Current Research and Trend Analysis of Converter Support Mechanism

Yang Yu*, **Qing Wang, Ming Zeng**

Steelmaking Division, CISDI Engineering Technology Co., LTD., MCC, Chongqing 401122, China

Abstract: The running quality of the converter referrs to the safety indexes as well as the other other is wear, impact, vibration and abnormal noise, etc., which is closed related to the supporting mechanism of the converter This paper systemically sorts out and analyzes the supporting mechanism of the converter in variant securities from the last center to the preset, and summarizes the characteristics of the supporting mechanism of the converter and the main factors that determine the running quality of the converter, especially the large scale converter The main factors that influence and determine the running quality of converter, especially large converter, are put forward for the first time by means of means of comparative comparative analysis The results show that six typical under suspension support mechanisms are mainly used in variables countries in the world today; The main factors affecting the running quality of converter are: 1) the components of the suspension mechanism, 2) the number of the suspension mechanism, and 3) the layout of the suspension mechanism The technical progress in these three aspects and how to use them relatively are the development trend and direction of inproving the running quality of converter.

Keywords: Converter; Support Mechanism; Running Quality; Vibration and Abnormal Noise

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1 Introduction

The advantages and disadvantages of converter equipment are embodied in the converter running quality (whether there are safety indicators such as wear, impact, vibration, and abnormal sound). The converter running quality is closely related to the converter support mechanism, which is the mechanical equipment connecting and supporting the converter vessel and the trunnion ring, and transmitting the tilting moment to rotate the converter. With the deformation of the converter vessel and the trunnion ring during the operation of the converter, the redistribution of the transmitted load in the connecting device often causes local overload, and thereby causes serious deformation and damage [9], resulting in the generation and expansion of the gap of the support mechanism, affecting the running quality of the converter. Therefore, the converter support plays a crucial role in the converter design and is the key technology in the design of the converter equipment [1].

What are the main factors that affect and determine the running quality of the converter, especially the large converter? For a long time, the global industry has lacked an overall and comprehensive understanding. Many metallurgical engineering companies and many steel mill users at home and abroad may pay different attention to the design of the converter support mechanism and the actual application experience in production, and often only focus on one important factor, while ignoring other important factors, resulting in slow improvement of the converter running quality. Therefore, it is necessary to comprehensively and accurately find out the influence of converter support mechanism and determine the main factors for the running quality of converter, especially large converter, so

*Corresponding author: Yang Yu, Yang.Yu@cisdi.com.cn

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as to define the target and direction of efforts and quickly and effectively improve the running quality of converter, which is beneficial to the development and introduction of new converter support technology.

2 Analysis of Factors Affecting Running Quality of Typical Converter Support Technology

For nearly a century since the invention and industrial application of converter, the converter support structures in various countries are different according to the working principle, and the connection and support types are also different. Through long-term production practice and verification of converter steel making, some converter support technologies have fallen behind or been eliminated, such as: Nippon Steel's three-point ball hinge upper support converter [7, 8, 10, 26] (the gap between block seats is difficult to control, T-shaped bolts are broken, and the operation safety is poor); Pull rod converter of former Soviet Union [2] (poor deformation compatibility, uneven supporting load and poor running quality); German wire bundle four-point suspension converter [10] (complicated manufacturing, wire bundle fracture, impact and abnormal sound); Ukraine four-point screw rod suspension converter [2] (screw looseness, shifting and impact, separated block seat); And Kawasaki Heavy Industries pin wedge connected two-point support converter [10, 12] (forced rigid constraint, poor impact absorbing ability, pin wedge loosening accident, difficult site repair of pin wedge), etc., the above converter support structure will not be studied in this paper.

In the following, the main technical features and existing problems of the six typical converter lower suspension supporting mechanisms which are mainly adopted and popular in the world and have been retained and developed so far are analyzed one by one, and the impact on the converter running quality is analyzed to find out the factors closely related to the converter running quality.

