A Study on a Technology to Produce Inorganic Fibers by Melting Coal Ash

Yoshitaka Ishikawa

Material Recycling Laboratory, Chigasaki Research Institute, Electric Power Development Co., Ltd.,Chigasaki 1-9-88, Chigasaki,Kanagawa,253-0041,Japan

KEYWORDS: coal ash, fusion, inorganic fiber

INTRODUCTION

Coal is an important energy source as a substitute of oil and its use is growing mainly in the electric power industry these years. The reason is that coal has an abundant reserve, can be supplied stably, and is excellent in terms of economy. However, with an increase in coal demand, the production of coal ash is also increasing.

In 2003, approximately 9.9 million tons of coal ash was produced in Japan from coal-fired thermal power plants in the electric power industry and in other industries, with a production ratio of 75% and 25%, respectively. Although about 80% of the total quantity was reused mainly in the cement industry, the remaining 20% of coal ash, or approximately 1.50 million tons, was carried to the landfill sites to be disposed of as the controlled industrial wastes (See Fig. 1).

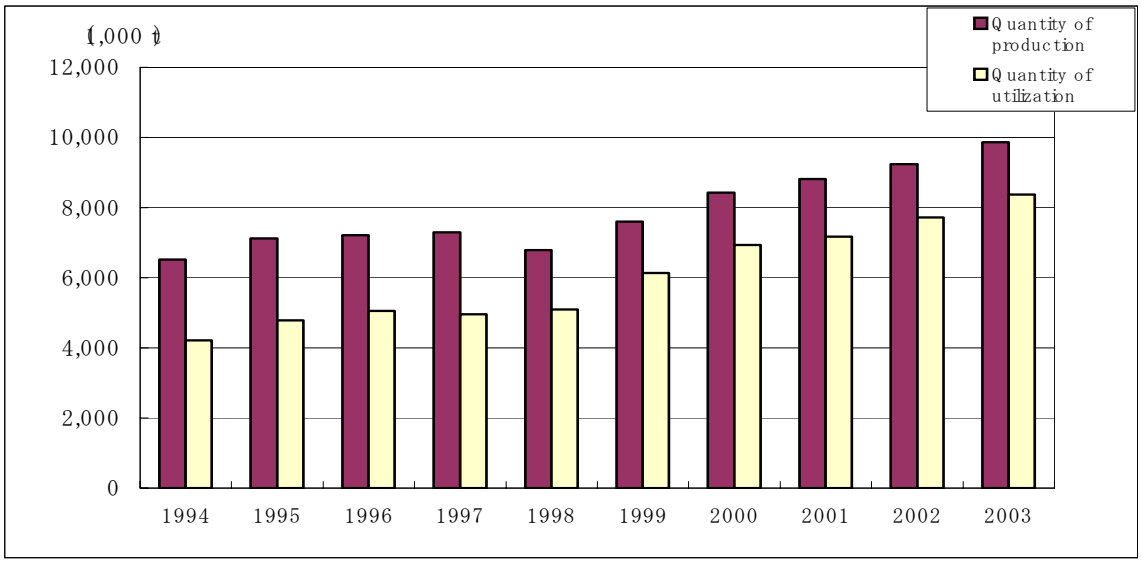

Fig. 1 Production and effective utilization of coal ash (Japan)

On the other hand, with the enforcement of the Law for Promotion of Recyclable Resources (Recycle Promotion Law) in 1991, coal ash was designated by the Cabinet Order as the by-product whose quality and other attributes must be

improved for use as a recycled resource (designated by-product). Also, with the enforcement of the Basic Law for Establishing the Recycling-based Society in June 2000, social interests over the control of waste discharge and the recycling of resources are growing more than ever.

To facilitate effective utilization of coal ash, it is mandatory to reduce its treatment cost and to solve environmental problems such as leaching of trace elements. Also, installation of a coal ash disposal site began to be restricted from the environmental viewpoint. Today, new installation or expansion of a coal ash disposal site is no more allowed in many areas, as is the case with the Seto Inland area. What is required in this situation is to prolong the use of existing disposal sites as much as possible.

