INNOVATED SOLUTIONS FOR AUTOMATED CHARGING AND STOKING

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ABSTRACT

Automatic Charging and Stoking Machines for use at ferroalloy furnaces are in operation for more than 20 years. Dango & Dienenthal Maschinenbau GmbH (short: DDS) has developed several machine generations. Today advanced solutions help to achieve better charging and stoking results to minimize cost and to improve the working environment around the furnaces. Three different alternatives can be considered:

Rail-mounted solution

The machine(s) travel(s) on an overhead monorail to one or several furnaces and is locked in the desired working position from where charging and stoking is performed.

Mobile solution

This machine travels on the charging platform and is also locked at the respective working position to perform charging and stoking.

Automation of a standard mobile charging and stoking machine

A standard charging and stoking machine can be adapted for automation. A reliable navigation system is included. Charging and stoking is performed with the moving machine. Advantage versus other solutions: considerable lower investment cost and possibility to upgrade the mobile charging and stoking machine for later automation.

Overall, automatic charging and stoking can save up to 10 per cent of the specific smelting energy. A better and more consistent furnace operation can be achieved. Different programs are used to cope with different furnace conditions and changing raw materials. All machine movements can be recorded and correlated to other furnace parameters. Working environment on the charging platform is greatly improved.

1. CHARGING AND STOKING OF FERROALLOY FURNACES: REQUIREMENTS: MANUAL OR AUTOMATIC?

Ferroalloys are produced in electric reduction furnaces (submerged arc furnaces). Especially silicon-based alloys are produced in open or semi-closed furnaces. Smaller and medium sized furnaces are frequently charged by machines whereas larger furnaces are charged through charging tubes. Stoking operation is required to distribute the material and to push it into the reduction zone between the electrodes. Also slag bridges and crusts must be broken to achieve a uniform gasification of the furnace for better production.

Experience has shown that the furnace should be worked at as evenly as possible. In this way gas blowers can be avoided resulting in energy savings and production increases.

Figure 1 shows furnace losses with respect to stoking works. The vertical lines show the times when the mobile charging machine is switched on. Three crews have worked the furnace in different patterns. It can be clearly seen that the lowest furnace losses occur during the period of crew 2 when the furnace was worked in

even intervals. Automatic operation removes the human element from the charging and stoking operation. No machine operators or extra personnel are required as machine supervision is carried out by the personnel in the furnace control room. All machine movements are recorded and can be correlated to other furnace parameters. Experience has shown that up to 10 % of the specific smelting energy can be saved through automatic operation. Furthermore damages to furnace vessel, hood and electrodes because of machine contact are avoided.

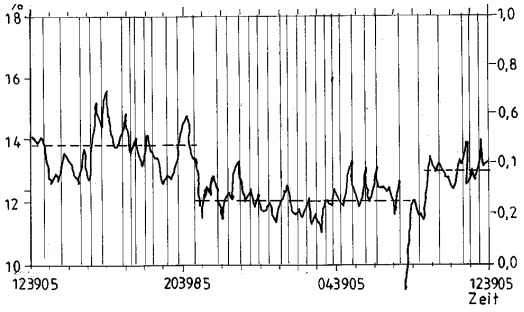

Figure 1: Furnace Losses

2. MANUAL SOLUTIONS: ADAPTED FORKLIFT TRUCK OR FRONT END LOADER OR DEDICATED CHARGING AND STOKING MACHINE?

2.1 Adapted Forklift Truck or Front End Loader

Some plants use modified forklifts or front end loaders for their charging and stoking work. These machines have significant disadvantages compared to dedicated machines:

- Obstructed view into the furnace (especially with front end loaders).
- Extended overall length.
- All auxiliary hydraulic equipment is installed in front of the machine and is therefore subject to the full furnace heat radiation.
- This kind of machine is not designed for frequent reversing operations as needed especially for stoking.

These disadvantages result in substantially higher repair and maintenance costs. Cases are known where several of these machines had to be bought in order to have one operative.

