

An experimental work on the effect of the eccentric rotation of heat sink on the convective heat transfer



Hamdy Hassan^{a,b,*}, Souad Harmand^{c,d}

^a Egypt-Japan University of Science and Technology (E-JUST), Alexandria, Egypt

^b Mechanical Engineering Department, Assiut University, Assiut, Egypt

^c UVHC, TEMPO, F-59313 Valenciennes, France

^d Université Lille Nord de France, F-59000 Lille, France

ARTICLE INFO

Keywords:

Heat sink
Rotating
Eccentric
Convective heat transfer
Temperature

ABSTRACT

The convective heat transfer from air-cooled rotating heat sink helps to estimate the cooling efficiency of the rotating machines cooled by fins. An experimental work for the effect of eccentric rotating of the finned heat sink on the convective heat transfer from this heat sink is presented in the work. The used heat sink is composed of a copper tube with annular fins and its axis of rotation is parallel and offset to the tube axis. The heat sink is heated at the inner surface of the tube with constant heat flux. The experimental work is performed at different radii of rotation, rotational velocities and powers input to the heat sink. The results illustrate that increasing rotational velocity and radius of rotation decreases the temperature of the heat sink. Nusselt number at the heat sink base decreases with decreasing the radius of rotation and rotational Reynolds number. Nusselt number remains approximately constant through the heat sink length at low rotational velocity. At higher rotational velocity, Nusselt number rises with approaching to the center of the heat sink. Nusselt number increases with increasing the rotating axis length.

1. Introduction

The cooling of electrical machines, magnetic disk storage systems, and other rotating machines is sometimes performed by fins [1]. Furthermore, one or more fins are used to cool the heat-pipe brake disc during the braking process of electrical machines [1]. Rotors of electrical machines are often provided by fins on their surface to improve their cooling process. There are many applications of the cooling of the rotating devices with fins but few studies are available for this cooling method. Studying the convective heat transfer during the rotation of the heat sink will help to estimate accurately the temperatures of the rotating machines cooled by fins. Moreover, the optimum cooling conditions of these machines will be reached.

So, some of the previous experimental and theoretical researches concentrated on the study of heat transfer phenomena during rotating objects specially heat sink. Sparrow [2] and Watel [3] studied the convective heat transfer in an unenclosed air-cooled concentric rotating cylinder with fins. They showed that augmentation of fin spacing and rotational Reynolds number increase Nusselt number. Moreover, fin spacing has high significant effect on the heat transfer at low rotational velocities. The heat transfer of impinging jet on the rotating heat sink

was presented experimentally by Jeng et al. [4]. The impinging coolant was air and the heat sink with and without Al-foam was considered. Their results stated that the average Nusselt number of the heat sink is greater with Al-foam than without Al-foam. Decreasing Reynolds number decreases the average Nusselt number. Furthermore, increase the heat sink length to fin diameter increases the Nusselt number for the same rate of jet flow. Jeng et al. [4,5] presented an experimental study to predict the thermal characteristics of flow inside stationary and rotating finned nozzle. The study was performed at different distances of the nozzle to fin tip, Reynolds numbers, and fins numbers. The effect of flow behavior between co-rotating and co-angular finned surface inside duct is presented by Islam et al. [6]. They also presented the effect of duct height on the heat transfer coefficient inside the duct. They illustrated that the heat transfer coefficient of the co-rotating pattern increases with increasing the low ratio of the duct to fin height and then decreases with increasing this ratio. An experimental work was presented by Latour et al. [7] for the local convective heat transfer dissipated from a rotating finned cylinder. They gave a thermal image on the surface of the fins by using an infrared thermo-graphic camera. They stated that the convective heat transfer is influenced only by the rotational velocity and fin spacing. Tawfik [8] studied experimentally

* Corresponding author. Egypt-Japan University of Science and technology (E-JUST), Alexandria, Egypt.

E-mail addresses: hamdyaboali@yahoo.com (H. Hassan), souad.harmand@univ-valenciennes.fr (S. Harmand).

Nomenclature

D	heat sink diameter m
L	heat sink length m
h	heat transfer coefficient $W/m^2.K$
k_f	air thermal conductivity $W/m.K$
Nu	Nusselt number
P	total power W
Pr	Prandtl number
q''	heat flux W/m^2
R	radius of rotation m

Re	Reynolds number
T	temperature K
T_a	ambient temperature K

Greek symbols

ν	kinematic viscosity m^2/s
ω	rotational velocity rpm
α	thermal diffusivity m^2/s
ΔT	temperature difference K

the heat transfer characteristics of fins extended outward from a rotating shaft. His study was carried out at different geometrical parameters including the orientation angles of the fins, different numbers of fins, different fins lengths and different rotational velocities. He stated that the influence of the orientation angle on the heat transfer decreases with raising the rotational velocity. Moreover, Nusselt number doesn't depend on the number of fins at high rotational velocity. Also, Nusselt number depends weakly on the number of fins at low Reynolds number. Voria and Ringuette [9] studied experimentally the vortex formation during the rotation of low-aspect-ratio of trapezoidal flat-plate fins. They found that, at large rotational amplitudes, a secondary vortex is created while the plate still moves. Yang et al. [10] studied numerically the optimization of the heat transfer characteristics and fluid flow of air jet impingement on a rotating and a stationary heat sink. They found that a heat transfer enhancement is noticeable in the case of smaller Reynolds number ($Re = 5019$) and Nusselt number augments with decreasing Reynolds number. Gaba et al. [11] presented a theoretical analysis on the performance of rectangular annular fins subjected to rotation. They studied the effect of rotation on the temperature distribution of the fin for insulated tip fin. They stated that the fin temperature decreases with increasing rotation velocity.

