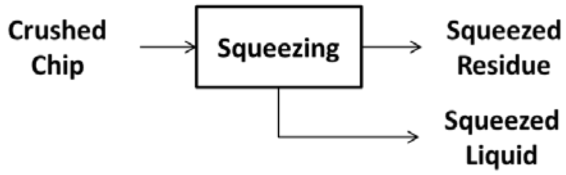


Figure 6 Squeezing Test Flow

Figure 7 shows the relation between squeezing pressure and moisture content of the squeezed residue when the crushed palm trunk chips were squeezed by the Squeezer. By conventional technologies, the moisture content of the squeezed residues could not be less than 50wet%, while the newly developed Squeezer was able to significantly reduce the moisture content of the squeezed residues down to approximately 30wet% by locally applying a high pressure to compress the crushed chips.

Figure 8 shows the relation between the moisture content of the squeezed residues and the input heat quantity required for the drying step. Being able to decrease the moisture content of the squeezed residues to as low as approximately 30% by use of the developed Squeezer down from approximately 50% in the case of conventional technologies, we achieved significant saving of the heat quantity required for the drying step down to approximately 36% of the conventional technologies defined as 100%.

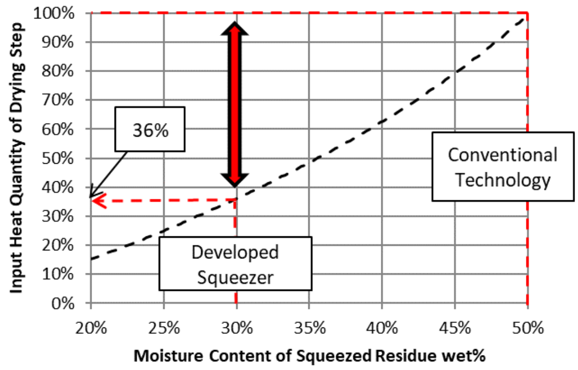


Figure 8 Required Heat Quantity Comparison between Nippon Steel & Sumikin Engineering Squeezer and Conventional Technology

### 5.2 Evaluation of coarse grinding effect by the new-type Squeezer

In the pelletizing step where wood chips are formed into pellets, it is necessary to inject the raw material into the small holes having a diameter of 6 to 10mm provided on the die. For this purpose, typical pellet production processes employ a grinding step arranged before the pelletizing step to grind down the chips with a hammer mill or the like to the size capable of entering the hole.

As a result of using the crushed palm trunk chips into the

Squeezer developed by Nippon Steel & Sumikin Engineering, as shown in Figure 9, the squeezed residues was coarsely ground down to smaller particles, compared with the crushed chips before squeezing. As a result of testing the squeezed residues processed by the developed Squeezer as feedstock with an average die for pelletizing with 6mm-diameter holes in the pelletizing step, the squeezed residues was properly formed into pellets as same as generally available wood pellets, making it possible to eliminate the grinding step from the pellet production process.

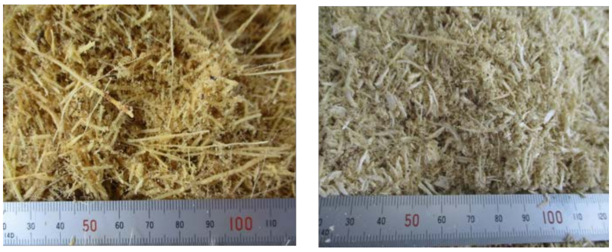

Figure 9 Crushed Chip and Squeezed Residue (Photo)

### 5.3 Evaluation of potassium reduction effect by water washing and squeezing step

To verify the potassium elution effect by water washing, an immersion test was conducted on the crushed palm trunk chips as shown in Figure 10. In the test, potassium elution to the immersion water was examined by measuring the potassium concentrations in both crushed chips and immersing water after one-hour immersion in different amounts of water. As a result, potassium in the crushed chips eluted to the immersing water in different concentrations from 400 to 800 mg/L as shown in Figure 11.