The present research is an attempt to develop a technology for utilizing coal ash in an environmentally-safe manner by reducing its volume and making it harmless with the adoption of the fusing process. It also intends to attain energy conservation by using inexpensive coal as a fuel and by recycling exhaust gas.
In this study, an inorganic fiber production technology is developed in which coal ash is fused at high temperature in a fusing furnace using coal as a fuel and then processed into fibers with the application of compressed air. This study also aims to reduce the cost of fiber production by co-installing the coal ash fusing and fiberization system at the coal-fired thermal power plant which produces coal ash as the by-product of electric power generation.

OBJECTIVES OF STUDY AND ITS SCHEDULE

To establish a technology that can produce coal ash fused fibers at low cost and with reliability, the current study puts emphasis on the following items.

(1) To develop a fusing furnace that can fuse coal ash stably using coal as a fuel.
(2) To establish a fiberization technology that can produce fibers from fused coal ash, so that it can become a substitute of inorganic fibers such as asbestos.
(3) To evaluate the applicability of coal ash fused fibers as a heat insulating material, a sound absorbing material, and a concrete strengthening material, and to improve basic engineering data for practical application. Also, characteristics of this fiber are investigated to find its effective usages. Marketability of the fiber and its environmental impact are also evaluated.

The schedule of this study is shown in Table 1. This study is a national R&D project which is carried out with a grant from the Ministry of Economy, Trade and Industry (METI) of Japan.

Table 1 Schedule of study

Year (Fiscal year) / Subject of study	2002	2003	2004	2005
1. Feasibility study	▬			
2. Development of a coal-fusing furnace		▬	▬	
3. Verification test of a coal-fusing furnace			▬	▬
4. Production of fibers using fiberization equipment		▬	▬	
5. Evaluation of coal ash fused fiber quality		▬	▬	
6. Applicability of coal ash fused fiber to products and their evaluation		▬	▬	▬

COAL ASH FUSING AND FIBERIZATION SYSTEM

1. Concept of the coal ash fusing and fiberization system

The concept of the coal ash fusing and fiberization system to be developed in this study is shown in Fig. 2. Coal ash is fused using a circular combustion type fusing furnace which will be explained later. The fuel cost can be reduced with the use of inexpensive coal as a fuel. Exhaust gas from the fusing furnace is conveyed to the exhaust gas system of the boiler at the existing coal-fired thermal power plant. With this, the initial cost of the fusing furnace can be reduced and heat energy from exhaust gas can be utilized. Part of coal ash which is fused in the fusing furnace is fiberized using fiberization equipment and the remaining part is recovered as solid slag using slagging equipment. Coal ash fused fibers with excellent quality are sold to the fiber market as the product. On the other hand, the vitrification process that makes slag like vitreous sand can prevent the leaching of trace elements and thus coal ash is made harmless. Solid slag is usable as a fine aggregate for concrete or as a material for road bases.

