The VAI-CON® Link Suspension System; From the Development to Six Years of Operational Experience

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One of the most important elements of the LD converter equipment is the suspension system. Due to the steadily increasing number of converter upgrading projects, VAI developed an improved suspension system which is referred to as the VAI-CON® Link Suspension System. After the first implementation in 1997 orders for a total of 25 references have followed. The latest reference was from U.S. Steel Kosice, which recently decided to have this system installed on their 180-t LD converter. The system is maintenance-free and, due to its robust design, direct contact with liquid steel poses no serious danger to the main system components.

INTRODUCTION

Since the invention of LD steelmaking in 1949 by VOEST in Linz, Austria, the process has been continuously improved in addition to the equipment itself. One of the most important elements of the converter equipment is the suspension system. Since the introduction of LD steelmaking VAI has developed and applied statically determined suspension systems. This means that not only is the converter suspended in a stable and secure manner in the trunnion ring, but that all shape distortions caused, for example, by thermal expansion or long-term deformations are not hindered in their growth. Hence, no additional stresses are introduced into the system.
Originally, VAI applied a bracket-type suspension system, followed by the VAI-CON® Disk Suspension System, which was replaced by an improved design solution referred to as the VAI-CON® Link Suspension System. The first such unit was installed in December 1997 on the 170-t LD converter at ISPAT ISCOR Newcastle in South Africa. Since that time, orders for a total of 25 references for the VAI-CON® Link Suspension System have been received from Austria, Brazil, China, Italy, Poland, South Africa and Sweden as of December 2003. The latest reference was from US Steel, the largest North American steel producer, which recently decided to have this system installed on the 180-t LD converter at their steel works in U.S. Steel Ko_ice, s.r.o., Slovak Republic.
The equipment is maintenance-free and extremely robust. Even direct contact with liquid steel poses no serious danger to the main system components—as confirmed at ISPAT ISCOR Newcastle and Vanderbijlpark Works as well as at SSÅB Luleå, Sweden.

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Figure 1: 300-ton LD Converter with VAI-CON® Disk Suspension System Showing the Toggle-Link, POSCO Kwangyang Works, Korea

DEVELOPMENT OF THE VAI-CON® LINK SUSPENSION SYSTEM

In the early 1990s VAI commenced with the development of a new converter suspension system for stationary LD (BOF) converters. The system incorporates the well proven toggle link of VAI's previous disk suspension system (VAI-CON® Disk) which transfers the tilting torque from the vessel shell to the trunnion ring. Figure 1 shows the disk suspension system installed at the 300-ton LD converter of the Kwangyang Steel Works in South Korea. The most important components of this suspension system are the two disks which are bolted to the trunnion ring in the area of the pins, the disk eye and its star-ribs (welded to the vessel shell) and the toggle link that is equipped with spherical plain bearings. These components are all maintenance-free and have been in operation for more than fifteen years.

Toggle Link and Spherical Plain Bearings

VAI has a long tradition of using spherical plain bearings in converter suspension systems. This type of bearing was first used for exchangeable converters in a three-point suspension system. The bearings were positioned on large pins which compensated for the thermal expansion of the vessel through axial movements between the pin and the inner racer of the bearings. Although the bearings were greased, the lubrication effect decreased and the pin eventually seized in the bearings. The bearing design was consequently changed from a sliding contact to a swivel contact. This was an important step in the improve-

ment development. The link between the trunnion ring and the converter with two bearings on its end transformed any deformation of the vessel into very small swivel movements (rotational deformation) in the bearing itself.

This extremely small swivel angle and the long time in which this angle occurs (from room temperature to maximum temperature at the end of a campaign) render any lubrication or grease unnecessary—a prerequisite for a maintenance-free system. However, additional requirements placed on the bearings would have to be fulfilled in order to ensure their reliability in a steelmaking environment over extended periods of time, as follows:

- Greater clearance in the bearings
- Thermal stabilized bearings (up 300 °C)
- Coated bearing surfaces
- Oversized bearings (decreased allowable capacity).

