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# A method for flattening the solidification front in directional solidification technology

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**Abstract**

Nonplanar solidification front causes defects in directional solidification process. The transverse temperature gradient, which can be divided into radial temperature gradient and circumferential temperature gradient, is one of the reasons causing the nonplanar solidification front. This paper presents a method by varying the wall thickness of the mould to decrease the circumferential temperature gradient and hence flatten the solidification front. The equations for calculating the wall thickness were deduced by heat transfer analysis. The optimized mould contour was obtained by solving the equations numerically. It was proved by simulation that the circumferential temperature gradient can be almost reduced by 40%. Furthermore, the starting time difference of solidification at one cross section along the circumferential direction almost reduces by half. Additionally, this paper also researches the influences of parameters of the mould and the furnace etc. on the shape of the mould and the circumferential temperature gradient. The circumferential temperature gradient decreases as the thermal conductivity and the emissivity of the mould increase. And the temperature of the cooling ring impacts little on the circumferential temperature gradient. According to the development trend of the blade manufacturing, this method may be applied widely.

*Keywords:* A1. Directional solidification, A1. Heat transfer, A1. Radiation, A1. Computer simulation, A2. Bridgman technique
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## 1. Introduction

The manufacturing of a turbine blade mainly employs the directional solidification (DS) technology at present because the blade possesses many advantages such as superior strength, excellent thermal fatigue property and corrosion resistance at high temperature [1]. Many DS technologies have been proposed since Bridgman [2] invented the DS method, such as high rate solidification (HRS) process, liquid-metal cooling (LMC) process and gas cooling casting (GCC) process etc. [3]. However, according to the studies of Hugo et al. [4], Schadt et al. [5] and Wang et al. [6], the DS technologies abovementioned do not completely eliminate the defects caused by the thermal non-uniformity. The nonplanar solidification front is one of the most important defects of the thermal non-uniformity during the DS process [5]. Fu et al. [7, pp. 504] stated that the horizontal heat flow causes the nonplanar solidification front. One consequence of the nonplanar solidification front is that the solidification interface becomes nonplanar and deviates from the baffle [8]. Many defects are caused by the deviation between solidification interface and the baffle [8]. Schadt et al. [5] pointed out that the nonplanar solidification front causes freckles of the single crystal blade. Boettinger et al. [9] indicated that nonplanar solidification front in DS process causes unstable state that accumulates solute boundary layer. Li et al. [10] discovered

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