New Generation FF Series Ladle Slide Gate

Achieving higher performance & longer service life of Slide Plate

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Recent technological advances in steel making technology demand longer service life of various supporting process equipments for higher production efficiency and economical operation. Ladle slide gate system is one of the critical flow control equipments for casting liquid steel in the steel making process. The basic function of ladle slide gate system is to control the flow of liquid steel from ladle to tundish as shown in Figure-1 and it requires a slide gate mechanism along with other related refractory components shown in Figure-3 for its successful operation. Slide Gate Plate (SGP) is one of the critical refractory components in the slide gate refractory system for casting and metering liquid steel. It has been observed that the service life of SGP is a limiting factor for achieving higher performance in slide gate refractory system. Now it has been found that the performance of SGP is greatly dependent on the type of slide gate mechanism used to run apart from many other controlling factors like refractory quality, plant operating conditions and steel grades. So new generation slide gate system is the key to success for achieving higher service life of SGP for higher productivity and economical operation. Hence a detail report on field results has been presented to demonstrate the performance of SGP with new generation FF slide gate system against conventional Flocon and other systems. It has been found that SGP service life has increased to many fold in various steel plants with Kro FF mechanism having same refractory quality. This new FF system also ensures higher safety and reliability along with higher service life. It also helps to a great extent for making quality steel due to lesser nitrogen pick up into the system.

IFGL Refractories Limited, the flagship company of the SK Bajoria Group, has a distinct technological & business focus – Specialz Refractories for the Steel Industry. The Slide Gate Refractories Plant started in the year 1984, as a joint venture with Flodge Ltd., UK and as an exclusive Indian Licensee of Flocon Slide Gate Systems, developed by US Steel Corporation and patented worldwide by their wholly owned subsidiary USS Engineers and Consultants Inc.

Special Refractories for Steel Making

Fig. 1 : Schematic Diagram of Liquid Metal Flow During Steel Making
Now IFGL Refractories Limited has entered into a technical collaboration with Krosaki Harima Corporation, Japan for the production and supply of FF Series Ladle Slide Gates & its Refractories from concept to commissioning.

**Fig. 2 : FF Series Ladle Slide Gate System Schematic View**

**Special Features of FF Series Ladle Slide Gate:**

The FF Series Ladle Slide Gate is a two plate linear, hydraulically driven gate. The gate valves are designed for small, medium and large capacity ladle. Figure-2 shows the schematic view of FF Ladle Slide Gate system and the main features of FF Series Ladle Slide Gate are as follows:

- Safety and Reliability
- Simple & Robust
- Higher Stroke Length
- Auto Face Pressure Loading
- Outboard Spring Design
- Optical Configuration
- Plate Crack Control
- Higher Face Pressure
- Lower Nitrogen Pick up
- Increased Plate Life

**FF Series Ladle Slide Gate Refractory Assembly:**

The complete refractory assembly of FF Series Ladle Slide Gate is shown in the Figure-3. Here only one piece well block and one piece upper nozzle are there unlike conventional Flocon design where two pieces well block and two pieces ladle nozzles (upper nozzle and lower nozzle) are there which are shown in Figure-4. The fixed and slider refractory plates are identical in shape and size. Steel encased Collector Nozzle is detachable and it is available in standard or customized design. Whereas in Flocon design top and bottom plates are different and collector nozzle is inbuilt with bottom plate.

**Fig. 3 : Schematic View of FF Series Ladle Slide Gate**

**Fig. 4 : Schematic View of 6300 Flocon Gate Refractroy Assembly**

**FF Slide Plate Design and Plate Configuration:**

Innovative shape design based on 3D stress modeling and finite element analysis studies is shown in Figure-5. Standard steel can has been replaced by hot steel band for crack control. Distribution of internal stress is optimized based on octagonal shape, hot banding and plate clamping, virtually eliminating the crack in stroke area. Figure-5 shows the details of plate clamping and plate configuration.

