无缝钢管的壁厚精度控制

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［摘要］　对无缝钢管壁厚偏差产生的机理研究和分析，结合企业实际情况，通过采取控制管坯加热温度、提高轧制工具安装精度和芯棒精度等措施，进行有效控制和改进。经对比改进前后毛管和成品钢管壁厚精度情况，改进后钢管壁厚偏差带缩减了 8.5%，偏差达到企业内控标准的要求。

关键词　无缝钢管　壁厚精度　偏差　控制

1　引言

在无缝钢管的生产过程中，壁厚精度是钢管质量的重要指标之一。无缝钢管壁厚精度（壁厚偏差）的控制，体现了无缝钢管生产装备及工艺调整的整体水平，也反映了该机组生产的产品质量水平。因此各无缝钢管生产单位都在提高钢管壁厚精度控制水平上下功夫，制造出高尺寸精度的无缝钢管，为占据更多的市场份额奠定基础。

2　无缝钢管壁厚偏差产生的机理及原因

2.1　钢管壁厚偏差的表达式

壁厚正偏差：$+\Delta S=\dfrac{S_{max}-S_N}{S_N}\times 100\%$

壁厚负偏差：$-\Delta S=\dfrac{S_N-S_{min}}{S_N}\times 100\%$

式中：S_{max} — 钢管截面上壁厚的最大尺寸；

S_{min} — 钢管截面上壁厚的最小尺寸；

S_N — 钢管壁厚的名义尺寸。

2.2　影响尺寸精度的因素

2.2.1　现有工艺流程

热轧管生产线主要工艺流程：

管坯准备 → 环形炉加热 → 穿孔机穿孔 → Assel 轧管机 → 再加热炉 → 定减径机组 → 冷床冷却 → 矫直机组 → 精整区加工

从上述工艺流程可以看出，无缝钢管的尺寸变形主要集中在穿孔、轧管和微张减三大机组，而钢管壁厚是由穿孔最初成型，轧管和微张减对工序过程中的钢管壁厚不断进行干预，从而最终确定钢管的壁厚精度。

2.2.2　主要工序对钢管尺寸精度的影响

见表 1。

表 1　Assel 轧管机组主要工序对钢管尺寸精度的影响

工序	穿孔机	Assel 轧管机	定减径机
成品壁厚	—	◎	○
外径、内径	—	—	○
壁厚不均	◎（螺旋状）	○	◎（内表面形成多边形）
椭圆度	—	—	○
长度	—	○	◎
弯曲度	—	—	—
管端形状	—	—	◎（管端增厚）

注：◎表示影响大；○表示影响小；—表示影响很小。

2.3　壁厚偏差产生原因

2.3.1　管坯的加热

管坯的加热过程是非常重要的，如果加热管坯受热不均匀，将会产生阴阳面，使得穿孔机顶头在穿孔过程中受力不均匀而发生偏移，导致毛管低温面壁厚，高温面壁薄。

2.3.2　穿孔机穿孔过程中产生的偏差

由于穿孔机顶头在穿孔时与支撑顶杆的第一架定心辊间所形成的是悬臂梁结构，使得顶头在穿孔过程中不规则跳动，毛管在顶头不规则跳动的作用下受力不均，形成毛管壁厚偏差。

2.3.3　设备制造与安装精度

（1）　在设备制造中，如果穿孔机的轧辊和导板的结构稳定性较差，使其在穿孔时产生较大的跳动，对毛管壁厚精度产生影响。

（2）　对定心辊来说，其中心在实际安装与调整时，不易找准三个定心辊抱紧顶杆时产生的理论圆心，这样就会造成在穿孔时顶杆受到定心辊抱紧而产生的径向力不均。稳定性差是产生毛管壁厚偏差的主要原因之一。

2.3.4　工具精度的影响

当穿孔轧制工具不精确时，管坯穿轧变形区的正确几何形状遭到破坏，如顶头后孔偏心，使用过度磨损的导板、轧辊等都容易造成穿孔后毛管壁厚不均。当穿孔顶杆发生弯曲、Assel 轧管机芯棒由于冷热疲劳发生弯曲，也都能使钢管的壁厚精度下降。

