# Preparation of Metal Filter Element for Fail Safety in IGCC Filter Unit

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## Abstract

Metal filter elements as the fail safety filter are fabricated by the methods using cold isostatic pressure (compress method) and binder (binder method) to form the filter element and tested in a experimental and bench units. The fail safety filter on the filtration system is mounted additionally in order to intercept the particle leak when the main filter element is broken. So it should have two contrary functions of a high permeability and being plugged easily. The filter element having high porosity and high plugging property was fabricated by the bind method. It has the porosity more than 50%, showed very small pressure drop less than 10mm$H_2O$ at the face velocity of 0.15m/s, and plugged within 5 minutes with the inhibition of the particle leak larger than 4μm.
The test result of corrosion tendency in IGCC gas stream at 500 °C shows SUS310L material is very reasonable among SUS310, SUS316, Inconel 600, and Hastelloy X.

**Key words:** Fail safety filter, Metal Filter element, Corrosion, Filter performance

## Introduction

The filtering using the filter elements of ceramics and metals has been the most effective and prominent method to remove particles in the advanced power generation processes like IGCC (Integrated Gasification Combined Cycle) and PFBC (Pressurized Fluidized Bed Combustion) (Mitchell, 1997; Serville et al., 1996). However, the profound problem in the utilization of filter unit at high temperature and high pressure is the vital particulate leak into gas turbine when filter element is broken. So much of the reliability of the advanced gasification and combustion system depends on the elimination of the potential problems from the dust removal system. There have been many efforts to improve the filter element (Eggersheidt and Zievers, 1999; Westheide et al., 1999; Spain and Starrett, 1999; Jha et al., 1999) and filter design (Isaksson, 1999; Chalupnick et al., 1999; Davidson et al., 1999) technologies in order to overcome the potential problems. Recently, PALL co. introduced a reliable system using a fail safety filter element mounted on the top position of the main filter element in order to block the particles leak in the case of the damage of the main filter element. In this case, the fail safety filter element has to satisfy the contrary property to keep the lowest pressure drop in order to save the space of filter unit and the high filtration efficiency simultaneously in order to protect the gas turbine. The filter element of larger pore size will reduce the pressure drop but increase the particle leak or prolong the plugging time. So it is important to prepare the fail safety filter element that is easily plugged by fine particles with large pore size. And the fail safety filter element has to be free from the damages due to the chemical and mechanical impacts, especially due to the reaction with IGCC gas like $H_2S$ and steam.

The aim of this study is to develop the fabrication method of the metal filter element suitable for the fail safety functions and to select the proper metal material.

## 1. Preparation of metal filter element

The metal filter elements were fabricated by two methods, the cold isostatic press (compress method) and the using binder (binder method), to form the filter element. In the compress method, the metal powder was formed in the molder for cylindrical type (OD 0.06m) of filter element and compressed in the isostatic unit of 1,000, 1,500, and 2,000bar for 200 seconds, respectively. The metal powder was filled in the space between the concentric molder of pipe type. The materials of pipes are Steel and Teflon for inner and outer pipe, respectively. So the filter element is compressed by the deforming of Teflon pipe when the pressure is applied. In the binder method, the mixture of metal powder and metal binder solved in the water solution of poly vinyl alcohol was formed as the same type and size of filter element by the compress method. The formed metal filter elements were sintered in the vacuum oven of 1,100 to 1,300 ℃ for 1 or 2 hrs. The vacuum chamber was kept in $2\times 10^{-4}$torr after be washed with Ar gas. Temperature of the sintering oven was increased at the rate of 10℃/min from room temperature and kept for 1 or 2 hrs and then decreased naturally to room temperature during about 3 hrs. SUS310L (particle sizes of 53-63, 63-120, and 120-180μm) and SUS316L (particle sizes of 120-180, 250-420, 420-600, and 600-840μm) were used as the filter materials. The filter elements were denominated like C0L53-63/2 [indicating compress method (C), SUS310L (0L), powder size in μm (53-63), and thickness in mm (2.5)] and B6L600-840/5 [indicating bind method (B), SUS316L (6L), powder size in μm (600-840), and thickness in mm (5)]. The binder metal composes of the elements of Ni, $Ni_6Cr_6Si_7$, and $BNi_2$ and particle size less than 5μm. And the element composition is 10.67, 19.04, and 70.29% for Si, Cr, and Ni, respectively, according to the analysis using EDS.

