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*Serial Report*

# Development History of SILENT PILER (Part 2)

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## Environmental Considerations and IT Enabling

The model ECO100 (Photo 1) was marketed as a successor model of the SA Series in 2002. Advanced environment-conscious technologies and information technologies were introduced to promote reducing the overall burden on the environment across the machine lifecycle as well as during construction.

Photo 1. Model ECO100

Fig. 1 shows the names of the components of SILENT PILER™ for readers' reference. In terms of structure, the rails for the sliding parts, such as upward/downward motion and rotation of the chuck, and front/backward motion and rotation of the leader mast were increased in length to reduce loads and prevent backlash. In terms of materials, special alloy steel and high-tensile steel plates corresponding to loads and morphology were used to save weight. Also, forged parts of more tenacious materials were used instead of cast parts in the chuck and the like, where stress was concentrated, to take advantage of fiber flows*. Thus longer life of the machine was realized. The gripping force of the clamp claws was improved to obtain larger reaction force on this and later models (Fig. 2).

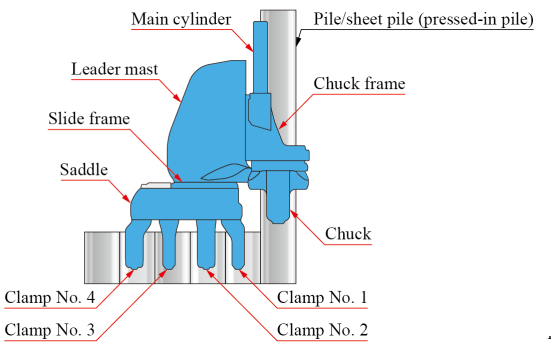


Fig.1. Names of the components of SILENT PILER

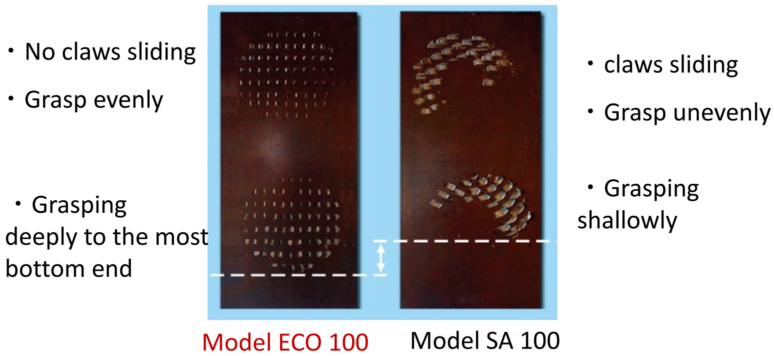


Fig.2. Improvement of gripping force, marks of clamp claws

Fuel consumption of the power unit was reduced by 7% to 10% due to electronic control, and the tier-2 exhaust gas regulations of the time, in and outside Japan, were met. The ECO mode was newly provided to reduce the engine speed of the power unit by about 20% compared to the power mode and reduce the rated output, having a lower noise level than the regulatory standards. Consequently, the machine can be operated at low fuel consumption and a low noise level while maintaining hydraulic force unless high-load/high-speed operation is required in the construction site. In terms of IT, as for the hydraulic force and operation status of the machine, "GIKEN IT System" was introduced in which values from the press-in sensor and stroke sensor in the machine and operation information were collected in a controller of the press-in piling machine and displayed in real time by the maintenance software through the mobile communication network. This allows the operation status of the piler to be checked from a remote location with a PC and appropriate advice to be provided to local operators on the site from the information center.

In 2007, the multi-model of press-in piling machine SCU-ECO400S (S Series) (Photo 2) with the function for hard ground conditions mounted as standard, was launched. A single unit of this model can perform press-in piling with augering, as well as standard press-in and press-in piling with water jetting, by attaching and detaching the hose reels and standard press-in attachment (Fig. 3).

For the S Series machines, the main body and pile auger were light-weighted and downsized compared to the dedicated machines applicable for hardground conditions, in order to be used as a general-purpose machine. To achieve its maximum excavation efficiency despite the downsizing, a Chuck Lock function (Fig. 4) was newly equipped, in which a lock-plate fixed on the chuck was held and fixed using the hydraulic cylinder mounted on the chuck frame. In addition, a Leader Mast Lock function was also equipped, in which the lock plate on the center pin of the slide frame was held and fixed using a hydraulic cylinder mounted on the side of the leader mast to secure the rotating part of the main body firmly during augering. This is the structure that prevents the loss of force. This enabled reliable transmission of auger torque supported by a solid reaction base, resulting in an improvement of the efficiency and accuracy of pile installation. Around this time technologies for hardground conditions were being developed including auger head test equipment, and so on.

