高温氢腐蚀知识。 High Temperature Hydrogen Corrosion Knowledge.

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高温氢腐蚀的特点： Characteristics of high-temperature hydrogen corrosion:

氢脆 Hydrogen embrittlement

由氢本身引起钢材脆化现象。氢原子渗入钢材后，使钢材晶粒结合力下降，而造成钢材的延伸率和断面收缩率的下降或出现延迟破坏现象。若氢气由钢材中释放出去，钢材的机械性能仍可恢复。氢脆为暂时的，可通过钢材加热使氢脆消除。

It is a phenomenon of steel brittleness caused by hydrogen itself. After hydrogen atoms penetrate into steel, the binding force of steel grains decreases, resulting in a decrease in the elongation and 断面收缩率 of steel or the occurrence of delayed fracture. If hydrogen is released from the steel, the mechanical properties of the steel can still be restored. Hydrogen embrittlement is temporary and can be eliminated by heating the steel.

表面脱碳 Surface decarburization

钢材与高温氢接触后，形成表面脱碳。表面脱碳不形成裂纹，其影响是强度及硬度略有下降，而延伸率增高。

Steel in contact with high-temperature hydrogen forms surface decarburization. Surface decarburization does not form cracks, and its effect is a slight decrease in strength and hardness, while the elongation increases.

氢腐蚀(内部脱碳) Hydrogen corrosion (internal decarburization)

高温高压下的氢渗入钢材之后和不稳定碳化物形成甲烷。钢中甲烷不易逸出，而使钢材产生裂纹及鼓泡，并使强度

和韧性显著下降。其腐蚀反应是不可逆的，是永久性脆化。

Under high temperature and high pressure, hydrogen penetrates into the steel and reacts with unstable carbides to form methane. Methane is not easily released from the steel, causing cracks and bubbles in the steel and significantly reducing its strength and toughness. The corrosion reaction is irreversible and leads to permanent embrittlement.

影响氢腐蚀的主要因素： The main factors affecting hydrogen corrosion:

1.高温氢腐蚀的特征： 1. Characteristics of high-temperature hydrogen corrosion:

高温氢腐蚀是在高温高压条件下扩散侵入钢材中的氢与不稳定的碳化物发生化学反应，生成甲烷气泡（包含甲烷的成核过程和成长），即Fe3+H2→CH4+3Fe，并在晶间空穴和非金属夹杂部位聚集，引起钢材强度、延性和韧性下降与劣化，同时发生晶间断裂。由于这种脆化现象是发生化学反应的结果，所以它具有不可逆的性质，也称为永久脆化现象。

High-temperature hydrogen corrosion occurs when hydrogen diffuses into steel under high temperature and high pressure conditions, reacts with unstable carbides to form methane bubbles (including the nucleation and growth process of methane), i.e., Fe3+H2→CH4+3Fe, and accumulates in intercrystalline voids and non-metallic inclusions, causing the strength, ductility, and toughness of steel to decrease and deteriorate, and intercrystalline fractures to occur. Since this brittleness phenomenon is the result of a chemical reaction, it is irreversible and is also known as permanent brittleness.

在高温高压氢气中操作的设备所发生地高温氢腐蚀有两种形式：一是表面脱碳，二是内部脱碳。

There are two forms of high-temperature hydrogen corrosion that occur in equipment operated in high-temperature and high-pressure hydrogen: surface decarburization and internal decarburization.

2.影响高温氢腐蚀的主要因素： 2. Main factors affecting high-temperature hydrogen corrosion:

a.温度、压力和暴露时间的影响。温度越高或者压力越高发生高温腐蚀的起始时间就越早，腐蚀速率越大；

The influence of temperature, pressure, and exposure time. The higher the temperature or pressure, the earlier the initiation time of high-temperature corrosion, and the greater the corrosion rate;

b.合金元素和杂质元素的影响。氢腐蚀的机理是不稳定碳化物的分解，所以在钢材中添加能形成稳定碳化物的元素（铬、钼、钒、钛、钨）就可使碳的活性降低，从而提高钢材抗氢腐蚀的能力。在加氢高压设备中广泛采用铬-钼钢系，这是原因之一；

The influence of alloying elements and impurity elements. The mechanism of hydrogen corrosion is the decomposition of unstable carbides, so adding elements that can form stable carbides (chromium, molybdenum, vanadium, titanium, tungsten) in steel can reduce the activity of carbon, thereby improving the steel's resistance to hydrogen corrosion. The use of chromium-molybdenum steel in hydriding high-pressure equipment is one of the reasons for this;

c.热处理的影响。钢材的抗氢腐蚀性能，与钢材的显微组织也有密切的关系。施行回火且回火温度越高，由于可形成稳定的碳化物，抗氢腐蚀能力得到改善；

The influence of heat treatment. The resistance of steel to hydrogen corrosion is closely related to the microstructure of the steel. The application of tempering and the higher the tempering temperature, due to the formation of stable carbides, the resistance to hydrogen corrosion is improved;

d.应力的影响。在高温氢腐蚀中应力的存在会产生不利影响，试验证明，在高温氢气中蠕变强度会下降，特别是

由于二次应力（如热应力或由冷作加工所引起的应力）的存在更会加速高温氢腐蚀。

The influence of stress. The presence of stress in high-temperature hydrogen corrosion has an adverse effect, and tests have shown that the creep strength will decrease in high-temperature hydrogen, especially due to the presence of secondary stresses (such as thermal stress or stress caused by cold working) which will accelerate high-temperature hydrogen corrosion.