2.1 SMS/DANIELI LAMELLE Leaf Spring Connected Converter

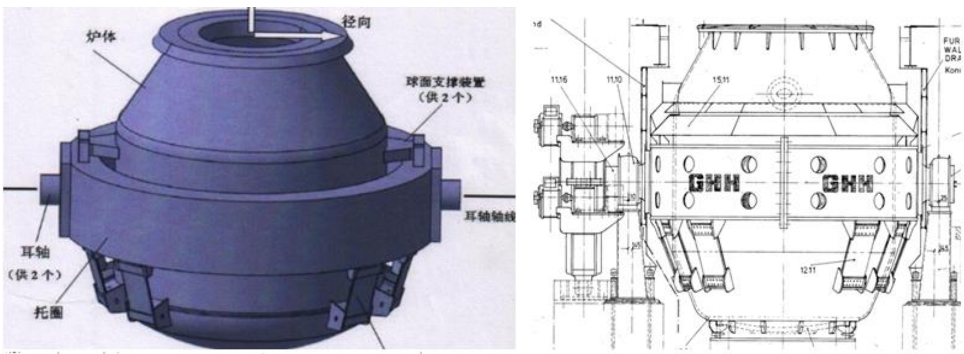

Figure 1 GHH/SMS leaf spring converter [13]

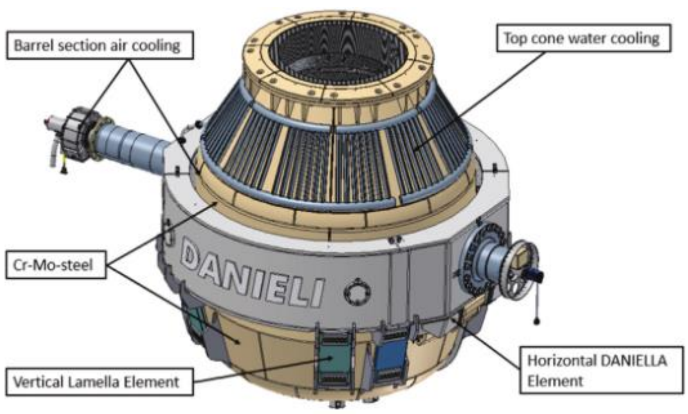

Figure 2 Danieli Latest Technology Converter [17]

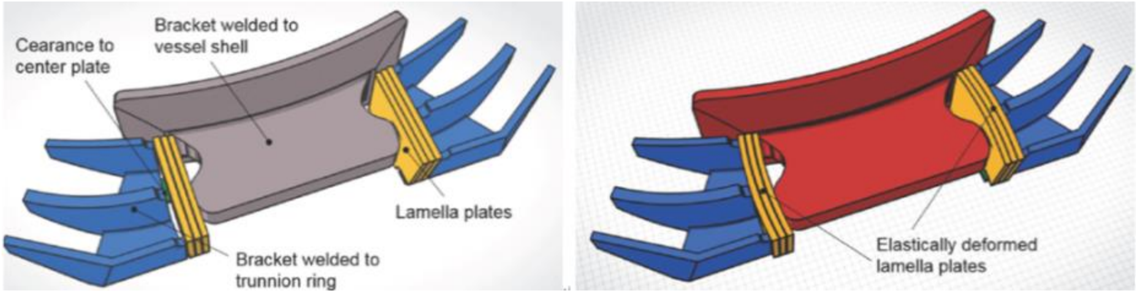

Figure 3 Danieli Horizontal Support Block Seat [17]

Technical features: the suspension system is vertical support of 8~10 groups of laminated plates (multi-layer steel plate lamination). The supports at both ends of the leaf spring are welded on site on the converter vessel and the trunnion ring. The two ends of the leaf spring are connected with the trunnion ring support and the converter vessel support through screws. The horizontal support of the converter is two sets of spherical block seats, which are located right above the trunnion support block [13]. The system can flexibly absorb the stress imposed by thermal expansion on the converter vessel and the trunnion ring [14]. The technology is relatively mature; The converter running quality is good under normal working conditions of horizontal support block seats. Italian Danieli state-of-the-art (latest technology) converter is basically similar to German SMS, which both adopt leaf springs for vertical support of the converter. The difference is that the horizontal support block seat is located right below the supporting blocks at both ends of the trunnion, and the block seat structure (Horizontal DANIELLA Element) is reinforced [17].