2.2 Dedicated Charging and Stoking Machine

Purpose built Charging and Stoking Machines (Figure 2) eliminate these disadvantages. They are better in performance (adapted to the process), ergonomics and maintenance requirements and costs and are good value for money. Here are some of the design features helping to achieve a better performance in a harsh working environment:

- Low operator's seat position: good view to all sides, also on tools and into the furnace (Figure 3).
- Good manoeuvrability because of small turning radius (Figure 4).

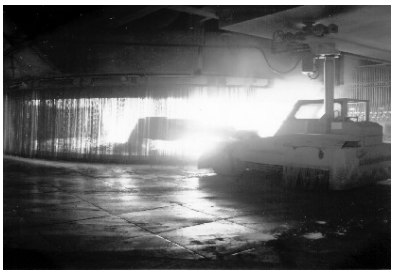

Figure 2: Charging and stoking machine at FeSi furnace

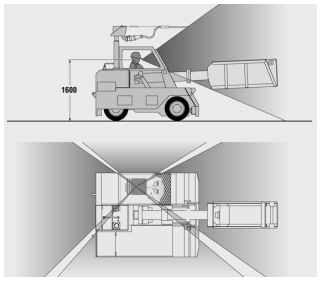

Figure 3: Operator's view

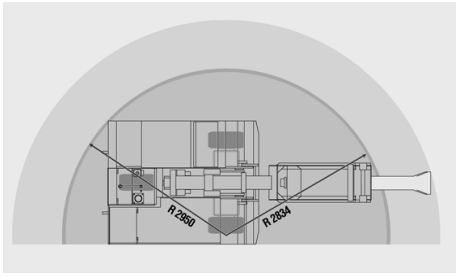

Figure 4: Turning radius

- Retractable peel arrangement: very compact machine while travelling on the charging platform, extended peel length only at the furnace where it is needed.
- Hermetically sealed hydraulic system. No atmospheric air can penetrate the system. (Figures 5 and 6). Therefore reduced maintenance costs.

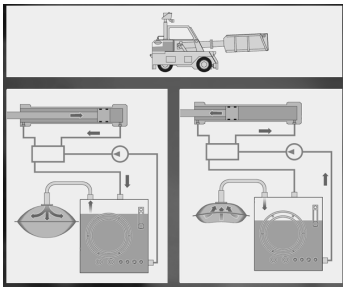

Figure 5: Hermetically sealed hydraulic system

3. AUTOMATIC SOLUTIONS

3.1 Rail-Mounted Automatic Charging and Stoking Machine (Type SKS)

As already described earlier, an automatic charging and stoking system does not only remove the operator from a very harsh and uncomfortable working environment but can also greatly improve furnace performance. In principle the same movements are carried out like with a mobile Charging and Stoking Machine: machine travel, advance/retract, swivel and tilt of the stoking tool. While the mobile operator driven machine performs the stoking operation with the moving machine also using inertia forces, the rail-mounted Automatic Charging and Stoking Machine (Figures 7 and 8) travels to the desired working position where it is locked (Figure 9).

A stoking rail with stoking trolley is swivelled into the desired position. The stoking trolley moves forward and backward on the stoking rail. A separate cylinder can also tilt box or stoking tool. In this way the same working profile is achieved like with a mobile operator driven machine.