**Fig. 5 : Plate Clamping and Plate Configuration**
In the Figure-5 it has been shown that the forces are acting on the plate from the four corners resulting no cracks in the sliding longitudinal direction which is very much detrimental for SGP. It has been observed that all cracks are in oblique in nature and stroke area is free from cracks.

Auto Face Pressure Loading

Normally for conventional gate manual and hard work is required to open and close the gate. But in FF gate no special tool is required and it is free from hard and heavy work.

**Table-1: Specification of different Models.**

<table>
<thead>
<tr>
<th>Model</th>
<th>FF50</th>
<th>FF60</th>
<th>FF90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke Length (mm)</td>
<td>160</td>
<td>200</td>
<td>230</td>
</tr>
<tr>
<td>Face Pressure (KN)</td>
<td>60</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>No. of Springs</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Spring Cooling</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Table-2: Physical Dimension of Different Models.**

<table>
<thead>
<tr>
<th>Model</th>
<th>Recommended Bore Size A (mm)</th>
<th>Stroke Length B (mm)</th>
<th>C (mm)</th>
<th>D (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF50</td>
<td>50</td>
<td>160</td>
<td>245</td>
<td>630</td>
</tr>
<tr>
<td>FF60</td>
<td>70</td>
<td>200</td>
<td>419</td>
<td>700</td>
</tr>
<tr>
<td>FF90</td>
<td>100</td>
<td>230</td>
<td>446</td>
<td>724</td>
</tr>
</tbody>
</table>

FF Series Ladle Slide Gate provides much more safety compared to any other gates due to its higher stroke length and other related special features which are mentioned in the Table-2. A comparison of FF Series gate with Flocon series gate is shown in the Table-3 for basic understanding. The FF50 gate which is comparable with Flocon 4200 gate as per bore size is having 46 mm higher stroke length than Flocon 4200 gate. Similarly FF60 is having 48 mm higher stroke length than Flocon 6300 gate. So the additional stroke length provides basic safety in the operation and it also helps to take higher multiple life in the plate.

**Table-3: Comparison of FF Series and Flocon Series Gate.**

<table>
<thead>
<tr>
<th>FF Series</th>
<th>Flocon Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF50</td>
<td>50</td>
</tr>
<tr>
<td>FF60</td>
<td>70</td>
</tr>
<tr>
<td>FF90</td>
<td>100</td>
</tr>
</tbody>
</table>

**Quality Improvement in Steel**

Minimum nitrogen pick up in steel improves steel quality due to unique design of pressure distribution in the collector nozzle and mechanism tightness. Figure-8 shows the actual run graph recorded in a plant after installation of FF Gate. It has been observed that nitrogen pick up has come down drastically from 60 ppm to 20 ppm after installation of FF gate. So the FF Series gate provides additional advantage to make quality steel against competitor ladle slide gate.

**Table-4: Comparison of FF Series and Flocon Series Gate.**

<table>
<thead>
<tr>
<th>FF Series</th>
<th>Flocon Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF50</td>
<td>50</td>
</tr>
<tr>
<td>FF60</td>
<td>70</td>
</tr>
<tr>
<td>FF90</td>
<td>100</td>
</tr>
</tbody>
</table>

**Physical Dimensions of Different FF Series Models**

Physical dimensions of 3 FF models are mentioned in the Table-2. So depending on the ladle size and plant logistics model is selected for installation.

**Fig. 8: Graph of Nitrogen Pick up Run After Installation of FF Gate**

Additional Advantages in FF Series Ladle Slide Gate

Following additional advantages are provided by the above gate apart from the basic advantages mentioned above.

(1) Faster circulation of ladles
(2) Less number of ladle requirement
(3) Minimal consumables
(4) Higher spring life
(5) Lower inventory control due to higher plate life
(6) Energy saving

Quality Selection – Some Basic Guide Lines

The quality of ladle slide gate plate is selected based on many factors of steel plant and its operating conditions. Here some basic guide lines are mentioned for understanding and a specific selection can be made by judicious design.

(A) Based on Steel Chemistry

The basic refractory quality of slide plate must be compatible with steel chemistry of casting grade. Otherwise serious problem may occur any time and may lead to disaster. Here few steel grades are mentioned and corresponding refractory quality of slide plates are shown in Table-4 as a matrix. However specific selection requires many factors into consideration.

