# Benchmarking for Process Improvement of Steel-Making at Bokaro Steel Plant

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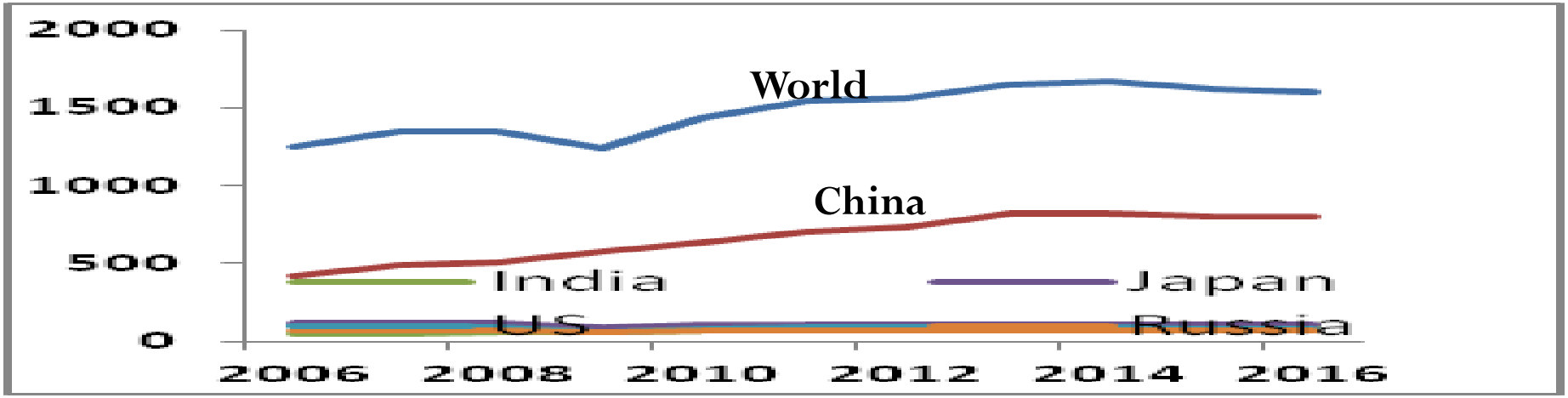
# Indian steel Industry Scenario