3　改进措施及钢管壁厚精度比对结果

为了解决实际生产过程中产生的钢管壁厚控制不稳定的问题，经历时四个月对常规产品进行跟踪，并通过一系列控制和改进手段来提高钢管壁厚精度。选取常规产品 Φ139.7 mm×7.72 mm 的平端光套管作为比较对象，通过罗列出改进前后的钢管壁厚精度及具体的改进控制手段说明改进方案的客观可行性。

我厂采用美国进口 Puboscope 漏磁–超声波在线联合无损探伤设备对所生产的钢管进行全长测厚，覆盖钢管的整个管体，数据由图表曲线形象地显示出来，较过去的人工端部测厚更为先进，数据更加精确、直观。

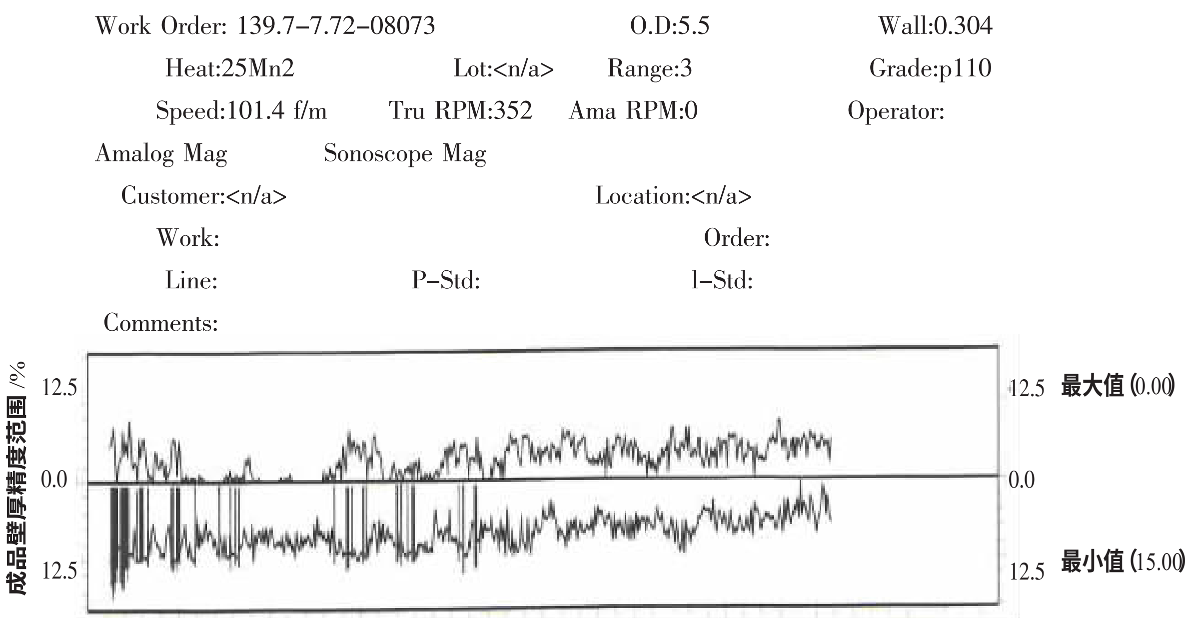
3.1　改进前

通过一段时间的现场追踪和数据采集，对现场生产的钢管的壁厚尺寸精度的合格率做了统计见表 2。

对已生产的 Φ139.7 mm×7.72 mm 的平端光套管成品钢管，通过全长测厚，尺寸精度满足企业内控标准要求的钢管合格率平均为 64.1% ，最低为的 46%，合格钢管的穿孔毛管的壁厚精度范围在–8.3%~+10%，成品壁厚精度范围在–12.5%~+10%，从图 1 中可以看出，不合格的钢管的壁厚精度在–15% ~ +10% 已超出企标的规定。

表 2　2008 年改进前生产情况

日 期	生产支数 (N)	合格支数(N)	合格率(%)
4 月 24 日	1 126	709	63
4 月 25 日	1 312	903	68.8
4 月 26 日	976	722	74
4 月 27 日	1 103	578	52.4
4 月 28 日	1 176	923	78.5
4 月 29 日	1 092	502	46
4 月 30 日	1 134	739	65.2



