PRESSURIZED STEAM AGING PROCESS FOR STEEL SLAG

BY

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SYNOPSIS:

Steel slag has hydraulic property and becomes rigid; it is useful for roadbed material. On the other hand, unprocessed steel slag generally includes unmelted quicklime (CaO). CaO expands when it reacts with water. The unprocessed slag is not used for an industrial product immediately.

Steel slag needs aging treatment before used as roadbed material. Through aging, steel slag certainly hydrates with water and then it finishes expansion completely. A primal aging stores steel slag under natural atmosphere at open yard for two years. An open yard steam aging accelerates reaction but it still needs a few days. Anyway, both need a longer process time, a wider yard and manpower.

Sumitomo Metals has developed pressurized steam aging process; it can reduce the conventional aging time dramatically. This process carries out hydration under pressurized steamy atmosphere, it increases reaction speed 24 times higher than that of the open yard steam aging and shortens aging time to only two hours. Equipment of this process needs a small installation space. Because of the fully automatic process, it reduces labor cost and energy consumption. The most remarkable merit is enhancing stability of product quality by uniform reaction. This process has been operated stably for more than ten years at Wakayama steelworks.

Keywords: Pressurised Steam Aging, Steel Slag, CaO, Roadbed, Shorten Aging Time, High Temperature, Small Space, Improve Labor and Energy Consumption, Uniform Quality

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1. Introduction

Steel slag, which is generated when molten iron is refined, has hydraulic property and becomes rigid; it is widely used for road construction material like roadbed. Steel slag roadbed makes road so hard that grooving is prevented. It realizes smooth driving and contributes for reducing repair cost.

On the other hand, unprocessed steel slag generally includes unmelted quicklime (CaO). CaO expands when it hydrates with water. The unprocessed slag is not used for an industrial product immediately. Steel slag needs aging treatment before used as roadbed material. Through aging, steel slag certainly reacts with water and then it finishes expansion completely. Sumitomo Metals has developed pressurized steam aging process; it can reduce the conventional aging time dramatically.

The procedure and its property will be described in the following.

2. What is hydrate reaction?

Steel slag is generated when molten iron is refined. Therefore, it is common that unprocessed steel slag includes unmelted quicklime (CaO). CaO expands when it reacts with water by hydrate reaction (Fig. 1). The unprocessed steel slag is required to react with water or steam and finishes expansion completely through aging treatment before utilizing for industrial material.

![Fig. 1 CaO expansion by hydrate reaction](image)
3. Production condition at Wakayama steelworks

At Wakayama steelworks, annual crude steel is about four million ton/year. Steel slag generation is around 450,000 ton/year. In this slag, 40% is recycled in steelworks, 30% is used as civil engineering and other 30% is used as roadbed material (Fig. 2).

![Fig. 2 Steel slag utilization at Wakayama (2009)](image)

4. Conventional method and problem

The most primal aging is only storing steel slag at outside. Moisture from rain gradually reacts with unmelted quicklime but reaction time is extremely long, i.e., about two years. Hot water dipping aging shorten reaction time widely but still needs one week. Recently, open yard steam aging becomes popular, but its reaction time is at least two days. Furthermore it needs large yard, which three walls are fenced with concrete walls (Fig. 3). A cover sheet is often applied and put on the slag to have uniform reaction; even sheet covering work is heavy and dangerous. But the open steam aging yard is so wide that obtaining of uniform reaction is difficult only with rough steam piping and cover sheets.

![Fig. 3 Conventional open yard steam aging](image)
5. Development method

Sumitomo Metals had studied to increase aging efficiency and found out a procedure to increase aging reaction speed dramatically. The process is aged under steamy atmosphere with high pressure and temperature. Fig. 4 shows aging reaction time change by temperature. According to saturated steam temperature increase, pressurized steam aging reaction speed increases 24 times as higher than open yard steam aging. This phenomenon had confirmed by small autoclave at laboratory base. Then it was found that aging reaction was completed within only two hours under 0.5 MPaG steamy atmosphere.

![Fig. 4 Relation between aging time and temperature](image)

6. Actual plant

In 1995, the fist pressurized steam aging process has been introduced at Wakayama steelworks. Fig. 5 shows schematic drawing of actual pressurized steam aging process. In this case, main components are one autoclave, two slag baskets and one travelling car system. The typical production amount of this one autoclave type is 12,000 ton/month.

