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BRIEF REPORT

INDUCTION HEATING OF A SPHERICAL
ALUMINUM MODERATOR VESSEL

FOR
THE ADVANCED NEUTRON SOURCE (ANS)

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BRIEF REPORT

**INDUCTION HEATING OF A SPHERICAL
ALUMINUM MODERATOR VESSEL
FOR
THE ADVANCED NEUTRON SOURCE (ANS)**

a. The research I conducted as a participant in the program:

This research project aims at the analysis of the induction heating of a spherical aluminum moderator vessel. Computer modeling is presented for the design and analysis of the induction heating system. The objective is to apply 15 kW of heat as uniformly as possible to the outer wall of a 410 mm diameter sphere of thickness 1.5 mm. The report also aims at the analysis of a system model which is simulated using the Eddycuff electromagnetic software. The computer model is built with the finite element analysis software Patran. The induction heating system analysis shows that the predicted performance is in close agreement with the computer simulated data. Hardware constraints such as power supplies and matching load are also analyzed in terms of performance and cost. Physical modeling is also suggested, in which the coil and the workpiece are scaled down.

As a summer research faculty at the Oak Ridge National Laboratory (ORNL) my task was to identify and design a heating system to apply 15 kW of heat to a cold source vessel to simulate the Advanced Neutron Source reactor. The heating is to be conducted at a cryogenic temperature as low as (20°K - 25°K). The central complaint against the common mode of radiant heating is the resulting high temperatures which would create substantial design problems. An alternative method known as induction heating is identified as a heating source to create 15 kW of heat for

the moderator vessel. The cold source loop of the ANS is shown in Fig. I-1.

A computer model was developed using the finite element modeling (FEM) techniques with the FEM software Patran. The model consists of an aluminum sphere of 410 mm diameter, thickness of 1.5 mm and an inner sphere of 1 mm thickness with a gap of 2 mm which gives a total thickness of 4.5 mm. Several induction heating experiments were carried out on the finite element model using Eddycuff electromagnetic analysis software on an IBM RISC system/6000 to simulate heating of 15 kW on a cryogenic cold source system for the Advanced Neutron Source reactor. The report also focuses on the hardware requirements of building an induction heating system.

COMPUTER MODELING

b. Significant findings reached as a result of my research.

Modern numerical analysis techniques allow computer simulation of the complicated electromagnetic interactions between the coil and the workpiece, permitting a more rational design for a broad range of applications.

Model description: Finite element model of the ANS moderator vessel of diameter 410 mm, outer sphere thickness 1.5 mm, inner sphere thickness 2 mm, and a gap of 1 mm, which gives a total of thickness of 4.5 mm was developed and deployed making use of the finite element analysis software Patran. The NAS INP file for the described model was generated and the file was transferred to the Eddycuff electromagnetic analysis software directory.

Several induction heating experiments³ were carried out on the finite element model using the Eddycuff electromagnetic analysis software on an IBM RISC 6000 to simulate heating of 15 kW on a cryogenic cold source system for the Advanced Neutron Source reactor. Table V-1 indicates the current and frequency at which the heating rate was observed during the simulation.

From Table V-1 and the plots in Appendix A, it shows that at a dual frequency of 150/180 Hz and current of 8.5 kA, a uniform heating of 4.8 w/gm was achieved in the inner sphere and 6.154 w/gm in the outer sphere. But the maximum heating of 9 w/gm which is close to the desired of 10 w/gm was obtained at a current of 8.5 kA and 200 Hz.

³ The input, output and plot files are shown in Appendix A.

c. Additional areas of research:

The results of the computer model were promising. It is suggested that the results should be verified by building a small scale physical model for the induction heating of the spherical aluminum moderator vessel (approximately half the scale of the ANS moderator vessel). Such a model would be used for simulating and comparing the heating coil and current configuration with that of the computer model. In the physical model, the temperature distribution in a small workpiece similar to that in a full-scale application will be developed, enabling the testing of non-standard geometries at considerably reduced cost compared with full scale testing. The final analysis of this project is to model the spherical aluminum vessel for the Advanced Neutron Source reactor in sufficient detail using complex finite element and half scale modeling methods, so that proposed changes to the design can be evaluated in a qualitative manner prior to the fabrication of hardware. It is expected that this modeling effort would lead toward the development of a predictive analysis tool for the Advanced Neutron Source reactor.