图中壁厚偏差为 - 15%～+10%

图 1　改善前的壁厚精度情况

3.2　改善壁厚精度的措施

选定常规产品中 J55 钢级的 Φ139.7 mm×7.72 mm 平端光套管作为研究对象，通过运用如下手段，来提高钢管的壁厚精度。

3.2.1　管坯加热

环形加热炉的加热温度要均匀，禁止急速升降温度。对于不同材质的坯料要严格按照不同的工艺技术规程规定的加热制度进行温度控制，每次升降温要保持平稳缓慢，最大升降温幅度不得超过 30 ℃。环形炉加热四区温度严格控制在 1 280±10 ℃，再加热炉加热温度严格控制在 930±8 ℃

3.2.2　定心辊

确定机内定心辊的磨损情况，确认其安装是否到位，液压缸是否锁紧，从而保证其中心的稳定。调整抱芯辊的中心、打开角度及各动作的开口大小一致，且抱芯辊中心在轧制线上。

3.2.3　轧制中心线

穿孔机轧制中心线应与穿孔小车中心线保持一致，避免采用“上轧制”或“下轧制”工艺。设备在改进、安装、调试过程中，要对穿孔机轧制中心线的标高与

穿孔小车中心线的标高进行测量，使其保持标高一致，并与穿孔机的主机端面保持垂直，从而确保穿孔机轧制中心线与穿孔小车中心线一致，避免了“上轧制”或“下轧制”，使管坯在穿轧时保持受力均匀平衡，避免了管坯轧制时单面受力而影响壁厚精度。

3.2.4 轧制工具

对于磨损的顶头、导板、轧辊等轧制工具要及时更换。轧制工具是坯料变形的主要参与者，因此轧制工具的精度势必会对生产出来的钢管尺寸精度造成影响。穿孔的轧制截面为两个轧辊、两个导板和中间的顶头构成，如图2所示。在轧辊、导板等都进行精确定位后，顶头则对壁厚的影响起到了至关重要的作用。

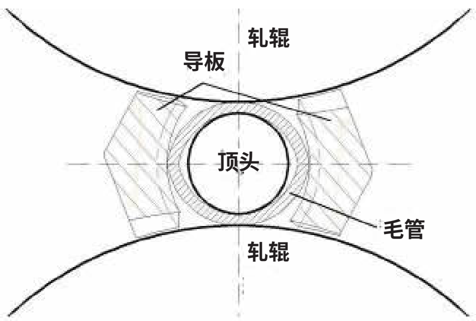


图2 穿孔机穿轧截面示意图

3.2.5 轧制工具安装精度

确保轧制工具的安装精度，辊距、导距的中心必须在轧制线上。导板安装要保证其背部准确安装到凹槽内，确保导板的安装精度。以穿孔小车的中心及穿孔前导嘴的中心为端点拉轧制线，采用内卡，钢板尺等测量工具对穿孔机的辊距、导距进行测量控制，要求辊距控制在128±2 mm，导距控制在148±2 mm，且以轧制线为中心，保证导距和辊距的中心在穿孔轧制中心线上，即上下辊距相等，左右导距相等。

3.2.6 穿孔顶杆

穿孔顶杆严格进行筛选，穿孔顶杆一般选择外径为Φ108 mm~Φ114 mm，壁厚要求≥25 mm且壁厚均匀的厚壁管，由于其内部要装有外径约Φ35 mm的水管，因此选取厚壁管的壁厚不易太厚，一般不超过35 mm。

3.2.7 轧机芯棒

轧机的芯棒要选用壁厚较厚的厚壁管加工，但是要保证其壁厚的均匀性，一般芯棒壁厚精度偏差不得超过±0.8 mm 对于规格较小的芯棒，可采用实心坯料代替。轧机的芯棒要频繁的参与轧制，冷热疲劳的作用则尤为突出，如果壁厚不均或是壁厚较薄，则很容易使芯棒发生弯曲变形和表面磨损，从而严重影响产品的壁厚质量，壁厚均匀的厚壁管和实心坯料则弥补了这一缺陷，使芯棒弯曲变形的概率大幅降低，可以有效地提高钢管的壁厚精度。

3.2.8 芯棒的精度

提高轧机芯棒的加工精度。轧机的轧制截面是由三个轧辊及中间的芯棒构成，如图3所示。在轧辊等都进行精确定位后，芯棒的精度对壁厚的影响起到了至关重要的作用。芯棒的长细比较大，一般采用先车外径然后打坡口焊接，或者采用长料直接车削成型。外径加工精度由原先的±0.3 mm提高到±0.1 mm，并且对于长度较长的坯料加装移动托架进行辅助 芯棒坯料的直度由原来的3 mm/m提高到1.5 mm/m，并且芯棒全长的直度偏差不得超过5 mm。焊接要保持两端水平放置，需要焊接的两段芯棒之间插入一个精加工的销子进行定位，以防止由于焊接造成的总直度偏差过大，焊接后要将焊口处用角磨机处理光滑。以高精度的芯棒参与轧制，会提高钢管的壁厚精度。