* "Fiber flows" are fibrous flows of metal structure formed when metal materials are forged; metal structure flows in the rolling/forging direction. When fiber flows flow along the shape of a forged product, the impact value as well as the fatigue strength are higher than when they are discontinued.

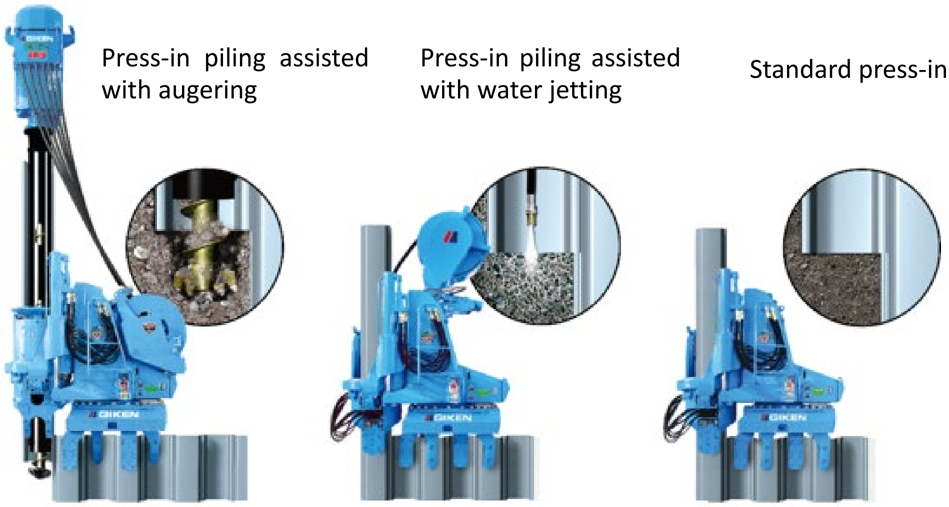


Photo 2. Multi-model SCU-ECO400 (S Series)

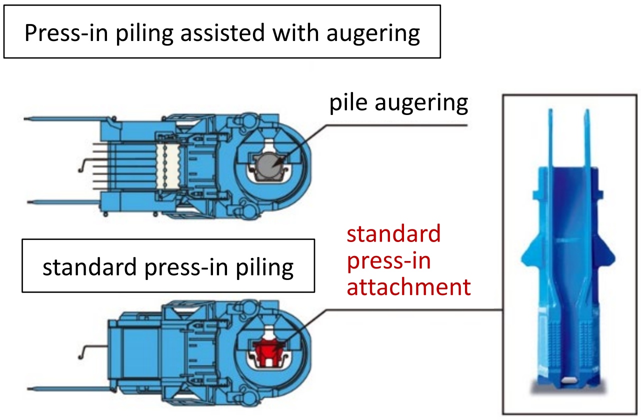


Fig.3. Press-in attachment

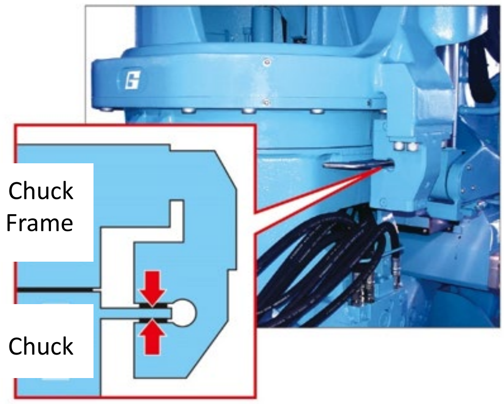


Fig.4. Chuck Lock Function

## Modularization design

Although the S Series was a single unit that is applicable to a wide range of conditions, further cost-down and higher production efficiency were needed for the purpose of global business development. In 2011, the 25 models that had been developed before were integrated into 5 types of base machines. The production efficiency was improved by modularizing main components including the leader mast and saddle. This is the birth of the F Series (Photo 3). Starting with the model F201 marketed overseas in 2013, the model F301 (Hat Piler), model F101 (U Piler for 400 mm wide sheet piles), and the model F111 (versatile press-in piling machine for 400 mm wide sheet piles) were marketed by 2015. In 2016, 2 models, F401 and F501, which were applicable to a "Gyropress Method", were announced.