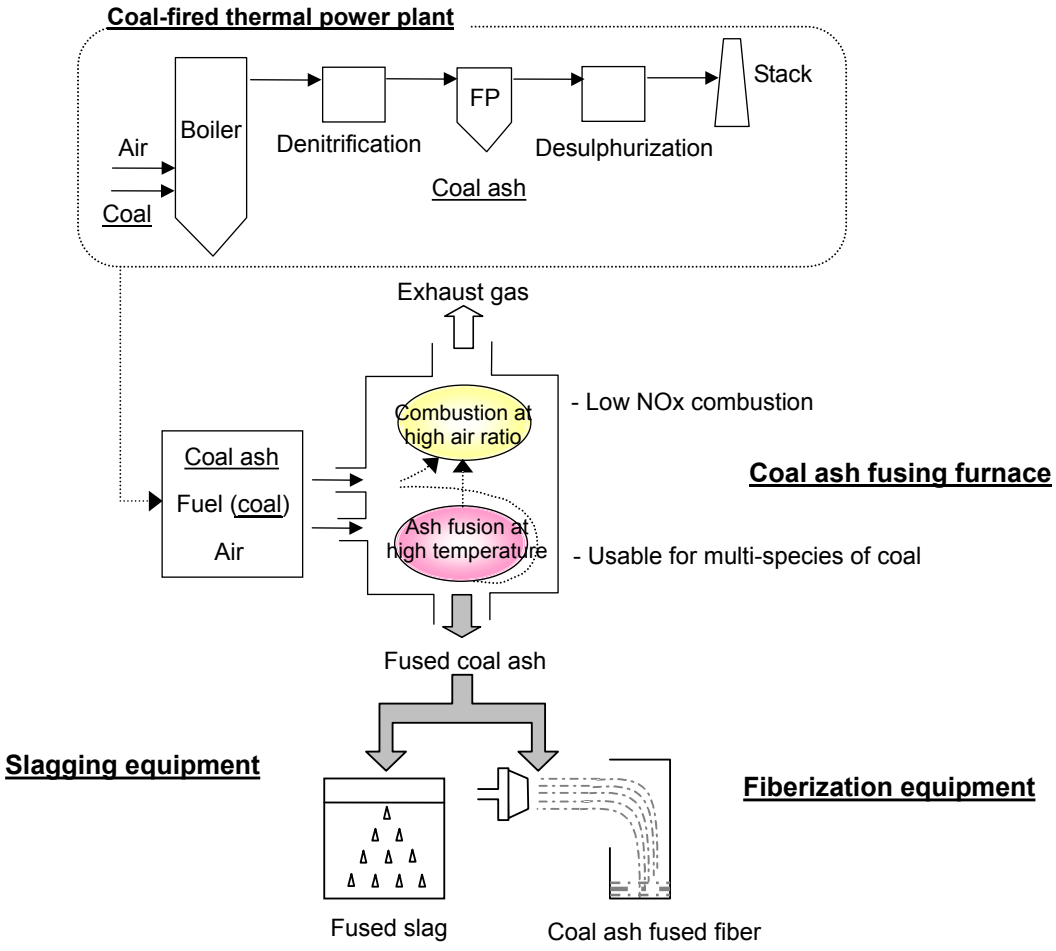

Fig. 2 Concept of the coal ash fusing and fiberization system

2. Features of the circular combustion type fusing furnace

In this study, the circular combustion type fusing furnace having excellent features was selected for the process to fuse coal ash at low cost. Advantages of this fusing furnace are as follows.

(1) Basic concept of the fusing furnace

The basic concept of the circular combustion type fusing furnace is depicted in Fig. 3. The adequacy of this concept has been verified with the coal gasification furnace. The features of the furnace are stated below.

1) Feature of the heat supply system to coal

In the circular combustion type fusing furnace, pulverized coal, air for combustion, and coal ash are supplied in such a manner that they will circulate in the furnace. Therefore, the inlet is placed in the tangential direction to the inner wall of the circular furnace body, as shown in Fig. 3.

Coal particles and coal ash particles that are fed into the furnace can have sufficient residence time to combust or to fuse while circulating around the lower part of the furnace. The fused coal ash particles are pressed against the furnace wall by circulation force and then flow down on the wall. Therefore, scattering of fused coal ash due to an ascending flow can be restrained, which contributes to the improvement of fusing efficiency and fusing reliability. The fused coal ash is collected at the furnace bottom and then discharged outside the furnace from the slag tap at the bottom of the furnace.

2) Feature of the fused slag discharge system

The fused slag is discharged outside the furnace from the slag tap at the bottom of the furnace. Because coal ash is discharged from the furnace bottom and combusted exhaust gas from the furnace top, scattering of fused coal ash is controlled and stable discharge is secured.

3) Other features

The upper part of the furnace can be designed to allow a complete combustion of the coal that is fed into the furnace. This makes it possible to restrain not only the discharge of unburned coal but also the emission of combustible gas such as CO.

