都兰金辉矿业有限公司磨机
现场运行情况考察报告及磨机衬板优化方案

Investigation Report of Mill Operation on Site and Optimized Plan of Mill Liner in Dulan Jinhui Mining Co., Ltd.

都兰金辉矿业有限公司选矿厂使用 Φ6×3m 半自磨机（一段）和 Φ4.27×7.3m 溢流型球磨机（二段）用于金矿石粉末破碎选矿。为优化磨机衬板设计、延长衬板寿命、提高磨机台效、降低原矿石粉末破碎成本，中实洛阳重型机械有限公司派员于 2013 年 10 月 28 日赶赴磨机工作现场进行了磨机运行实际工况现场考察。现将具体考察情况总结汇报如下：

Φ6×3m SAG mill (first stage) and Φ4.27×7.3m overflow ball mill (second stage) are applied to crush and separate gold ore in mining processing factory of Dulan Jinhui Mining Co., Ltd. In order to optimize mill liner design, prolong service life of mill liner, increase mill efficiency and decrease cost of crushing ore, CIC Luoyang Heavy Machinery Co., Ltd. Sent technicians to investigate the actual operation conditions of mills. The conclusions are the following:

现场情况 Conditions on Site

都兰金辉矿业有限公司选矿厂使用恒速 Φ6×3m 半自磨机（一段）和 Φ4.27×7.3m 溢流型球磨机（二段）用于金矿石粉末破碎选矿。矿石普氏硬度 f=10—12，入磨物料粒度较小，80—120mm 粒度物料约占 18%左右（见图一）；一段、二段磨机磨内添加最大磨球直径均为 Φ120mm 磨球；磨机衬板选材均为 HMCB02，磨机端衬板均为两圈分割的设计结构。半自磨机设计为溢流排矿设计；筒体衬板设计为高低矩形提升条间隔排布的设计方案；磨机额定台时产量为 100 吨 / h，实际最高台时产量曾经达到 91.6 吨 / h，,目前实际台时产量为 65 吨 / h；观察磨内衬板磨损情况发现，在连续工作 45 天后半自磨机筒体衬板高位提升条部位磨损严重（见图二）。磨机电声系统反映半自磨机磨音较为沉闷（电声信号输出为 4mA）。二段破碎 Φ4.27×7.3m 溢流型球磨机筒体衬板工作面几何曲面设计形状为单波峰设计结构。衬板波峰厚度为 116mm，波谷厚度为 50mm。衬板峰、谷高差为 66mm；磨机电声系统反映溢流磨磨音较为清脆（电声信号输出为 11mA）。就半自磨机工况情况而言，衬板磨损速度及磨损形态异常、磨机台时产量不能达标、磨音异常。就溢流磨工况情况而言存在磨音异常问题。

Φ6×3m constant speed SAG mill (first stage) and Φ4.27×7.3m overflow ball mill (second stage) are

applied to crush and separate gold ore in mining processing factory of Dulan Jinhui Mining Co., Ltd. Protodikonov's Hardness of ore is f=10-12, feeding material size is small, and 80-120mm material covers about 18% (see Fig. 1). Max. diameter of milling balls in the two kinds of mills is Φ120mm. All material of mill liners are HMCB02, and the structure of mill end liner are all segmentation design of two loops. For the SAG mil, overflow type for discharging minerals, and cylinder liners are designed as spacing configuration of high & low rectangular lifting bars . Rated output per hour of each mill is 100ton/h, and actual output per hour of each mill reached to 91.6 ton/h, now output per hour of each mill is 65ton/h. We found that cylinder liners in the high lifting bars places are worn seriously after running 45 days(see fig. 2). Electroacoustic system reflected the sound of milling is heavy (electroacoustic output signal is 4mA). For the Φ4.27×7.3m overflow ball mill, working faces of cylinder liners are designed as geometric shape with single wave peak. Thickness of wave peak is 116mm, and thickness of wave valley is 50mm. The difference between wave peak and valley is 66mm. Electroacoustic system reflected the sound of milling is clear (electroacoustic output signal is 11mA). So for SAG, wearing speed and conditions of liners are abnormal, and output per hour of each mill can not reach to the requirement, and milling sound is abnormal. And for the overflow ball mill, milling sound is also abnormal.