Main problems: Since there are vertical suspension points in front of and behind the furnace of GHH/SMS and DANIELLA converter support system, the probability of burning loss and breakdown of leaf spring caused by steel leakage of converter vessel and steel slag splashing is increased. As the leaf spring almost surrounds the lower part of the trunnion ring of the converter vessel, the trunnion ring of the converter vessel has poor natural heat dissipation and is easy to be deformed. GHH/SMS and DANIELLA vertical supports use the bending elastic deformation of the laminated spring plate to support the converter vessel and adapt to the thermal deformation of the converter vessel. The leaf spring often breaks under the bending and torsional deformation caused by the tension and compression fatigue load [15, 16], resulting in a high risk of equipment accidents. In addition, regardless of whether the horizontal support block seat is located right above the supporting blocks at both ends of the trunnion (GHH/SMS) or right below them (DANIELLA), the bending moment, relative deformation, and "alternating elastic slip" AES of the shell and trunnion ring at this position are the maximum [2], [3], resulting in unstable "foundation surface" of the block seat installation. The block seat has a separate structure [10, 13, 17], even if the DANIELLA converter vessel and trunnion ring block seat structure are reinforced (Figure 3), as the block seat is of open-split structure and provided with a gasket group, after the converter operates for a period of time, due to the unilateral stress of the block seat, under the inertial alternating impact load of thousands of tons of strong mass of the converter vessel, the gasket group is difficult to ensure the continuous and stable block seat gap, affecting the running quality of the converter.

2.2 Voestalpine CON-Link Five-link Support Converter

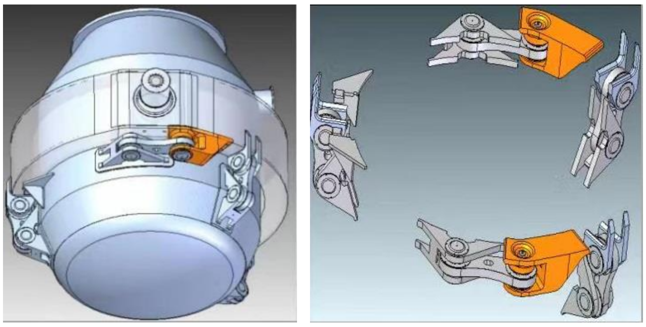

Figure 4 Voestalpine CON-Link Five-link Supporting Converter [18]

Technical features: The converter support system is composed of five groups of double spherical hinge pull rods and one guide seat, which are flexible connection mechanisms of rigid members. The swing rod mechanism with static and fixed constraints is used to absorb various deformations. Three of the five groups of swing connecting rods are used for vertical connection between the converter vessel and the trunnion ring, and two groups are used for horizontal connection between the converter vessel and the trunnion ring. The horizontal connecting rods are located right below the support blocks at both ends of the trunnion. There are joint bearings at both ends of each group of connecting rods to form a universal swing rod. The guide seat in front of the furnace trunnion ring (charging side) is used to limit the axial movement of the converter shell along the trunnion [18]. A full connecting rod mechanism is adopted for connection and support, so there is no need to adjust the converter during installation and operation. The connecting rod joint bearing can adapt to the thermal deformation of the converter vessel and trunnion ring without clearance [24]. The converter tilting is free of impact, vibration, and abnormal sound, and the running quality is good [1].

Main problems: the horizontal connecting rod is located below the trunnion support block, with the maximum alternating misalignment displacement (AMD) [1]. The horizontal swing rod adopts one group of horizontal swing rods directly below each side of the trunnion support block. The converter tilts 90 °horizontally. There are two connecting rods at both ends of the trunnion under stress. The supporting part of the converter vessel is weak, with a small safety margin and large risk. Even if only one connecting rod in the supporting system is damaged, the entire bearing mechanism will lose its function [9, 19], [20, 25, 26] and therefore cannot be adapted to large converters.