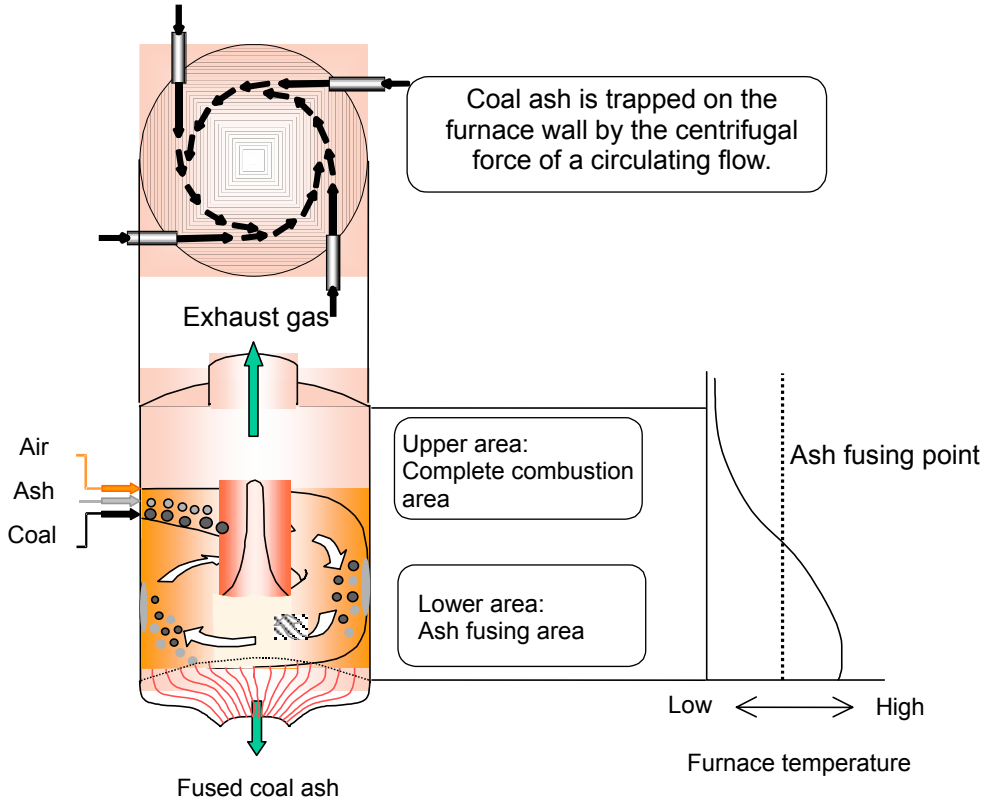

Fig. 3 Description of the circular combustion type fusing furnace

(2) Connection of a fusing furnace to a boiler

Coal to be used as fuel in the circular combustion type fusing furnace is supplied in the same manner as done to the boiler. Namely, pulverized coal with a grain size of 10□m is fed using compressed air. The coal ash collected by an electrostatic precipitator and stored in the silo is appropriate as the coal ash to be fed to the furnace.

Exhaust gas from the outlet of the fusing furnace will be recovered, adjusted to an appropriate temperature, and then supplied to the boiler. This enables heat recovery from the exhaust gas in the furnace. In addition, even though an unburned combustible or coal ash remains in the exhaust gas, it can be combusted in the boiler and coal ash recovered by the electrostatic precipitator installed in the subsequent process.

3. Fused coal ash fiberization system

The rough structure of the fused coal ash fiberization system is shown in Fig. 4. The system consists of the fiberization process, the fiber collecting process, and the product manufacturing process. Experimental results obtained from each process are described below.

(1) Fiberization process

The ordinary production method of coal ash fused fiber is to fuse coal ash in the furnace, to take it out as a fine flow, and to fiberize it by blowing or spinning.
In the current experiment, $CaCO_3$ was added as the fusing point-lowering additive and test fibers were produced by the blowing method. From the experimental results, it was confirmed that the blowing method is fully adequate for fiberization. It was also confirmed that the blowing method is easier than the spinning method in such points as the adjustment of fiber diameter.
As the ancillary equipment of the fiberization process, a compressor which conveys high-pressure air needs to be installed adjacent to the blowing equipment.

(2) Fiber collecting process

In this process, the following method is taken to collect fibers. Fibers that are formed in the fiberization process are still floating when they are guided into the fiber collecting chamber. In this chamber, they are made to deposit on the mesh conveyor by the reduction of pressure from below the mesh conveyor using a suction fan. The fibers in a bulk form are taken out immediately after collection.
From the experimental results, it was confirmed that collection of coal ash fused fibers is easy as with other inorganic fiber cases.