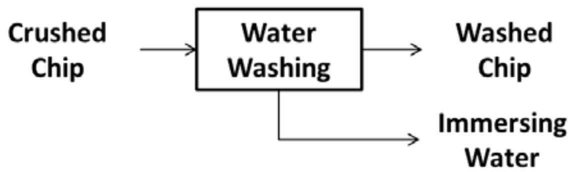


Figure 10 Steeping Test Flow

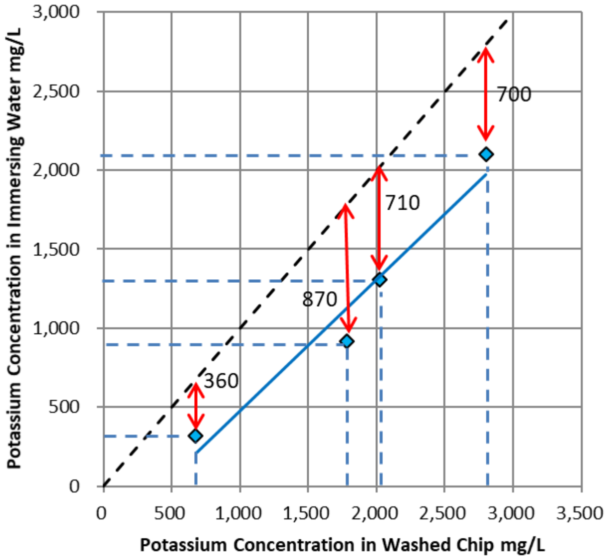


Figure 11 Potassium Balance between Crushed Chip and Immersing Water

Next, to examine the potassium removal effect by the water washing step and the squeezing step, tests were conducted comparing the potassium reduction effects between the two cases where one is the crushed chips squeezed without water washing and the other is the crushed chips squeezed after water washing, as shown in Figure 12.

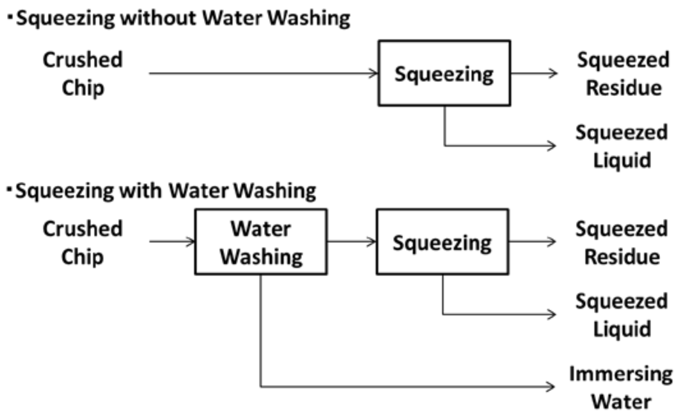


Figure 12 Potassium Reduction Test Flow

The residual rates of potassium remaining in the squeezed residues produced in the above tests are shown in Figure 13. By using the developed Squeezer for the squeezing step without water washing, the potassium concentration was lowered to 27% of that before squeezing. However, it still did not meet the target potassium concentration required for the application to mono-combustion in dedicated biomass-fired power plants or mixed combustion with high ratio of biomass in coal-fired power plants. On the other hand, in the case where the water washing step was added before the squeezing step, it proved that the potassium concentration was further lowered to 15% of that before water washing, well satisfying the required value. From the results of the tests, it was confirmed that fuel pellets of required quality can be produced from OPT as feedstock by integrating the water washing and squeezing steps into the pellets production process.

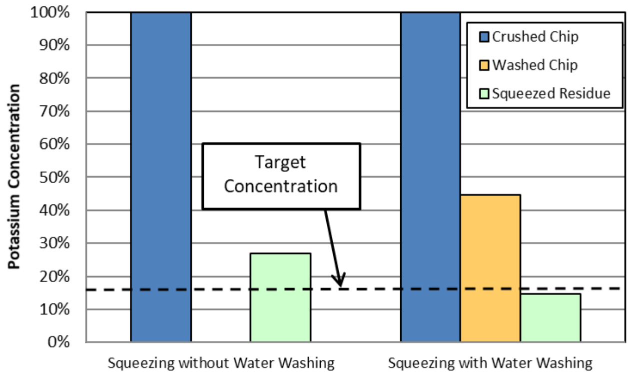


Figure 13 Potassium Reduction Test Result

## 6 Conclusion

In this paper, we discussed the process to produce fuel pellets that satisfy the quality level applicable to mono-combustion in dedicated biomass-fired power plants and mixed combustion with high biomass ratio in coal-fired power plants in Japan from OPT which is abundant, unutilized biomass having high moisture content and high ash content such as potassium, describing Nippon Steel & Sumikin Engineering's development process of the Squeezer making use of the rolling mill technology.

Because the newly developed Squeezer has a structure that is capable to apply a high pressure to materials, a higher squeezing performance can be exerted than any other squeezers based on conventional technologies, which has made it possible to drastically reduce the drying heat quantity required for the drying step. In addition, the pellets production process was able to eliminate one whole step – the grinding step – as a result of the new-type Squeezer being able to process coarse grinding adequately while squeezing. Also, the newly established method to significantly reduce potassium from OPT, by washing the crushed chips to elute potassium and squeezing them to release absorbed water with potassium, has made it possible to accomplish the production of fuel pellets that satisfy the target quality.

From now on, active efforts will be made to ensure long-term and stable supply of biomass fuel applicable to mono-combustion in dedicated biomass-fired power plants or mixed combustion with high biomass ratio in coal-fired power plants in Japan by establishing a marketing channel of OPT Pellets produced from abundant, unutilized old oil palm trunks, to contribute to the sustainability of oil palm plantations in Indonesia, Malaysia, etc. as well as to explore or cultivate needs for the new-type squeezer in order to extend/expand its application to the squeezing and grinding of materials such as wood chips and agricultural residues other than palm trunks.

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