During my studies at ORNL, I also arranged a seminar on the electromagnetic analysis software EMAS from MacLean Schwindler Corp. The demonstration showed that the software can be used for Eddy current analysis of the problem in consideration.

The above said work can be carried out at the investigator's home institution Savannah State College, a unit of the University system of Georgia in Savannah, Georgia.

Activities planned following completion of the appointment:

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Figure I-1 : Cold Source Loop of the Advanced Neutron Source (ANS)

Table V-1 : Current, Frequency and Heating

Run	Current (kA)	Frequency	Maximum Heating (kW)	Max. Outer Heating (W/gm)	Max. Inner Heating (W/gm)
1	6.5	1 kHz	11.1	7.5	.75
2A	6.5	200 Hz	8.66	4.349	2.67
2B	6.5	200	15.74	7.692	3.864
3	7.5	180	15.7	7.5	4.5
4	7.5	180/150	15.2	5.418	3.75
5	7.5 (1,2,3) 8.5 (4,5,6)	180	22.42	7.7	3.86
6	7.5 8.5	180 150	22.33	6.154	3.84
7	8.5	180	25.72	8.46	4.6
8	8.5	150/180	25.06	6.154	4.615
9	8.5	200	21.48	9	5.5

RESULTS

RUN 1:	@ 6.5 A	f: 1 kHz	Δs : 12,36,60	
1.09542E+04	1.11229E+04	1.10969E+04	1.11137E+04	1.11018E+04
1.11122E+04	1.11047E+04	1.11119E+04	1.11069E+04	1.11122E+04
RUN 2A:	@ 6.5 A	f: 200 Hz	Δs : 12,36,60	
5.20680E+03	8.47594E+02	1.70340E+03	6.47977E+03	8.51941E+03
5.00996E+03	8.48052E+02	1.84256E+03	6.66320E+03	8.66912E+03
RUN 2B:	@ 6.5 A	f: 200 Hz	Δs : 10,30,50	
9.47593E+03	1.58035E+03	2.97101E+03	1.16060E+04	1.54826E+04
9.24590E+03	1.56489E+03	3.12892E+03	1.18550E+04	1.57407E+04
RUN 3:	@ 7.5 A	f: 180 Hz	Δs : 10,30,50	
1.10687E+04	2.75228E+03	1.38448E+03	8.41891E+03	1.57055E+04
1.48576E+04	6.87105E+03	9.64255E+02	3.97556E+03	1.24952E+04
RUN 4:	@ 7.5 A	f: 180/150 Hz	Δs : 10,30,50	
1.16916E+04	3.77481E+03	9.02804E+02	5.55270E+03	1.27023E+04
1.52148E+04	1.10348E+04	4.78252E+03	2.55713E+03	5.80795E+03
RUN 5:	@ 7.5 A, 8.5 A	f: 180 Hz	Δs : 10,30,50	
1.56493E+04	3.78130E+03	1.99391E+03	1.21427E+04	2.24291E+04
2.09934E+04	9.52370E+03	1.28528E+03	5.84843E+03	1.80651E+04
RUN 6:	@ 7.5 A, 8.5 A	f: 180/150 Hz	Δs : 10,30,50	
1.71847E+04	5.68366E+03	1.08017E+03	7.4089E+03	1.79370E+04
2.23371E+04	1.69006E+04	7.56777E+03	3.2757E+03	7.12566E+03
RUN 7:	@ 8.5 A	f: 180 Hz	Δs : 10,30,50	
1.82097E+04	4.48057E+03	2.01210E+03	1.35341E+04	2.57278E+04
2.45550E+04	1.13803E+04	1.39100E+03	6.13588E+03	2.02393E+04
RUN 8:	@ 8.5 A	f: 150/180 Hz	Δs : 10,30,50	
1.92443E+04	6.22661E+03	1.29504E+03	8.81379E+03	2.06908E+04
2.50671E+04	1.82806E+04	7.79669E+03	3.82242E+03	9.05310E+03
RUN 9:	@ 8.5 A	f: 200 Hz	Δs : 10,30,50	
1.30747E+04	2.27465E+03	4.05897E+03	1.58249E+04	2.12303E+04
1.28083E+04	2.26408E+03	4.25949E+03	1.61120E+04	2.14825E+04