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A Study on Comparison of Figure of Merit for Common Thermocouples in the High Temperature Range

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Abstract – This paper about the vitality change attributes of progressed thermoelectric materials like Platinum, Rhodium, Constantan, Chromel and Alumel (of sorts B, E, R, K and S) in the impact of connected electric field elements. These sorts of the materials are for the most part taken as the temperature estimating apparatuses in the basic liquid conditions of certain materials and other high temperature conditions. However, here, their reaction just to Seebeck impact is broke down as the working of thermo generator components. This is a methodology of their utilization in those conditions where the squander warm is accessible along with the electric fields. The age of thermo emf is researched in the normalmode to the temperature scope of 3300Cand at that point contrasted and their comparative exhibitions under the impact of connected electric field in different introductions (parallel and opposite) for various extents at a similar temperature extend.

Keywords: Figure of Merit, Thermocouples, High Temperature.

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INTRODUCTION

Thermoelectricity is an outstanding marvel to produce thermo-emf dependent on the temperature inclination of intersections of a thermocouple with the utilization of traditional and progressed thermoelectric materials. The innovation is getting to be acclaimed because of countless of thermoelectric gadgets, which can produce extensive vitality and are likewise favorable because of their contamination free nature, no moving parts and no unpredictable outlines. Squander warm is accessible not just in the residential zones like in kitchens yet additionally in the ventures i.e. Generators, Electric Motors, Computers and in the Furnaces moreover. A thermo-generator making utilization of productive and savvy thermocouples is constantly looked to recuperate squander warm by changing over it into valuable thermo-electric power. The planned utilization of minimal effort and effortlessly accessible traditional thermoelectric materials in a thermo-generator is the essential methodology of present research work with an expect to explore the thermo-emf age. With this point, thermocouples are tentatively researched and figure of legitimacy (FOM) so acquired in the high temperature extend is contrasted and its hypothetical qualities with the end goal to confirm the present test and hypothetical outcomes.

The point of the examinations is to assess the appropriateness of established thermocouples for their conceivable use in waste warmth recuperation. High figure of legitimacy (FOM) alongside ease and simple accessibility are constantly viewed as essential parameters of a thermocouple towards its reasonableness as a thermo-component in a thermo-generator. This exploration work presents exploratory outcomes in contrast with hypothetical estimations of FOM for two traditional thermocouples in the high temperature go from 40-3300C. The age of thermo-emf as a component of temperature slope is estimated for all thermocouples to figure their FOM. At that point, the hypothetical and test consequences of FOM are contrasted and found with be at a critical variety because of distinction in pieces and other exploratory conditions, notwithstanding, demonstrating the indistinguishable conduct.

Distinctive established thermo-electrical materials have additionally been explored by numerous specialists because of their minimal effort and simple accessibility. By and by, we have additionally chosen the established thermoelectric materials (Iron, Nichrome and Constantan) for examinations making their two thermocouples: Fe-Constantan and Constantan-Nichrome. These thermocouples were explored for the age of thermo emf in a high temperature run from 40 to 3300C, as waste warmth is for the most part accessible in this temperature go. The figure of legitimacy for these thermocouples was computed from the test information which was then contrasted with their hypothetically ascertained qualities with fortify the realness of present exploratory examinations. The standard conditions (Rowe D.M. 1995; Tritt M. T. 2001) of thermoelectricity are utilized for the computations. The natural portrayal by XRF of by and by utilized (showcase accessible) thermoelectric materials is likewise done for conceivable quality correlation and repeatability of exploratory outcomes.

METHODOLOGY

The figure of legitimacy, a dimensionless amount given by ZT = ^~p~, is a standout amongst the most vital terms to depict the execution of the thermoelectric materials. Parameters an, o, X and T are the Seebeck consistent, electrical conductivity, warm conductivity of the thermoelectric material and the temperature distinction of the two intersections of the thermocouple individually. It is obvious from the connection that to improve the figure of legitimacy, warm conductivity ought to be least and the electrical conductivity ought to be greatest to the conceivable. Specialists working in the modern use of thermoelectricity are arranged to enhance the figure of value of thermo-electric materials. In the present work, test estimations of figure of legitimacy are contrasted and their hypothetical qualities for chose thermocouples with the end goal to find out their quality, appropriateness and repeatability.