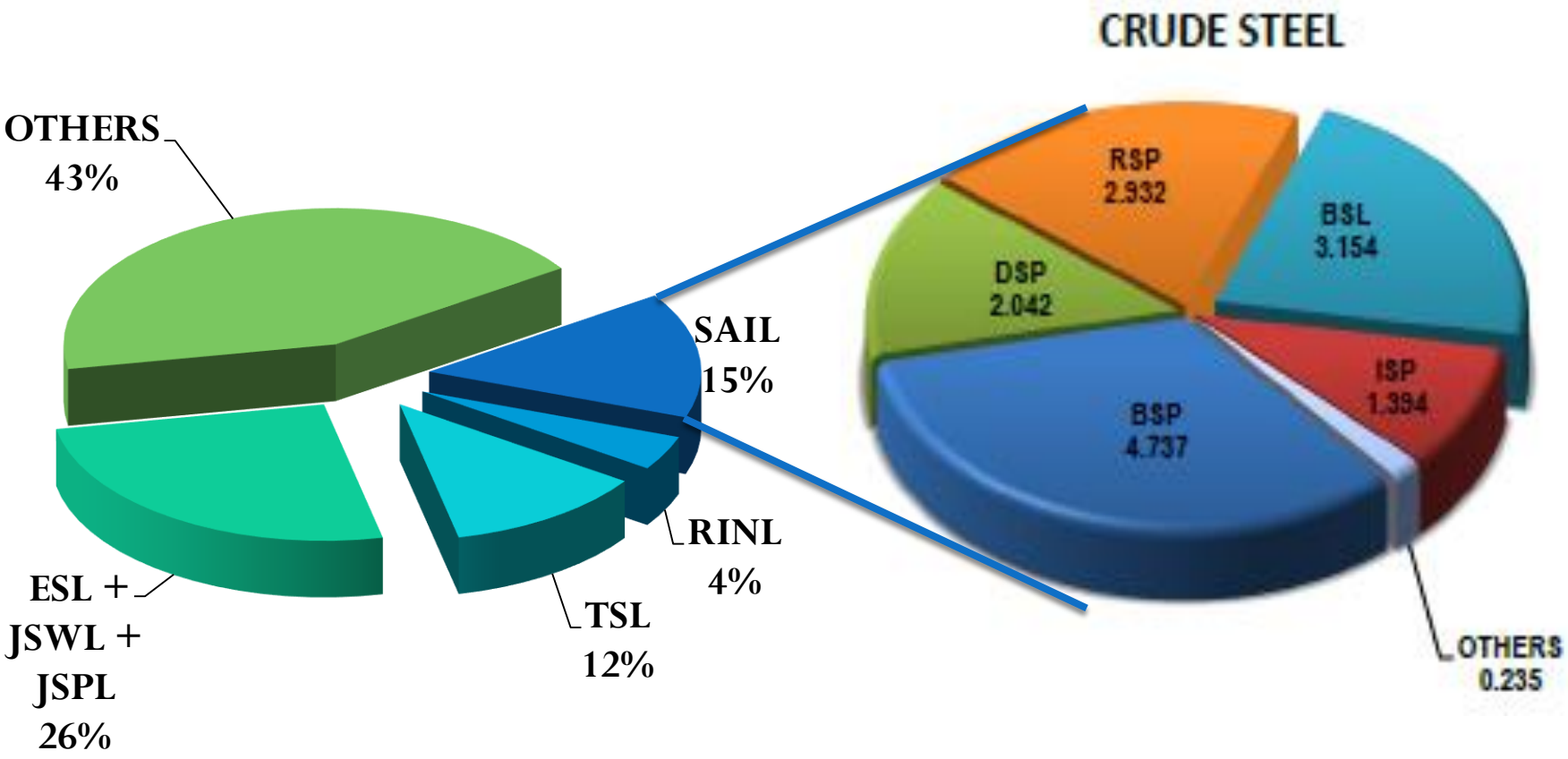
# Indian Steel Industry

- World crude steel production reached 1,630 million tonnes (Mt) for the Cal. year 2016, up by 0.8% compared to 2015.
- India is the world's 3rd largest producer of crude steel (95.6 Mt) in Cal. Yr 2016
- The country is also the 3rd largest consumer of finished steel in the world preceded by China and the USA