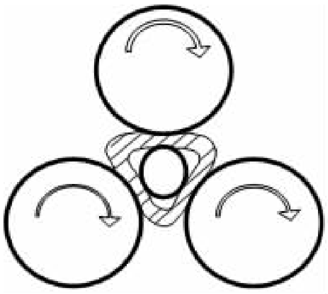


图3 轧机轧制截面示意图

3.2.9 完善工艺

通过改进、完善生产工艺提高壁厚精度。将定减径机组的电机转速设定在1 000~1 200 r/min，张力系数控制在0.32左右，控制壁厚增厚范围在0.3±0.05 mm，有效地遏制了中间拉薄和壁厚增厚超过控制范围的情况发生，提高了壁厚精度。

3.3 改进后

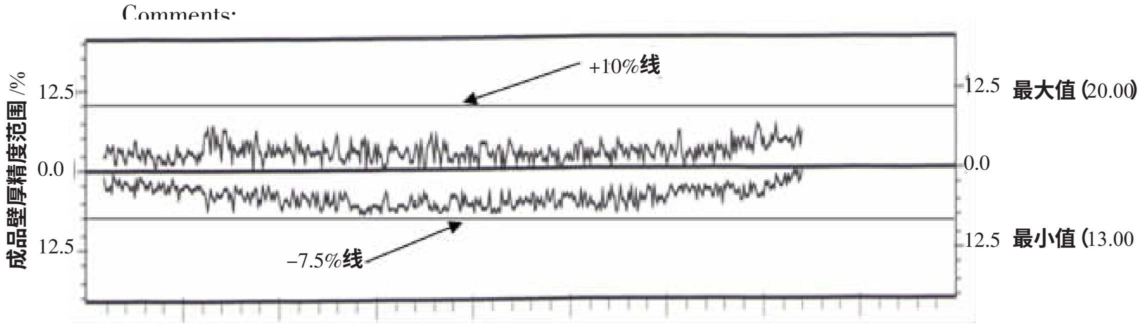
实施上述措施的四个月后，再次对一段时间内的现场追踪和数据采集，对现场生产的钢管的壁厚尺寸精度的合格率做了如下统计，见表3所示。

表3 2008年改进后生产情况

日 期	生产支数(N)	合格支数(N)	合格率(%)
8月29日	1 053	881	83.7
8月30日	1 137	879	77.3
8月31日	1 045	919	87.9
9月1日	1 289	1012	78.5

该生产线经过上述方案进行控制和改进，所生产的钢管同样通过该无损探伤进行全长测厚，尺寸精度全部满足企业内控标准要求，合格钢管的穿孔毛管的壁厚精度范围在-3.3%~+6.7%，成品壁厚精度范围在-7%~+8.5%，壁厚测量报告如图 4 所示。

Work Order: 139.7-7.72-p110-08030　　O.D:5.5　　Wall:0.304
Heat:　　Lot:<n/a>　　Range:3　　Grade:p110
Speed:100.0 f/m　　Tru RPM:352　　Ama RPM:0　　Operator:
Amalog Mag .7　　Sonoscope Mag　7.3
Customer:<n/a>　　Location:<n/a>
Work:　　Order:
Line:　　P-Std:　　l-Std:
Comments:



图中壁厚偏差为 - 7.5%～+8.5%

图 4　改善后的壁厚精度情况

从上述全长测厚报告结果来看，改善后收到了明显的效果，见表 4，钢管壁厚偏差得到了有效的控制，精度较之前提高了约 0.502 mm，提高了公称壁厚的 6.5%，其偏差均达到企业内控标准的相关要求。其中合格钢管的穿孔毛管的壁厚精度提高了约1 mm。

表 4　钢管壁厚精度对比

状态	平均合格率	合格钢管的毛管		合格成品钢管	
		壁厚偏差	提高精度	壁厚偏差	提高精度
改进前	64.1%	- 8.3%～+10%	8.3%（1mm）	- 12.5%～+10%	6.5%（0.502mm）
改进后	81.6%	- 3.3%～+6.7%		- 7.5%～+8.5%	