Special treatment of basically standard steel/steel spherical plain bearings to make them completely maintenance-free and their installation in the suspension system of a steelmaking converter was the solution.
The VAI-CON® Link bearings are key factors for the success of the VAI-CON® Link Suspension System.

The Link Element

The VAI-CON® Link arrangement, schematically shown in Figure 2, consists of the link, spherical plain bearings, pins and lugs welded to the vessel shell and trunnion ring. The link is supported by a spherical plain bearing on a plain pin which itself is supported in two lugs. Two side bearings are also used to facilitate pin insertion. These also compensate for any misalignment of the lugs, such as shrinkage during welding, etc. The two side bearings are smaller as compared to the main bearing because they assume only half the load. A bushing between the main bearing and the plain pin compensates for any diameter discrepancies between the bearing and the pin.
The link itself is of solid design and can withstand extreme conditions such as high vessel shell temperatures of up to 500 °C, large amounts of dust, as well as contact with water, slag or liquid steel. Typical materials used for the link are 21CrMoV57 or ASTM B 193 B7, which are well-known bolt materials for applications at highly elevated temperatures.
The bearings are protected by heavy cover plates against contact with liquid steel, slag and dust, etc. The pin itself is sealed with Fey rings and a heat-resistant oven rope with a holder ring against impact with slag, liquid steel or heavy dust. Figure 3 shows the actual link arrangement.

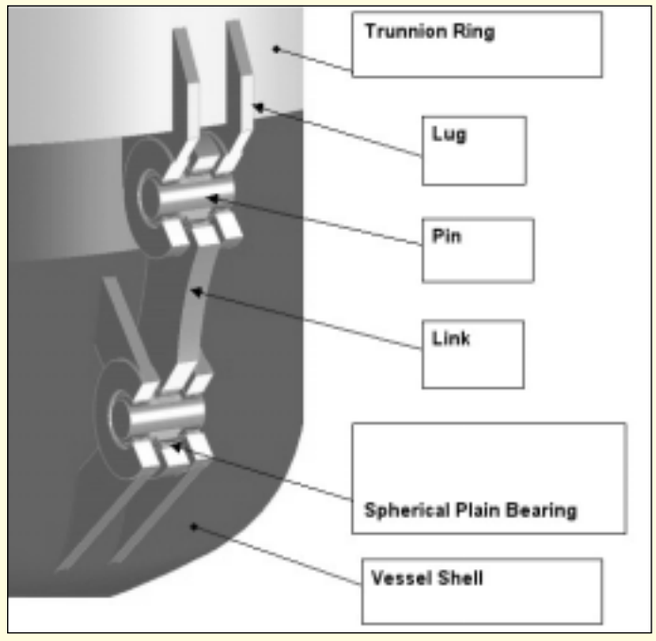

Figure 2: Details of Link Arrangement.

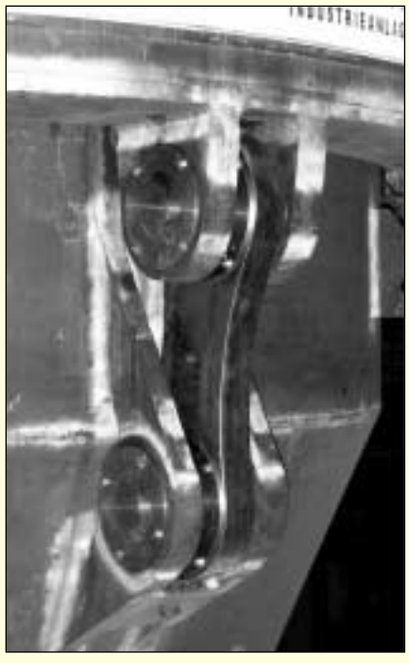

Figure 3: Vertical Link Arrangement.

