上面应该来一段很综述的关于THM coupling的

Properly designed and executed cementing operations is important as it is widely applied across the various Earth Science-related geotechnical applications, such as radioactive waste disposal, deep-well plug and abandonment (P&A), drilling and completion in unconventional reservoir and Enhanced Geothermal (EGS) Reservoir, and carbon capture, utilization and storage (CCUS)(Gruber et al., 2021; Hargis et al., 2021; Koťátková et al., 2017; Olson et al., 2015; Vrålstad et al., 2019). A successful cementing job will avoid the unnecessary deficiencies during the life circle of each project which will make it more environment friendly and improve the system efficiency. Despite the advancements in technological development of cementing materials over the last several decades, the problems of well cementing still persists due to the harsh environments where cementing is placed (Ahmed et al., 2020; Allahvirdizadeh, 2020; Kiran et al., 2017). Taking the P&A as an example, over the years and across companies, the upper range of the reservoir’s pressure and temperature has been pushing up to 40000 psi and 600 F (DeBruijn et al., 2008; Khalifeh et al., 2020). The cement is originally designed for low temperature and low pressure conditions, and under such harsh conditions, its stability over an extended period of time is unknown. To leverage this problem, extensively pioneering researches have being focusing on reinforcing the cement by adding various additives, which is aiming for improving the mechanical properties and reducing hydraulic properties (Cai et al., 2022; Ge et al., 2018; Katende et al., 2020; Krakowiak et al., 2018; Massion et al., 2021; Massion et al., 2022; Qin et al., 2021; Samarakoon et al., 2022).

However, known as the cementitious saturated porous material with permeability ranges from mili-darcy to nano-darcy (Banthia et al., 1989; Goto et al., 1981; Meng et al., 2021; Picandet et al., 2011), the cement’s behavior can be influenced by the thermo-hydraulic-mechanical (THM) coupling in the porous space, especially when it is experiencing a large temperature and pressure variations. Within the permeability range mentioned above, a very lager pore pressure could be induced by the THM coupling and the pore pressure will be progressively reestablished over the time, which will also lead to the changing of the effective stress and cause the shear failure, hydraulic fracturing or even tensile failure (Ghabezloo et al., 2010). While THM coupling phenomena has been studied by considerable researchers, their applications have been mainly focusing on the wellbore stability during drilling and fluid injection into borehole (Gao et al., 2017; Song et al., 2019; Tao et al., 2010; Zhou et al., 2009). The THM coupling effect in the cementing designs and operations has rarely been properly considered and fully investigated under the HTHP conditions, which could result in jeopardizing the cementing integrity and lead to many serious consequences.

To include these mutual interactions between thermal, hydraulic and mechanical systems in the non-isothermal conditions, Biot (Biot, 1977) firstly extended the tradition theory of poromechanics and include the uncoupled thermal effects by incorporating the thermomolecular diffusion and dynamic forces using the variational Lagrangian thermodynamics approach. Later on, the thermal diffusion process was coupled in solid and fluid deformation by Derski (1979), as well as others (Bear et al., 1981; Kurashige, 1989; Smith et al., 1993). The abovementioned porothermoelastic analytical solutions are obtained by neglecting the non-linear term associated with connective heat transfer thus it is called as linear porothermoelastic model that is especially prevailing for the low permeability material (Chen et al., 2005; Delaney, 1982; Gomar et al., 2014; Wang et al., 2003). Within the framework of linear porothermoelasticity, substantial studies have been performed for coupled THM behavior of isotropic porous media to understand the mechanism of relative cases, but most of their work are assuming the fluid flux and heat flux are dominated by the pore pressure gradient and thermal gradient, respectively (Ghassemi et al., 2002; Ghassemi et al., 2009; Valov et al., 2022). That is to say that the thermo-osmosis (fluid flex generated by thermal gradient) and mechano-caloric effects (heat flux generated by pore pressure gradient) are neglected. However, as for porous material with low permeability, these two effects actually play important rules (Gonçalvès et al., 2010; Roshan et al., 2015; Trémosa et al., 2010).For example, Carnahan (1983) has shown that the thermos-osmosis flow through kaolinite can be two orders of magnitude higher than Darcy’s flow near the nuclear waste repository. Thus, when designing the cementing under the HTHP conditions, both the thermos-osmosis and mechano-caloric effects should be taken into considerations. To our best knowledge, their influences on the cement integrity are still unclear.





In this paper, we will use P&A application as case studies to introduce so-called fully-coupled porothermoelastic model by incorporating both of the thermos-osmosis and the mechano-caloric effects (the second effect also known as thermal filtration effect (Cheng, 2016)). The motivations of creating this porothermoelastic-osmosis-filtration (PTEOF) model is to have a comprehensive understanding of the cement’s behaviors under the HTHP and build up a general framework and solutions for further studies and analysis. Drawing on the important contributions of Sarout et al. (2011) on modifying the theory of linear chemoporoelasticity into a convenient form whereby the interpretations of the phenomenological parameters can be clarified, this paper will not only include a detailed parametric studies of each parameters in PTEOF, but also it includes a discussion of the implications of these results for future HTHP cementing design and operations.

最后夹一些conclusions:

定义下thermal-omisis and mechanoo-caloric

This THM coupling will progressively reestablish the pore pressure inside the cement, which will also lead to the changing of the effective stress and cause the shear failure, hydraulic fracturing or even tensile failure.

It is well-known that properly designed and executed cementing operations will avoid the unnecessary deficiencies during the life circle of the well (drilling, completion and abandonment) and maintain the well integrity. Despite the advancements in technological development of cementing materials over the last several decades, the problems of well cementing still persists due to the harsh environments where cementing is placed. Moreover, with the recent global commitments to reduce the carbon emissions and the consumption of fossil fuels, considerable emphasis has been placed on developing the clean and renewable energy, i.e. geothermal energy, and at the same time, leading to thousands of off-shore production wells needs to be permanently plug and abandonment (P&A). These operations and activities are pushing the current cement to service at even higher temperature and pressure, which is further challenging the cementing sealing integrity. Taking the P&A as an example, over the years and across companies, the upper range of the reservoir’s pressure and temperature has been pushing up to 40000 psi and 600 F (DeBruijn et al., 2008; Khalifeh et al., 2020). The cement is originally designed for low temperature and low pressure conditions, and under such harsh conditions, its stability over an extended period of time is unknown. To leverage this problem, extensively pioneering research has being focusing on reinforcing the cement by adding various additives, which is aiming for improving the mechanical and reducing hydraulic properties. However, known as the cementitious porous material with permeability ranges from milidarcy to nanodarcy, the cement’s behavior can be influenced by the thermo-hydraulic-mechanical (THM) coupling, especially when it is under such high temperature and high pressure conditions. This THM coupling will progressively reestablish the pore pressure inside the cement, which will also lead to the changing of the effective stress and cause the shear failure, hydraulic fracturing or even tensile failure.

The pore pressure fields inside the cement that is progressively reestablished by far-field boundary conditions will

模仿老板的文章介绍poroelascivitvity

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