Table-4: Quality Selection Matrix Based on Steel Chemistry

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Mild Steel</th>
<th>Calcia Added Steel</th>
<th>High Mn Steel</th>
<th>High Si Steel</th>
<th>High O2 Steel</th>
<th>High O2 &amp; Mn Steel</th>
<th>Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT</td>
<td>Above 30 ppm</td>
<td>Above 0.8%</td>
<td>Above 70 ppm</td>
<td>Molten grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALU-ZIR-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ALU-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SPL-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>MAG-SPL-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>MAG-ALU-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ZIR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

(B) Based on Sliding Stroke Length

The quality of slide plate is also dependent on sliding stroke length of plate. Normally for smaller plate magnesia based plates are highly suitable but for bigger plate alumina based plates are most suitable. A matrix is shown in the Table-5 for some basic guide lines.

Table-5: Quality Selection Based on Sliding Stroke Length

<table>
<thead>
<tr>
<th>QUALITY</th>
<th>&gt;200 mm</th>
<th>150-200 mm</th>
<th>&lt;150 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALU-ZIR-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ALU-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SPL-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>MAG-SPL-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>MAG-ALU-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ZIR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

(D) Based on Calcium ppm in Steel

Calcium concentration in the steel plays an important role for the selection of slide plate quality and a basic guide line is shown in Table-7 just for understanding. However specific design can be made with proper understanding and judicious consideration.

Table-7: Quality Selection Based on Calcium ppm in Steel

<table>
<thead>
<tr>
<th>QUALITY</th>
<th>&lt;10 ppm</th>
<th>10 - 20 ppm</th>
<th>20 - 30 ppm</th>
<th>&gt;30 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALU-ZIR-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ALU-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SPL-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>MAG-SPL-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>MAG-ALU-C</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ZIR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Technical Specification of Different Quality Slide Gate Plate

IFGL Refractories Limited is manufacturing complete range of slide plate quality for meeting the requirement of steel plant for casting any steel grade. Following qualities of slide plate are manufactured in the plant.

(1) Alumina-carbon
(2) Alumina-Zirconia-Carbon
(3) Magnesia-Carbon
(4) Magnesia-Alumina-Carbon
(5) Magnesia-Spinel-Carbon
(6) Spinel-Carbon
(7) Zirconia Insert for specific requirement

Technical specification of different brands of slide plates are shown in Table-8 and Table-9.
Table-8: Technical Data for Different Quality Slide Plate

<table>
<thead>
<tr>
<th></th>
<th>AC-34</th>
<th>AC-30</th>
<th>AC-40</th>
<th>AZC-400</th>
<th>AZC-480</th>
<th>AZC-450</th>
<th>AZC-485</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEMICAL ANALYSIS(Wt.%)</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
</tr>
<tr>
<td>Al2O3</td>
<td>93.00</td>
<td>86.00</td>
<td>75.00</td>
<td>82.00</td>
<td>75.00</td>
<td>75.00</td>
<td>75.00</td>
</tr>
<tr>
<td>SiO2</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>4.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
</tr>
<tr>
<td>MgO</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
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<tr>
<td>PHYSICAL PROPERTIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk Density (g/cc)</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Apparent Porosity(%)</td>
<td>3.00</td>
<td>4.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>CCS (Kg/m2)</td>
<td>3500</td>
<td>3500</td>
<td>3500</td>
<td>3500</td>
<td>3500</td>
<td>3500</td>
<td>3500</td>
</tr>
</tbody>
</table>

