0% detected as AI

The percentage indicates the combined amount of likely AI-generated text as well as likely AI-generated text that was also likely AI-paraphrased.

Caution: Review required.

It is essential to understand the limitations of AI detection before making decisions about a student's work. We encourage you to learn more about Turnitin's AI detection capabilities before using the tool.

Detection Groups

1 AI-generated only 0%
Likely AI-generated text from a large-language model.

2 AI-generated text that was AI-paraphrased 0%
Likely AI-generated text that was likely revised using an AI-paraphrase tool or word spinner.

Disclaimer
Our AI writing assessment is designed to help educators identify text that might be prepared by a generative AI tool. Our AI writing assessment may not always be accurate (it may misidentify writing that is likely AI generated as AI generated and AI paraphrased or likely AI generated and AI paraphrased writing as only AI generated) so it should not be used as the sole basis for adverse actions against a student. It takes further scrutiny and human judgment in conjunction with an organization's application of its specific academic policies to determine whether any academic misconduct has occurred.

Frequently Asked Questions

How should I interpret Turnitin's AI writing percentage and false positives?
The percentage shown in the AI writing report is the amount of qualifying text within the submission that Turnitin's AI writing detection model determines was either likely AI-generated text from a large-language model or likely AI-generated text that was likely revised using an AI-paraphrase tool or word spinner.

False positives (incorrectly flagging human-written text as AI-generated) are a possibility in AI models.

AI detection scores under 20%, which we do not surface in new reports, have a higher likelihood of false positives. To reduce the likelihood of misinterpretation, no score or highlights are attributed and are indicated with an asterisk in the report (*%).

The AI writing percentage should not be the sole basis to determine whether misconduct has occurred. The reviewer/instructor should use the percentage as a means to start a formative conversation with their student and/or use it to examine the submitted assignment in accordance with their school's policies.

What does 'qualifying text' mean?
Our model only processes qualifying text in the form of long-form writing. Long-form writing means individual sentences contained in paragraphs that make up a longer piece of written work, such as an essay, a dissertation, or an article, etc. Qualifying text that has been determined to be likely AI-generated will be highlighted in cyan in the submission, and likely AI-generated and then likely AI-paraphrased will be highlighted purple.

Non-qualifying text, such as bullet points, annotated bibliographies, etc., will not be processed and can create disparity between the submission highlights and the percentage shown.

Constructal Heat Release of Radial Permanent Magnet Generator

A Prasetyadi[1,a)] and Ronny Dwi Agusulistyo[2,b)]

[1]Department of Mechanical Engineering, Sanata Dharma University, Sleman, Indonesia
[2] Mechatronics, Faculty of Vocation, Sanata Dharma University, Sleman, Indonesia

[a)] Corresponding author: pras@usd.ac.id
[b)] ronny_dwi@usd.ac.id

Abstract. Constructal theorem indicates a pattern of optimum efficient flow in a form geometrical design. A permanent magnet generator should keep its permanent magnet temperature below its critical. The constructal pattern in the form of rotor and stator radii ratio was studied for optimum heat flow generated from losses. A theoretical approach was applied to a 2D model of radial permanent magnet generator assumed to have specific thickness of the laminated core for its stator. The heat was released to the frame in order keeping temperature of the magnet below its critical temperature as the main requirement for performance. Geometric parameters showing thickness and width of the stator were found as the constructal pattern that meet the targeted output. Ratio of the stator and rotor radii proportional to magnetic field strength, square of convective coefficient, and inverse of conductive coefficient are shown as the solution of minimizing the rotor temperature.

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]. In those studies, the source and sink of the heat are separated and the flow is in single direction.

Electric machines generate heat source inside its frame and the magnetic field generator is located in the center of the generator. 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, it is worthy to assume that the heat in electric machinery is generated in the core of the winding. This heat is transferred to the frame 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]. At the same time, the heat also transferred to the rotor where the magnetic sources were lied. The heat flow is not single direction anymore, at least in a specific time before the equilibrium.

Study of the heat release of a generator for optimum ratio of the stator and rotor radii is the aim of this work. It is structured in the paper consisting of 4 parts. The first part introduces the problem. The second part goes deeper on the

Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022
AIP Conf. Proc. 3077, 050010-1–050010-5; https://doi.org/10.1063/5.0201388
Published under an exclusive license by AIP Publishing. 978-0-7354-4964-0/$30.00

problem of generator with focusing on the model. The third part shows the constructal development of the problem to find the ratio of rotor and stator. The final part will conclude the work.

