LIFTING SYSTEMS FOR RH-TYPE VACUUM DEGASSING PLANTS

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In ladle metallurgy, the RH technology has become established as one of the dominant means for mass production of high-quality vacuum-treated steel. For dipping the snorkels into the heat, various types of lifting equipment have been developed. State-of-the-art configurations match the request for short cycle times and highly efficient vacuum treatment. This article explains different vessel lifts and ladle lifts, putting forward the pros and cons of the respective solutions. Due to the individual requirements of the respective site, different concepts may be feasible or even justifiable.

The RH-type vacuum degassing plant mainly consists of a refractory lined reaction vessel and two so-called snorkels – two large steel pipes attached to the bottom of this vessel. Both snorkels are completely refractory lined on the inside, but only the lower parts are refractory coated on the outside. The inlet snorkel is equipped with a number of gas injection pipes arranged in the lower section in one or two levels.

The degassing process starts after both snorkels have been sufficiently immersed into the melt. Having achieved the required immersion depth, the reaction vessel is evacuated by means of a vacuum pump.
PLANT CONCEPTS

Various configuration concepts for RH plants have been developed to meet different customer demands. A single plant comprises the treatment station with a vacuum vessel and a vacuum pump, which gives it a certain degree of flexibility as regards the lifting concepts. The treatment and the snorkel maintenance are performed in the treatment position. For refractory relining, the vacuum vessels have to be conveyed into the repair station by crane. Downtimes for snorkel maintenance, vessel exchange and vessel heating are factors which determine the availability of this plant concept.

A duplex plant consists of two treatment stations, each with one vacuum vessel. Both units are equipped with an alloy addition system, and treatment is carried out in both vessels by switching over to the vacuum pump via a movable bend. Snorkel maintenance takes place at one vacuum vessel while the second vessel is undergoing treatment. During the vessel exchange, the plant can continue to be operated temporarily as a single plant. These possibilities lead to high plant availability. However, they also cause initial limitations to the lifting systems. These are explained individually in the description of the lifting systems.

A fast-vessel exchange plant possesses a treatment station and two preheating positions. After a number of treatments, the vessel can be conveyed into the stand-by position by means of a vessel transfer car. In this position, the snorkel maintenance takes place, with the vessel being kept hot, or the vessel can be removed and taken to the repair station. Compared with the other two types of plants, the fast-vessel exchange plant offers an extremely high degree of flexibility. As the vessel is positioned in the exchange car, only the ladle lift is required for the work.

DRIVE-THROUGH OR DEAD-END CONFIGURATION

In the so-called drive-through solution, the ladle transfer car can be driven through underneath the plant and can thus, if required, supply the transfer position in another bay without further intermediate transport. This solution may also allow for the changing of the ladle transfer car during the treatment, though this is not possible with all lifting concepts. Sometimes, the changing of the ladle transfer car in the treatment position is possible. This enhances the flexibility of the plant and, through the saving of travel time and turret loading time, also increases the availability of the plant.

In contrast, when using the so-called dead-end solution, the ladle transfer car can only be driven into the treatment position from one side. In single and duplex RH plants, the snorkel maintenance takes place on the treatment track and, in fast-exchange plants, in the respective parking position of the vessel. However, there are no limitations as to the lifting systems.

VESSEL LIFT VS. LADLE LIFT TECHNOLOGY

Over the years, SMS Mevac and its predecessor firms Vacometa and Messo have designed a very wide range of lifting concepts, which had to be very flexible in view of the developments in vacuum process technology. The various lifting concepts are subdivided into those with vessel lift, i.e. the RH vessel is immersed in the steel works ladle, and concepts with ladle lift, where the ladle is lifted into a position below the stationary vessel.

A further differentiation is made according to the lifting method. Vessels can be lifted up by using a winch, hydraulics or rocker arm units. Ladles can be lifted by a bottom-ram cylinder or by various types of frames using hydraulic cylinders, winches or ladle rockers. The different lifting systems must also be in harmony with the plant concepts, such as the single plant, the duplex plant and the fast-exchange plant.
Limitations affecting the vessel lift are the movement of the vacuum vessel in relation to the vacuum pump components mounted on the structural steelwork of the plant and also the connection to the alloy addition system. Here, the connection must be designed with vacuum-tight swivel joints between the gas cooler and the connecting piping to booster No. 1. The connection between the alloying chute and the alloying nozzle at the vessel must be made with a pressed-on expansion joint component. These elements are potential leakage points and require regular maintenance.

