汽轮机级联二维湿蒸汽流动分析

摘　　要

蒸汽在汽轮机动叶栅中流动时，由于膨胀和蒸汽焓的降低使得蒸汽越过饱和线，足够过冷后，会发生凝结成核并出现第二相。这种湿蒸汽的非平衡凝结流动广泛存在于火电汽轮机的末几级和核电汽轮机中。这就会增大汽轮机的湿汽损失，降低汽轮机的效率，同时水滴的形成还会造成动叶片的水蚀，威胁汽轮机的安全运行。所以无论从机组的经济性还是安全性考虑，对动叶栅中湿蒸汽的流动分析都具有重要意义。

本文主要是对汽轮机动叶栅顶部通道湿蒸汽进行二维流动分析，在欧拉/欧拉坐标系下建立数学模型，采用非等温修正的凝结成核模型和低压修正的水滴生长模型，建立二维叶栅中湿蒸汽凝结流动的数值模型，对动叶栅中不同工况的两相流动进行数值模拟。研究对象为 Bakhtar 叶栅，对五种不同背压的流动工况分别进行了数值模拟，并将叶片附近的压力分布与实验数据进行了对比，结果吻合较好，验证了数值模型的精度。最后通过数值模拟得出了动叶栅顶部通道内压力、温度、马赫数、水滴数和湿度的具体分布规律。结果表明：动叶栅顶部通道中湿蒸汽的凝结起始于叶片吸力面，且冷凝量在叶片喉部处达到最大。冷凝量随背压的降低逐渐增大。随着蒸汽由亚音速工况过渡到超音速工况，各种参数的分布都会有所变化，以水滴数的变化最为典型，最大水滴数的区域由吸力面喉部处转移到压力面后缘处。对于湿度，动叶栅中尾缘区的湿度要小于主流区。

关键词：动叶栅；湿蒸汽；二维流动;两相流动；凝结；数值模拟

Title Two dimensional wet steam flow analysis of turbine cascade

Abstract

When the steam flows in the turbine cascade, because of the expansion and the decrease of steam enthalpy, the steam will cross the saturation line. When it is sufficiently subcooled, it will condense and form the second phase. This kind of non-equilibrium condensation flow of wet steam widely exists in the last stages of thermal power turbine and nuclear power turbine. This will increase the wet steam loss of the turbine and reduce the efficiency of the turbine. At the same time, the formation of water droplets will cause water erosion of the moving blades and threaten the safe operation of the turbine. Therefore, it is of great significance to analyze the flow of wet steam in the moving cascade considering the economy and safety of the unit.

In this paper, the two-dimensional flow analysis of the wet steam in the top passage of the turbine cascade is carried out. The mathematical model is established in the Euler / Euler coordinate system. The non isothermal modified condensation nucleation model and the low-pressure modified water drop growth model are used to establish the two-dimensional numerical model of the wet steam condensation flow in the turbine cascade, and the two-phase flow in different working conditions of the turbine cascade is simulated. The research object is Bakhtar cascade. The numerical simulation of five different back pressure flow conditions is carried out respectively, and the pressure distribution near the blade is compared with the experimental data. The results are in good agreement, which verifies the accuracy of the numerical model. Finally, the distribution of pressure, temperature, Mach number, water drop number and humidity in the top passage of the cascade is obtained by numerical simulation. The results show that the condensation of wet steam in the top passage of the moving cascade starts from the suction surface of the