# Indian Steel Industry

## PERFORMANCE OF INDIAN PLANTS (2016-17) (97.3 MT)



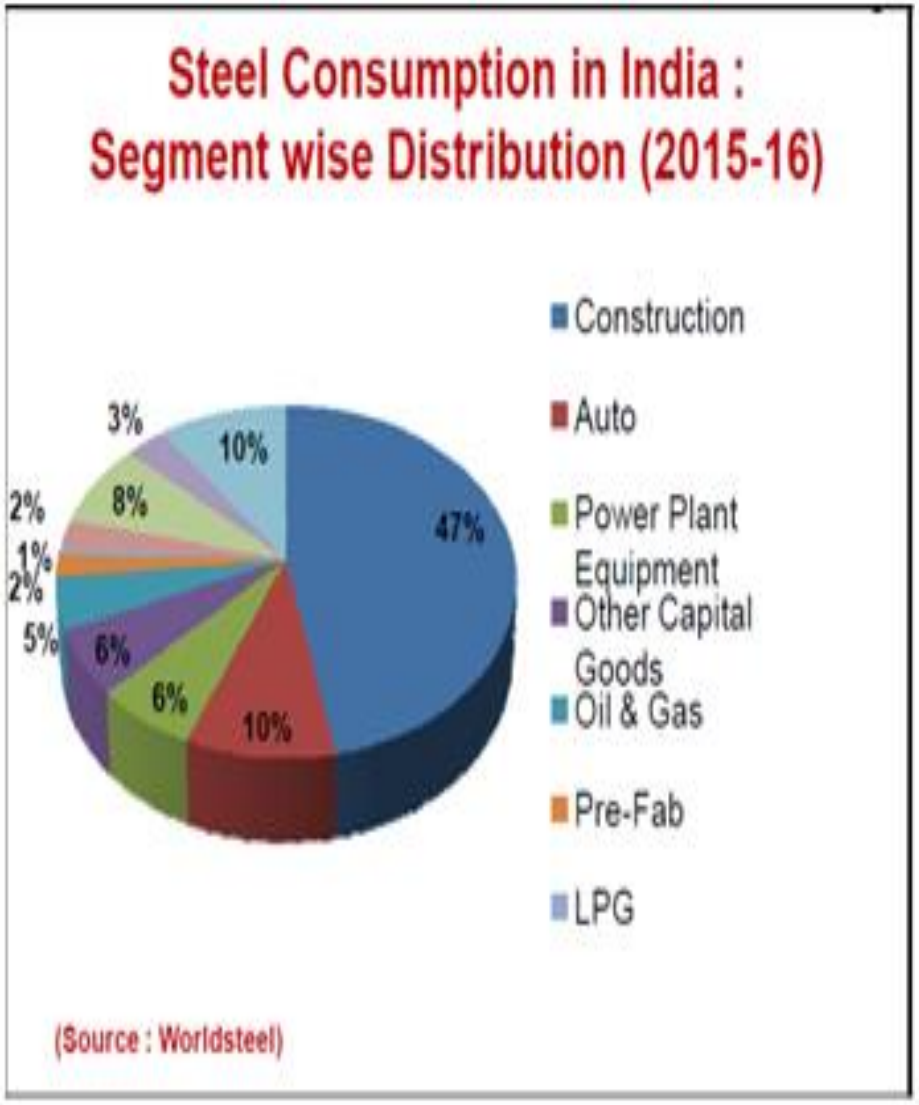

## PERFORMANCE OF SAIL PLANTS ( 2016-17 )

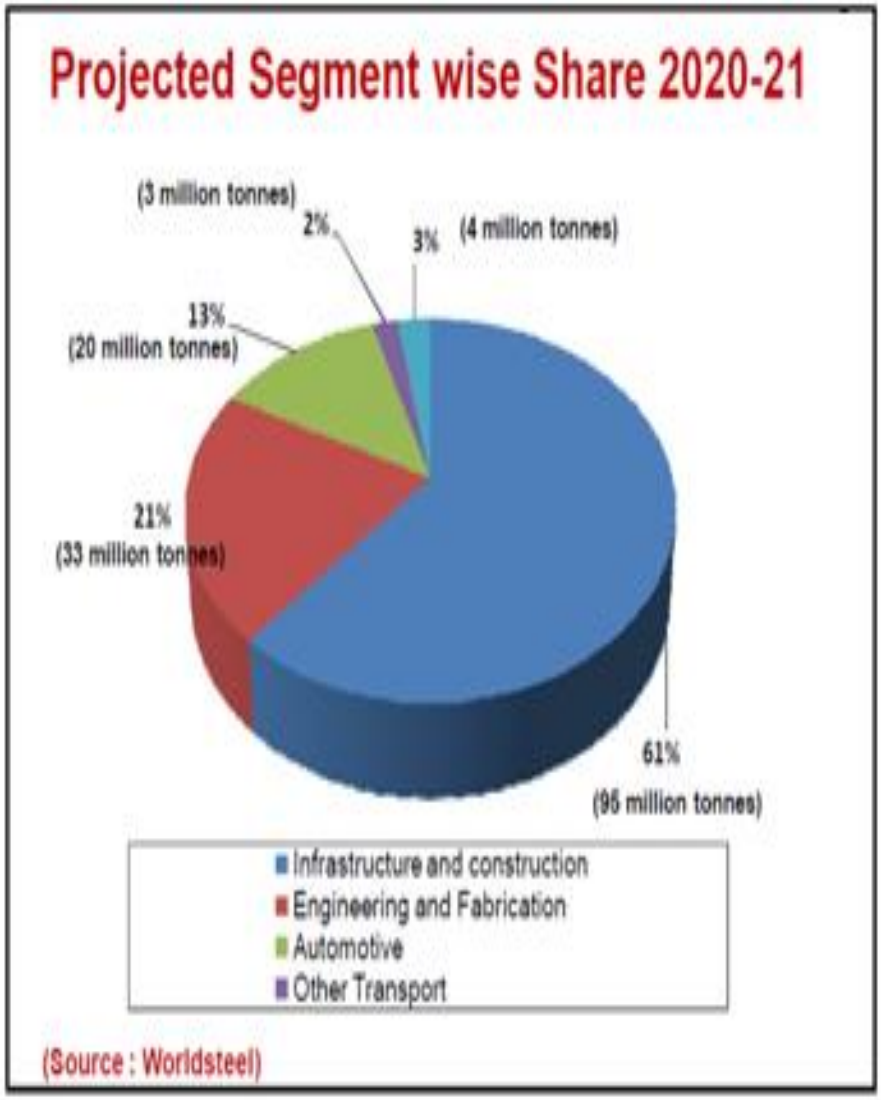
# Technologies for Production of Steel

| Rank | Country | Crude Steel Production | | | Crude Steel Production by Process | | |
|---|---|---|---|---|---|---|---|
| | | Ingot | Continuous Casting | Steel Casting | Oxygen Blown | Electric Furnace | Total |
| 1 | China | 12.4 | 795 | 1.2 | 766 | 42 | 808.4 |
| 2 | Japan | 1.3 | 103.5 | 0.32 | 81 | 24 | 104.8 |
| 3 | India | 14 | 82 | 0.025 | 41 | 55 | 95.6 |
| 4 | US | 0.5 | 78 | 0 | 26 | 52.5 | 78.5 |
| 5 | Russia | 11.5 | 58 | 1.4 | 47.3 | 21.8 | 70.8 |
| World | | 60 | 1564 | 4.0 | 1210 | 412 | 1630 |

**Crude Steel Production by Process ,** Source: World Steel in Figures 2017, WSA

# Segment-wise steel demand



# Focus on emerging high performance Value Added Steel products

| | |
|---|---|
| **Low Strength & High Strength Steels**<br>• Interstitial Free (IF),<br>• Bake Hardened Steel (BH) and<br>• Rephosphorised Steel (ReP)<br>**Line Pipe Steel** : API X80/100/120 PSL1/PSL2<br>**Silicon Steel**: CRNGO , CRGO<br>**Seismic Resistant Steel**<br>**Head Hardened Rail** | **Advanced High Strength Steels (AHSS)**<br>• Dual Phase (DP)<br>• TRIP<br>• Complex Phase (CP)<br>• Martensitic Steel<br>• High Manganese Steels (HMS)<br>• Twinning-Induced Plasticity Steels<br>• Maraging Steels<br>• High Strength Low Alloy Steel<br>• Ultrafine Ferrite (UFF):<br>• Ultra High Crack Arresting Steel: |

# Worldwide Process development and Technological features in Steel Making

**BOF**

- Low S/P hot metal from BF
- Minimum re-blows in BOF
- Maximization of Combined Blowing usage
- Online sampling and dynamic modelling process control
- Sub-lance system
- Pre & Post Tap Slag arrester for effective slag off in BOF while tapping
- Clean , pre-heated and soaked ladles