**VESSEL LIFTING CAGE WITH WINCH**

In this system the vessel is raised and lowered in a lifting cage by means of a winch lifting system. A major challenge is the design of the winch system, and also the guidance of the loads and stresses in the structural steelwork. The lifting load of the winch is designed for the RH vessel, gas cooler, vacuum alloying system, etc. The suction line is to be attached with an articulated three-joint system in order to connect the exhaust line to the vacuum pump on the “stationary” part. This is achieved by means of vacuum-tight pivot bearings. For a safe lift, and also for the general safety of the plant, the system is equipped with various safety devices, such as overload limiters and slack-rope limiters in conformity with crane standards. The system must also undergo regular and intensive maintenance, the ropes must be checked regularly and be changed at stipulated intervals.
VESSEL LIFTING FRAME WITH HYDRAULIC CYLINDER

A modified version of this system is the solution involving one or two hydraulic cylinders. Here also, the vessel is raised and lowered with a lifting frame, though in this case the movement is performed with two hydraulic cylinders. The distribution of the loads in the system is comparable, though the movement of the lifting frame by hydraulic cylinders represents a considerable simplification of the system and, since the forces are only applied at the ends of the hydraulic cylinders, the diversion of the loads through the structural steelwork is no longer necessary, i.e. the structural steel masses are smaller now. Likewise, the elaborate rope monitoring and regular inspection are no longer necessary.

However, monitoring systems for misalignment and positioning are indispensable also for this version. As before, the exhaust line is equipped with pivot bearings. A separate snorkel maintenance car must be provided for snorkel maintenance. These systems can also only be used for the single and duplex versions.

ROCKER ARM UNIT FOR VACUUM VESSEL

For the rocker arm units, technology from the “DH” process has been transferred to the “RH” technology. The vacuum vessel is moved by means of a rocker arm system which essentially consists of a lifting platform, lock platform, rocker arms, torsion tube, parallel guide, rocker box with rocker, structural steelwork and bearing support. The vacuum vessel and the gas cooler are installed on the lifting platform. The vacuum vessel can be lifted out in upwards or downwards direction with the crane. The gas cooler is connected with the vacuum pump via an exhaust line and three swivel joints. The upper platform is supported on the lifting platform and serves as a means of support for the hot exhaust line during vessel exchange and also for the vacuum lock and the pertaining conveyor belt. The two platforms are kept in a horizontal position by a parallel guide. This guide is designed as a bar with bearings at the ends, so as to absorb the horizontal forces from the tilting moments of the lifting platform. The purpose of the main platform is to accommodate the necessary
equipment items for plant operation, such as lance system, control systems, etc. The conveyor belt to the vacuum lock must be mounted in an articulated manner on the lock platform so as to allow it to follow the lifting and deflecting movements of the lifting platform. The rocker arm unit can be operated with one or two hydraulic cylinders. The cylinders are designed such that lifting and lowering can also be performed with one cylinder, though at reduced power. In the case of the two-cylinder solution, the cylinders are designed correspondingly smaller.

A counterweight is installed in order to lift the vacuum vessel out of the ladle should the hydraulic system fail. The counterweight comprises specially trimmed slab parts and is installed at the time of erection. It is heavier than the lifting platform with all its equipment during the treatment and with the steel taken from the ladle. If an energy supply failure occurs, the vacuum vessel can be lifted out of the ladle with the aid of the heavier rocker, after first releasing the pressure from the hydraulic cylinder manually. A separate snorkel maintenance car must be provided for snorkel maintenance.

**VESSEL LIFTING – PROS AND CONS**

The vessel lifting systems basically need the movement of large masses and also the movable connection with the vacuum system and with the alloy addition systems. These requirements alone lead to a great number of technical solutions and maintenance needs. What all systems have in common is the so-called “drive-through solution”, in which the ladle transfer car can be driven through underneath the plant and can thus, if required, supply the transfer position in another bay without further intermediate transport. Here it is not possible to change the transfer car during the treatment.