RADIAL GENERATOR MODEL

Radial generator has flux perpendicular to its axis. Mostly, the generator has rotor in the center of the device and its stator is designed around the rotor. Two types of generators are known, the permanent magnet and electromagnetic generator. If the rotor has permanent magnet as the flux source, it is called as permanent magnet radial generator. The produced EMF of such machine depends on differential of the flux which is related to ratio of the rotor and stator. A stator diameter reflects magnetic reluctance. However, the higher ratio of the rotor and stator radii is, the EMF of its electricity is higher. The current of the generator is a function of its magnetic flux density, inverse of the wire permittivity, number of windings, and length of the magnetic flux path. However, due to its hysteresis, the magnetic flux path also affects core loss. It also implies that ratio of the rotor is important in heat of a generator.

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. It means that the heat transfer from the core to rotor and from the core to the frame before releasing it to the atmosphere is important in determining the temperature of the rotor where the permanent magnet placed.

A permanent magnet generator needs to keep the temperature of its permanent magnet below the permanent magnet critical temperature. Above the critical temperature, the permanent magnet loss its magnetic capacity significantly. Its magnetic flux density decrease affects the capacity to generate EMF. To keep the temperature of the rotor below its critical temperature, it is consecutive to remove heat from the heat source in the winding core. It is the stator core.

The analysis of the heat flux in a generator, especially focuses on its core, frame and 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 assuming the machine is highly symmetrical. The permanent magnet is applied on rotor. All of the parts have equal angle, therefore the boundaries between rotor, air gap and stator are proportional to the respective radii, named r_{ra}, r_{as}, and r_{sf}.

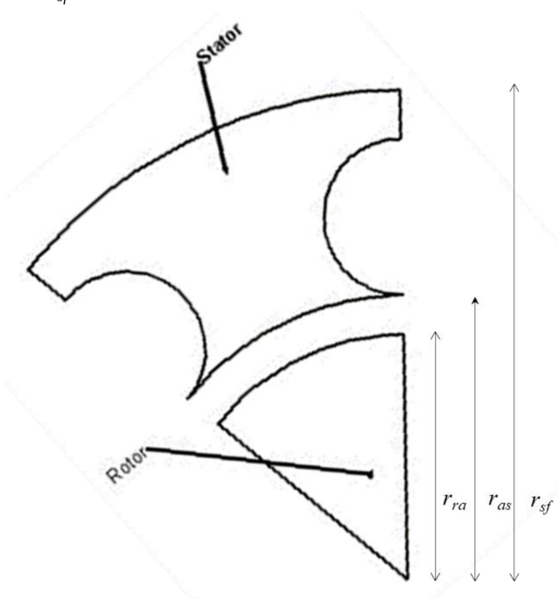

FIGURE 1. Boundary of the rotor and stator

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). *T*, *A*, *q*, and *k* are temperature, cross-section of the boundary, heat, and conduction coefficient, respectively. For the boundary of solid and fluid, the convection happens as described following Newton equation (2). The combination of convection and radiation heat transfer coefficients can be used for the boundary between stator and frame. The convection and radiation take places 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.

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

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

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

It is assumed that all the heat flux generated on the stator core because it is directly connected to the windings and where the core loss occurs as Irasari and Kasim found [20]. Accordingly, the resistive model can be pictured in Fig. 2. The model unites frame as part of the stator. It also assumes that the air gap and the rotor are a single entity due to its dimension.

The temperature of the rotor is function of heat capacity of the rotor. It can be expressed in a simple way as shown in equation (4). The q_{sr} is heat transfer between stator and rotor. 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).

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

$$T_s = \frac{1}{kA}\int q_{sa}\,x\mathrm{d}t \tag{5}$$

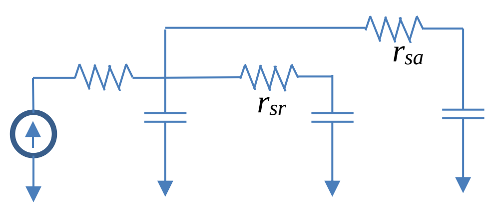

FIGURE 2. The resistive model of heat transfer coefficient. R_{sr} , and R_{sa} are heat flux resistance between stator and rotor, and the heat flux resistance of stator and air, respectively

CONSTRUCTAL DEVELOPMENT

The constructal expresses design effect for minimum intended flow. It means that geometry of the system is 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 where the permanent magnet remanence start to decrease. Using the model on Fig. 1, the environment temperature is the base line. The heat capacitor 1 is the heat capacity of the stator, the heat capacitor 2 is the heat capacity of the rotor, and the last heat capacitor belongs to atmosphere. In transient time, the heat flows to the rotor until its temperature is equal to the stator. It implies the heat of copper loss is equal to heat flux to rotor and environment as in equation (6). The subscript *cl*, *sr*, and *sa* refer to copper loss, stator to rotor, and stator to atmosphere, respectively.

