Dismantling of the graphite pile of Latina NPP: characterization and handling/removal equipment for single brick or multi-bricks

Giuseppe Canzone[a], Rosa Lo Frano[b], Marco Sumini[c], Francesco Troiani[a]

[a] *Sogin Spa- Roma, Italy*

[b] *Department of Industrial and Civil Engineering (DICI) – University of Pisa, Italy*

[c] *Department of Industrial Engineering, University of Bologna, Italy*

Abstract

This work describes the issues related to the dismantling of the graphite pile of the 1st generation gas cooled reactor of Latina NPP (Italy). The retrieval of the graphite is a strategic matter for the decommissioning of this type of plant: the aim of this study is to describe and analyse the current approaches used to access the core and to perform the remote and dry extraction of graphite bricks from the top. The outcomes of this study could be useful to plan the removal of Latina NPP graphite: the extraction of the graphite would be carried out layer by layer by means of a dedicated remote controlled handling systems; this equipment would be duly designed according to the nuclear, physical and mechanical constraints of the graphite piles in core. Thus, the issues regarding the irradiated graphite have been analysed by FEM code, especially those related to the core geometry and the proposed technique of hooking the graphite bricks by a 'gripper' tool inside the axial channel. Data on fresh nuclear grade and irradiated graphite, used for the numerical simulations, have been obtained by means of theoretical models and experimental tests, carried out on samples extracted from the reactor. The results obtained could support the final design of proper lifting, gripper tools and handling equipment, for single brick or multi-bricks, and could implement graphite waste management strategy.

Introduction

When dealing with the decommissioning of gas-cooled graphite-moderated reactors, concerns arise due to the large amount of radwaste in the form of graphite stack fragments that was generated during the reactor lifetime (on average 1500-2000 tons per reactor, as evaluated by the IAEA). The most obvious source of irradiated graphite is from reactor moderators and reflectors. In this study, the current approach for the management of radioactive graphite, and specifically the procedure adopted for the remote and dry extraction of graphite from the Latina reactor will be described and analysed.

Decommissioning strategy of Latina NPP

The Latina plant is a Magnox reactor type, definitively shut down in November 1986. During its 23 years of operation, the plant really produced 4200 Equivalent Full Power Days (EFPD). Since 90's Sogin S.p.A (Italian State Owned Company appointed for Nuclear Decommissioning and Radioactive waste management) is managing the plant, with specific regard to decommissioning activities.

In Fig.1, it is shown synthetically the general decommissioning approach considered for Latina plant: the dismantling of reactor foresees firstly the empting of reactor pit and then the removal of graphite, to be obtained disassembling or demolishing/tearing down the core bricks[1-2].

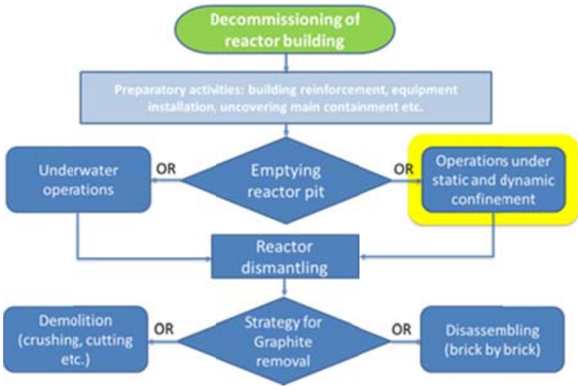

Figure 1: Decommissioning approach taken into account for Latina NPP[2]

The removal of the graphite from the core is a concern mainly because of the material changes caused by the irradiation effects. In consideration of that and of the possible aging effects several techniques for the removal of irradiated graphite have been examined: by critically reviewing the state of art acquired over the past years the 'in-air' dismantling seems the more reasonable and possible solution for a direct demolition or a retrieval 'brick-by brick' retrieval. The carried out feasibility study concerning the disassembling of the graphite stack brick also showed that the mechanical retrieval, the lifting and, in general, the mechanical handling of the bricks are possible avoiding or limiting/minimizing the number of brick breaks.

Graphite behaviour

The Latina reactor graphite used as moderator and reflector has a high anisotropy; for that reason they are called respectively Pile Grade A (PGA) and Pile Grade B (PGB). Both two were manufactured in UK at the end of the 50^s to be used in the early Magnox reactors.

Figure 2 show the single '4-sides' and '8-sides' brick scheme and the arrangements used to combine and assemble together these prismatic bricks. As it is possible to observe they are restrained each other with mechanical tying that allow to avoid in plane deflection and accommodate thermal expansion without any significant increase of stress state.

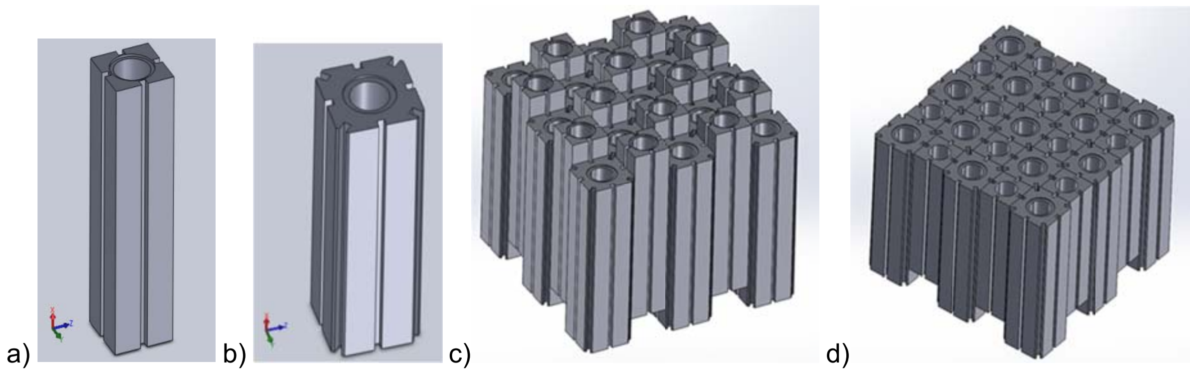

Figure 2: Graphite a) '4-sides' brick, and b) '8-sides' brick c) Graphite network for a generic arrangement of the moderator (9 layers) and for d) the upper reflector layer.

