# Low Frequency NMR Relaxometry Studies of Elastomeric Thermal Insulation Liners for Aerospace Structures

Ramesh Babu D[a,c], Kuchipudi Srinivas[b], R Narasimha Rao[a], A Madhusudhana Rao[c], Ch. Sri Chaitanya[d]

[a] Department of Mechanical Engineering, National Institute of Technology Warangal, Warangal, India-506004

[b] Advanced Systems Laboratory, Kanchanbagh, Hyderabad, India-500058

[c] Defence Reseach and Development Laboratory, Kanchanbagh, Hyderabad, India-500058

[d] Department of Mechanical Engineering, Velagapudi Ramakrishna Siddhartha Engineering College, Kanuru, Vijayawada, India - 520007

## 1. INTRODUCTION

Rocasin rubber, a copolymer of acrylonitrile and polybutadiene and EPDM (Ethylene Propylene Diene Monomer) are being used as thermal insulation liners for industrial and aerospace applications [1-3]. This study employed low frequency NMR relaxometry to analyze Rocasin and EPDM rubber aiming to determine their realized thickness, homogeneity, presence of voids and variations in mechanical properties. The nondestructive evaluation of insulation liners using NMR relaxometry proved to be an invaluable tool for this purpose. Additionally, single sided low frequency NMR studies were conducted to evaluate the thickness profiles of three different rubbers: Silicone rubber, EPDM and Rocasin. These relaxometry studies were performed across the insulation liner thickness at various zones of the elastomer sheet, taking into account sample to sample variations to understand the impact of processing and high temperature curing. The findings highlighted the importance of compositional homogeneity and achieving an optimum cure state for both Rocasin and EPDM to ensure their effectiveness in final applications [4, 5]. Comprehensive results on low frequency NMR depth profile as well as relaxometry data ($T_1$ & $T_2$ relaxations) of insulation liner samples were presented in this study.

## 2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

To further explore the sensitivity of single sided NMR technique to the compositional variations, NMR depth profile measurements were conducted on three different elastomers of Silicone rubber, EPDM and Rocasin samples placed one over the other as shown in figure 1.a . The obtained depth profile data (figure 1.b) confirmed the precise thickness of each layer with an impressive accuracy of ±50µm. Notably, the NMR profile exhibited distinct amplitudes corresponding to the composition, as determined by the proton density.

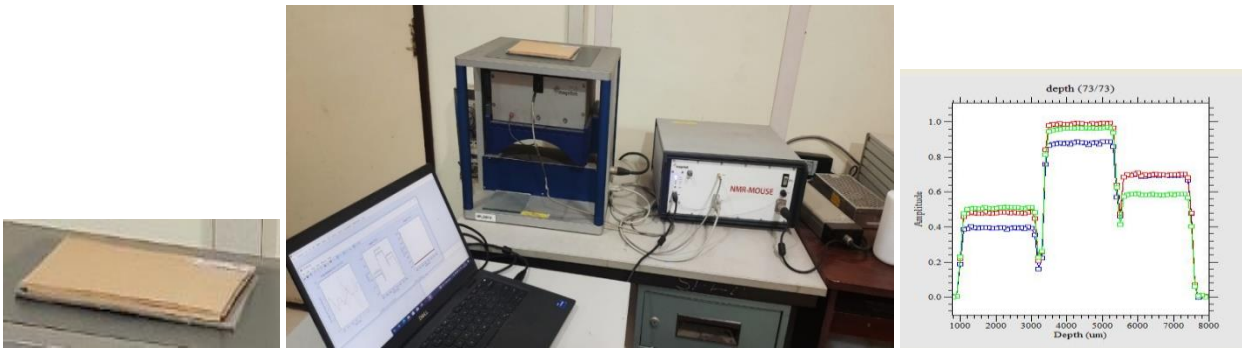


Figure 1. (a) Rocasin samples, (b) setup of NMR and (c) Profile data of the test

Moreover, the study encompassed relaxometry investigations on EPDM and Rocasin samples cured at two different temperatures. For larger Rocasin and EPDM samples, distict zones were

identified and evaluated to assess the longitudinal and transverse relaxation times ($T_1$&$T_2$) within the sample (refer figure 2). The primary objective was to analyze the variation in homogeneity across different zones. The research unveiled notable differences in $T_1$ and $T_2$ relaxation times between EPDM and Rocasin rubber attributable to variation in cross link density and mechanical properties of the two materials.