二、原因分析　Cause Analysis

1、半自磨机工况分析 Performance Analysis of SAG Mill

（1）衬板衬板磨损速度及形态异常——贵公司半自磨机筒体衬板设计为矩形提升条（见图三）高低相间的设计方案。依据半自磨机衬板设计规范，该设计方案适用于变频调速、进料粒度较大的半自磨机。当半自磨机筒体衬板提升条设计方案为矩形设计时，因该设计衬板提升条陡直，故而对磨内介质提升能力较强。因此在新衬板安装初期，应调整磨机转速为最大转速 60%时方可保证抛落的磨球冲砸至磨底迎球侧物料的富集区域以实现对物料的高效破碎。此时如果磨机转速过高，抛落的磨球将直接冲砸至对面的筒体衬板上，此时磨机衬板磨损加剧，磨机台效下降。同时因采用此设计方案的半自磨机内外层介质在运动过程中分层现象严重，故而磨机台效较低，因此一般不采用该设计方案。针对贵公司恒速半自磨机而言，此设计方案明显不当。当（半）自磨机入料粒度较大时采用高低提升条相间排布的设计方案以利于对大量大物料的有效提升。但当磨机入料粒度较小时，采用该设计方案则会导致被提升介质的提

前滑落，不利于磨机台效的充分发挥。综上所述，因贵公司半自磨机筒体衬板设计不当，在磨机恒速运行前期，抛落磨球直接冲砸衬板造成衬板快速磨损，衬板快速磨损后，提升能力下降，致使磨内介质抛落轨迹异常，此时磨音沉闷、磨机台时产量下降。

Irregular wear rate and wear form of the liners—Your design of the liners for the shell of the SAG Mill is rectangular lifting bars with high and low alternative distribution (See Picture 3). According to the designing standards of SAG mill liners, this design is suitable for SAG mills with frequency control and larger feed particle size. Rectangular design of the lifting bar of liners for the SAG Mill is with higher lifting capacity for the medium inside the mill, because the lifting bar is steep and straight. Therefore, in the early period after installation of the new liners, the speed of the mill should be adjust to 60% of the max speed, to ensure that the grinding ball falls and smashes into the material enrichment area for high efficiency crushing of the material. In this period, if the speed of the mill is too much higher, the falling grinding ball would smash directly to the opposite liners inside the mill. Then, the wear of the liners would be aggravated and the per-set efficiency of the mill would be lowered. Also for the medium inside the SAG Mill are seriously layered during the operation the per-set efficiency of the mill would be lowered. In this situation, this kind of design is usually being rejected. For your constant-speed SAG mill, this kind of design is obviously improper. When the feeding particle size of the mill is large, the high and low alternative distribution design of the lifting bars is good for the effective lifting of large number of material. But when the feeding particle size is small, this design will cause the material slip down earlier, and bad for the full play of the per-set efficiency of the mill. In conclusion, your design of the liner for SAG mill shell is improper. In the early period, the mill is operating with constant speed, and the falling grinding ball smashes to the liners directly and causes rapid wear of the liners. After rapid wear, the lifting capacity of the liners declined, and the falling track of the medium goes irregularly. And the grinding sound becomes flat, and the per-set per-hour production of the mill is lowered.

端衬板两圈分割方案错误——贵公司半自磨机端衬板采用的是两圈分割的设计方案。由现场照片可见，端衬板的强烈磨损区域正处于内外圈端衬板的交界部分（见图四）当内圈端衬板下部磨损报废时该衬板上部几乎没有磨损。此时拆换衬板将导致极大的浪费。

The segmentation of the liners into two loops is nor proper.— Your end liners of the SAG mill are segmented into two parts. Seeing from the on-site picture, the strong wear areas are mostly in the joint parts of the inner loop and the outer loop (see picture 4). When the inner loop is too worn to be used any more, the upper part of the inner loop is almost without any abrasion at all. In this situation, replacement of the inner loop liners is a great waste。

2、溢流型球磨机工况分析　Operation Performance Analysis of the Overflow Ball Mill

贵公司 Φ4.27×7.3m 溢流型球磨机磨音检测系统显示溢流磨磨音较为清脆（电声信号输出为 11mA）。该台溢流型球磨机用于金矿石的二段研磨粉末，就其工序功能而言应重点凸显其对入磨矿浆的研磨粉末功能。只有充分保证排矿细度才能实现目标选矿元素和脉石的有效分离。针对凸显研磨功能的溢流型球磨机而言，磨球配置一般较小，尽可能减小磨球间的空隙以利于磨球接触研磨。衬板设计应正确导向磨内介质呈接触态泻落翻动以研细入磨物料。尽量减少磨内介质呈分离态抛落运动。此时磨音应呈现为较为低沉的磨音。贵公司溢流磨磨音异常原因是因为溢流磨投料量不足、磨机筒体衬板设计方案有误所致。Φ4.27×7.3m 溢流型球磨机作为跟随半自磨机进行二段破碎的磨机而言，因半自磨机台产不能达标直接导致了该台磨机缺料运行。此问题在半自磨机台产不能达标问题解决以后也将随之解决。就磨机筒体衬板设计而言，该台磨机筒体衬板单波峰的设计结构和 66mm 的峰谷高差属于典型的凸显破碎功能的一段磨机的衬板设计结构。在此设计方案下，在磨机运转过程中大量磨内介质呈分离态抛落状运动。此时磨机破碎功能凸显、粉末研磨功能下降，并呈现出较为清脆的磨音。