Fig. 6 shows typical aging procedure. The brief process flow is described as follows:
- a) First of all, operator charges steel slag for a basket by power shovel. Then power on this process, the following procedures are operated automatically.
- b) After one aging treatment finished and door opened, travelling car pulls out the aged basket from autoclave and then puts the basket on a stock position.
- c) Put a new basket on the travelling car and move it in front of the autoclave, then put the basket into the autoclave.
- d) The door closes automatically and steam is injected into the clave.
- e) Increasing pressure pattern, constant aging and decreasing pressure pattern are controlled automatically by process computer.
- f) New aging cycle has started, post-aged basket is pulled on the travelling car again and moved to a discharge deck, and then aged slag is discharged automatically.
Fig. 5 Schematic diagram of pressurized steam aging process

Fig. 6 Schematic process flow of pressurized steam aging
Fig. 7 shows pressure and temperature movement during aging. In Wakayama case, constant aging time is sufficient with only 2 hours under 0.5 MPaG, even in actual process. Time to increasing pressure to 0.5 MPaG needs around 30 minutes, reducing pressure is around 15 minutes and time to exchanging the basket for next treatment is also 15 minutes. Therefore, one cycle time becomes 3 hours during sequential operation.

![Typical temperature and pressure change during aging](image)

Fig. 7 Typical temperature and pressure change during aging

Fig. 8 shows hot water immersion expansion test result after aging. To utilize steel slag for roadbed, there are several strict standards, specified by JIS (Japan Industrial Standard), to be clear before shipment. One of the strict JIS standard is hot water immersion expansion test. Steel slag is dipped in 353 K water in 6 hours a day and kept this dipping for 10 days and then expansion ratio is measured. The JIS standard of this hot water immersion expansion ratio should be under 1.5 %. The expansion ratio at Wakayama is controlled under 0.5 %.

![Hot water immersion expansion ratio after aging](image)

Fig. 8 Hot water immersion expansion ratio after aging

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*Note: The image references and the table content are not transcribed here.*
Table 2 shows comparison of performance between open steam and pressurized steam aging process. Equipment of this process needs a small installation space. Steam consumption unit is widely improved. Because of the fully automatic process, labor load is extremely reduced. The most remarkable merit is enhancing stability of product quality by uniform reaction under uniform pressurized atmosphere.

Table 2  Comparison of performance between open steam and pressurized steam aging (24,000 ton/month, two autoclaves base)

<table>
<thead>
<tr>
<th></th>
<th>Open steam aging</th>
<th>Pressurized steam aging</th>
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</thead>
<tbody>
<tr>
<td>Aging time</td>
<td>2 days</td>
<td>2 hours</td>
</tr>
<tr>
<td>Cycle time</td>
<td>1 week</td>
<td>3 hours</td>
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<tr>
<td>Process area</td>
<td>2600 m²</td>
<td>700 m²</td>
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<tr>
<td>Steam consumption</td>
<td>140-250 kg/ton</td>
<td>85 kg/ton</td>
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<tr>
<td>Labor cost</td>
<td>250 yen/t-slag</td>
<td>75 yen/t-slag</td>
</tr>
<tr>
<td>Equipment cost (Index)</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Automation</td>
<td>Impossible</td>
<td>Full automatic</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Product quality</td>
<td>Not uniform</td>
<td>Excellent, uniform</td>
</tr>
</tbody>
</table>

Pressurized steam aging process has been operated stably for more than ten years at Wakayama steelworks. Fig. 9 shows change of annual reclamation amount at Wakayama. Since the pressurized steam aging process has been introduced in 1995, reclamation amount is decreased and keeps zero for these recent years.

Fig. 9  Annual reclamation amount change
7. Conclusion

Sumitomo Metals has developed pressurized steam aging process, which can shorten aging time dramatically. Reaction speed is 24 times higher than conventional open yard steam aging and treatment time is shortened into only 2 hours. To compare the conventional process, installation space is small, both labor and energy consumption have improved. The most remarkable merit is enhancing stability of product quality by uniform reaction under uniform pressurized atmosphere. This process has been operated stably for more than ten years at Wakayama steelworks. Two autoclaves have been introduced for two another special steel companies, respectively. This process greatly contributes to realize recycling society with reducing environmental load. Therefore, this process won METI’s Director-General’s Prize of Industrial Science and Technology Policy and Environment Bureau at Clean Japan Center Resource Recycling Technology and System contest in 2007.