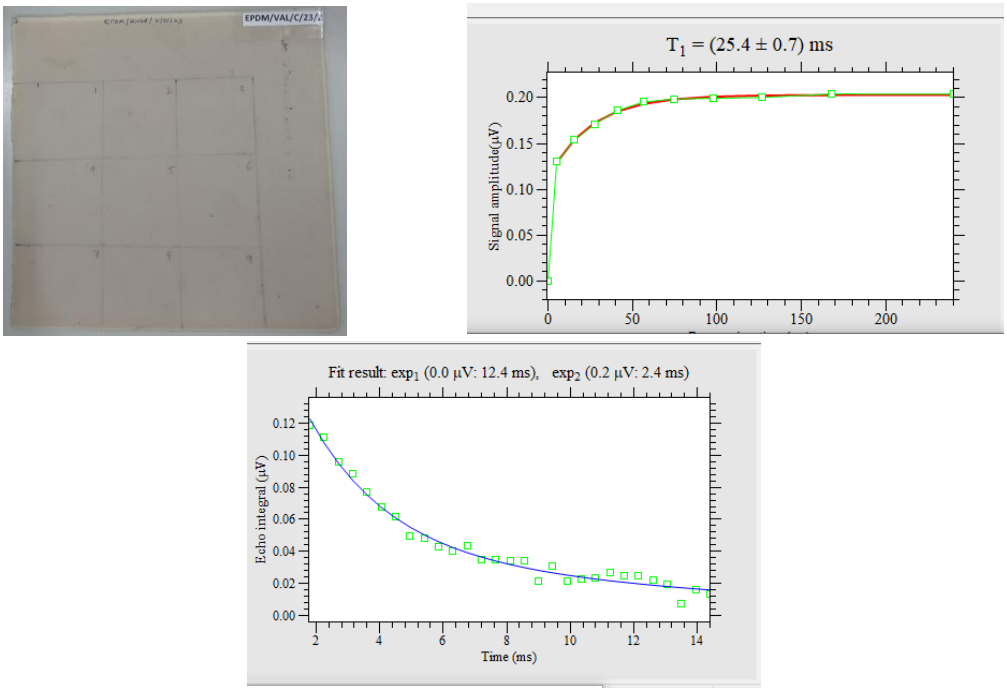


Figure 2. (a) Rocasin sample divided into 9 zones, (b) T1 relaxation charts, and (c) T2 relaxation chart

The results presented above demonstrate both homogeneity variation within the same sample and also marginal difference in average relaxation times between Rocasin & EPDM. NMR has emerged as promising non-destructive tool for evaluating elastomers and insulation materials. Moreover its capability to identify the compositional variations and assess cross link density under different curing and aging conditions adds its significance in the field.

## REFERENCES


1. Halmen, Norbert, Christoph Kugler, Eduard Kraus, Benjamin Baudrit, Thomas Hochrein, and Martin Bastian. "Single-sided NMR for the measurement of the degree of cross-linking and curing." *Journal of Sensors and Sensor Systems* 7, no. 1 (2018): 21-30.2.
2. Sahoo, S. K., R. Narasimha Rao, Kuchipudi Srinivas, M. K. Buragohain, and Ch Sri Chaitanya. "A novel NDE approach towards evaluating adhesive bonded interfaces." *Materials Today: Proceedings* 26 (2020): 1191-1197.
3. Guo, Pan, Liling Wang, Rui Wang, Bing Li, and Zhirui Zhao. "Portable Non-Destructive Magnetic Resonance Sensor for Assessing the Aging Status of Silicon Rubber Insulators." *Nanomaterials* 12, no. 21 (2022): 3847.
4. Blümich, B., Blümich, P. and Pauly, 2005. *Essential NMR* (pp. 15-57). Berlin: Springer.
5. Sahoo, Sanjaya K., R. N. R. Srinivas Kuchipudi, and M. K. Buragohain. "Detection of planar defects in multilayered GFRP composite structures using low-field nuclear magnetic resonance." *Mater Eval* 79, no. 9 (2021): 897-904.