2.3 Danieli Connecting Rod Suspension Dani-ella Supporting Structure Converter

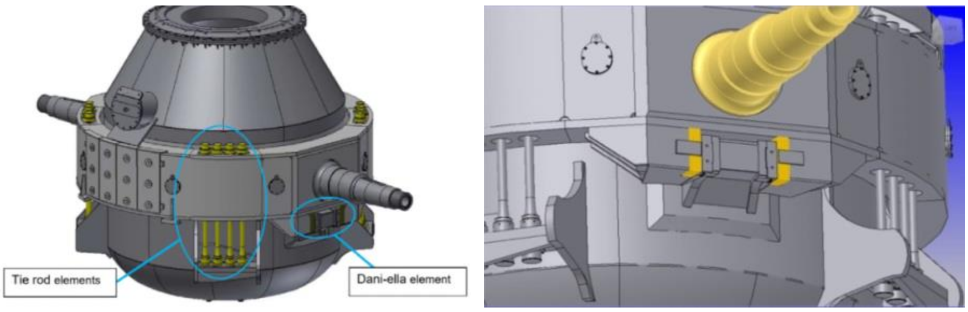

Figure 5 Connecting Rod suspension Dani-ella Supporting Structure Converter [21, 22]

Technical features: 4 groups of vertical pull rods (4 pull rods for each group) are used as the vertical support of the converter; One block seat is set under the trunnion support block on the drive side and floating side as the horizontal support of the converter. Both sides of the converter vessel block seats are in an arc shape, and the trunnion ring block seat is of multi-rib plate (six lateral ribs) and two groups of longitudinal baffles and base plate reinforced support structure [21, 22].

Main problems of vertical support: spherical washer, high-strength pull rod, and nut are respectively used at the upper and lower ends of each pull rod to rigidly connect the converter vessel with the trunnion ring, forming the upper and lower spherical hinge support [22]. In this way, after the supporting bolt is stressed and elongated, there is a gap between the nut and the spherical washer, resulting in displacement [8]. In serious cases, the spherical hinge bolt is broken under the lateral horizontal force due to the shaking of the converter vessel caused by the loose gap of the bolt [20]; Relative slip and wear will occur between the spherical surfaces of ball hinges at both ends due to thermal expansion. It is difficult to control the tightening torque of spherical nuts. With large tightening torque, occlusion will occur between spherical surfaces of ball hinges, which is unfavorable to adapt to the thermal deformation of the converter vessel; When the tightening torque is too small, there will be clearance between spherical joints, and the furnace will move along the axial direction vertical to the trunnion ring plane [7, 8], causing serious impact and abnormal sound.

Main problems of horizontal support: the horizontal block seat is located right below the trunnion support block, where the "alternating elastic sliding" AES is the maximum [2, 3]; Because the arc surface and plane line contacted spherical support block seat (different from DANIELLA Element) are used between the converter vessel block and the trunnion ring block, this linear contact block seat is easy to be worn, similar to the spherical support block eat structure - A Converter Adaptive Block Seat Mechanism [6], the deformation compensation mechanism and equipment structure are relatively complex and fragile. This kind of separated spherical converter block seat will deform, damage, form gap and make abnormal sound due to thousands of tons of heavy load and alternating fierce impact load of the converter during use.

2.4 CISDI-SACS Four-point Suspension Converter of MCC CISDI

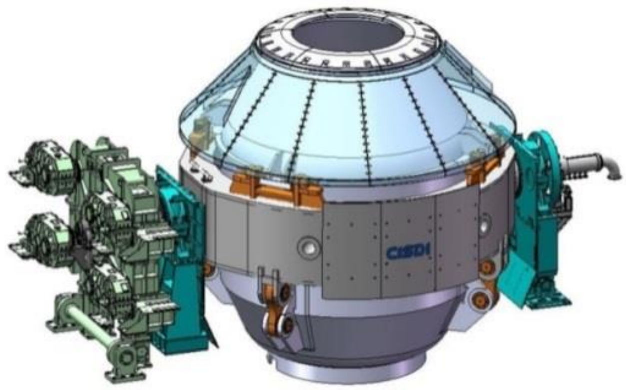

Figure 6 CISDI-SACS four-point lower suspension converter [3]