(3) Product manufacturing process

The coal ash fused fibers collected in the above process are now carried to the needling equipment by means of a mesh conveyor and then twined into a mat-like form. After that, the mat is added with a binder, burned, and then cut into an appropriate size to be shipped out as a final product. In the current experiment, the manufacturing process was continued up to the production of final products, and it was verified that good quality products can be manufactured.

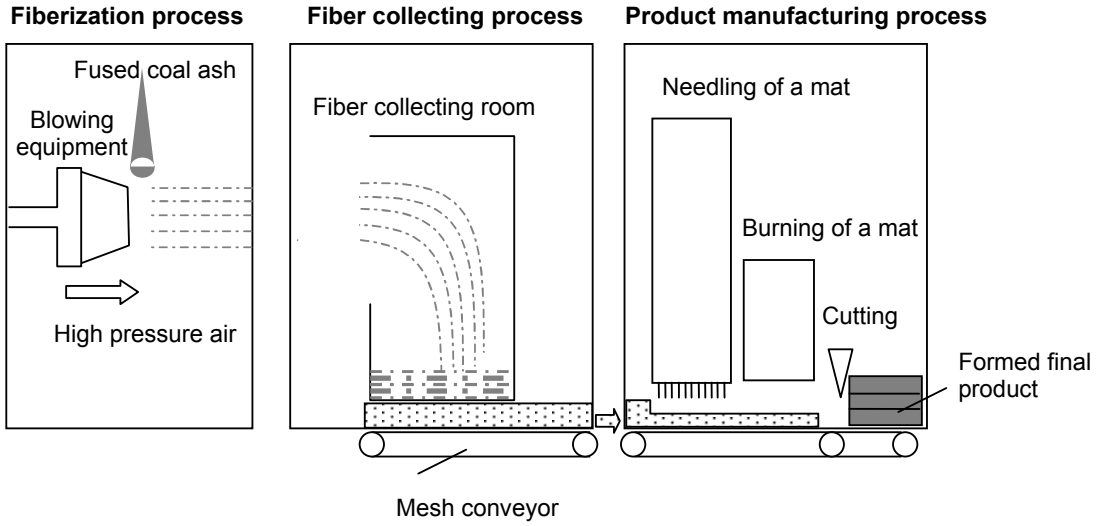

Fig. 4 Structure of the fiberization system

BASIC PROPERTIES OF COAL ASH FUSED FIBER

The basic properties of coal ash fused fiber that is produced by adding CaCO3 by the amount of 30% of the total weight of coal ash and CaO (here CaCO3 is converted into CaO) are described here. Also, the basic properties of this fiber are compared with the properties of other fibers.

(1) Features of coal ash fused fiber

Coal ash fused fiber is colored white as a whole. Its touch and appearance are very much like those of rock wool. Fibers are congregated like a ball and the fiber length is relatively short. Shots (solids) are found at a ratio of some percent, although it differs by the type of coal ash (See Photo 1).
Table 1 shows the basic properties of coal ash fused fiber.

Table 2 Basic properties of coal ash fused fiber

Item	Value
Average diameter of a fiber (μm)	3.4
Content of shots (solids) (%)	1.3
Bulk density (ton/m^3)	0.14

(2) Chemical analysis results of coal ash fused fiber

Table 2 shows the results of a chemical analysis test performed on the coal ash fused fibers which are produced as a trial product. SiO2 accounts for approximately 45% and Al2O3 approximately 20%. The reason that CaO accounts for 30% is probably that Ca was applied as the fusion point-lowering additive.

Table 3 Chemical analysis results of coal ash fused fiber

Item	Value (wt%)
ig. Loss	0.2
SiO_2	46.0
Al_2O_3	21.3
Fe_2O_3	2.7
CaO	27.2
MgO	0.8

(3) Thermal property

When coal ash fused fibers were heated up to the state of read heat inside the gas burner and then put into water, the fibers did not break into pieces, show a condensation of color, nor lose their softness. Even when the fibers were heated up to 1300°C in the air using a heat analyzer, no increase or decrease of weight was seen in the thermogravimetric curve.