THEORETICAL CALCULATIONS

The figure of value of the considerable number of thermocouples is computed from the connection (Tritt, M.T., 2001):

$$Z = \frac{(\alpha_a - \alpha_b)^2}{[(\rho_a \lambda_a)^{1/2} + (\rho_b \lambda_b)^{1/2}]^2} \qquad (5.1)$$

Here, CLa and CCjj are the Seebeck constants (in V/°C) and dad and pb are the resistivity (particular protections) (in Q m) of both the materials of a thermocouple. Likewise, AaandAb are the warm conductivities (in Win'iC1) of both the thermoelectric materials. To ascertain figure of legitimacy from condition 1, hypothetical estimations of all the physical parameters are utilized as of the unadulterated materials. These qualities used to figure the Seeback steady aab of a thermocouple are given in Table 1.1. Figured estimations of Seebeck Constant (ccab) and Z for various thermocouples are given in Table

Table 1.1

Sr. No.	Parameter	Iron	Constantan	Nichrome
1.	Thermal Conductivity X (Wm $^{-1}$K^{-1})	80.4	19.5	11.3
2.	Electrical Conductivity o (S m^{-1})	1.041x10^{7}	2x10^{7}	6.67x10^{5}
3.	Seeback constant, a (pV/ ^{0}C)	19	-35	25

Table 1.2 Theoretical values of Seebeck Constant (aab) and Z for different Thermocouples

Sr. No.	Parameter	Fe-Constantan	Constantan-Nichrome
1.	Seebeck Constant a_ab (V/ ^{0}C)	5.4x10^{-5}	6x10^{-5}
2.	Z (^{0}C^{-1})	1.22x10^{-5}	2.95x10^{-5}

Experimental Calculations

The condition of thermoelectricity to clarify the age of thermo emf, is for the most part spoken to in course readings as: E = aT ±/ST2f2, where an and *P* are the Seebeck constants in pV/°C and pV/°C2 separately and T is the temperature distinction (T= Ti+T2/2). Thermo-control, the rate of progress of size of thermo-emf w.r.t. the temperature angle, is given as: ^ = CL + (IT. At long last, the condition of thermo-emf age is by and large taken as ^ = an on the grounds that P is little when contrasted with an and for the two thermoelectric materials making a thermocouple, an is supplanted by CCab and moves toward becoming as:

(5.2)

Thus, the figure of merit is given by:

ZT = pA (5.3)

Taking p = ~ & $\frac{Ra\ A\ a}{—}$ = K, the ZT can be written as:

(5.4)

where, p, X, *a* and i are the resistivity, thermal conductivity, area of cross-section and length of the thermoelectric material respectively. As the final resistance of the thermocouple is a series combination of

$$ZT \quad \frac{(\frac{dE}{dT})^2 T}{RK}$$

individual resistances, so R (of thermocouple) is calculated as:

(5.5)

Taking the value of K as:

$+K_7\ K = —$ (5.6)

The physical parameters of thermocouple wires and thermo-emf age are estimated by utilizing a standard advanced multimeter (make HP 34401A) with an exactness up to six decimal spots. Temperature of thermocouple intersections is

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estimated with the assistance of a mercury thermometer with an exactness of 0.50C. The deliberate physical parameters of various wires used to make thermocouples are given in Table 1.3.

Table 1.3 experimentally measured Parameters of Selected Thermoelectric Materials

S. No.	Parameter	Copper	Iron	Constantan	Nichrome
1.	Resistance (Ohm)	0.1918	0.7062	0.5174	1.6874
2.	Area of CrossSection (m2)	1.51x10-6	9.5x10-7	1.112x10"6	9.7x10-7
3.	Length (m)	48x10-2	48x10-2	48x10-2	48x10-2
4.	Resistivity p (Ohm-m)	6x10-6	1.4x10-6	1.2x10-6	3.41x10-6
5.	Electrical Conductivity o (Q"1m"1)	1.67x106	7.143x105	8.33x105	2.933x105

Sr. No	Parameter	Fe-Constantan	Constantan-Nichrome
1.	$\wedge = a_{ab}(V/°C)$	$1.955x10^{-5}$	$1.074x10^{-5}$
2.	$Z = (dE/dT)^2 / RK$ $(^0c^{-1})$	$310x10^{-8}$	$153.3x10^{-8}$

Table 1.4 Experimental values of Seebeck Constant (aab) and Z for Different Thermocouples

