Postprint: Study on Internal Pressure Load Sharing Ratio of Lined Rock Cavern Gas Storage Structures

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Abstract

Gas storage facilities are critical components of compressed air energy storage (CAES) power stations. Lined rock cavern gas storage facilities have attracted widespread industry attention due to their characteristics of flexible siting and scalable capacity. Accurately obtaining the magnitude of internal pressure loads borne by each structural layer of lined rock cavern gas storage facilities is a prerequisite for their safety evaluation and structural design analysis. Based on the elastoplastic theory of structural stress analysis, this study proposes a calculation method for the load sharing ratio of each structural layer in lined rock cavern gas storage facilities and verifies its accuracy. On this basis, the influences of factors such as sealing layer type, surrounding rock grade, lining structural type, lining reinforcement ratio, and maximum operating pressure on the internal pressure sharing ratio of each structural layer are investigated. The research results indicate that the surrounding rock is the primary component bearing the internal pressure load of underground gas storage facilities, with its load sharing ratio reaching over 90%. Changes in factors such as lining structural type, lining thickness, and operating pressure have relatively minor effects on the internal pressure sharing ratio, whereas factors such as sealing material type, surrounding rock grade, and lining reinforcement ratio exert more significant influences on the load sharing ratio of the lining and surrounding rock structural layers. Under the premise that the lining has entered a plastic state, whether pre-set cracks are installed in the lining has essentially no effect on the load sharing ratio, while increasing the lining reinforcement ratio can substantially enhance the internal pressure proportion borne by the lining. The research findings can provide theoretical support for the structural design and safety evaluation of lined rock cavern gas storage facilities.

Full Text

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Abstract

Gas storage facilities are critical components of compressed air energy storage (CAES) power plants. Lined rock cavern gas storage has garnered widespread industry attention due to its flexible siting options and scalable capacity. Accurately determining the magnitude of internal pressure loads borne by each structural layer of lined rock cavern gas storage is a prerequisite for safety evaluation and structural design analysis. This study proposes a calculation method for determining the load sharing ratio among structural layers in lined rock cavern gas storage based on elastoplastic theory, and validates its accuracy. Building upon this foundation, the research investigates the influence of various factors—including sealing layer type, surrounding rock classification, lining structural configuration, lining reinforcement ratio, and maximum operating pressure—on the internal pressure sharing ratio of each structural layer. The findings demonstrate that the surrounding rock constitutes the primary load-bearing element of underground gas storage, with its load sharing ratio exceeding 90%. Variations in lining structural configuration, lining thickness, and operating pressure have relatively minor effects on the pressure sharing ratio, whereas factors such as sealing material type, surrounding rock classification, and lining reinforcement ratio significantly influence the load distribution between the lining and surrounding rock. Provided the lining has entered a plastic state, the presence of preset cracks has essentially no impact on the load sharing ratio, while increasing the lining reinforcement ratio can substantially enhance the lining's share of internal pressure. These research results provide theoretical support for the structural design and safety evaluation of lined rock cavern gas storage facilities.

Keywords: compressed air energy storage; lined rock cavern gas storage; plastic deformation theory; sealing structure; load sharing

Note: Figure translations are in progress. See original paper for figures.