- On line purging with inert gas during transportation
- Use of basic and zonal lined ladles
- Arrest temp drop of 0.5 deg C /min during transportation

# Worldwide Process development and Technological features in Steel Making

## LADLE FURNACES

- Addition of synthetic slag
- Optimum arcing time
- Measured alloy addition & Moisture free addition
- Gentle ladle stirring ( high stirring energy)
- High degree of automation /Computerized dynamic process control
- Multiple porous plug in Ladle
- Ca wire Injection
- Al wire injection
- Carbon injection system
- Automatic sample , oxy-probe and temperature lance
- Modern electrode system

# Worldwide Process development and Technological features in Steel Making

## VACUUM DEGASSING

- Low level of vacuum
- Minimum slag entrapment
- Good circulation
- Less arcing ( in VAD )

# Worldwide Process development and Technological features in Steel Making

**CONTINUOUS CASTER**

- Closed casting practice
- Slag Detection System
- Improvement in Hydraulic Mould Oscillator
- Improvement in Mould Proper
- Automatic Mould Level Control System (AMLC)
- Mould Monitoring System (MMS)
- Electro Magnetic Stirring
- Electromagnetic Brake (EMBR)
- Dynamic Secondary Cooling System
- Soft Reduction & Strand Taper Control

# Steel Making & Casting Facility at Bokaro Steel Plant

# FACILITIES AT SMS-II & CCS, BSL

- 2 Nos. of Mixer – 2500T
- 2Nos. 300T Converters with combined blowing
- 2Nos. of Ladle Furnace
- 2 Nos. Twin Strand Vertical Mould Slab Caster.
  - Slab Width 950-1850 mm
  - Slab Thickness 225mm
- Slab yard with piler and slab inspection facility

# BOF Combined Blowing Practice

- FeO in conv. slag -17 TO 20%
- "P" in steel - <0.020%
- Better desulphurization: Final S <0.015 %

# Ladle Furnace Practice

- Temperature & Composition homogenisation
- Trimming addition
- Desulphurisation
- CaSi/CaFe injection for better castability & inclusions modifications.