Model F101

Model F111

Model F201

Model F301

Model F401

Model F501

Photo 3. F Series machines

**Approach to installation conditions and piles**

The development of piling machines is directly linked to the development of press-in piling methods. There were various barriers in construction sites other than ground conditions and each of them has been overcome. There are various types of SILENT PILER (Photo 4): “Clear Piler” for the condition under the overhead restriction such as under bridge, “Zero Piler” for zero clearance to adjacent structures such as buildings, “Concrete Piler” for concrete sheet piles, “Tubular Piler” for steel tubular piles with interlock, and “GYRO PILER” that installs steel tubular piles directly in existing concrete structures with rotary cutting to reinforce the structure. Technology is still evolving.

Clear Piler

Zero Piler

Concrete Piler

Tubular Piler

GYRO PILER

Photo 4. Types of SILENT PILER

## Latest model “SMART PILER”

The latest model, Smart Piler SX1 (Photo 5) was released in April 2020. This model drastically improved the upward/downward motion speed and responsivity of the chuck. The highest press-in speed is 1.5 times higher than that of the model F101, and 3 times higher than that of the model SA75. The responsivity was improved by eliminating time lag in switching the valve to reverse the upward/downward motion of the chuck; the penetration and extraction, that is, press-in at the highest speed and instant shifting to extraction, can be repeated automatically at high speed. This prevents plugging and forming a pressure bulb to realize the smart press-in piling work, in which piles are penetrated while keeping press-in force low. Moreover, the lightest body in the history (3,850 kg) * led to an improvement of the operating efficiency.

Photo 5. SMART PILER SX1

* Within machines for 400 mm wide U-shaped steel sheet pile

## Development History of Gyropress Method™

### Birth of Tubular Piler

One of many types of SILENT PILER is “Tubular Piler”, a press-in piling machine for steel tubular piles with interlock, which are the piles suited to port construction works, flood and tidal surge protection in river basins, anti-seismic strengthening of bridge pillars, bridge foundations, and so on.

Tubular Piler started to be developed in 1986. During the development, a different method to hold piles was needed for the sheet piles and for the tubular piles. While the sheet piles are held by a clamp from outside to mobilize the fictional force, the tubular piles are likely to buckle if they are excessively held from outside. Then the method adopted was to expand a clamp part from inside the tubular pile, mobilizing the frictional forces between the clamp and the inner surfaces of the piles as shown in the Photo 6. Thus, Tubular Piler was completed and first used on a construction site in 1990. The tubular piles are applicable to different design requirements by altering the pile diameter and thickness, which allows efficient construction of many various structures for different purposes. However, it had a big issue of soil plugging at the pile toe. If piles are plugged, a higher press-in force is necessary and eventually piles cannot be penetrated. As the countermeasures for this issue, water jetting was initially used to assist in pile installation. However, it was not possible to install piles into stiff and hard ground in many cases, and then pile augering was used instead. The machine for hard ground conditions was launched in 1997 and its use was expanded rapidly. Yet pile installation was frequently hindered by very stiff base rock layers or existing concrete structures (Photo 7). To solve this problem, GYRO PILER started to be developed.

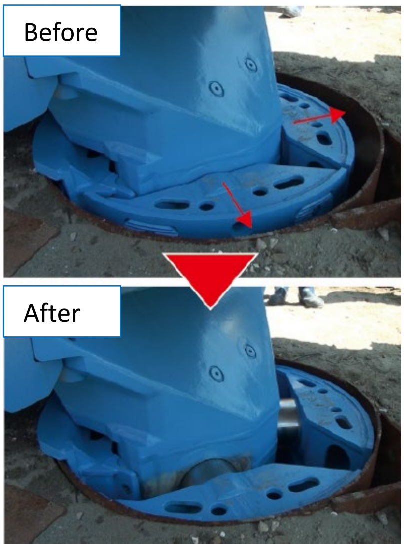


Photo 6. Clamps of Tubular Piler

Photo 7. Construction in Ibaraki Prefecture with Tubular Piler for hard ground

**Birth of "GYRO PILER", steel tubular pile rotary press-in piling machine**

The press-in piling machine presses in piles using static load, so it had a weakness to overcome in that it was difficult to install piles into hard ground. Mr. Kitamura, the developer, had been wanting to solve this issue for years. After trying several ideas, in 1982 he conducted a demonstration experiment of Prototype 1, which installed steel tubular piles by rotating them into the ground. Subsequently in 1986, a demonstration experiment of Prototype 2 was conducted, which was the model KGK-100H with the chuck changed into a rotary type. However, the rotary type was difficult with technologies and part performance of the time, so the development was stopped once. Even so, it was essential to overcome the ultra-hard ground conditions to expand the market of implant structures on the permanent construction. Then, full-scale development of the rotary press-in piling machine was started in 2002. At the same time, it was decided that steel tubular piles with pile toe ring bits (Photo 8) would be developed to press piles by rotating them into harder ground, providing the proposal to Nippon Steel Corporation, the major blast furnace steel manufacturer.