In the differential thermal analysis, no conspicuous endothermic or exothermic peak was observed when the temperature was below 1000°C, but evident exothermic and endothermic peaks were observed when the temperature was about 1050°C and 1180°C, respectively. The former was caused by the crystallization of coal ash fused fibers and the latter was caused by the melting of them. When examining the inside of the platinum pan after thermal analysis, fused and solidified coal ash fibers were observed. Consequently, it can be said that the application temperature of fused coal ash fibers is better to be below 1050°C, which is the temperature not causing crystallization, but if the application time is short, fibers can be used around the fusing point, namely 1180°C, just like ceramic fibers.

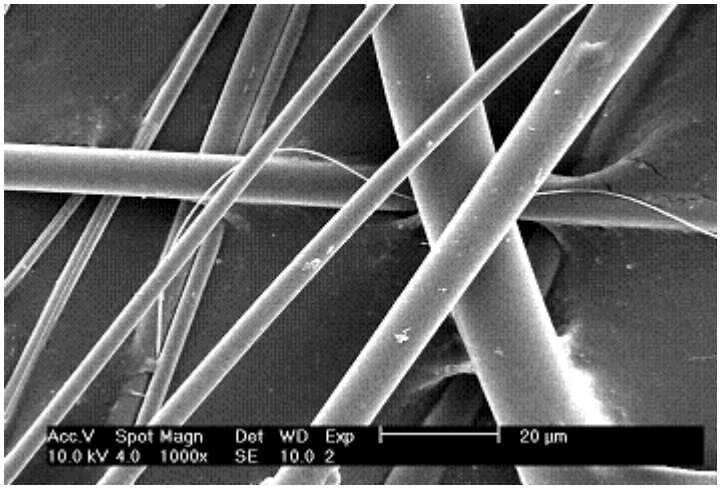

Photo 1 Coal ash fused fibers produced as a test product

PROSPECT OF PRACTICAL APPLICATION

The fused coal ash fiber has an excellent quality compared with the quality of other inorganic fibers such as rock wool. Therefore, promising applications are to use as a heat insulating material, a sound absorbing material, a refractory material, an incombustible material, and a concrete strengthening material.

Figure 5 shows the annual consumption of inorganic fibers in Japan. Despite the fact that asbestos is carcinogenic, approximately 80,000 t/year of asbestos had been used in Japan until recently. Now, it is determined that use of asbestos which has carcinogenicity is no more allowed. Therefore, if coal ash fused fiber can gain a status as a substitute of asbestos, it will not only promote the effective utilization of coal ash but also contribute to the conservation of our living environment.
If the price of coal ash fused fiber is assumed to be roughly identical to that of asbestos, which is approximately 100 yen/kg, the market scale of this fiber becomes as large as 8 billion yen/year. Also, if a fusing furnace which is used in the current study is adopted, low-grade coal ash not satisfying the JIS standard which has little application and has been disposed of at ash pits will become usable as fibers, bringing a significant effect on the expansion of coal ash utilization.

The flow for putting this fusing system into practical application is shown in Fig. 6.

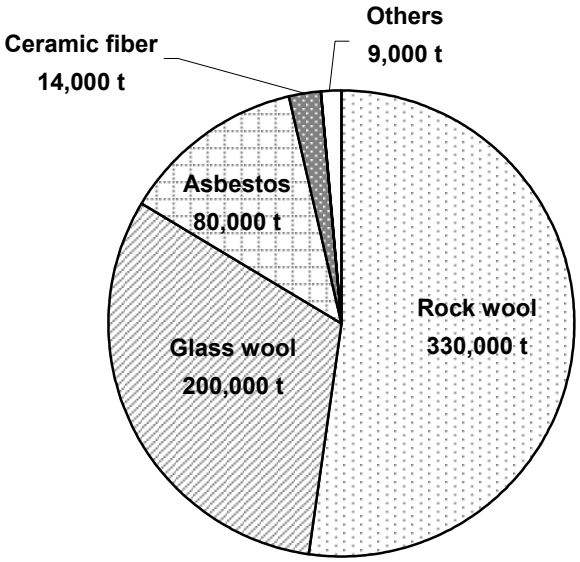

Fig. 5 Market of inorganic short fibers in Japan (2001)