## 2. Performance of metal filter element

Fig. 1 is the experimental unit for the test of metal filter element. The filter element mounted in the test unit was exposed in the selected dust stream in order to be measured the pressure drop and dust leak across that. Particle size in the test column and filter outlet was measured on site by a aerodynamic particle counter (API AEROSIZER). The fly ash used for the dust stream was collected in the 3rd electric precipitator of a conventional coal power plant and classified in the fluidized bed column using dry air at room temperature. About $0.001m^3$ of fly ash was filled initially and blew out at a given superficial velocity. So the particles having the settling velocity smaller than the superficial velocity are blowed out from the bed. A part of this outlet stream was chosen as the particle stream.

Fig. 2 shows the hardness change, denoting the strength, of SUS310L metal filter element (C0L100-/2.5) fabricated in the thickness of 2.5mm with SUS310L powder under 100μm and sintered at 1,100 or 1,200 ℃. The strength increases almost linearly with the formation pressure. And the hardness change is more sensitive in pressure than in the sintering temperature. The porosity of the filter element decreased with the formation pressure but showed the slight high value at the compression pressure of 2,000bar as shown at Fig.3. The filter element denoted in Fig.3 was prepared by sintering at 1,200℃ for 1 hr. This result implies the metal powder compressed at high pressure is sintered easily and leads to the particle growth because of the high contact area. However, pressure drop across the filter element formed at high pressure of 2,000bar was higher than that of one formed at 1,500bar as shown at Fig.4. So the result implies that the large pores formed at the high compression pressure process are apt to be closed during the sintering process.

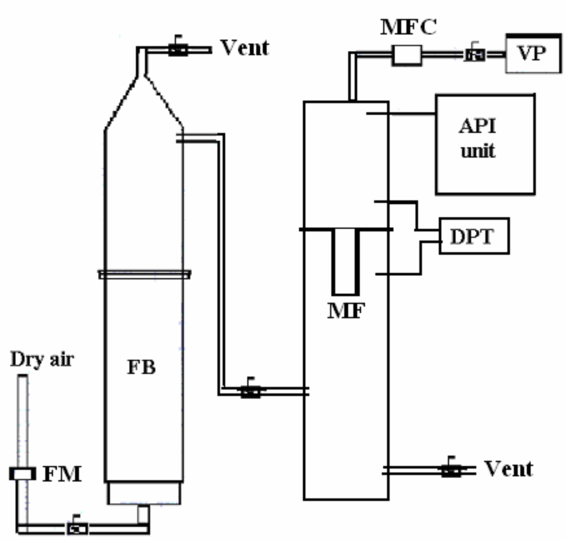



Fig. 1. Test unit for the fail safety filter performance: Differential pressure transmitter (DPT), Fluidized bed (FB), Flow meter (FM), Metal filter element (MF), Mass flow controller (MFC).

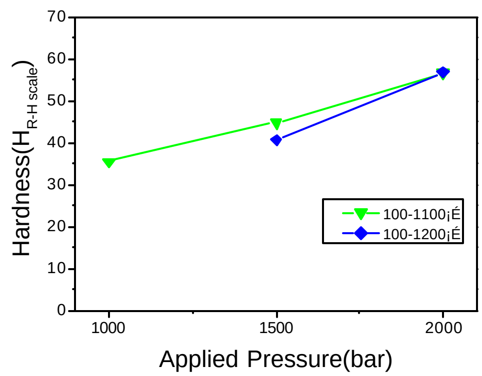



Fig. 2. Dependence of CIP pressure on the hardness of filter element.

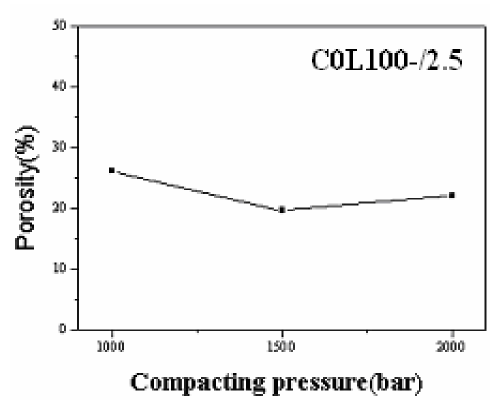



Fig. 3. Porosity change of filter element with CIP pressure.

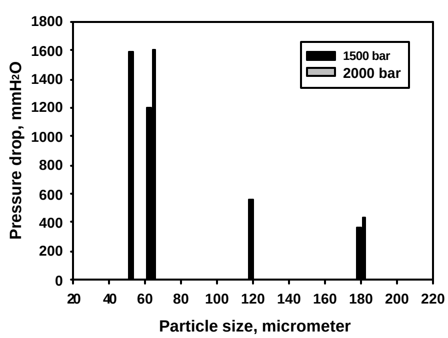



Fig. 4. Powder size effect on the pressure across the filter media.