Figure 6: Hermetically sealed hydraulic system: expansion bladder

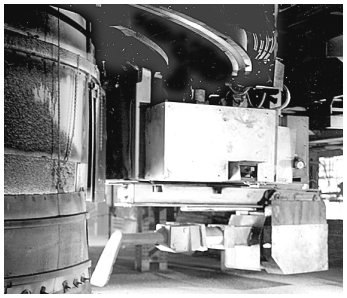

Figure 7: Rail-mounted automatic charging and stoking machines type SKS

Figure 8: Rail-mounted automatic charging and stoking machines type SKS

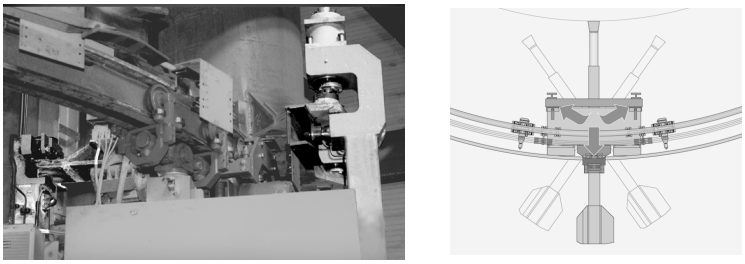

Figure 9: Locking of SKS machine

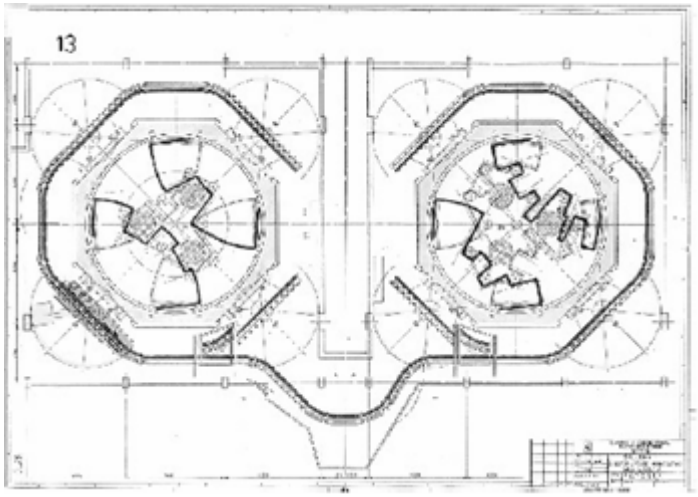

Figure 10: Working pattern of SKS machine

In addition, a special working profile is incorporated in the machine control limiting advance stroke, swivel and tilt in certain areas (Figure 10). In this way machine contact with furnace vessel, hood or electrodes is not possible. Repairs of those "secondary damages" can be very expensive and time consuming.

Hermetically sealed hydraulic system and insulation of the machine against the strong electric field at the furnace are realized with this machine in a similar way as with the mobile operator driven charging and stoking machines.

Operation of the Automatic Charging and Stoking Machine is program controlled. The responsible metallurgist decides how he wants to work his furnace. With this information, one or several operating programs are written. For each set of raw materials and a specific furnace condition a program is selected with a selector switch on the control desk. Machine control is connected with the host computer of the plant so that the implemented charging and stoking pattern can consider other desired furnace parameters.

All movements of the machine are recorded and displayed on a visualization screen in the furnace control room (Figures 11 and 12). From past experience it is therefore possible to optimise furnace operation or to duplicate a certain furnace situation of the past.

Figure 11: Control desk in the control room with TV monitoring

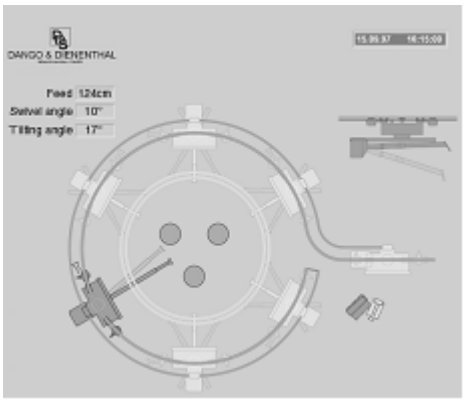

Figure 12: Visualization screen

As mentioned before, up to 10 % savings of the electric energy input per ton of ferroalloy produced could be achieved. For FeSi 75 this amounts to about 800 kWh per ton of metal.

The rail-mounted Automatic Charging and Stoking Machine travels on a monorail suspended from the floor above. The machine can travel on different radii in order to reach optimal positions at the furnace and at charging bunkers. Filling of the charging box as well as changing box against a stoking tool is automatic and does not require operator interference.