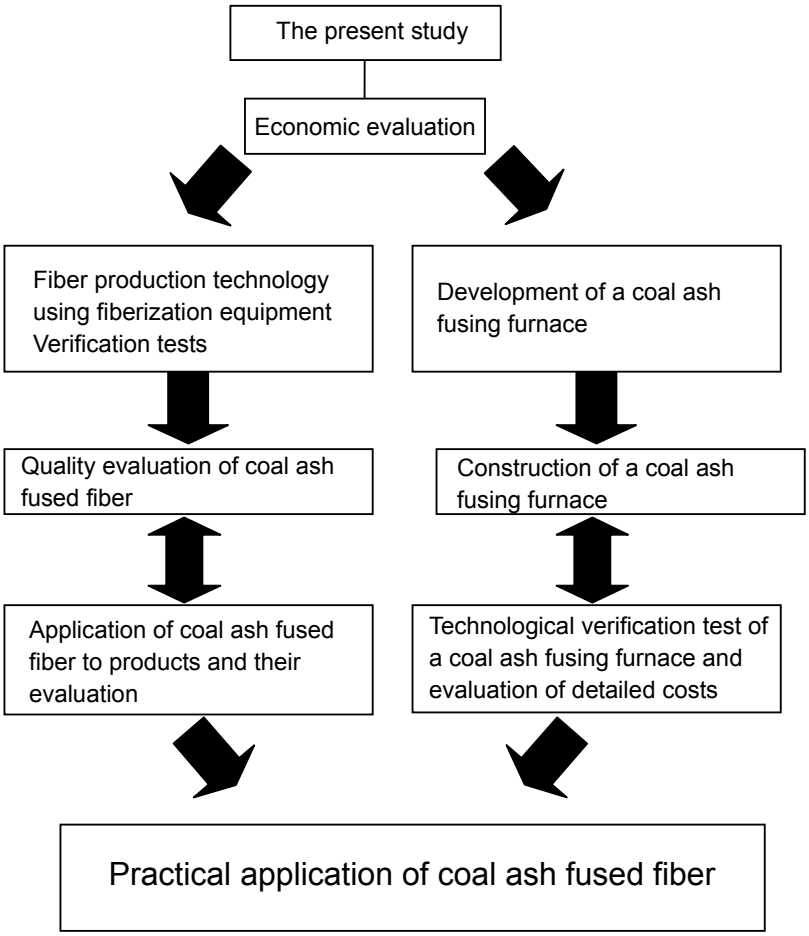

Fig. 6 Flow for the practical application of the coal ash fusing system

CONCLUSIONS

The following conclusions were drawn from the current study.

(1) Concerning the coal ash fusing and fiberization system which produces fibers from fused coal ash, it was found that use of the circular combustion type fusing furnace is advantageous in terms of economy. Also, it is possible to build a system that can improve heat efficiency if designed to return exhaust gas to an existing thermal power plant.

(2) It was confirmed that production control becomes easy if the blowing method which uses high pressure air is adopted for the fiberization process of the inorganic fiber production system using coal ash fusion.

(3) The fiber which is produced by adding CaCO3 has an average diameter of approximately 3μm. The chemical composition of this fiber is approximately SiO2 45%, Al2O3 20%, and CaO 30%.

(4) The fiber which was produced as a test product has an excellent thermal resistance, nearly equivalent to that of a ceramic fiber.

(5) It was found that coal ash fused fiber has a potentiality to become economically competitive in the present short fiber market in Japan, keeping abreast of rock wool and glass wool.

REFERENCES

[1] Ishiga,T.,Ishikawa,Y.,Morihara,A.,Kawano,K.,Horiuchi,S.,Shimizu,K.：Coal Ash Fusing System for Pulverized Coal Power Plant and Application of Coal Ach Slag for Concrete Aggregates,ACAA Symposium,2003, pp.19-1－19-10

[2] Ishikawa, Y.：Application of Coal Ash Slag for Concrete Aggregates, Advances in Waste Management & Recycling (in Dundee Univ.), 2003, pp. 611 - 620