RESULTS AND ANALYSIS

The examination of hypothetical and trial figuring's of figure of legitimacy for the chose thermocouples demonstrate that there is certifiably not an ideal coordinating between the hypothetical and test esteems for any of the thermocouple. There is a much contrast between the hypothetical and exploratory exhibitions. This shows with increment in temperature the warm and electrical conductivities differ so that the trial ZT is low than the hypothetical qualities in the whole temperature extend. Confounding in hypothetical and test results if there should arise an occurrence of chose thermocouples may have emerges because of the distinctions in:

i) Composition of materials considered for hypothetical estimations with those tentatively accessible

ii) Theoretical and test estimations of warm conductivities of thermoelectric materials

iii) The chose thermo electric materials are the market accessible materials and subsequently their test exhibitions are not quite the same as the hypothetical outcomes which are for the mass and unadulterated materials.

iv) The examination work legitimize the conduct of thermocouples i.e. straight varieties of ZT w.r.t. the temperature angles in both the hypothetical and trial perceptions.

v) The hole among hypothetical and trial bends increments with increment in temperature inclination which can be because of increment in warm conductivity alongside that of the vitality transformation attributes.

vi) Only the equivalent hypothetical estimation of warm conductivity is utilized in both the trial and hypothetical examinations, yet the ZT stanzas temperature angle bends demonstrate that variety in warm conductivity increments with the temperature slope. This prompts the persistent expanding hole between the hypothetical and test ZT esteems.

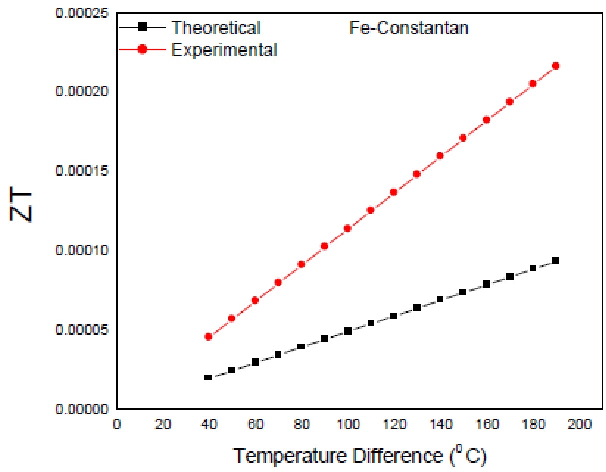

Figure 1.1 Experimental and theoretical comparison of the figure of merit of Fe-Constantan thermocouple

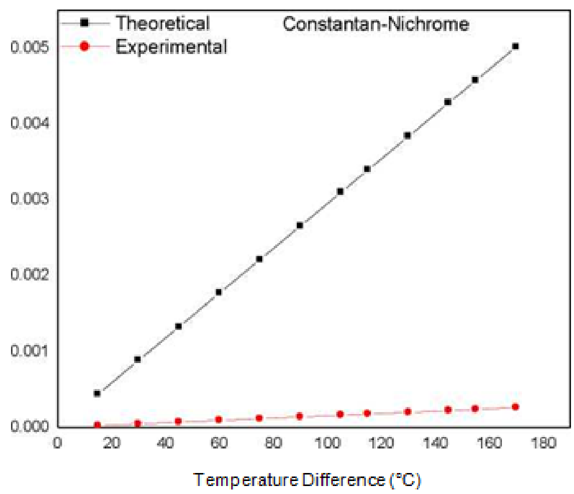

Figure 1.2 Experimental and theoretical comparison of the figure of merit of Constantan-Nichrome thermocouple

CONCLUSIONS

This examination part infers that:

- Fe-Constantan develops as a superior thermocouple bolstered by the trial hypothetical investigations. Subsequently, demonstrating the unwavering quality of market accessible materials of this thermocouple in examination of the other chose thermocouples.

- Mismatching of hypothetical and test estimations of figure of legitimacy for Constantan-Nichrome thermocouple emerges primarily because of the distinction in the Nichrome arrangement. Hypothetical sythesis of unadulterated Nichrome was taken as nickel (80%) + chromium (20%) while basic portrayal shows the principle nearness is of iron component. The nearness of copper likewise acquires vulnerability the hypothetical and exploratory estimations of thermocouples with copper as a piece of it. This might be doled out to some sort of error in the estimations of its physical properties.

REFERENCES

1. L.I. Anatychuk and K. Misawa (1999). CIMTECH-World Ceramics Congress and Forum on New Materials No 9, Florence , ITALIE (14/06/1998), 24, p. 689.