Technical features: 4 vertical suspension mechanisms are set between the lower edge of the trunnion ring and the converter shell, and 4 horizontal support block seats are set on the surface of the trunnion ring right above the vertical suspension mechanism. When the converter is rotating, the weight of the converter vessel is shared by 4 vertical suspension mechanisms and 4 horizontal block seats [3]. MCC CISDI-SACS (Self-Adaptive Constraint System) four-point lower suspension converter solves the problem of "alternating elastic slip" AES of the block seat of the horizontal support converter because the horizontal block seat is right above the vertical suspension, so as to minimize the AES value [2, 3]. The integral block seat technology of the pre-stressed pull rod of CISDI can effectively control the block seat clearance [11].

Main problems: Due to the working principle of the block seat structure, there must be a gap between the converter vessel block seat and the block seat of the trunnion ring. Due to the friction and abrasion of different degrees between the converter vessel block seat and the block seat of the trunnion ring during the operation of the converter [5], the gradual increase of the block seat gap affects the running quality of the converter. Therefore, it is necessary to regularly maintain the block seat device and replace the wearing parts.

2.5 Primetals Vaicon Link 2.0 Eight-link Suspension Converter

Figure 7 Primetals Vacon Link 2.0 eight-link suspension converter [23]

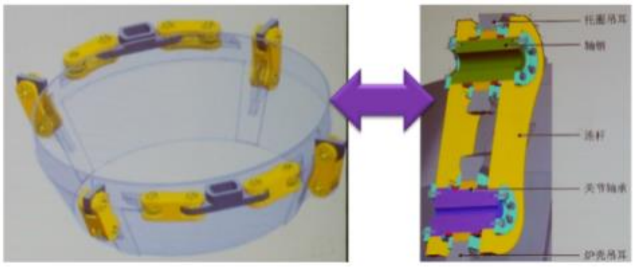

Figure 8 Voestalpine CON-Link suspension system improved version [18, 23]

Technical features: From Figure 7, it can be seen that the Primetals eight-link supporting mechanism consists of 4 groups of vertical suspension mechanisms in front of and behind the converter and 4 groups of horizontal pull rods at both ends of the trunnions, of which 4 groups of horizontal pull rods are respectively located under the trunnion on the drive side and floating side of the trunnion ring, and 2 groups of horizontal pull rods are set on each side. It can be seen from the structural principle of the Vaicon Link 2.0 suspension mechanism that Figure 7 Primetals eight-connecting rod is the improved version of Figure 8 Voestalpine CON-Link five-linkage, which belongs to the invention patent of Tilting Converter of Voestalpine [18, 23]. The eight-connecting rod mechanism of the Vaicon Link 2.0 suspension system is more suitable for the working condition of a large converter than the CON-Link five-connecting rod mechanism. One group of suspension mechanisms is added in the vertical direction of the converter, which improves the uneven stress of three-point vertical suspension, reduces the suspension load of each group, and increases the safety margin of the converter. The original one group of horizontal pull rods is changed to two groups of horizontal pull rods at the weak part of the horizontal connecting rod support of each trunnion of the converter, which significantly improves the support strength and rigidity of the converter in the horizontal station. Theoretically, the Vaicon Link 2.0 eight-connecting rod converter support system is free of vibration and abnormal sound, requiring no adjustment during the installation of the connecting rod and the tilting operation of the converter. It is maintenance-free, and the converter running quality is good [10, 24, 26].

Main problem: the horizontal connecting rod support mechanism is set under the trunnion trunnion ring support block, which is the position suffers the maximum "alternating misalignment displacement" AMD of the whole trunnion ring due to bending and torsion and the most unfavorable working condition of the horizontal connecting rod [1], which may change the working principle of tensile and compressive stress of the connecting rod two-force member bar, weakening the rigidity and strength mechanical property and affecting the working life of the horizontal connecting rod mechanism.