Operation of the Automatic Charging and Stoking Machine at several furnaces is also possible through a respective arrangement of the monorail. Power supply is ensured through a protected contact line parallel to the monorail of the machine. Also switches for monorail and contact line can be used. The whole concept is quite flexible and allows installation also on existing furnaces (Figures 13 and 14).

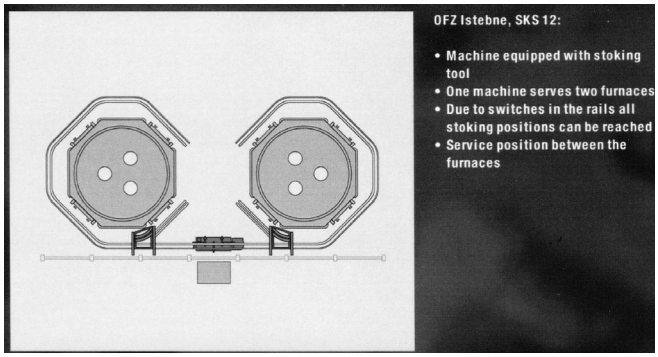

Figure 13: SKS machine serving 2 furnaces. Use of switches

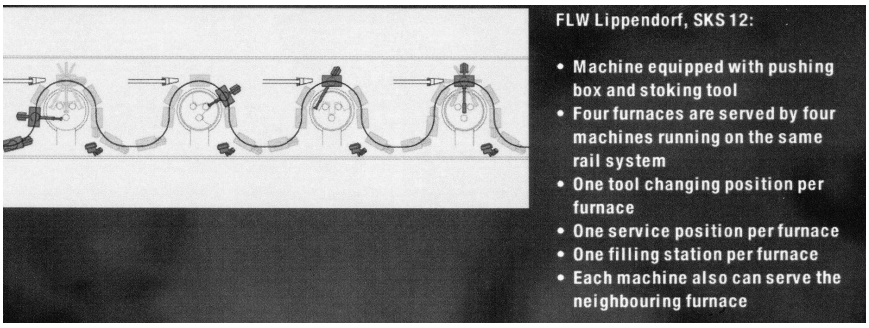

Figure 14: 4 SKS machines serving 4 furnaces

3.2 Mobile Automatic Charging and Stoking Machine (Type MAS I)

The floor above the charging floor is not always strong enough to support a rail mounted Automatic Charging and Stoking Machine including the rail structure. Therefore a mobile and driverless Automatic Charging and Stoking Machine was developed which runs on the charging platform on rubber tires. It travels to the desired working position where it is locked in the floor. Operation of this machine is identical to the rail-mounted version also conserving all advantages described before (Figures 15 and 16). Navigation is done by measuring the angles between contact line trolley and push-rod to the machine as well as between push-rod and machine axis (Figure 17). The position of the steering wheel is also measured and monitored. From the position of the contact line trolley and the angles as described above the machine position and orientation can be calculated and controlled.

As the centre line of swivel of the stoking rail is put as much towards the furnace as possible, a wide swivel angle inside the furnace is achieved with only a small door opening. The flow of secondary air into the furnace is herewith reduced as well as furnace heat radiation onto the charging platform.