2. J.G. Haidar, J.I. Ghojel (2001). Proc 20th of International Conference on ICT, China, p. 413.

3. J. G. Haidar and J. I. Ghojel (2002). 21st International Conference On Thermoelectronics.

4. Miyake (1996). Symposium on Thermoelectric Energy Conversion, 24.

5. L. H. Dubois (1999). 18th International Conference on Thermoelectrics.

6. R. Venkatasubramanian, E. Sivola and T. Colpitts (2001). Nature Magazine, 413, p. 596.

7. J. W. Stevens (2001). Energy Conversion and Management, 42, p. 709.

8. S. R. Brown, et. al. (2006). Chem. Mater, 18, p. 1873.

9. T. Fujii (2004). Trans Mater Res Soc Japan, 29, p. 2741.

10. S. Farhad, C. Mavriplis and L. H. Bennett (2005). Instrumentation Science & Technology, 33, p. 661.

11. M. Hamabe, et. al. (2003). Thermoelectrics, 22nd International Conference On - ICT.

12. S. Yamamoto, et. al. (2004). Trans Mater Res. Soc Japan, 29, p. 2849.

13. I. Fujii and I. Terasaki (2004). Trans Mater Res Soc Japan, 29, p. 2741.

14. A, Ledda M., Rosola E., et. al. (2006). Extremely low frequency electromagnetic field expo¬sure promotes differentiation of pituitary corticotrope-derived AtT20 D16V cells. Bio-electromagnetics. 2006; 27: pp. 641-51.

15. Piacentini R., Ripoli C., Mezzogori D., et. al. (2008). Extremely low-frequency electromagnetic fields promote in vitro neurogenesis via upregulation of Ca(v)1-channel activity. J Cell Physiol. 2008; 215: pp. 129-39.

16. Morris C.E., Skalak T.C. (2008). Acute exposure to a moderate strength static magnetic field reduces edema formation in rats. Am J Physiol Heart Circ Physiol. 2008; 294: pp. H50-7.

17. Ghibelli L., Cerella C., Cordisco S., et. al. (2006). NMR exposure sensitizes tumor cells to apoptosis. Apoptosis; 11: pp. 359-65.

18. Fanelli C., Coppola S., Barone R., et. al. (1999). Magnetic fields increase cell survival by inhibiting apoptosis via modulation of Ca2+ influx. FASEBJ. 1999; 13: pp. 95-102.

19. Jeong J.H., Kum C., Choi H.J., et. al. (2006). Extremely low frequency magnetic field induces hyperalgesia in mice modulated by nitric oxide synthesis. Life Sci. 2006; 78: pp. 1407-12.

20. Vernier P.T., Sun Y., Chen M.T., et. al. (2008). Nano-second electric pulse-induced calcium entry into chromaffin cells. Bioelectro-chemistry. 2008; 73: pp. 1-4.

21. Kim I.S., Song J.K., Song Y.M., et. al. (2009). Novel effect of biphasic electric current on in vitro osteogenesis and cytokine production in human mesenchymal stromal cells. Tissue Eng Part A. 2009;15: pp. 2411-22.

22. Hojevik P., Sandblom J., Galt S., et al. Ca2+ ion transport through patch-clamped cells exposed to magnetic fields. Bioelectromagnetics. 1995; 16: 33-40.

23. Barbier E., Vetret B., Dufy B. (1996). Stimulation of Ca2+ influx in rat pituitary cells under exposure to a 50 Hz magnetic field. Bioelectromagnetics. 1996; 17: pp. 303-11.

24. Grassi C., D'Ascenzo M., Torsello A., et. al. (20047). Effects of 50 Hz electromagnetic fields on voltage-gated Ca2+ channels and their role in modulation of neuroendocrine cell proliferation and death. Cell Calcium, 2004; 35: pp. 307-15.

25. Craviso G.L., Choe S., Chatterjee P., et. al., (2010). Nanosecond electric pulses: a novel stimulus for triggering Ca2+ influx into chromaffin cells via voltage-gated Ca2+ channels. Cell Mol Neurobiol. 2010; 30: pp. 1259-65.

26. Marchionni I., Paffi A., Pellegrino M., et. al. (2006). Comparison between low-level 50 Hz and 900 MHz electromagnetic stimulation on single channel ionic currents and on firing frequency in dorsal root ganglion isolated neurons. Biochim Biophys Acta. 2006; 1758: pp. 597-605.

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