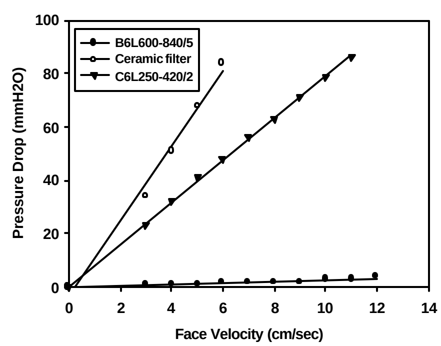



Fig. 5. The pressure drop across the Drop filter fabricated in the different method.

As shown at Fig.4, the pressure drops across the metal filter element fabricated by the compress method are very high. In order to reduce the pressure drop, the size of material powder should be larger, however, there is limit in the reduce of powder size because it is difficult to form the filter element with the large particles by the pressing force. The maximum allowable particle size was under 420㎛ in the case that the CIP pressure of 1,500 bar in the study.

In order to prepare filter element of high porosity, the binder method was applied, in which, the binder of small size and low melting point formed the neck in order to combine the large particle of filter material to form the large pore. Fig.5 shows filter element (B6L600-840/5) fabricated with the particle size of 600-840μm reveals very low pressure drop. Its average pore size and porosity are 200μm and 50%, respectively, and presents the pressure drop of 10 $mmH_2O$ at the face velocity of 0.15 m/s. The permeability of this filter element is very high compared to that of commercial ceramic filter element of 50 $mmH_2O$ at 0.04 m/s. This result implies that it is possible to reduce the length of the fail safety filter element to less than 0.3m which is one fifth of the main filter element of 1.5m with the reasonable additional pressure drop.

The metal filter element of the length of 0.3m was mounted in a hot bench unit using three filter elements of commercial size of 1.5m and tested the pressure drop and plugging behavior at 450 ℃ using an oil burning gas containing the IGCC fly ash. The additional pressure drop of 30 $mmH_2O$ was developed compared to the case of without the safety filter element. The fail safety filter was remarkably plugged within 5 minutes with the pressure drop increase of 100 $mmH_2O$ as shown at Fig.6. And the maximum size of slip particle was less than 3μm within 5 minutes after sudden expose of the dust stream across the filter element. So the result indicates there are much potential for the metal filter element fabrication with large particle size using the bind method. However, there remain further tasks to study in terms of strength and durability in the corrosion by the IGCC gas at high temperature.

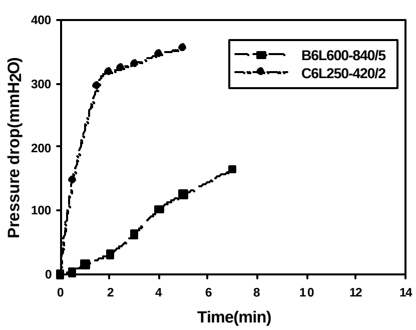



Fig. 6. Pressure drop across the metal filters in the dust stream.

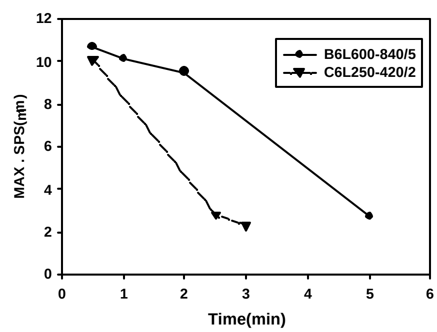



Fig. 7. The maximum particle slip size in the clean side of filter.

## 4. Corrosion test of metal filter elements

The corrosion tendency of corrosion-resistant alloys was evaluated to select the alloy suitable for the safety metal filter element in the IGCC system. The alloy specimens tested in the study were SUS310L, SUS316L, Inconel600, and Hastelloy X. All the specimens were exposed in the isothermal temperature of 500 ℃ with IGCC gas or synthesis gas involved $H_2S$ in a tubular test oven and cyclically investigated every 8hr during 80hr. IGCC gas from a pilot plant of IAE (Institute for Advanced Engineering) composed of CO 58%, $H_2$ 29%, $CO_2$ 10%, and $H_2S$ 500ppm in dry based. Corrosion products on the surface were measured in mass gain and identified by X-ray diffraction (XRD) and scanning electron microscope (SEM). Fe-based high chrome alloy, SUS310L and Ni-based high chrome alloy, Hastelloy X showed good corrosion resistance up to 600 ℃ in the and $H_2S$ concentration of 1.7%. The corrosion rate increased linearly with the concentration of $H_2S$ in the range of 0.3 to 4.99% $H_2S$. The corrosion rates for SUS310 and Hastelloy X were 237 and 660mg/dm$^2$day, respectively, in the $H_2S$ concentration of 4.99% at 500 ℃. The corrosion rate for SUS310, SUS316, Inconel600, and Hastelloy X were 45, 110, 576, and 140 mg/dm$^2$day, respectively, in the IGCC gas of 500℃. Fig.8 shows SUS310 was the best corrosion resistance material among those tested. This result agrees with report, by Jha et al. [1999], that 310 Stainless Steel showed highest sulfidizing resistance temperature of 500 ℃ while the other metal element showed the temperature below 350 ℃. The main corrosion products on the surface were identified as (Fe, Ni) sulphides with XRD analysis. Fig.9 also presents the result the sulfur product mass gain of SUS310 is also lest in the synthesis gas containing $CO_2$ and water. Fig.10 shows the SEM images and the elemental compositions of the metal filter element B6L600-840/5. The sulfur compounds was highly concentrated in the grain boundary of the filter element. So it is suspected that the binder is more suspected in the attack by sulfur corrosion than the SUS310 materials. So the further study is required for the durability test of the filter element prepared by the bind method.