# Continuous Casting Practice

- No naked steel stream is allowed
- Ladle Free Opening > 99 %
- Ar - shrouding at LSG nozzle/shroud and TSG nozzle/sen junctions
- $Al_2O_3$ formation & $N_2$ pick-up reduced
- $N_2$ pick up reduced from 10 - 15 ppm TO 5 ppm
- Better castability of steel
- Defect free and cleaner steel cast

# Comparative study of Major Techno-economic parameters

# Steel Making Operating Parameters
# Period: 2015-16

## Hot Metal De-Sulphurization

| Plant | BSP | RSP | ISP | TATA Steel (LD2) | JSW(SMS-II) |
|---|---|---|---|---|---|
| No. of Unit | 2 | 2 | 2 | 3 | 4+1(KR) |
| % Utilization | <1% | 1-2% | <1% | 100% | 100% |
| HM [S], % Input | 0.05 | 0.04 | 0.045 | 0.050 | 0.056 |
| Aim | 0.01 | 0.01 | 0.005 | 0.005 | 0.005, 0.001 (KR) |
| Achieved | 0.01 | 0.01 | 0.005 | 0.006 | 0.007, 0.003 (KR) |

# Steel Making Operating Parameters
# Period: 2015-16

| Sl. | Parameters | BSP SMS-II | BSL SMS-II | DSP | RSP SMS-II | ISP | JSWL SMS 1&2 | TATA Steel LD 1, 2& 3 (2014-15) | Voest Alpine Stahl, Austria (2011) | Arcelor Mittal, USA (2011) | Essar Steel Algoma Inc, Canada (2011) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No. of BOF X Capacity (t) | 3 x 130 | 2 x 300 | 3 x 130 | 3 x 150 | 2 X 150 | 3 x 130<br>4 X 175 | 2x165<br>3x160<br>2x165 | 3 x 180 | 3 x 300 | 2 x 265 |
| 2 | Average blow / day | 58.22 | 28.85 | 46.45 | 44.54 | 18.14 | 70<br>95 | 58.0<br>67.0<br>46.0 | 91.4 | 47.5 | 41.35 |
| 3 | Average blow / day / converter | 19.4 | 14.42 | 15.48 | 14.85 | 9.07 | 23.3<br>23.7 | 29.0<br>22.3<br>23.0 | 30.5 | 15.8 | 20.67 |
| 4 | Lining Life (avg)** | 8954 (avg) | 5132$ | 5988$ | 5258 | 2154 | 3761#<br>3290# | 4829<br>5141<br>4500 | - | 3000 | 10000 |

# Steel Making Operating Parameters
# Period: 2015-16

| Sl. No | Parameters | BSP SMS-II | BSL SMS-II | DSP | RSP SMS-II | ISP | JSWL SMS 1&2 | TATA Steel LD 1, 2& 3 (2014-15) | Voest Alpine Stahl, Austria (2011) | Arcelor Mittal, USA (2011) | Essar Steel Algoma Inc, Canada (2011) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Reblow (%) | 8.94 | 3.42 | 2.58 | 0.51 | 33.48 | 4.50<br>4.70 | 10.1<br>27<br>13 | | | |
| 6 | Tap to Tap Time (Min) | 59.98 | 50 | 69 | 60 | 81 | 50<br>50 | 40<br>45<br>45 | | | |
| 7 | Sp.$O_2$ Consm (Nm3/tcs) | 62.79 | 56.73 | 56.37 | 55.66 | 56.61 | | | | | |
| 8 | TMI Kg/TCS | 1142 | 1140 | 1136 | 1135 | 1150 | 1113<br>1111 | 1108<br>1126<br>1119 | 1092 | | |