From the literature review, it is noticeable that there is still a lack of information concerning the heat transfer characteristics of rotating heat sink. To the authors' best knowledge, there is no work focused on the heat transfer characteristics from an eccentric rotation of the heat sink despite its importance. So, the aim of this paper is to present an experimental study on the convective heat transfer from an eccentric

rotation of a heat sink. The used heat sink is fabricated from the copper tube of eight annular fins. The heat sink rotates about an axis parallel and offsets to the tube axis. The experimental work was studied at different radiuses of rotation, rotational velocities and input powers to the heat sink.

2. Experimental setup

The steady-state study of the convective heat transfer during the eccentric rotating heat sink is presented experimentally by the experimental setup shown in Figs. 1 and 2 and a setup layout shown in Figs. 3 and 4. The experimental setup is composed of a heat sink (1) fabricated from copper tube of 16 mm external diameter, 2 mm thickness and 40 mm long. The copper tube has eight annular copper fins (2) as shown in Figs. 3 and 4. Each fin has an inner diameter 16 mm, outer diameter 80 mm, fin thickness 2 mm and fin to fin spacing 3 mm. The heat sink is fixed to a rotating rod (3) which is fixed at horizontal rotating axis (4). The rotating rod (3) is balanced by using an external balance load (5) to minimize the system vibrations. The heat sink is heated at its base with constant heat flux by an electrical cartouche (6) of an electrical resistance 4.2Ω as illustrated in Fig. 4. Power supply (7) of model Heiningner LNG 32-15 supplies the electrical resistance of the cartouche by the required DC power. The transmission of the supplied power from the stationary unit to the rotating unit is carried out by using a fabricated slip ring (8). A thermal interface (9) is impeded between the cartouche and the base tube of the heat sink to minimize the contact resistance between them. The rotation of the system is

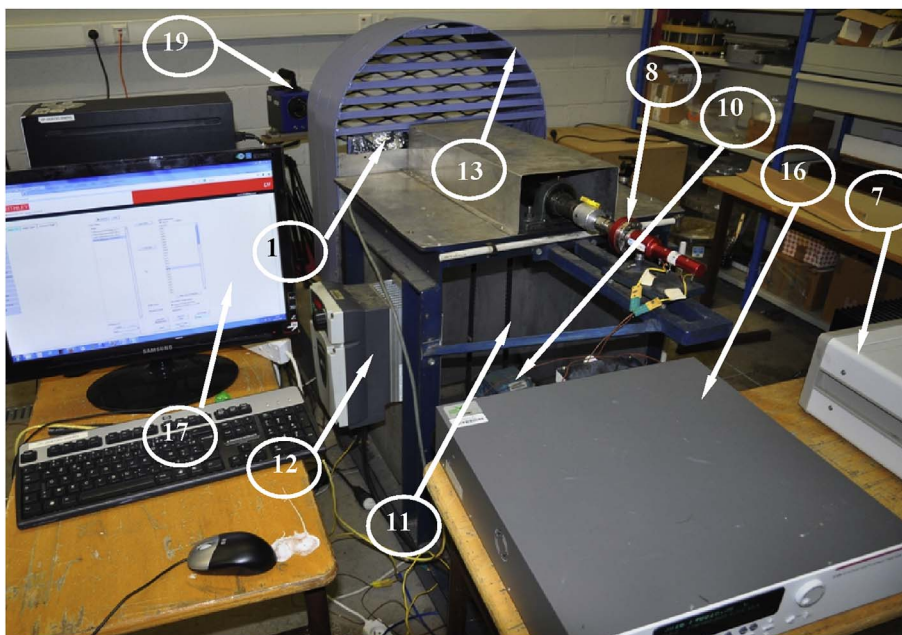


Fig. 1. Experimental setup.

1-Heat sink 2-Fins 3-Vertical rotating rod 4- Horizontal rotating rod 5- Balance load 7-Power supply 8-Slip ring 9- Thermal interface 10-Electrical motor 11-Transmitting belt 12-Digital regulator 13- Protection system 14- Thermocouples 15-Thermocouple signal transmitter 16- Central acquisition system 17-Computer 18-The infrared camera 19- Infrared camera.

Download English Version:

<https://daneshyari.com/en/article/4995112>

Download Persian Version:

<https://daneshyari.com/article/4995112>

[Daneshyari.com](https://daneshyari.com)