Abstract – IG-110 that is Isotropic graphite for nuclear applications, is the only product that is used for two types of High Temperature Gas-cooled Reactors, prismatic type HTTR and pebble-bed type HTR-10, that are currently in operation in the world. IG-110 is highly evaluated in the global market for its track record and physical stability. The Toyo Tanso Group won the contract to build graphite core internals for HTR-PM that is a world's first modular pebble-bed high temperature gas-cooled demonstration reactor. A decision was made to manufacture IG-110 graphite materials at Toyo Tanso Japan called TTJ and to process products and undertake temporary assembly at Shanghai Toyo Tanso called STT. Manufacture of graphite materials for which TTJ is responsible has been completed. As the next step, processing of products is scheduled to commence at STT from this autumn. Our graphite materials were required to be 2,000 mm or more in maximum length. The number of graphite blocks required exceeded 3,500. Although the graphite structure requirements including configuration were highly challenging, we were able to meet all the requirements with our engineering capabilities, i.e. decades of track record in manufacture and stability in characteristics. STT that will start the machining process this autumn is equipped with state-of-the-art processing machines and three-dimensional measuring machines. Notably, STT has high levels of engineering capabilities to process and inspect tens of thousands of internal components for reactors in accordance with drawings and to temporarily assemble these components.

I. INTRODUCTION

The Toyo Tanso group accepted an order of graphite for HTR-PM afterwards due to our experience in the graphite for atomic energy and high technology. Here we would like to show our manufacturing history of the graphite for nuclear application and processing and assembly inspection.

II. MATERIAL SECTION

Toyo Tanso is responsible for the manufacturing of graphite material.

IIA. Production experience for HTGR

For the first time in the world, in 1974, Toyo Tanso succeeded to produce the large sized isotropic graphite on production basis with conducted many kinds of research and development (R&D). After that, IG-110, fine grain isotropic graphite with high strength, was developed for graphite components of the nuclear reactor with collaboration between the JAEA and Toyo Tanso. Toyo Tanso had supplied the core graphite components to HTTR Japan, and HTR-10 China. In 2009, draft of standard for graphite core components in High Temperature Gas-cooled Reactor was formulated in the special committee of Atomic Energy Society of Japan where we participated. In 2010, we also participated in NGNP Industry Alliance.
II.B. Quality Control of Graphite

Properties required for the graphite for nuclear application are below.

1. To have superior anti-irradiation damage, and to acquire the appropriate irradiation data for component design such as thermal properties and mechanical properties.
2. To have high strength and consistent quality from the standpoint of structural safety.
3. To manufacture the isotropic graphite with large size.
4. To maintain good cost performance and the long-term stable supply.

IG-110 satisfies the above required properties. This is because we have enough knowhow to manage SPC and tightly control each process focusing on the important manufacturing parameters of the graphite for nuclear application, such as Raw Materials, Binder, Grain and Molding method. Manufactured blocks for HTR-PM, which are over 3,500 blocks and approximately 1,300 tons of weight, have stable properties and meet customer requirements.

II.C. Property data of IG-110 Graphite for HTR-PM

We tested 1,100 blocks in the tensile strength test for the first shipping of IG-110 for HTR-PM. Average strength was 26.6MPa, Weibull modulus was 19.0, and the deviation was very small. Su level showed 24.2MPa and adequate safety was confirmed compared with the standard Su level for HTR-PM; 19.4MPa. In terms of purity, it was confirmed that the equivalent weight of boron totally satisfied the quantity described in ASTM Standard (D7219).

Fig. Weibull plots for tensile strength

II.D. Irradiation program

Heavy irradiation test is on-going at Oak Ridge National Laboratory and all data is going to be prepared in 2017. Measurement items are Dimensional change, Young’s modulus, CTE, Strength, Thermal conductivity and Creep etc. Meanwhile, IG-110 graphite is the only one understanding the irradiation behavior in the true reactor because it is adopted in a nuclear reactor of HTTR and HTR-10.

III. MACHINING SECTION

The machining process was just kicked off by last month in STT. For machining the graphite internal components, STT got the Certification of the Civil Nuclear Safety Equipment Manufacturing while the stimulating machined parts were also qualified by National Nuclear Safety Administration in 2012.

This project include many challenges and high requirements, such as, component volume is huge with 3500pcs bricks and 26000pcs small parts, very high machining precision, 22 months processing lead time, pre-assembly with sectional type of 15m height and 4.5m diameter , and large investment.

STT is developing an efficient way which can make the task can be done by a style of standardization, modularization and lean production. Modularized machining based on standardization of 4M1E (Man, Machine, Material, Method and Environment). Material is defined to 12 different size types based on the drawing. About 160 standardized machining programs are made based on 30 basic programs before processing, each basic program is one feature that is classified according to drawings. Meantime, insert different kinds of inspection program into the machining program to achieve measurement online. Design standardized machining jigs and CMM inspection jigs and make inspection program before processing. Modularized machining is also developed with standardization library, such as material library, machining equipment library, machining jigs library, cutter library, machining program library, CMM inspection program library. Each library includes standard modules, choose different module group to machining different kinds of component if required, that can support to achieve more precise and efficient processes.

Pre-assembly is one of the important process. STT try to do some researches on different pre-assembly solutions, choose the best solutions thru lots of tests.
The overall processing time is over 50,000 hours! The subject to be discussed for the next coming HTR projects is how to improve the machining efficiency further more based on the practice in STT this time, for example, how to shorten processing time from 22 months to 12 months. STT will make contribution to the development of HTR and national nuclear power.

IV. Summary

1. Resources of the graphite material made for HTR-PM is beyond 3,500 blocks and 1200 tons in gross weight.

2. About the characteristic of the graphite material
   ① There is the production experience to an atomic energy use with severe quality control in us for many years. This is the reason that was able to satisfy severe requirements of HTR-PM, size, mechanical characteristic, impurity.
   ② The purity showed the value less than the graphite structure design policy of the ASTM standard, and it was proved that it was a purity characteristic to be satisfied with as graphite for enough.

3. IG-110 graphite has excellent strength properties and small variation. Therefore, it was verified that the IG-110 is the high quality graphite regulated by graphite design.

4. We got an approval for processing from National Nuclear Safety Administration (China). We are convinced that we accomplish processing and assembly inspection based on the customer requirements hereafter.