1. Pendaftaran (Juli 2022)



2. Penerimaan Abstrak (8/8/2022)





3. Penerimaan Presentasi (13/8/2022)

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Date: 13 August 2024

Letter of Acceptance for Abstract

Dear Authors: Andreas Prasetyadi (a*), Ronny Dwi Agusulistyo (b)

We are pleased to inform you that your abstract (ABS-111, Oral Presentation), entitled:

"Constructal Heat Release of Radial Permanent Magnet Generator"

has been reviewed and accepted to be presented at BTS 2022 conference to be held on 21 September 2022 in Yogyakarta, Indonesia.

Please submit your full paper and make the payment for registration fee before the deadlines, visit our website for more information.

Thank You.

Best regards,

Ir. Margono Sugeng, M.Sc BTS 2022 Chairperson



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4. Unggah artikel lengkap (7/9/2022) Unggah artikel revisi (12/12/2022)



5. Review Artikel



Constructal Heat Release of Radial Permanent Magnet Generator

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Abstract, Constructal theorem indicates a pattern of optimum efficient flow. In a radial permanent magnet generator, the constructal pattern was studied. A 2D model of radial permanent magnet generator was assumed to have specific thickness of the laminated core for the stator. Heat was released to the frame in order keeping temperature of the magnet below its critical temperature. Geometric parameters showing thickness and width of the stator were found as the constructal pattern that meet the targeted output.

1. INTRODUCTION

Constructal theory considered as the way to design optimum system was introduced by Bejan and has been studied for many fields [1]–[9]. The constructal approach was applied for analyzing of cooling system [6], [10]–[13], solar energy harnessing system [14]–[16], mechanics[5], and fluids[14], [17], [18]. The method proposes to minimize the flow over its resistance reflecting the characteristic of the system. In a finite system, the character of the system has geometric meaning such as area, volume, length, or its specific ratio.

Thermal is one of fields which the constructal has extensively studied. For a cooling system in electronic devices, it is found that contact surface of heat sink is important [19]. Kalbasi and Salimpour also mentioned that ratio of vertical and horizontal fin surface of highly conductive material has minutes effect. However, Ghodoossi and Eggrican reported that tree network of high conductivity links inside heat generator was the result of optimization heat cooling of finite are heat generator with fins [12]. Heat trajectory inside of the heat generator is important for studying.

Electric machines have generated heat source inside the frame. Heat mostly is produced due to core loss and copper loss. The additional loss of mechanical matter happens on the bearing. While the copper loss is located around the core, we can assume that the heat in electric machinery is generated in the core of the winding. This heat is transferred to the frame working as the heat sink as well. The frame released heat to the atmosphere through the frame surface with some fins attributed the character mentioned by Kalbasi and Salimpour [12].

The structure of the paper consists of 4 parts. The first part introduces the problem. The second part goes deeper on the problem of generator with focusing on the model. The third part show the constructal development of the problem. The final part will conclude the work. **Commented [A1]:** The structure of the abstract must contain background (optional), purpose sentence (mandatory), method sentence (mandatory) research steps or data collection method, result sentence (mandatory), discussion sentence (mandatory), conclusion and implications (mandatory). We haven't found it yet, please fix it.

Commented [A2]: 3 important points that must be included in the introduction (1) crucial issues or fundamental issues supported by references to relevant and global international journals. (2) please check relevant previous research and adjust it with existing references (3) research gaps and objectives. We have not found a specific purpose of this research.

2. RADIAL GENERATOR MODEL

Radial generator has flux perpendicular to its axis. Mostly, the generator has rotor in the center of the device. The stator is designed around the rotor. If the rotor has permanent magnet as the flux source, it is called as permanent magnet radial generator. The EMF depends on differential of the flux which is related to ratio of the rotor and stator. The current of the generator is function of its magnetic flux density, inverse of its permittivity, number of windings, and length of the magnetic flux path. However, due to its hysteresis, the magnetic flux path also affects core loss.

Winding is the main source of heat due to its copper loss. The copper loss contributes more than 90% [20]. However, the same author also reported that the temperature of the winding was equal to temperature of the frame. But the temperature of the winding is different from the magnet.

Permanent magnet generator needs to keep the temperature of its permanent magnet below its critical temperature. Above the critical temperature, the permanent magnet loss its magnetic capacity. Its magnetic flux density decreases which affects the capacity to reach intended temperature.