# Steel Making Operating Parameters Period: 2015-16

| Parameters | RSP | BSP | BSL | DSP | TATA Steel (2014-15) | JSW |
|---|---|---|---|---|---|---|
| No. of LFs | 3X150 | 2X130 | 2X300 | 3X130 | 3X165<br>2X160<br>2X165 | 3 X135<br>4X175 |
| No. of heats / day | 44.54 | 45 | 28.85 | 42.7 | 57<br>44<br>46 | 70<br>95 |
| Heating rate, $^0$C/min. | 3-4 | 3-4 | 3-4 | 3 - 5 | 2-4<br>2.5-3.5<br>4.0 | 4 |
| Avg. LF in Temp. $^0$C | 1560-80 | 1550-1570 | 1570-1600 | 1540-60 | | |
| Sp. Electrode cons. kg/tcs | 0.29 | 0.4 | 0.12 | 0.57 | | |
| Carryover slag, kg/t | 8-10 | 6-8 | 5 – 7 | 15-16 | 4-5<br>1-1.5<br>3-4 | 2.5<br>2.2 |
| Average power consumption, kWh/ton | 36.73 | (LF-1) 16.54<br>(LF-2) 17.67 | 13.22 | 41.7 | 44.46<br>28.3<br>32.0 | 30.0<br>26.0 |
| Treatment time, minutes | 25-35 | 30-35 | 30-40 | 35-40 | 58<br>41<br>60 | 35<br>55 |

# Steel Making Operating Parameters
# Period: 2015-16

| Parameters | BSP | | BSL | RSP | | TATA Steel (2014-15) | JSW (2014-15) |
|---|---|---|---|---|---|---|---|
| | Old Caster #1,2,3 | New Caster #6 | | Old Caster #1,2 | New Caster #3 | | |
| Slab Size (mm) | 200-250 X 1300-1500 | 220 X 1100 1800 | 200/225 X 900-1850 | 220 X 950-1500 | 220-250-300 X 1200-2500 | 215x 950-1550 | 220 X 800-1300 |
| Casters | 3x1 strand | 1x1 strand | 2x2 strands | 2x1 strand | 1x1 strand | 3x1 strand | 5x1 strand |
| Casting Range Speed m/min | 0.50-1.2 | 1.0-1.4 | 1.0-1.9 | 0.8 – 1.3 | 0.8 – 2.0 | 1.0-1.7 | 1.0-1.85 |
| Avg. | 0.9 | 1.1 | 1.4 | 1.00 | 1.01 | 1.24 | 1.25 |
| Max. | 1.2 | 1.4 | 1.9 | 1.3 | 1.5 | 1.7 | 1.85 |

# Steel Making Operating Parameters
# Period: 2015-16

| Sl. No. | Parameters | | BSP | | BSL | RSP | TATA Steel (2014-15) | JSW (2014-15) |
|---|---|---|---|---|---|---|---|---|
| | | | Old Caster #1,2,3 | New Caster #6 | | | | |
| | Slab Size (mm) | | 200-250 X 1300-1500 | 220 X 1100-1800 | 225 X 900-1850 | 220 X 950-1500 (Old) 220-250-300 X 1200-2500 (New) | 215X 800-1500 | 220 X 800-1300 |
| 2 | Tundish Life | Range | | | 7-13 | 6-22** | - | - |
| | | Avg. | 5.7 | 19.9 | 10.06 | 9.11 | 14.4 | 10.73/11.33** |
| | | Max. | 12 (TTM) | 34** | 13 | 22 | 25 # | |

# Continuous Casting Operating Parameters
# Period: 2015-16

| Parameters | BSP | | BSL | RSP | DSP | | ISP | TATA Steel | | JSW | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bloom | Slab | Slab | Slab | Billet | Bloom | Billet | Slab | Billet | Slab | Billet |
| % Utilisation | 77.05 | 61.21 | 68.66 | - | 77.5 | 88.0 | 52.12 | 93.3 | 92.2 | 83.5 | 85.6 |

# Steel Ladle ( LF-CC Route), 2015-16

| Parameters | | RSP SMS-II | BSL SMS-II | DSP | RINL SMS-I |
|---|---|---|---|---|---|
| Capacity , T | | 150 | 300 | 130/110 | 150 |
| Type of lining | | MgO-C | MgO-C, AMC | MgO-C, AMC | MgO-C |
| Avg. Life (14-15), heats | | 96.57 | 104.84 | *67.32* | 85.2 |
| Avg. Life (15-16), heats | | 113.2 | 102.27 | *74.46* | 98.09 |
| Highest life till 2015-16 | | 154 (15-16) | 140 (Nov'14) | 105 | 145 |
| Sp. cons. ,kg/tcs, | 14-15 | 4.62 | 3.42 | 6.44 | 3.68 |
| | 15-16 | 4.12 | 3.43 | 6.42 | 3.14 |
| Mid Repairs S/Z , | 1st | 60 | 46-54 | 40-50 | 45-55 |
| | 2nd | 90 | 80-90 | 65-70 (occasional) | |
| W/B & S/B life | | 60 | 46-54 | 21-25 | 50-55 |
| Retainer plate life(Camp.) | | 2 | 1 | 1 | 5-6 |
| Repairs / Campaign | | 2 | 2 | 2-3 | 1 |