For snorkel maintenance, it is necessary to provide a separate snorkel maintenance car. This has to be arranged at the side for the drive-through solutions and on the track system of the ladle transfer car for the dead-end solutions.

**LADLE LIFTING CRADLE WITH BOTTOM-RAM CYLINDER**

A successful ladle lifting system is the “single cylinder lifting system”. In this system, a hydraulic cylinder and a guide frame are used for lifting the ladle together with the ladle transfer car. The system using the lift cylinder has been utilized successfully in several combinations, such as for lifting the ladle and the ladle transfer car, lifting with the ladle and the lifting trough, supply via a ladle turret with lifting of the ladle and the lifting trough.
etc. The concept is highly versatile and can be utilized in all plant concepts. However, the ladle transfer car cannot be changed during treatment.

The lifting unit can also be used without problems for snorkel maintenance, i.e. the skull cutter can be driven into the treatment position by means of a snorkel maintenance car and then pressed underneath the vessel with the aid of the lifting unit. For this purpose, the lifting load is reduced by the control system in relation to the load required for ladle lifting. The hydraulic cylinders, and also the pipes, are protected against ladle break-through by protective hoods.

**Ladle Lifting with Lateral Hydraulic Cylinders (Vertical)**

A ladle lifting system developed by SMS Mevac [3] uses hydraulic cylinders installed vertically at the sides. This system is capable of lifting the ladle together with the lifting cradle on which it is placed. The guide frames are arranged next to the ladle transfer car and are integrated into a stable and robust side guard. The lateral guide frames perform a pressing movement under the lifting cradle. The guide frame, the hydraulic cylinders, and also the pipes, are protected against ladle break-through by protective hoods.

For maintenance of the guide frames below floor level, means of access to the roller guides have been provided. It is not possible here to change the ladle transfer car during the treatment because the lifting cradle needs to travel together with the transfer car.

**Ladle Lifting with Lateral Hydraulic Cylinders (Suspended)**

A ladle lifting system with hydraulic cylinders suspended at the sides has also been developed by SMS Mevac. This system is capable of lifting the ladle out of the ladle transfer car by means of a lifting beam with laminated hooks. The lifting beam with the two laminated hooks is suspended from the four hydraulic cylinders. The hydraulic cylinders are in turn suspended in an articulated manner in the top part of the structural steelwork. The guide frames are arranged laterally next to the ladle transfer car and are integrated into a stable and robust side guard. The hydraulic cylinders are designed such as to allow lowering in an emergency even if a cylinder fails.

The guide frame, the hydraulic cylinders, and also the pipes, are protected against ladle break-through by protective hoods. It is possible here to change the transfer car during the treatment.
LDLLE LIFT ON THE TRANSFER CAR

A further concept solution is the ladle lift by means of hydraulic cylinders on the ladle transfer car. This solution was developed by SMS Mevac to take account of the fact that in some RH plant projects sufficient space was not available for the customary lifting concepts. The lifting and travelling movements have been combined. This provides a high degree of flexibility in the plant concepts, with single, duplex and fast-exchange plants being possible here. Since the transfer car is occupied by the ladle, no car changing can take place and, for the snorkel maintenance, a separate car with lifting hydraulics needs to be provided.

LDLLE LIFT WITH WINCH

A highly reliable, yet at the same time complex ladle lifting system is the solution involving a crane winch. Rope drums and reeings are used to create a pulley block system for enabling the effective lifting load at the winch to be reduced. The ladle is lifted out of the ladle transfer car by means of laminated hooks, each of which is attached to its own lifting beam.

It is important here not to underestimate the need for an elaborate control system and also for safety shut-down facilities. Since this winch is comparable with a crane installation, the design criteria and the maintenance and servicing work are likewise comparable. For a safe lift, and also for the general plant safety, the system is equipped with various safety devices, such as overload limiters and slack-rope limiters in conformity with crane standards. The system must also undergo regular and intensive maintenance, the ropes must be checked regularly and be changed at stipulated intervals. The transfer car can be changed during the treatment.