The analysis of the heat flux in a generator, especially focuses on core, frame and its rotor. To simplify the system, the structure of the core, frame, and its rotor is mentioned in Fig 1 neglecting the axial direction. It represents part of complete rotor and stator. The permanent magnet is applied on rotor. All of the parts have equal angle, therefore the boundaries between stator, air gap and stator are proportional to the respective radii, named r_{er} , r_{er} , and r_{ef} .



Figure 1. Boundary of the rotor and stator

Heat transfer between two material depends on the boundary between the materials. For transferring between two solid material, conduction heat transfer take places. It follows Fourier law as mentioned in equation (1). For the boundary of solid and fluid, the convection happens as described following Newton equation (2). The conduction heat transfer can be used for the boundary between stator and frame. The convection takes place in the border of the stator air gap and rotor air gap. While the radiation occurs on the boundary, therefore the equation (2) should consist also radiation coefficient as shown in equation (3) with h_{conv} and h_{rad} as the convection coefficient and radiation coefficient, respectively.

$$q = -kA\frac{dT}{dx} \tag{1}$$

$$q = hA\Delta T \tag{2}$$

$$h = h_{conv} + h_{rad} \tag{3}$$

Assuming the heat flux generated on the stator core because it is directly connected to the windings and where the core loss occurs. The resistive model can be plotted in Fig. 2. The model unites frame as part of the rotor. It also assumes that the air gap and the rotor are a single entity.

The temperature of the stator is function of heat capacity of the stator. It can be expressed in a simple way as shown in equation (4). The total heat stored in the rotor is inverse function of heat transfer. The similar approach can be done for the heat transferring from stator to the frame and air. It is shown in equation (5).

$$T_{r} = \frac{1}{hA} \int q_{sr} \mathrm{d}t \tag{4}$$

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$$T_{s} = \frac{1}{kA} \int q_{sa} x \mathrm{d}t$$

(5)



Figure 2. The resistive model of heat transfer coefficient. r_{sr} , and r_{sa} are heat flux resistance between stator and rotor, and the heat flux resistance of stator and air, respectively

3. CONSTRUCTAL DEVELOPMENT

The constructal expresses design effect for minimum intended flow. It means that geometry of the system explored for finding minimum loss of the flow. In the context of the research, the design is aimed for minimum temperature of the rotor for keeping it from critical temperature changing the magnetism of the permanent magnet.

The boundary of the stator to rotor can be simplified as arc of stator shoe. While the air gap is very small, therefore the arc of both is equal and a function of average radii of stator and rotor (r_{ra} and r_{as}). It can be written as equation (6). Accordingly, the frame addition to the stator with assumption that the frame has higher conductivity than stator [20], the radii of the stator can be written as equation (7) with c_1 as the conductivity ratio of frame and core.

$$r_{r} = \frac{r_{ra} + r_{as}}{2}$$
(6)
$$r_{s} = r_{sf} + c_{1} \left(r_{f} - r_{rs} \right)$$
(7)

The flux resistance is function of boundary as shown in equations (4) and (5). For the considered system, the boundary is function of the angle and its radii. Therfore, the boundary is function of radii. To meet maximum temperature of the rotor, it is noted that the flux from core to stator should be 0. It occurs when ΔT of the stator and rotor is 0. When it happens, the flux totally flowing to frame. The ratio of outer radii of the stator and rotor should follow equation (8)

$$\frac{r_s}{r_r} = \frac{h}{k} \frac{\int q_{sa} x dt}{\int q_{sr} dt}$$
(8)

The maximum temperature of the rotor and specific time of maximum load condition can be applied for determining specific flux. The solutions of the equations (4) and (5) provide relation of r_r and r_s as shown in

equation (9). Assuming $r_r = 1$, then $r_s = \frac{h^2}{2k}$. It can be sure that $r_s > r_r$.

$$r_s = h \left(\frac{h}{k} r_r^2 - r_r r_s \right) \tag{9}$$

While specific output is reached when specific speed of the rotor following equation (10),

$$= \omega r_r$$
 (10)

It can be derived that $r_s = \frac{Bsh^2}{k}$, or $\frac{r_s}{r_r} = \frac{Bh^2}{k}$ to meet minimum temperature of the rotor.

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4. Conclusion

It could be derived the ratio of stator and rotor radii to meet minimum temperature of the stator in radial permanent magnet generator. The ratio was found in condition of specific voltage output and assumption of close air gap which can be simplified as the stator radii. This ratio can ensure the temperature of the stator safe from overheating.

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