2.6 CISDI-SACS Eight-link Converter Technology of MCC CISDI

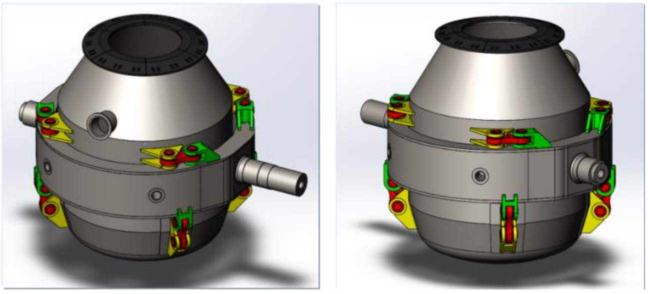

Figure 9 CISDI-SACS eight-connecting rod suspension converter technology [1]

Technical features: 4 groups of vertical connecting rod mechanisms are arranged between the lower edge of the trunnion ring and the converter shell, and 4 groups of horizontal connecting rod mechanisms are arranged right above the vertical connecting rod mechanisms, wherein the horizontal connecting rod mechanisms are installed on the upper surface of the trunnion ring, and 4 groups of vertical connecting rod mechanisms and 4 groups of horizontal connecting rod mechanisms are used to connect and support the converter vessel and the trunnion ring vertically and horizontally. The technology adopts a full connecting rod mechanism, the horizontal connecting rod support is located at the position that has minimum bending deformation and "alternating misalignment displacement" AMD of the converter vessel and the trunnion ring [1], the number of suspension vertical and horizontal supports is 4 groups, the main parts of the vertical and horizontal connecting rod mechanisms are exchanged, and the spare parts of the equipment are reduced. Therefore, the CISDI-SACS eight-connecting rod technology idea is more suitable for large and medium-sized converters.

Main problems: needs for high-temperature resistance of horizontal support connecting rod joint bearing, relatively high investment of joint bearing, and thermal protection of horizontal connecting rod mechanism shall be solved.

3 Optimization Analysis of the Suspension Mechanism for the Converter in the Current Word

The converter support system is divided into vertical support and horizontal support. The installation and stressed structure of the vertical support equipment of the lower suspension converter is under the converter trunnion ring. The center of gravity of the converter type moves down, the dynamic positive moment characteristics of slagging at the furnace mouth are good, the operation is safe, the suspension mechanism is far away from the furnace mouth, the impact of molten steel and slag splashing is reduced, the thermal protection is good, and becomes the main trend of the converter support system technology. A large number of engineering practices have verified that the key to affecting the running quality of the lower suspension converter lies in the design of the horizontal support mechanism. Therefore, the following research mainly focuses on the horizontal support mechanism of the lower suspension system of the converter.

The following is a comprehensive comparison and analysis of the technical and economic indicators of the six typical converter lower suspension support technologies mainly used in the world, to find out the factors that affect and are closely related to the running quality of the converter, especially the large converter, and to point out the development trend and direction of the converter support technology in the future.

Table 1 Comparison of suspension support technologies and economic indicators of six typical converters in the world