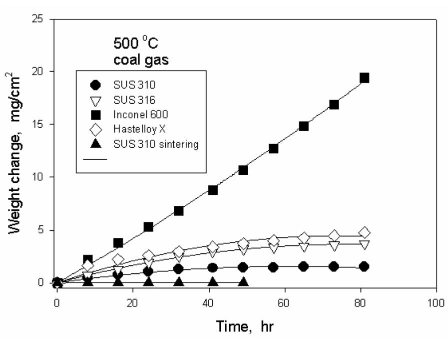



Fig. 8. Mass gain of metal surface in IGCC gas.

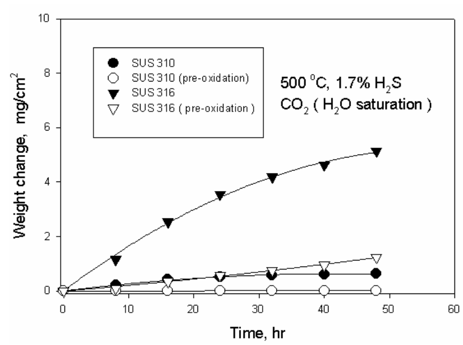
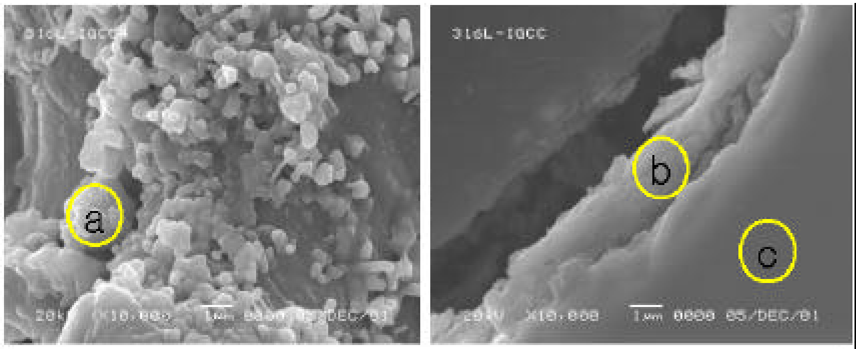



Fig. 9. Mass gain of metal in synthesis gas.

## 5. Conclusions

In order to prepare the metal filter element for the fail safety of IGCC filtration system, the fabrication method of the filter element having high porosity and high plugging property was developed. The filter element of porosity of more than 50% was prepared by the binder method and showed very low pressure drop less than 10mm$H_2O$. It was plugged within 5 minutes with the leak of the maximum particle size less than 4μm. The result of corrosion test in IGCC gas of 500 ℃ showed SUS310L was a reasonable corrosion-resistance material for the fail safety filter element of IGCC gas cleaning. The corrosion rate of SUS310 was 45 mg/dm $^2$day in the IGCC gas of 500 ℃.




| Element (w/o) | O | Si | S | Cr | Fe | Ni | C | Cu |
|---|---|---|---|---|---|---|---|---|
| Initial surface | 2.1 | 4.26 | - | 18.1 | 40.8 | 34.8 | - | - |
| Surface | 5.9 | 2.3 | 7.8 | 11.1 | 27.4 | 20.5 | 22.1 | 2.4 |
| a | 2.8 | 2.5 | 4.6 | 12.1 | 31.5 | 19.8 | 13.8 | 10.2 |
| b | 3.4 | 1.8 | 0.6 | 14.4 | 34.5 | 27.9 | 16.7 | - |
| C | - | 4.3 | - | 18.3 | 36.3 | 41.1 | - | - |

Fig. 10. SEM images of the SUS316 filter element (B6L600-840/5) corroded by $H_2S$.

## ACKNOWLEDGMENTS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