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Experimental study of the convective heat transfer from a rotating disc subjected to forced air streams

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ABSTRACT

The convective heat transfer from a rotating disc subjected to forced streams of air has been investigated experimentally by means of an electrically heated disc in a wind tunnel. Mean heat transfer coefficients have been obtained for a wide range of air crossflow velocities and rotational speeds. The influence of finite disc thickness and incidence (angle of attack) on heat transfer has been investigated. The extreme conditions of a stationary disc in a crossflow and a rotating disc in still air have been considered, too. Concerning the onset of rotational heat transfer augmentation it is found that a universal ratio exists between the rotational and the crossflow Reynolds numbers.

1. Introduction

Convective heat transfer from a rotating disc has been studied extensively in the literature (see, for instance, the reviews by Dorfman [1], Owen and Rogers [2,3], or Shevchuk [4]), because this configuration represents an obvious starting point for analysing a lot of technical applications occurring in the areas of turbo machinery, computer hard discs, CVD reactors, train wheel or disc brake design. The majority of the investigations considers enclosed rotating discs or free rotating discs with or without an outer forced flow perpendicular to the disc plane. Even the latter basic case is still subject of actual research, as demonstrated for instance by the work of Elkins and Eaton [5] or Shevchuk [6]. Configurations based on a rotating disc subjected to an outer crossflow parallel to the plane of rotation have found much less attention, and the heat transfer from an inclined rotating disc (i.e. with an angle of attack to the uniform stream) was obviously not investigated so far.

Dennis et al. [7] have studied in 1970 experimentally the mean heat transfer coefficient for a large range of rotational and crossflow Reynolds numbers by means of an electrically heated disc placed in a parallel air stream of a wind tunnel. They have reported “that the freestream turbulence in the tunnel must have been high”, perhaps yielding systematically higher heat transfer rates. Booth and de Vere [8] have conducted in 1974 a comprehensive set of measurements of the radial variation of the heat transfer coefficients for the same configuration but obviously without knowledge of the prior work [7]. The both authors have concluded that “in any situation the level of heat transfer coefficients is determined in the main by the speed of the transverse air flow”. Such a statement is at least partially in contradiction to the findings of Dennis et al. [7]. He et al. [9] have employed in 2005 the naphthalene sublimation technique for obtaining the local Sherwood number of a rotating disc for a limited range of a local Reynolds number, but unfortunately they have not made a distinction between the rotational and the crossflow Reynolds numbers. Recently, aus der Wiesche has presented results of an extensive large-eddy-simulation (LES) study [10]. His numerically data have indicated much lower heat transfer coefficients as measured experimentally by Dennis et al. [7].

Since the deviations between the available data are substantial, an independent re-investigation has been performed. This present study considers in addition to the classical axisymmetric configuration also the influence of finite disc thickness and incidence (angle of attack) on the heat transfer. The basic flow fields caused by the crossflow are illustrated by means of Fig. 1 for a stationary disc. Whereas the forced flow perpendicular to the disc leads to an axisymmetric stagnation flow, Fig. 1a, the combination of rotation and transverse crossflow leads to a non-axisymmetric stagnation flow in case of an inclined disc, Fig. 1b. The parallel flow over a disc with finite thickness is characterized by flow separation at the leading disc edge followed by reattachment of a turbulent boundary

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