The mill sound inspection system of your Φ4.27×7.3m overflow ball mill shows that the sound of the overflow ball mil is clear (With the output of the electroacoustic signal is 11mA). This overflow ball mill is used for the second stage grinding of the gold ore. The grinding function should be prominent in the whole process. The effective separation of the mineral element and gangue depends greatly on the discharging fineness. For this kind overflow ball mill, the equipped grinding ball is usually small, for the most possibility to reduce the space in-between each ball and also for the sake for the contact and grinding of the grinding balls. The right designing of liner should lead the grinding media falling in contacting state to play the funtion of grining the mineral, and it should prevent the liner falling in separating state, the normal working voice of mill should be the low voice. The abnormal of this project overflow mill is caused by the insufficient of mineral feeding and the wrong designing of shell

liner. The insufficient of feeding mineral is because that the outputing of sag mill is not up to the standard. Once the outputing of sag mill is up to the standard, the problem will be solved. The orginal designing of the shell liner including the single wave peak and the 66mm peak height difference has the problem of making the mill play a funtion of crushing instead of grinding, this desinging will make the grinding medis falling in a sparating state, reduce the working efficiency of the mill and make the mill working in a abnormal working voice(louding vocie)

解决方案 Solutions

半自磨机——立足于贵公司磨机现场的具体情况，针对半自磨机筒体衬板设计而言，采用梯形提升条全高设计方案（见图五、六）以实现对磨内介质全面的有效提升，并正确导向磨球抛落位置至磨底迎球侧物料富集区域以实现对入磨物料的高效破碎。此设计优化方案可明显延长衬板使用寿命、提高磨机台时产量（改造成功范例：铜化集团新桥矿业 Φ6.4×4.88m 半自磨机；江铜集团银山矿业 Φ7×3.5m 半自磨机）。就磨机端衬板设计而言，采用三圈分割的设计方案进行设计（见图七）。现场实际经验表明，该方案实施后，半自磨机内圈端衬板几乎不需更换（改造成功范例：铜化集团新桥矿业 Φ6.4×4.88m 半自磨机）。

SAG Mill - based on the detailed condition on site, we CIC designed the lifting bars of cylinder liners to high trapezoid(see fig. 5 & 6), in order to effectively lift medium in the mill and guide the milling balls to be thrown on the working faces of material enrichment area on the bottom of mill and achieve high efficiency crushing of feeding material. The optimized plan can dramatically prolong the service life of mill liners, decrease output per hour(successful examples: Φ6.4×4.88m SAG in Tonghua Corporation Xinqiao Mining Co., Ltd and Φ7×3.5m SAG in Jiangtong Corporation Yinshan Mining Co., Ltd.). For the mill end liners, we designed them as segmentation structure in three loops(see Fig. 7). Actual running experience shows that mill end liners in the inside loop are all not needed to replace after being applied our optimized design plan(successful examples: Φ6.4×4.88m SAG in Tonghua Corporation Xinqiao Mining Co., Ltd).

溢流型球磨机——为实现溢流型球磨机粉末研磨功能的充分发挥，针对贵公司的矿石属性，我方建议磨内主添加磨球选配最大直径为 Φ80mm，衬板设计为双波峰结构（见图八），峰谷高差为 50mm。此时方可凸显 Φ4.27×7.3m 溢流型球磨机的研磨功能。同时对磨机端衬板进行三圈分割设计以降低磨机内圈

端衬板报废残余重量（改造成功范例：嵩县丰源钼业 Φ4.27×6.1m 溢流型球磨机）。

Overflow ball mill - base on the features of the ore and sufficiently play the grinding function of overflow ball mill, we suggested the size of main milling balls is Φ80mm, and designed the liners as double wave peaks(see Fig. 8) and difference between wave peak and valley is 50mm. Meanwhile, we CIC designed the end mill liner as segmentation structure in three loops in order that decrease the weight of residual scrapping end liners in the inside loop (successful examples: Φ4.27×6.1m overflow ball mill in Songxian Fengyuan Molybdenum Industry Co., Ltd).