4　结论

4.1　实践证明，通过采取有效的措施，无缝钢管的壁厚精度确实得到很大的改善。从-15%~+10.0%提升至-7.5%~+9.0%，使钢管壁厚偏差带缩减了 8.5 个百分点。

4.2　理论和实践证明，穿孔工序是控制钢管壁厚公差的决定性工序，即只有将壁厚偏差控制在穿孔阶段，才能较好地解决无缝钢管成品的壁厚精度问题，并且是不以降低生产能力和提高运行成本为前提的。

4.3　穿孔后的工序，如 Assel 轧管、定减径工序也能减小荒管的壁厚偏差，但其纠偏能力是极为有限的，远不如在穿孔机上控制的效果好。

4.4　穿孔机的安装精度、运行精度、工具精度，都是钢管壁厚精度的决定性因素。

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ABSTRACTS
TIANJIN METALLURGY

Otc . 2009 No . 5 Total No . 155

Practice of Increasing 50 t EAF Molten Iron Ratio

Ji Guojun, Zhang Huiquan, Wang Guoqing, Zhang Jinjin

Abstract: The adoption of measures of increasing 50 t EAF molten iron ratio and optimizing charge blending, power and oxygen supply systems and foaming slag process prominently improves the quality of liquid steel, reduces charging number, shortens tap-to-tap time and lowers melting power consumption. All EAF economic and technical indices are raised with good economic benefit.

Key Words: EAF steel-making, molten iron ratio, process optimization, increase

Maintenance Practice of Stack of BF 3, Meishan

Zhang Haibin

Abstract: The blast furnace 3, Meishan at the later phase of its campaign, with seriously eroded stack and mostly damaged cooling equipment, restrains the normal production of the blast furnace. By methods of stack grouting lining technology and rational operation system, the problem of stack erosion is effectively solved. The gas utilization ratio of the blast furnace rises with stable furnace conditions. All economic indices are optimized.

Key Words: blast furnace, stack, grouting, cooling equipment, gas flow, maintenance

Design Characteristics of Indian 260 m^3 Blast Furnace

Zhao Qiqiang, Li Jie, Qi Xuezhong

Abstract: The paper summarizes the design characteristics of the newly built 260 m3 blast furnace at ISL Company, India, which is contracted to Huatian Engineering and Technology Corporation, MCC. The internal lining of the said blast furnace is a combination of carbon brick with ceramic cup at furnace bottom and hearth. Carbon brick are lined at belly and lower stack while phosphate impregnated clay brick at upper stack. The proven open loop cooling method of industrial water is applied and proper water flow rate is chosen.

Key Words: blast furnace, stack, hearth, lining, design

Optimization Practice of Injection System of BF 3, No.2 General Ironworks, Masteel

Chen Jun, Zhan Shengwang, Zhao Xingliang

Abstract: The injection system of BF 3, No.2 General Ironworks, Masteel shows inadequate injection capacity due to design reasons. Optimization measures are taken on the injection equipment, bringing the injection capacity from 18t/h to 25t/h. The pilot air flow and fluidization volume are optimized for injection operation and injection ratio is constant. The coal shortage and breakage incidents are eliminated. The injection requirement by blast furnace is ensured.

Key Words: blast furnace, pulverized coal, injection, system, operation, optimization

Comments on PQF and FQM Three-roll Retained Mandrel Pipe Mills

Zhang Dantian, Zhong Xidi

Abstract: The paper briefly introduces the process characteristics and equipment features of PQF and FQM three-roll retained mandrel pipe mills, which were imported from abroad successively by Chinese pipe industry since entering the 21st century. Through comparison and analysis, the consistency of core technology of metal deformation and the difference of mandrel running method and production efficiency in production are demonstrated. The core technology of metal deformation, electrical drive and automation control system and multilevel online inspection technology all represent the contemporary top technology and equipment level of seamless pipe production.

Key Words: PQF pipe mill, FQM pipe mill, process characteristic, equipment feature, core technology, difference

Study on Quenching and Tempering Process of 70 kg Grade High Strength Plate

Song Leiming, Liu Peng, Lu Yan, Chen Fushan

Abstract: The authors analyze the mechanical properties and structure of 70 kg Grade low carbon high strength plates produced with different quenching and tempering processes and define its quenching and tempering process as: quenching temperature: 930℃ with 40 min holding time; quenching temperature: 630℃ with 45 min holding time. The rolled plate with such process yields high strength and good low temperature impact property.