Table-9: Technical Data for Different Quality Slide Plate

<table>
<thead>
<tr>
<th></th>
<th>MC-15</th>
<th>MC-16</th>
<th>MC-30</th>
<th>MSC-40</th>
<th>MSC-42</th>
<th>MSC-43</th>
<th>SPC-40</th>
<th>SPC-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEMICAL ANALYSIS(Wt.%)</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
<td>Typical Value</td>
</tr>
<tr>
<td>Al2O3</td>
<td>18.00</td>
<td>18.00</td>
<td>18.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
</tr>
<tr>
<td>SiO2</td>
<td>3.00</td>
<td>4.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>MgO</td>
<td>76.00</td>
<td>75.00</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Residual Carbon</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
</tr>
<tr>
<td>PHYSICAL PROPERTIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk Density (g/cc)</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
</tr>
<tr>
<td>Apparent Porosity(%)</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>CCS (Kg/m2)</td>
<td>1750</td>
<td>1750</td>
<td>1750</td>
<td>1750</td>
<td>1750</td>
<td>1750</td>
<td>1750</td>
<td>1750</td>
</tr>
</tbody>
</table>

State of the Art Production Facilities for Slide Gate Refractories

IFGL is producing complete range of slide gate refractories based on the knowledge and technical know-how of Harima Corporation, Japan. A state of the art production facilities are installed to manufacture superior quality new generation slide gate refractories for higher performance. Main focus is to maintain quality and consistency of the products and accordingly all necessary equipments are set up to control the quality. High intensity Eirich Mixer, 2000 Ton SACMI Hydraulic Press and 630 Ton Laeis Hydraulic Press are some of them installed as a part of our state of the art production facilities.

(B) FF90 Gate Under Operation

FF90 gate was installed in Plant-D having ladle capacity of 320 Ton. Two FF90 gates were working simultaneously in the same ladle for ingot casting. Average plate life is achieved 5.25 heats with a maximum of 6 heats against 1 heat of existing Metacon CS-80 gate which is shown in Table-11.
The bore of the plate is also perfectly circular and edges of bore is very sharp.

Fig.13 : FF90 Plate After 5 heats with AZC-850 quality at Plant-D

(C) FF60 Gate Under Operation

FF60 gate was installed in Plant-A having ladle capacity of 150 Ton. It’s a single strand slab caster having casting duration of around 60 minutes. Average plate life is achieved 5.42 heats with a maximum of 7 heats against average 2.5 heats of existing Flocon 6300 gate which is shown in Table-12.

Table-11: FF90 ladle Slide Gate Performance

<table>
<thead>
<tr>
<th>Plant</th>
<th>Plant-D Model</th>
<th>Plant-E Model</th>
<th>Plant-F Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>FF90</td>
<td>Existing Flocon 6300</td>
<td>Existing Flocon 6300</td>
</tr>
<tr>
<td>Average Plate Life Heats</td>
<td>5.5</td>
<td>1</td>
<td>6.35</td>
</tr>
<tr>
<td>Maximum Plate Life Achieved in Heats</td>
<td>6</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

(E) Performance of FF60 Gate Against Existing Gates

Performance summary of FF60 gate at 3 different plants are shown in Table-12 against its existing conventional gate. It has been established that FF60 plate installed in FF60 gate is performing much better compared to existing one.

Table-12: FF90 Ladle Slide Gate Performance

<table>
<thead>
<tr>
<th>Plant</th>
<th>Plant-A Model</th>
<th>Plant-B Model</th>
<th>Plant-C Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>FF60</td>
<td>Existing Flocon 6300</td>
<td>FF60</td>
</tr>
<tr>
<td>Average Plate Life Heats</td>
<td>5.42</td>
<td>2.25</td>
<td>3.5</td>
</tr>
<tr>
<td>Maximum Plate Life Achieved in Heats</td>
<td>7</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Summary

From the above series of successful plant trial results of FF90 and FF60 ladle slide gate following conclusion can be drawn.

(1) The FF slide plate installed in new generation FF Series Ladle Slide Gate is performing much better than existing conventional plate.
(2) FF Series Gate definitely helps for making quality steel due to lesser nitrogen pick up in steel.
(3) New FF gate provides better safety and reliability in the operation due to its inherent design.
(4) Higher stroke length enables to take multiple heats in the plate with greater safety margin.
(5) Higher multiple heats makes the system economical.
(6) Finally new generation FF series ladle slide gate is the key to success for achieving higher performance in slide plate.