# Steel Ladle ( LF-CC Route), 2015-16

| Parameters | RSP, SMS-II | BSL, SMS-II | DSP | BSP, SMS-II | RINL | JSW (SMS-1) | JSW (SMS-2) | JSPL | TATA LD-II |
|---|---|---|---|---|---|---|---|---|---|
| Ladle capacity (T) | 150 | 300 | 130 / 110 | 130 | 150 | 135 | 180 | 110 | 160 |
| Avg. Life, heats, (2015-16) | 113.2 | 102.27 | 75.45 | 55.05 | 98.09 | 145(MgO-C) 200(Spinel) | 170 (Spinel) | 145 | 122 |
| No of BOF/*EAF* | 3 | 2 | 3 | 3 | 3 | 3 | 4 | *3* | 3 |
| Heats/day/ladle | 5 | 4- 5 | 4 | 4-5 | 5-6 | 6 | 7 | 3-5 | 5.5 |
| Ladles in circulation | 9-11 | 7 | 11-13 | 12-14 | 9-12 | 13 | 18+2 | 14-18 | 14 |
| Metal Holding Time (min.) | 180-240 | 120-150 | 220-250 | 135-150 210-270 | 250 | 100 | 120 | 180-210 | 150 |
| Hot Changing Porous Plug | Y | Y | Y | N | Y | Y | Y | Y | Y |
| Inner Nozzle | Y | Y | N | Y | Y | Y | Y | Y | Y |
| S/G plate life (heats) | 2 | New Gen-4.5 | 1 | New Gen-2-3 | 2-3 | 8.6 | 5.5 | 3-4 | 2-3 |
| Free opn% | 98 | 99.88 | >90 | >90 | 93-95 | 99 | 99 | >95 | 98.5 |

# Area of concern for Improvement

| | 2015-16 | Bench marking figures | 2016-17 | 2017-18 Till AUG |
|---|---|---|---|---|
| Avg blow/day | 28.85 | 46 TATA STEEL LD3 2014-15 | 29.9 | 37 |
| No. of heats/day/ converter | 14.42 | 23 TATA STEEL LD3 2014-15 | 14.45 | 18.5 |
| Avg.Tap to tap time | 50 | 40 TATA STEEL LD1 | 48 | 44 BEST 42 IN MAY17 |
| Caster % Utilisation | 68.66 | JSW 83.5 | 68.61 | 72.6 BEST MAY 17 81.7% |

# Improvement In Operational Practices in Recent at BSL

- Slag splashing after complete tapping of steel
- Use of coke & dolo chips for slag splashing
- Timely removal of body and mouth jam
- Minimising of jam build up in bottom and inside lip ring
- Reduction in reblows
- Reduction in Tap to tap time
- Increase in sleeve life by drainage of slag after every heat

# Area of concern for improvement

**BOF:**

1. Use of Iron Ore/DRI/Sinter as alternate coolant in all converters
2. Improvement in flux quality (i.e. cal. Lime & cal. Dolo) for improving slag formation
3. Improved and consistent quality of hot metal (w.r.t Si, S )
4. Control of slag FeO % to improve metallic yield, and ferroalloy / de –oxidiser recovery
5. Optimized soft blowing to improve de-phosphorization

**Slab Caster**

1. Introduction of mould coating at BSL
2. Hot tundish practice / vibro mass at BSL

# Area of concern for improvement

## The Potential Cost Reduction Areas

1. Reduction in Gross Metallic Input (GMI)
2. Improved Converter Lining Life.
3. Improved Ladle Lining Life
4. Ferro Alloy Consumption Control
5. Aluminum Consumption Control
6. Ca Cored Wire Consumption Control
7. Increased Tundish Life
8. Low superheat casting

# Conclusions

- By adopting, Good operational practices like straight blows, slag splashing, control on tapping temperature etc. yield and the quality of the prime output can be improved.
- Focus on high degree of cleanliness with ultra low S, P, & gases for production of high strength and advanced high strength steel development.

# Thank You