Numerical Modelling and Results

The removal of irradiated graphite is indeed depending on the feasibility of the gripping and the lifting system to be used to manage bricks. In this study a part from the graphite characterization that allowed to obtain useful information of material behaviour and potential damages it suffered over the lifeplant, is focused on the evaluation of the reliability of such systems that should be able to remove graphite bricks from the reactor vessel without breaks. In doing that, numerical investigation has been also performed to account the effects caused by the extraction force in terms of bearing load capacity of graphite brick.

Moreover to qualify and support this assessment, experimental results, which were obtained from the experimental investigation of nuclear grade graphite, not irradiated and without considering core restraints, have been taken into account (this study is part of a feasibility study aiming at the definition of an appropriate procedure to extract graphite bricks from the core configuration of Latina reactor without/minimizing the risk of fragmentation or rupture of the bricks themselves) [3].

A (3D) FEM model (Figure 3) has been thus set up and implemented assuming that the material behaves as anisotropic only along the extrusion direction of the brick[4-5], whereas in the remaining directions isotropic conditions have been imposed. A representation of the stress distribution caused by the retrieval/lifting is given in Figure 4 for the '4-side brick'. It is, in fact, possible to observe that the brick extraction results in an increase of stress applied thoroughly the brick itself. The mostly stressed area is at the annular step of the down base for both two '4-sides' and '8-sides' brick. Moreover it resulted that for a lifting force of 3 kN, the Von Mises stress did not overcome, in the transversal and longitudinal direction of the brick, the allowed limit value of nuclear-grade graphite. As a consequence of that it is possible to conclude that no rupture of the brick would occur during retrieval operation.

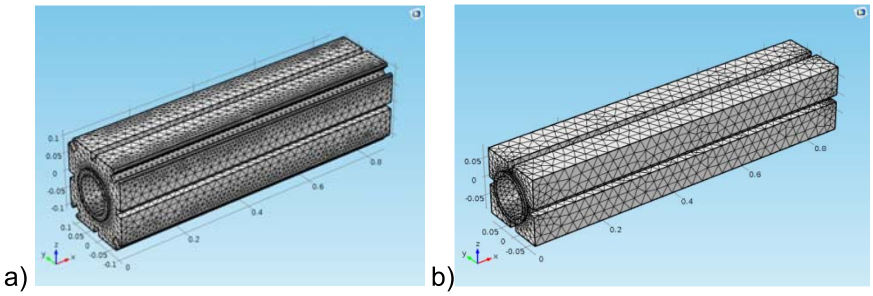

Figure 3: FEM of the single graphite element for a)'4-sides' brick, and b) '8-sides' brick.

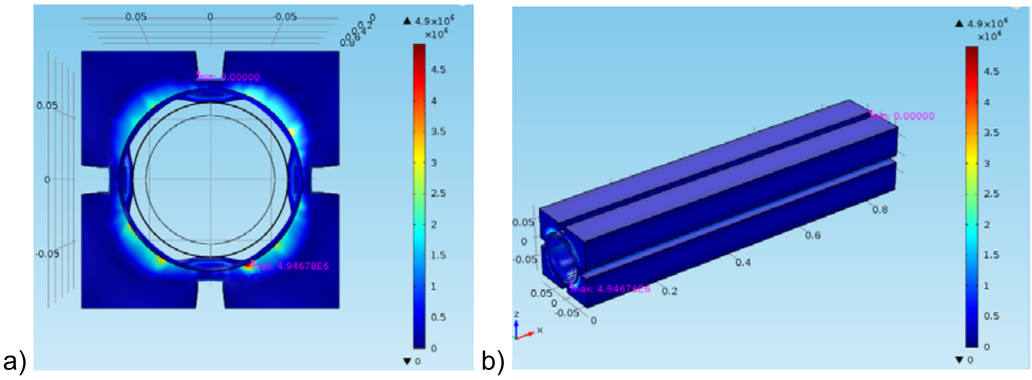

Figure 4: Maximum Von Mises stress due to lifting of '4-sides'brick.

Conclusion

Finally, although preliminary, modelling could be considered as a valuable technique in supporting the selected tool for retrieval operations of graphite bricks from the stack of the Latina NPP avoiding breaks. Further study seems necessary for a complete assessment of the technical solution presented in this paper, such as the investigation of material properties of the i-graphite, the effects of the cumulative damage of the graphite in the reactor, etc.

Acknowledgments

The authors would like to thank SOGIN Latina NPP Management for giving technical and historical support.

References and Citations

[1] EPRI, *Graphite Decommissioning Options for Graphite Treatment, Recycling, or Disposal, including a discussion of Safety-Related Issues*, Final Report, March 2006.
[2] IAEA, *Progress in Radioactive Graphite Waste Management*, IAEA-TECDOC-1647, 2010.
[3] SOGIN LTGR00070– *Prove fisico meccaniche su campioni di grafite irraggiata*.
[4] COMSOL 5.0, *Structural Mechanics Module User's Guide*, October 2014
[5] D.K.L. Tsang and B.J. Marsden, *Constitutive material model for the prediction of stresses in irradiated anisotropic graphite components*, J. Nuclear Material, 381, 129-136, 2008.