Key Words: plate, test, quenching and tempering, mechanical property, structure

Control over Seamless Pipe Wall Thickness Precision

Li Jinsuo, Wang Xin, Zhang Ling, Xu Zhe, Mu Chunling

Abstract: The mechanism of the formation of seamless pipe wall thickness deviation is studied and analyzed in the paper. Effective control and improvement are performed by way of taking measures of controlling billet heating temperature, increasing the installation precision of rolling tools and mandrel precision in combination with the actual situation. Comparison of wall thicknesses of blank pipe and finish pipe before and after improvement is made. After improvement, the pipe wall thickness deviation is reduced by 8.5%, which complies with company internal controlled standard.

Key Words: seamless pipe, wall thickness precision, deviation, control

Research on Improving Prestressed Steel Strand Straightness

Zhao Xuegang, Fu Yinxing

Abstract: The paper introduces the effect of prestressed concrete steel strand straightness on the length uniformity, tension stress uniformity, fatigue property and stress corrosion resistance of strand tendon. The authors analyze the factors affecting strand straightness and propose measures and suggestion for improving strand straightness.

Key Words: prestressed steel strand, straightness, tightness, tension, improvement

Research and Development of EH36 High Strength Hull Structure Plate

Yang Weizeng

Abstract: The chemical compositions of EH36 high strength ship plate steel are designed with low carbon, high manganese and Nb microalloying, and the EH36 high strength ship plate is successfully developed with TMCP process at TISC 3,500 mm Plate Rolling Mill. The mechanical properties and microstructure of the rolled ship plate are inspected and analyzed. Test results show the developed EH36 high strength hull structure plate, with good combination of strength and toughness, meets national standards and regulations of ship classification society.

Key Words: high strength ship plate, alloy, chemical composition, mechanical property, design, research and development

Effect of Rapid Solidified Al-Ti-B and Cu-P on Al-13.5Si-xCu-yNi Alloy Structure and Properties

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Abstract: The Al-13.5Si-xCu-yNi alloy was made by adding Cu-Ni intermediate alloy (Ni content: 40%) in ZL108 alloy. The advantages of mechanical properties of the alloy compared with ZL108 alloy are studied. The alloy is refined and modified with fast solidified Al-Ti-B and Cu-P thin ribbon. The best modification plan is formulated by observing alloy microstructure after refinement modification and testing its mechanical properties. The results show that rapid quenching ribbon modifier can provide finer alloy microstructure and improved overall mechanical properties compared with common massive modifier.

Key Words: Cu-Ni intermediate alloy, rapid solidification, modification treatment, test, structure

Study on Structure Features and Mechanical Properties of 08Al Hot Rolled Narrow Strip

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Abstract: In order to solve problems of cracking and pitted surface of 08Al narrow strip during pressing and bending at Guofeng Iron and Steel Company, OM, SEM and EDX methods are adopted to test and study the features of metallographic structure and mechanical property of the strip under hot rolled state. Results indicate that 08Al microstructure consists of heterogeneous equiaxial ferrite grains; free cementite precipitation is serious (about class III); few complex inclusions with most sizes ≤5 μm. 08Al narrow strip shows relatively high yielding strength and average plasticity. The high N content is the main reason for extended yielding platform or big difference of upper and lower yielding points at tensile test.

Key Words: narrow strip, hot rolled, structure, feature, mechanical property, analysis, research

Application of Inlet Air cooling and Humidifying Compressor Technique on Gas Turbine

Li Peng

Abstract: The gas turbine is the main equipment of gas-steam combined cycle type generator set. Adding inlet air cooling and humidifying compressor at gas turbine can effectively lower the running temperature of the compressor and raise gas turbine work under high temperature weather. The paper introduces the design principle, equipment characteris tics and consisting systems of inlet air cooling and humidifying compressor technique. The said equipment, applied at PG6561L generator set at Jigang Group, gives much more work and provides prominent effect.

Key Words: inlet air cooling, humidifying, compressor, gas turbine, combustion, temperature

Simulation Calculation and Analysis of Hearth and Bottom Temperature Field of HISGC BF No. 1

Sun Huaping