VAI-CON® LINK SUSPENSION SYSTEM

VAI has always strived to have a statically determined converter suspension system [1], [6] In the VAI-CON® Link Suspension System the link element is consequently arranged on the converter to achieve this. It consists of three vertical links, two horizontal links and a stabilizer. These six elements ensure that all six degrees of freedom of a body suspended in space are determined at any given time. Any additional support would generate an over-determined system, which must be avoided at all cost.
The first VAI-CON® Link Suspension System went into operation in December 1997 on a 175-ton LD converter at ISPAT ISCOR Newcastle in South Africa (Figure 4). The existing trunnion ring (of NIPPON Steel design) was re-used. This installation was followed by another four installations in South Africa and one in Europe in 1998.

Figure 4: Inspection of the VAI-CON® Link Suspension System at ISPAT ISCOR Newcastle, South Africa.

During the first quarter of 2003, VAI inspected the LD converter at ISPAT ISCOR Newcastle to obtain more information about the system after more than five years of operation. All slag-protection boxes of the three vertical links were opened. General visual inspection of the system showed that the equipment is in good condition, though skull formations were found in some locations between the lugs and the links, and removed. This is due to normal operation and is of no consequence. The spherical plain bearings on both ends provide each link with two degrees of freedom. Rigid-body rotation around the length axes of the link as well as the cross axis that is normal to the vessel shell is thus possible (Figure 5).
The arbitrary position of the links indicates that the spherical plain bearings are functional. The weld seams between the lugs and the vessel shell and the trunnion ring as well as the welds of the lugs themselves were all cleaned and checked (visual test, magnetic particle test, ultrasonic test). The test results were very positive and no problems were detected at all.
The bearing and pin were also in very good condition. A check of the clearance between the inner and outer racer of the bearing has shown that there was some dust accumulation in the bearing which has no affect on the main function of the system which is to allow unhindered deformation of the vessel shell.
A horizontal link is shown in Figure 6. Some skull formation and dust accumulation are visible between the lugs and the link. Exposure to high temperatures (under regular operating conditions) and water leakage from the offgas hood does not adversely affect the system.

Figure 5: Rigid-Body Rotations Made Possible by the Link.

Figure 7: Temperature Profile of a Horizontal Link Assembly (ISPAT ISCOR Vanderbijlpark, South Africa).

Figure 6: Horizontal Link Arrangement.

Figure 8: Peeling of Solidified Steel Off of a Horizontal Link Assembly After a Burn-Through.

OPERATIONAL EXPERIENCE

The VAI-CON® Link System is industrially proven and reliable as demonstrated in converters with sizes ranging from 55–375 tons. Maintenance personnel have all reported that the system is truly 100% maintenance free.
It has also been shown that the system is 100% stable in any converter position and that no rocking or sliding movements are possible. The system can withstand regular and even irregular operation conditions such as shock loads to due skull cleaning, full scrap chutes and water infiltration, etc.
A typical temperature profile of a horizontal link assembly is seen in Figure 7. It can be seen that the lugs operate much like cooling ribs as well. This has a positive effect in that the main bearings as well as the link are exposed to much less heat as compared to the vessel shell. A temperature drop of 100 °C was measured along the length of the lugs between the vessel shell and the bearing housing.
Even under high-temperature conditions such as at the end of a converter campaign, the maximum temperature measured in the area of the bearing was not more than 220 °C.