Photo 8. Tubular Piles with pile toe ring bits

"GYRO PILER", which was unveiled at the New Technology Presentation (Ariake, Tokyo) in the fall of 2003, installs steel tubular piles with pile toe ring bits by rotating them into the ground. It was first applied in a project in Hokkaido in 2004 (Photo 9). Because it was a reinforcement construction project of bridge pillars on the conglomerate ground with extrapolated SPT N-value of 1,500, it was considered difficult to install piles by the conventional piling methods. The construction was successfully completed using GYRO PILER GRA1030 (Photo 10); thus the new construction method "Gyropress Method" (Fig. 5) was established.

Photo 9. First installation in Hokkaido

Photo 10. Model GRA1030

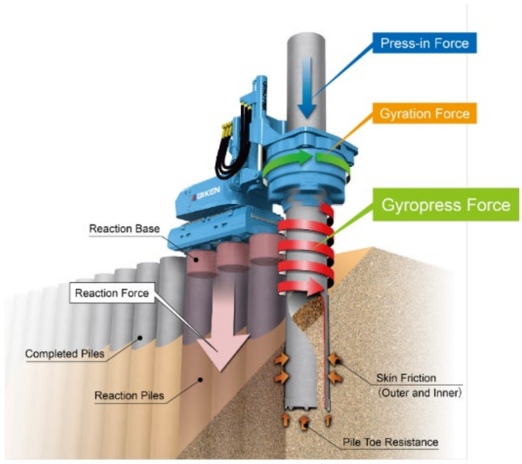


Fig. 5. Gyropress Method

Gyro Piler, which presses in piles penetrating through ultra-hard ground to build implant structures, was used increasingly more as it became well-known. Especially after the Great East Japan Earthquake in 2011, it was used for embankment improvement works implemented by National Government and restoration works in Tohoku district as the construction method which rapidly builds the structures that firmly withstand earthquakes and tsunamis. This led to the construction method being used widely at a rapid speed across Japan. Kitamura also encouraged development of GYRO PILER for large diameter piles immediately after the Great East Japan Earthquake, and developed the ultra-large model GRV2540 (Photo 11) which can rotary-press in steel tubular piles with 2,500 mm O.D. in the following year. It is capable of building the implant structures that withstand massive tsunamis, being of an exceptional scale (body weight 105 tons, maximum press-in force 4,000 kN, maximum rotation torque value 2,940 kN-m). Currently, there are various models including machines for batter pile installation and machines for ultra-low overhead clearance, in addition to the 6 models applicable for piles with 500 mm to 2,500 mm O.D.

Photo 11. Ultra-large model GRV2540

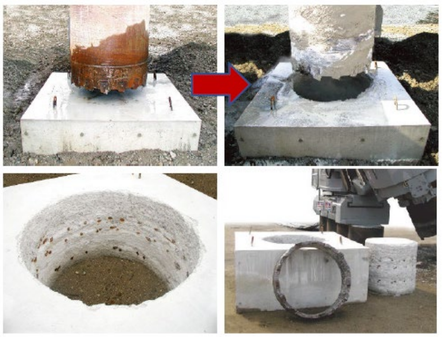

Photo 12. The test of concrete structures with rotary press-in piling

The use of Gyropress Method has grown rapidly in recent years and it became one of the representative implant methods. Its notable feature, the main factor of the growth, is not only that the method is applicable for the ultra-hard ground, but that it is not necessary to remove existing reinforced concrete structures by using customized steel tubular piles with an appropriate number of cutting bits set according to the pile diameter and hardness of the ground. It can build the firm implant structure rapidly by pressing in piles through concrete structures, which is an inestimable advantage (Photo 12).

**Combi-Gyro Method™**

The Combi-Gyro Method (Fig. 6) (Photo 13) is a construction method of walls having excellent functionality and economy, combining steel tubular piles with high rigidity and hat-shaped steel sheet piles with excellent water tightness, using one unit of press-in piling machine. It was developed jointly with the Nippon Steel Corporation, applying the Gyropress Method. One of its features is that it can build walls with the strength required in terms of design at low cost, by optimizing the combination of the pitch, diameter, and thickness of steel tubular piles. The walls can be used widely such as earth retaining walls and cutoff walls. This method is applicable for constructions of retaining walls for highways, river revetments, sea embankments, anti-seismic strengthening, liquefaction countermeasures, and the like.