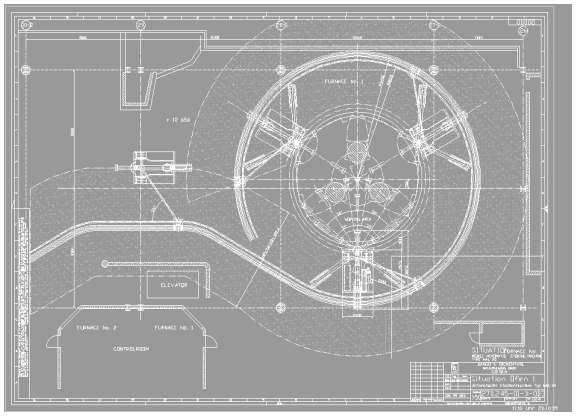

Figure 15: Mobile automatic charging and stoking machine

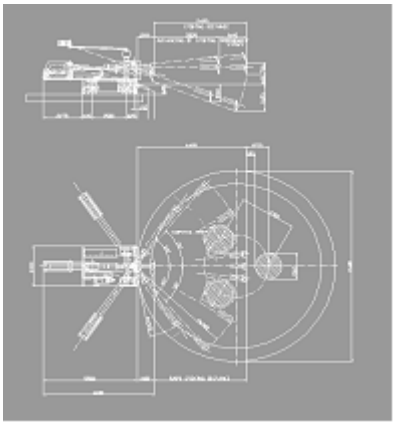

Figure 16: Mobile automatic charging and stoking machine - working pattern

Also this type of machine can work at several furnaces.

4. NEW IDEAS

4.1 Mobile Automatic Charging and Stoking Machine (Type MAS II)

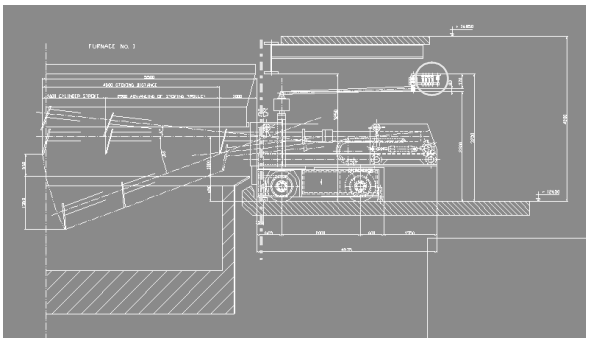

Figure 17: Mobile automatic charging and stoking machine

Both, rail-mounted and mobile Automatic Charging and Stoking Machines require high investment costs which amount to the costs of about 3 mobile Charging and Stoking Machines. In spite of the advantages of these machines resulting in a pay back between several months and 2 years (depending on personnel and power costs), it has been difficult for several plants to decide for such an investment. Therefore the idea was born to automate a mobile, operator driven Charging and Stoking Machine (Figure 18). The biggest problem here was the navigation, as stoking is not done with a stationary machine locked into position but with the moving machine. Not only the accuracy of the position of the machine was important. Especially the angle of orientation had to be correct. A slight error in this angle would lead to a much larger deviation of the tip of the stoking tool with the risk of damaging the electrodes.

Figure 18: Automated mobile and operator driven charging and stoking machine type MAS II

A laser-based system was found to solve this problem. A laser transmitter / receiver is mounted on the machine (Figure 19 and 20). Reflecting tags (Figure 21) are placed at suitable locations around the furnace. The transmitter / receiver must see several of these tags all the time. The navigation computer (Figure 22) is located on the machine. With the signals received, machine position and orientation is computed. These figures are input to the close-loop control of travel drive and steering of the machine. The required accuracy was verified in a workshop test.

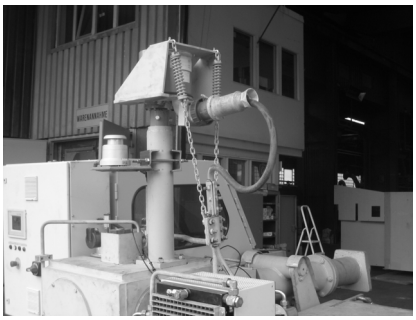

Figure 19: Laser transmitter / receiver

Figure 20: Laser transmitter / receiver

All machine drives are equipped with encoders. It is therefore possible to write a program which will carry out the desired charging and stoking functions as specified by the metallurgist. Also for this machine type, a special working profile will be established avoiding damages to electrodes, furnace or hood. Machine control will limit machine movements in the respective areas.