Experience Under Extreme (Abnormal) Operating Conditions

The extremely robust nature of the VAI-CON® Link System under extreme operating conditions was well demonstrated at ISPAT ISCOR Newcastle. After only six months of operation a serious burn-through occurred in LD Vessel No. 2 directly behind the trunnion ring during a regular hand-sampling process with the converter tilted approximately 90° in the charging direction. The liquid steel burned a hole in the vessel shell and into the inner web plate of the trunnion ring. There was a large explosion—fortunately without personnel injury—when the liquid steel came into contact with water from the trunnion ring water-cooling system. The outer web plate of the trunnion ring was then burned through and the vertical and horizontal links came into contact with liquid steel. The vessel shell, the trunnion ring, the piping and slag shields were heavily damaged.
An inspection of the suspension system underlined another major advantage of the system. Due to the heavy structure and solid dimensions of the components, the liquid steel instantaneously froze on the components forming a solid steel skin.
Figure 8 shows the horizontal link arrangement following a burn-through. The

solidified steel peels off the equipment after cooling down due to the tight temperature gradient in the frozen steel. This is an additional feature of the VAI-CON® Link system. It is capable of withstanding even the harshest of operating conditions. No part of the suspension system had to be replaced after this serious burn-through.

CONCLUDING REMARKS

In December 1997 the so-called VAI-CON® Link Suspension System first went into operation on a 175-ton LD converter at ISPAT ISCOR Newcastle in South Africa. Following six years of operation—including a major burn-through which damaged the vessel shell and the trunnion ring—a careful inspection confirmed the excellent equipment performance, the highly robust nature of all components, as well as the fact that the system was indeed maintenance free. The complete suspension system and the welds to the vessel shell and trunnion ring were examined and tested. The advantages the VAI-CON® Link Suspension System can be summarized as follows:

- The system is completely maintenance-free
- The system is statically determined thus allowing unobstructed vessel shell deformation
- All components are of solid design and resistant to contact with liquid steel
- Considerable space exists for natural air draft
- All components have been industrially in over 20 years of operation.

REFERENCES

VAI currently has six years of experience with the VAI-CON® Link Suspension System. The first installation was at ISPAT ISCOR Newcastle in December 1997. Another five installations have been in operation during the past five years. A total of 25 references for this system now exist worldwide (Table 1), for both trunnion ring retrofits as well as for completely new installations. The system can be tailored to the particular needs in the plant at favorable costs.

STEEL PRODUCER	Heat Size (t)	Retrofit	Start-up
ISPAT ISCOR Newcastle, RSA	175	yes	12/1997
ISPAT ISCOR Newcastle, RSA	175	yes	6/1998
ISPAT ISCOR Newcastle, RSA	175	yes	2/1999
ISPAT ISCOR Vanderbijlpark, RSA	170	yes	7/1998
ISPAT ISCOR Vanderbijlpark, RSA	170	yes	9/1998
ISPAT ISCOR Vanderbijlpark, RSA	170	yes	12/1998
HUTA Sendzimira, Poland	150	new trunnion ring	8/1998
VOEST-ALPINE Donawitz, Austria	67	new trunnion ring	10/1999
VOEST-ALPINE Donawitz, Austria	67	new trunnion ring	4/2000
ILVA Taranto, Italy	375	yes	12/1999
ILVA Taranto, Italy	375	yes	7/2000
ILVA Taranto, Italy	375	yes	10/2000
SSAB Luleå, Sweden	120	new trunnion ring	7/2000
SSAB Luleå, Sweden	120	new trunnion ring	8/2000
COSIPA, Brasilia	180	new trunnion ring	7/2001
COSIPA, Brasilia	160	new trunnion ring	9/2001
COSIPA, Brasilia	160	new trunnion ring	1/2002
XINGTAI, China	55	new trunnion ring	12/2002
Zhangjingang, China	180	new trunnion ring	1/2004
Zhangjingang, China	180	new trunnion ring	3/2004
Zhangjingang, China	180	new trunnion ring	2004
CSN, Brazil	240	yes	10/2004
US Steel Ko_ice, Slovak Republic	180	new trunnion ring	2004
Belgo Mineira, Brasilia	110	new trunnion ring	2004
Belgo Mineira, Brasilia	110	new trunnion ring	2004

Table 1: Worldwide References of VAI-CON® Link Suspension System.

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