综上所述，贵公司半自磨机、溢流型球磨机衬板优化设计后可明显延长贵公司磨机衬板使用寿命、提高磨机运行台效、降低原矿石破碎生产成本、助推贵公司经济效益。

In conclusion, after being optimized design of mill liners, service life of mill liners are obviously prolonged, running efficiency of mill is decreased, cost of crushing ores is reduced and economic benefit is promoted.

图一 较细的入磨物料

Fig.1 small Feeding Material

图二 提升条部位严重磨损的筒体衬板

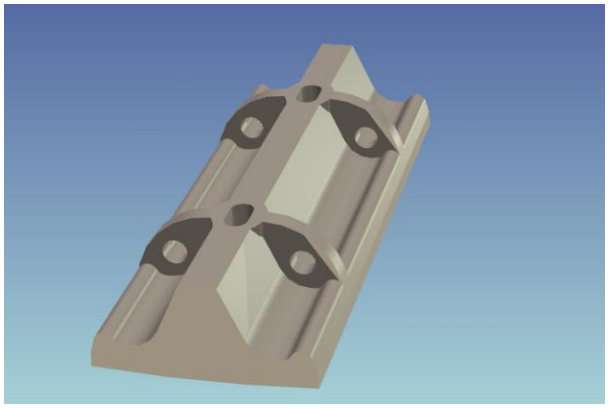
Fig.2 Cylinder liners with serious abrasion in the lifting

图三 矩形设计的半自磨机筒体衬板

Fig.3 Cylinder Liners with Rectangular

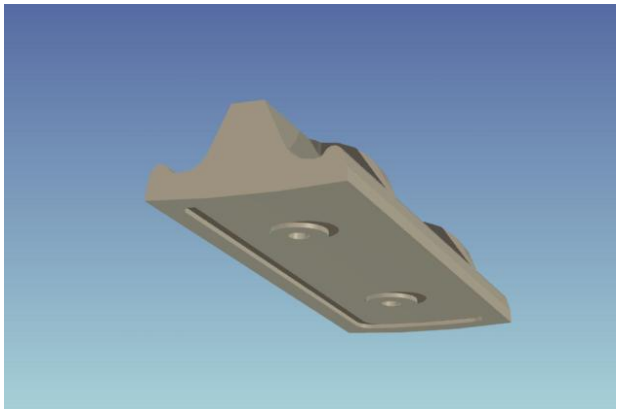
图四 端衬板磨损位置

Fig.4 Abrasion Conditions of End



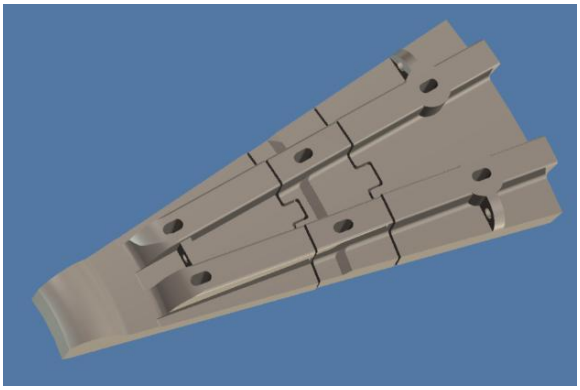
图五 筒体衬板梯形设计方案

Fig.5 Trapezoid Design Plan of Cylinder Liner



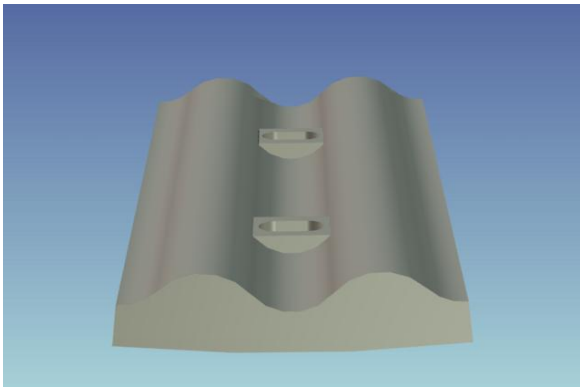
图六 筒体衬板梯形设计方案

Fig.6 Trapezoid Design Plan of Cylinder Liner



图七 磨机端衬板三圈分割设计方案

Fig.7 End Liner Segmentation Design Plan of Three loop



图八 溢流磨筒体衬板双波峰设计方案

Fig.8 Double Wave Peaks Design Plan of Overflow Mill Cylinder Liner