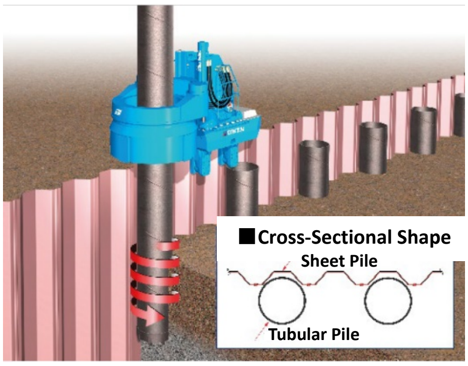


Fig. 6. Combi-Gyro Method

With the Combi-Gyro Method, firstly, hat-shaped steel sheet piles are pressed in contiguously and secondly, steel tubular piles are pressed in by rotating them using the steel sheet piles as a reaction force on the side of the steel sheet piles so as to support the steel sheet piles. The dedicated machines for the Combi-Gyro Method have been developed, a single unit of which can press in the hat-shaped steel sheet piles and steel tubular piles, by changing the chuck.

Photo 13. The construction site in Miyagi Prefecture with Combi-Gyro Method

**Skip Lock System**

The Skip Lock system is the system of more efficient mono pile installation, that is installing steel tubular piles with a constant spacing between piles. GYRO PILER with the originally developed “Skip Lock attachment” is used. Conventionally for mono pile installation by only GYRO PILER, dummy short piles needed to be pressed in between the permanent steel tubular piles, because only some clamps were able to grip piles due to the space between piles and then sufficient reaction force was not obtained (Fig. 7). However, the dummy piles needed to be removed finally, which resulted in unnecessary construction cost and period. Then the Skip Lock attachment was developed to secure a reaction force without dummy piles.

The attachment can be moved by a crane. Three attachments are fixed on the 3 installed mono piles and connected at the connection parts on the front and back of the apparatuses. Each attachment has 2 holding holes for the clamp. The 3 attachments make a bridge on the piles, which makes 6 holding holes for the clamp. During pile installation, all attachments and mono piles are unified by the hydraulic pressure, so it can secure a reaction force from 3 piles to fix the machine body firmly.

The Skip Lock system has been used mainly for constructing the disaster prevention infrastructure, such as foundation piles for sea embankments and landslide prevention piles, since it was first used in tide embankment construction in Fukui Prefecture in 2013. It was also used in the tide embankment reconstruction in Iwate Prefecture (Photo 14) that suffered a great damage from the Great East Japan Earthquake. Lately, it was used for installing landslide prevention piles in the construction site of the Kyushu Shinkansen in Nagasaki Prefecture (Photo 15) for the first time.

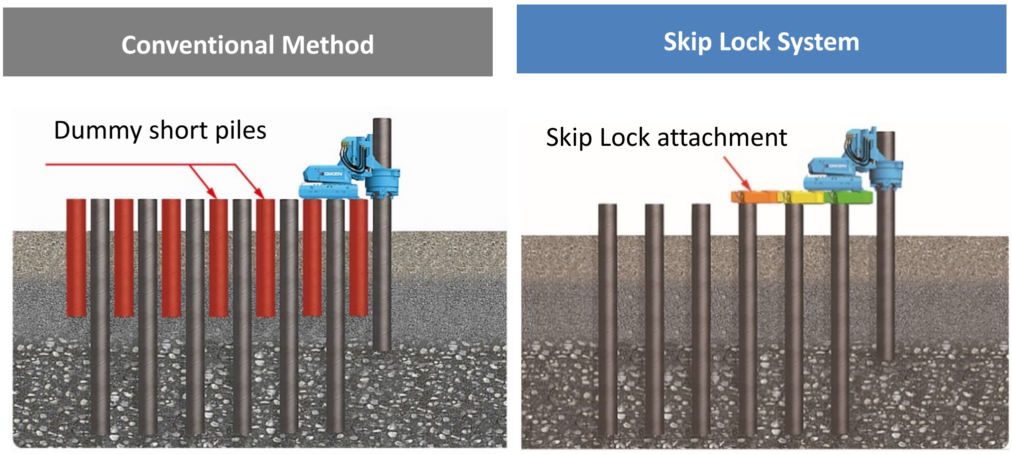


Fig. 7. The difference of conventional Method and Skip Lock System

Photo 14 Construction in Iwate Prefecture

Photo 15 Construction in Nagasaki Prefecture

(To be continued on Part3)