$$q_{cl} = q_{sr} + q_{sa} \tag{6}$$

According to the model of Fig. 1, equations (4) and (5) can provide equations (7) and (8) respectively.

$$T_s = q_{sr}.r_{sr} + \frac{1}{hA}\int q_{sr}\,\mathrm{d}t \tag{7}$$

$$T_s = q_{sa}.r_{sa} + \frac{1}{kA}\int q_{sa}\,x\mathrm{d}t \tag{8}$$

The second term of the equation (8) is the temperature of the atmosphere. Assuming this temperature is constant, it can be derived equation (9), with T_a as the atmosphere temperature.

$$r_{sa} = \frac{T_s - T_a}{q_{sa}} \tag{9}$$

Meanwhile, in steady condition, qsr should be zero, therefore $T_s = T_r$.

Heat resistance is function of conductor length. The heat resistance of the rotor is equal to its radii, and the stator resistance is proportional to difference of stator and rotor radii. 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 to average radii of stator and rotor (r_{ra} and r_{as}). It can be written as equation (10). 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.

$$r_r = \frac{r_{ra} + r_{as}}{2} \tag{10}$$

$$r_s = r_{sf} + c_1\left(r_f - r_{rs}\right) \tag{11}$$

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 (12).

$$\frac{r_s}{r_r} = \frac{h}{k}\frac{\int q_{sa}\,x\mathrm{d}t}{\int q_{sr}\,\mathrm{d}t} \tag{12}$$

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

$$r_s = h\left(\frac{h}{k}r_r^2 - r_r r_s\right) \tag{13}$$

While specific output is reached when specific speed of the rotor following equation (14),

$$s = \omega r_r \tag{14}$$

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.

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. The ratio of the rotor and stator radii is proportional to magnetic flux and convection coefficient square. It is inverse of conductive coefficient of the core.

ACKNOWLEDGEMENT

The authors would like to mention his gratitude for PKTC (The Center of Smart Technology) Faculty of Science and Technology, University of Sanata Dharma.

REFERENCES

1. A. Bejan and S. Lorente, International Journal of Engineering Edication **22**, 140–147 (2006).
2. A. Bejan and S. Lorente, Philosophical Transactions of the Royal Society B: Biological Sciences **365**, 1335–1347 (2010).
3. A. Bejan, International Journal of Heat and Mass Transfer **44**, 699–704 (2001).
4. L. A. O. Rocha, S. Lorente, and A. Bejan, International Journal of Heat and Mass Transfer **45**, 1643–1652 (2002).
5. A. Bejan, American Journal of Physics **78**, 692–699 (2010).
6. A. Bejan, Y. Ikegami, and G. A. Ledezma, International Journal of Heat and Mass Transfer **41**, 1945–1954 (1998).
7. L. Xia, S. Lorente, and A. Bejan, International Journal of Energy Research **35**, 806–812 (2011).
8. F. B. Seminar, A. Bejan, S. Lorente, B. Power, and L. The, (2010).
9. A. Bejan, Hydrology and Earth System Sciences **11**, 753–768 (2007).
10. O. O. Adewumi, T. Bello-Ochende, and J. P. Meyer, International Journal of Heat and Mass Transfer **66**, 315–323 (2013).
11. M. Mosa, M. Labat, and S. Lorente, International Journal of Thermal Sciences **145**, (2019).
12. L. Ghodoossi and N. Eğrican, Energy Conversion and Management **45**, 811–828 (2004).
13. O. Yenigün and E. Çetkin, International Journal of Heat and Technology **34**, S173–S178 (2016).
14. S. Lorente, A. Koonsrisuk, and A. Bejan, International Journal of Green Energy **7**, 577–592 (2010).
15. P. Negoias, 163–172 (2005).
16. F. Mendez, J. Armando, and O. Sanchez, International Journal of Thermodynamics **13**, 135–141 (2010).
17. Y. S. Kim, (2010).
18. E. Cetkin, S. Lorente, and A. Bejan, Journal of Applied Physics **107**, (2010).
19. R. Kalbasi and M. R. Salimpour, Applied Thermal Engineering **84**, 339–349 (2015).
20. P. Irasari, H. S. A, and M. Kasim, **22**, 102–109 (2011).