LDLLE ROCKER

On the basis of comprehensive experience, SMS Mevac has developed a new lifting system, known as the “ladle rocker” [4]. It brings together the advantages of the well-known systems and retains the flexibility. The following parameters were considered to be essential for the development:
= reliable protection against ladle break-through,
= hydraulics to be simple and operationally reliable, no synchronization control,
= safe lowering of the ladle in the event of power failure,
= suitable for dead-end and drive-through solutions,
= vessel exchange is possible in upward and downward directions,
= narrow type of construction for compact duplex plants,
= utilization as single, duplex and fast-exchange plants,
= accessibility of T+P systems,
= simple connection to the vacuum and alloying system,
= snorkel maintenance.

The technology used in the rocker arm units has been reworked for the ladle rocker plants. The ladle is moved by means of a rocker arm system which consists essentially of the lateral arms, the connecting tube (tension tube), the bearings with bearing support and the rocker box with rocker. The vacuum vessel and the gas cooler are situated on the permanent structural steelwork of the plant, thus removing the need for a swivel joint solution as used in the rocker arm units. This means that the possibility of leakages is no longer present and that maintenance tasks are reduced. The vacuum vessel is able to be removed in upward direction by the crane. Likewise, as opposed to the rocker arm unit, the vacuum locks and also any microalloy bins that might be present are situated on the permanent structural steelwork, thus considerably reducing the masses to be moved. Furthermore, the transition of the conveyor belts does not need to have an articulated design.

The ladle rockers can be operated with one or two hydraulic cylinders. In the drive-through solution, the ladle transfer car can be driven through underneath the plant and can thus, if required, supply the transfer position in another bay without further intermediate transport. It is not possible here to change the transfer car during the treatment. The cylinders are designed such that lifting and lowering can also be performed with one cylinder. The cylinder operation is assisted by a rocker.

In order to lower the ladle in the event of hydraulics failure, the rocker is designed such that excess weight is present on the ladle side. The rocker comprises specially trimmed slab parts and is installed at the time of erection. Controlled lowering is possible by means of a throttle valve in the hydraulic system.
For snorkel maintenance, it is necessary to provide a separate snorkel maintenance car. This has to be arranged at the side for the drive-through solutions and on the track system of the ladle transfer car for the dead-end solutions. As regards technology, the ladle rocker solution can replace all customary lifting systems and even improves the safety and availability of the plant.

**LADLE LIFTING - PROS AND CONS**

The ladle lifting systems utilize the movement of molten masses, although the most important part of the plant is installed on permanent structural steelwork. The connections to the vacuum pump and to the alloy addition system are therefore static and, consequently, are not prone to leakages. The maintenance expenditure is thus reduced and the availability is enhanced. In comparison with the vessel lifting system, the hydraulic systems for ladle movement are also smaller and of simpler design.

What all systems have in common is the so-called "drive-through solution", in which the ladle transfer car can be driven through underneath the plant and can, if required, thus supply the transfer position in another bay without further intermediate transport. It is only possible here to a limited extent to change the transfer car during the treatment. For snorkel maintenance, it is necessary to provide a separate snorkel maintenance car, which can be arranged on the track system of the ladle transfer car.

Changing of the ladle transfer car during treatment is basically possible, and while a vessel lifting system is severely limited in bays with a low height, the potential offered by the ladle lifting system can be exploited here. In the event of a treatment abort, it is always necessary to lift the vacuum vessel out of the steel bath when vessel lifting systems are being used, i.e. energy must always be available, whether electrical or hydraulic. With the ladle lifting system, the ladle can also be lowered without energy, and it is possible to do this manually via a throttle valve.

It is still the case that due to the requirements imposed by the plant locations, for new plants or installation in an existing steelworks, a large number of concepts are possible and, moreover, continue to be justifiable. Thanks to the further development of ladle lifting concepts, it is possible to use a modularized basic plant which functions by disconnecting the static plant components from the vessel. And when required, a variable range of ladle lifting systems can still be utilized here.

**CONCLUSION**

The decision as to which system to use for which plant concept is still strongly dependent on the customer’s wishes as regards the tap-to-tap times of the units installed upstream and on the continuous casters situated downstream and, of course, on the conditions prevailing in the steelworks. The vessel lifting systems described can be implemented with single and duplex plants and, to some extent, with fast-exchange plants, and a ladle turret can also be utilized conditionally.

**References**


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