Numerical Simulation of the Thermal Conductivity of Thermal Insulation Pipe by Vacuum and High Pressure Argon Pre-filled

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【Abstract】By analyzing the insulation effect of argon-filled tubing and vacuum-insulated tubing before and after hydrogen permeation respectively, a conclusion can be drawn that the insulated tubing filled with high pressure argon is better than the vacuum insulated tubing considering the lifetime and heat insulation effect.

【Key words】Hydrogen permeation; Vacuum insulated tubing; Argon filled tubing; Thermal conductivity

1 Comparison of the hydrogen permeation rate of the argon filled tubing and the vacuum insulated tubing

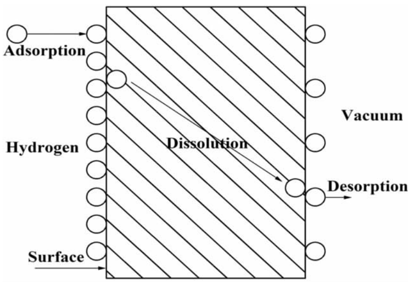

Figure.1 The principle diagram of the hydrogen permeation

From the microscopic point of view, hydrogen permeation process is carried out according to the following steps[1-3]:

First, the hydrogen molecules impact to the outer surface of the vacuum environment, and adsorbed by the outer surface;

Second, part of the hydrogen molecules which are absorbed by the outer surface can be dissociated into atomic state;

Third, hydrogen atoms reaches an equilibrium solubility on the outer surface;

Fourth, because of the existence of concentration gradient, hydrogen atoms are diffused to the surface of the vacuum side;

Fifth, hydrogen atoms are released into the vacuum environment after combined into the molecular state.

According to the law of diffusion, the formula of permeation rate of gas can be deduced:

$$Q=\frac{K\cdot A\cdot \Delta p^{1/j}}{h} \qquad (8)$$

Q——permeation rate of gas;

K——permeability coefficient of a gas to a solid;

A——area of surface;

Δp——the difference of gas pressure between two sides of the wall;

j——dissolution constant, if the solid is metal and the gas is diatomic molecule, such as hydrogen, j=2;

h——wall thickness.

According to the above formula, we can see that the rate of hydrogen permeation(Q) is proportional to the pressure difference of 1/2 times (Δp) 1/2. Existing in the insulated tubing is about 350℃ water vapor, and its pressure is about 21MPa. The pressure of argon filled tubing is about 1MPa, and the pressure of vacuum insulated tubing is close to 0. Therefore, we may safely draw the conclusion that ?p of the argon filled tubing is smaller than that of the vacuum insulated tubing, so, permeation rate (Q) of the argon filled tubing is smaller than that of the vacuum insulated tubing, namely hydrogen permeation of the argon filled tubing is slower than that of the vacuum insulated tubing.

2 Thermal conductivity of N80 steel, H_2, Ar and H_2-Ar gas mixture at different temperatures

According to the chemical compositions, standard steels can be classified into three major groups: carbon steels, alloy steels, and stainless steels. Carbon Steels are defined as follows [4]: alloying elements do not exceed these limits: 1% carbon, 0.6%copper, 1.65% manganese, 0.4% phosphorus, 0.6%silicon, and0.05%sulfur.

According to the N80 steels from Sumitomo, Mannesmann, the United States, the Czech Republic and other places, we can get its chemical compositions:0.3%-0.4% carbon, 0.02% copper, 1.25%-1.62% manganese, 0.013%-0.022% phosphorus, 0.25%-0.38% silicon, 0.005%-0.008% sulfur, therefore, it can be concluded that N80 is a typical carbon steel.

Carbon content is the main factors affecting the thermal conductivity of carbon steel [5]. Smithells Metals Reference Book [6] has provided the thermal conductivity of carbon steel whose carbon content is 0.4%, its value is as follows:

Table 1

T(℃)	100	200	400	600	800
λ(W/(m·℃))	41.9	41.9	38.9	32.7	26.0

Table 1 thermal conductivity of N80 steel as the change of temperature

The thermal conductivity of H_2, Ar and H_2-Ar gas mixture at different temperatures has been calculated in another paper[7].

3 The results and analysis of numerical simulation

The following two figure are the temperature maps and the heat-flux maps of the vacuum insulated tubing of C level -whose thermal conductivity(λ) is 0.02:

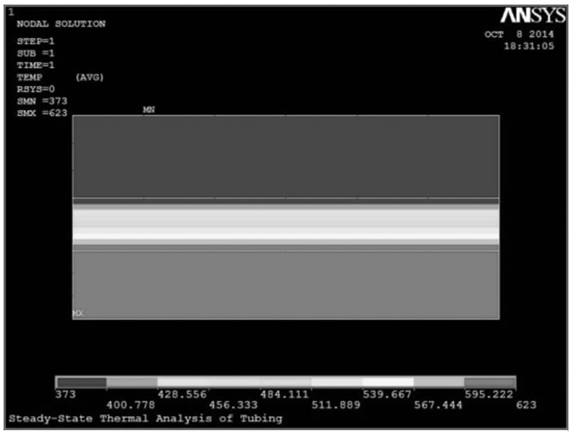

Figure.2 Temperature maps

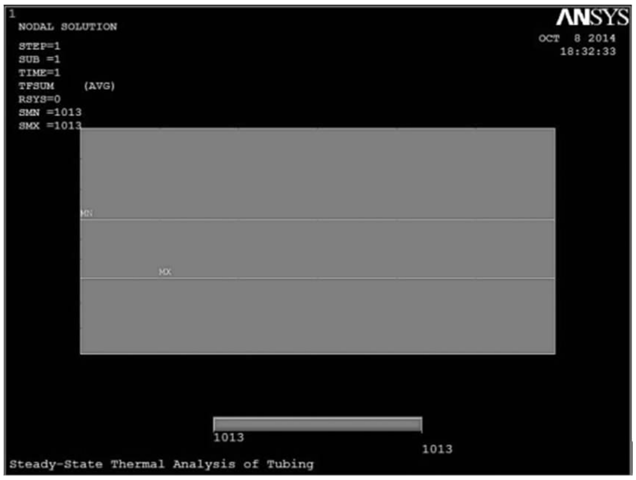

Figure.3 heat-flux maps

Besides, heat-flux densities of vacuum insulated tubing at different levels were calculated, as shown in the following table:

Table 2

Level	C(λ=0.02)	B(λ=0.04)	Failure critical point(λ=0.08)	After hydrogen permeation
Heat-flux density	1013	2023	4043	13629

Table 2 heat-flux densities of vacuum insulated tubing at different levels

In addition, the heat-flux density of argon filled tubing containing different content of hydrogen were calculated, as shown in the following table:

Table 3

The content of hydrogen	0	10%	20%	30%	40%	50%
Heat-flux density	1329	1841	2438	3090	3858	3858

Table 3 Heat-flux of argon filled tubing containing different content of hydrogen

By comparing the tables of (2) and (3), we can see that the insulation effect of argon filled tubing is slightly inferior to the vacuum insulated tubing of C class at the initial stage, however, it is enough to meet the requirement of thermal insulation effect.

When a certain amount of hydrogen is penetrated, the heat-flux density of the vacuum insulated tubing will reach to more than 13 thousand, so, the tubing cannot meet the requirements of thermal insulation effect at all.

However, when the content of hydrogen permeated into the argon filled tubing is above 40%, the tubing will be near to the critical value of failure. So that the heat insulated tubing life is greatly extended in the premise of perfect heat insulation effect. Therefore, the insulated tubing filled with high pressure argon is better than the vacuum insulated tubing considering the lifetime and heat insulation effect.

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(上接第100页)另外,由于比赛是实时的,而且仿真环境存在噪声干扰,所以采集的信息可能是不精确的,甚至机器的速度都会对比赛产生大的影响。基于以上,ID3算法能有效的消弱不确定的影响,使比赛的决策趋于稳定。下面主要针对传球策略,给出影响的属性集。

若要考虑场上所有因素,则状态空间很大,是目前的机器所不能支持的。下面根据主要和次要的矛盾,简化状态空间,考虑影响传球的主要干扰,忽略次要方面。当然,这可能会造成判断不准确,但是相比较运行时间而言,在误差允许范围内,可以提高传球成功决策率,有实际的应用价值的。

假设传球者为A,接球者为B,离B最近的两名对方球员为C,D,球为E,下面将属性因素总结如下:

1)A与B的距离为distAB,C与E的距离为distCE,D与E的距离为distDE,A与E的距离为distAE;

2)A与C的角度为AngAC,A与B的角度为AngAB,A与D的角度为AngAD,A与E的角度为AngAE;

3)球速度为Espeed,传球者速度为Aspeed,B速度为Bspeed,D速度为Dspeed,C速度为Cspeed。

学习目标是:A能传给B为T,否则F;属性集合大小13;

根据属性集,采集一定的训练样本,进行基于ID3的决策树构造;具体的构造方法如下:

1)把所有属性作为节点放入树的集合中;

2)如果所有的属性均在T中或者F中则决策树构造结束;否则转3;

3)选择莫个属性A根据训练样本值V1,V2,…Vn将训练集分成子集T1,T2,…Tn,计算属性A的信息增益,遍历所有属性,比较信息增益取最大值即为根节点;

4)循环3,迭代计算子结点等。

为了验证本文带球算法的可行性和有效性,我们将此方法应用于ROBOCUP仿真平台中球员的传球训练中。从统计数据中可以看出,随着训练次数的增加,我方球员的传球成功率逐渐提高,在趋于700次以后,我方的平均传球决策成功率趋于稳定。结果表明此方法是收敛并且有效的提高了我方的传球成功率。

4 不足与总结

本文根据ID3算法,给出了在RoboCup仿真比赛中训练学习传球策略的思路,但是由于考虑问题的局限性,并且算法本身也存在诸如不连续性、优先选取取值较多的属性的倾向等缺陷,要想将ID3算法运用于传球策略中并达到百分之百的成功率还有很多需要改进的地方。

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