Technical and economic indicators of converter suspension	Lamalla Suspension with leaf spring (SMS/Dani)	CON-Link: Five-link suspension (VAI)	Tie-rod Suspension (Danieli)	CISDI-SACS Four-point suspension (CISDI)	Vaicon Link 2.0 Suspension (Primetals)	CISDI-SACS Eight-link suspension (CISDI)
Horizontal support parts and characteristics	Split block seat components	Connecting rod mechanism	Split block seat components	Prestressed tie rod one-piece block seat component	Connecting rod mechanism	Connecting rod mechanism
Number of horizontal supporting mechanisms	2 block seats	2 connecting rods	2 block seats	4 block seats	4 Connecting rods	4 Connecting rods
Horizontal support arrangement	Position of trunnion support blocks on both sides	Position of trunnion support blocks on both sides	Position of trunnion support blocks on both sides	Right above the vertical suspension mechanism	Position of trunnion support blocks on both sides	Right above the vertical suspension mechanism
Check the operation of the large converter for impact, vibration, wear, and abnormal sound	The clearance will gradually increase, the number of horizontal supports is not enough, the rigidity and strength are weak, and the alternating elastic slip AES is the largest, which is easy to produce abnormal sound.	The supporting mechanism is free of clearance and abnormal sound, the number of horizontal supports is insufficient, the rigidity and strength are weak, the alternating misalignment displacement AMD is the maximum, and it is not suitable for large converter.	The clearance will gradually increase, the number of horizontal supports is not enough, the rigidity and strength are weak, and the alternating elastic slip AES is the largest, which is easy to produce abnormal sound.	The integral structure of the block seat enables effective control of the clearance, and alternating elastic slip AES is the minimum. The wearing parts of the block seat need regular maintenance to ensure no abnormal sound within a certain period of time.	The support mechanism is free of clearance and abnormal sound, with good horizontal support stiffness and strength, and the alternating misalignment displacement AMD is the maximum, which affects the working life of the support mechanism.	The support mechanism is free of clearance and abnormal sound, with good horizontal support rigidity and strength, minimum alternating misalignment displacement AMD, and long service life of the support mechanism.
Total number of horizontal support points and equipment safety margin	Low safety margin	Low safety margin	Low safety margin	High safety margin	High margin of safety	High safety margin
Suspension installation and operation adjustment	Required (including leaf spring and block seat)	Not required	Required (including tie rod and block seat)	Required (Block seat)	Not required	Not required
Suspension regular adjustment and maintenance (dynamic production cost)	Required (including leaf spring and block seat)	Not required	Required (including tie rod and block seat)	Required (block seat base plate)	Not required	Not required
Suspension anti-leakage characteristics	Relatively Poor (easy to be hit, but many leaf springs)	Poor (the middle point in the shell is the steel leakage area)	preferably	good	good	good
Suspension accident frequency rate	High (opened split block seat, broken leaf spring)	High (horizontal connecting rod and joint bearing)	Relatively high (opened split block seat, deformed and broken tie- rod)	Lower (pre-stressed closed integral block Seat)	Relatively Low (the position of horizontal connecting rod AMD is the maximum)	low
Requirements for rigidity of trunnion ring	Relatively high	low	Relatively high	low	low	low
Influence of furnace bottom heat dissipation	poor	good	good	good	good	good

Technical and economic indicators of converter suspension	Lamalla Suspension with leaf spring (SMS/Dani)	CON-Link: Five-link suspension (VAI)	Tie-rod Suspension (Danieli)	CISDI-SACS Four-point suspension (CISDI)	Vaicon Link 2.0 Suspension (Primetals)	CISDI-SACS Eight-link suspension (CISDI)
Piping arrangement and maintenance on the converter	Not convenient	Not convenient	Not convenient	Convenience (CISDI patent technology)	Not convenient	Convenience (CISDI patent technology)
Production Safety Reliability (Long Term)	Relatively good	weak	ordinary	Relatively good	good	good
Recognition of overseas European and American markets	high	high	Relatively high	Relatively low	high	high

By combining and analyzing the technical characteristics, advantages, and disadvantages of the six typical converter supports in the world and comprehensively comparing the technologies in Table 1, it can be seen that the structure and working principle of the converter support mechanism parts are different, the different clearance of the supporting mechanism has different influence on the impact, vibration, wear and abnormal noise of the converter during operation; The number of converter support mechanisms determines the load uniformity, operation stability and safety margin of large converter support mechanisms; The arrangement of the converter supporting mechanism is closely related to the working condition, stability and working life of the connecting mechanism. The above points have a key and important influence on the running quality and equipment safety of the converter.

Therefore, the research conclusion drawn in this paper is that the running quality of a converter, especially a large converter (safety, impact, vibration, wear, and abnormal sound) is mainly affected by the following three factors of the converter support mechanism:

1) Parts of suspension mechanism,
2) Quantity of suspension mechanism,
3) Arrangement of suspension mechanism.

The discussion and research on these three aspects of the conveter support mechanism by engineering technicians, and how to comprehensively use these are the development trend and direction to ensure and improve the running quality of the converter in the future.

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