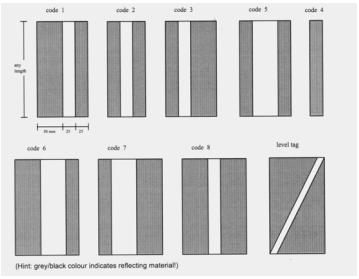

Figure 21: Reflecting Tags

The navigation system (receiver / transmitter, tags, navigation computer) was installed on a machine at a FeSi furnace. The system was not connected to the machine drives. The navigation could therefore not be activated. It was the aim of the test, however, to verify that dust, heat and electric field would not influence the system. We were quite pleased that measurements before and after the test were quite satisfactory.

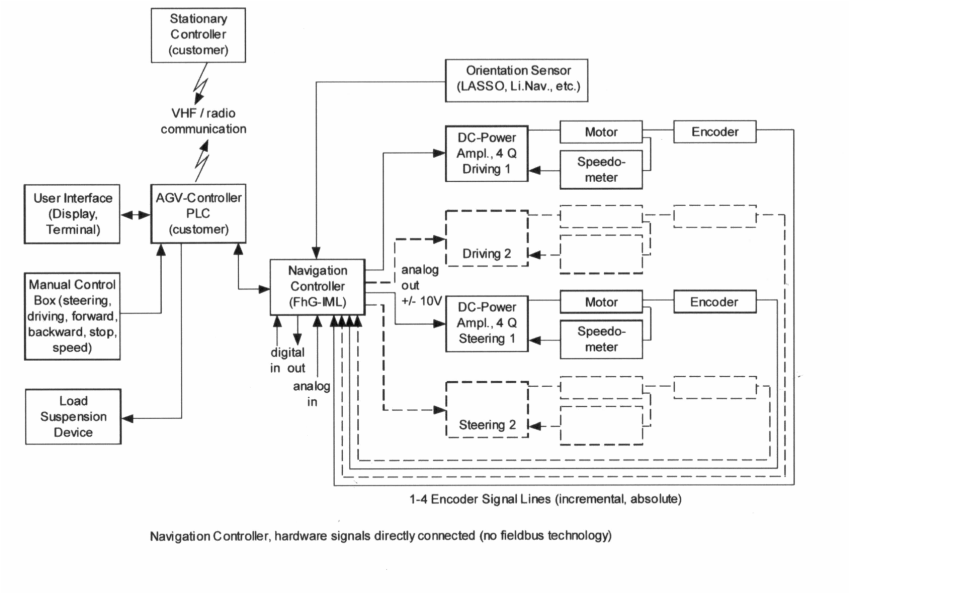

Figure 22: Navigation computer

It is expected that the overall costs for this machine type MAS II will be substantially lower than the rail-mounted Automatic Charging and Stoking Machine type SKS and the mobile version type MAS I. It is also possible to split the investment in 2 parts: Purchase of a standard mobile, operator driven Charging and Stok-

ing Machine which needs only be prepared for later automation, and later machine upgrade for automation adding the navigation system as well as the necessary hardware and software for automation.

4.2 New Versions of Rail-Mounted Automatic Charging and Stoking Machine (Type SKS) and Mobile Automatic Charging and Stoking Machine (Type MAS I)

Also proven designs need constant further development.

The rail mounted Automatic Charging and Stoking Machine Type SKS will also receive a pivot point of the stoking rail which is close to the furnace. This will allow small door openings during machine operation reducing furnace heat radiation and secondary air input.

The mobile Automatic Charging and Stoking Machine Type MAS I will receive the laser based navigation system as discussed for automating the mobile and operator driven Charging and Stoking Machine. This will add to its flexibility and make it independent from a contact line as pump drive by electric motor and trailing cable or by a Diesel engine would also be possible.

5 CONCLUSIONS

Automated charging and stoking of ferroalloy furnaces leads to a better furnace performance with substantial savings in electric power and manpower. Three machine versions are available for automatic operation:

- Rail-mounted Automatic Charging and Stoking Machine type SKS.
- Mobile Automatic Charging and Stoking Machine Type MAS I.
- Automated mobile and operator driven Charging and Stoking Machine Type MAS II.

Investment for the Automated mobile and operator driven Charging and Stoking Machine Type MAS II can be split into two parts: Machine investment and upgrade for automation.