STUDY ON DEFORMATION BEHAVIOR OF INCLINED SEABED DURING METHANE HYDRATE PRODUCTION

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1. Background and objective

Recently, Methane Hydrate (MH) has attracted much attention worldwide as one of the next generation energy resources. So far, a considerable amount of MH has been identified under the seabed in many locations throughout the world. However, the production of methane gas from MH bearing layer in the ground of seabed may cause a series of problems, such as the strength decrease of MH layer, settlement or landslide of the inclined seabed, and failure of production wells. In this study, the MH layer was considered to be in the solid-liquid two-phase state and the impact of dissociated gas was neglected for the purpose of simplification. Numerical simulations based on the Finite Difference Method (FDM) were performed by considering the influences of inclination angles of seabed and MH layer and the seepage of water in the ground, in order to predict the deformation behavior of the inclined seabed during MH production.

2. Numerical model

The numerical model is shown in Fig. 1. The depth of the surface of the model is 1000m under the sea surface. The dimension of the numerical model is 700m in width, and 575m (at the centerline of the production well) in height. The model is constituted by an upper rock layer, a MH layer and a lower rock layer. The height of the MH layer is 50m. The blue part stands for the MH bearing sediment and the yellow part is MH dissociation area which is 60m in width. The null part with a width of 2m in the center of MH dissociation area is the production well. Water could flow into this well during MH dissociation. The horizontal displacement of the well is fixed while the left and right sides of the well are permeable.

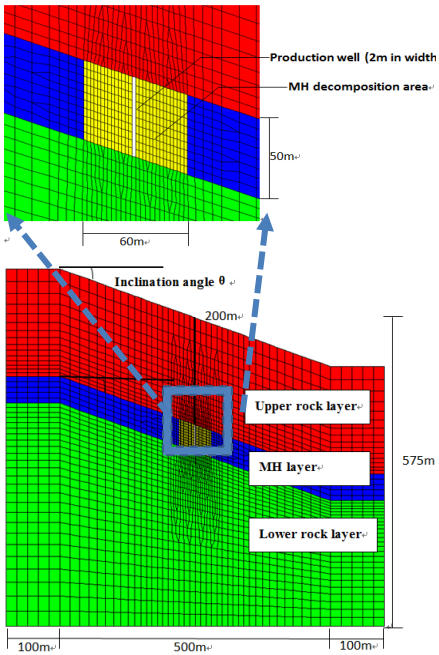

Fig.1 Numerical model

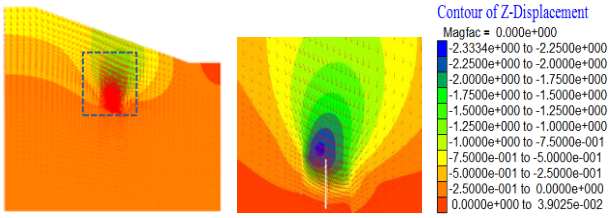

Fig. 2 Displacement vector contour

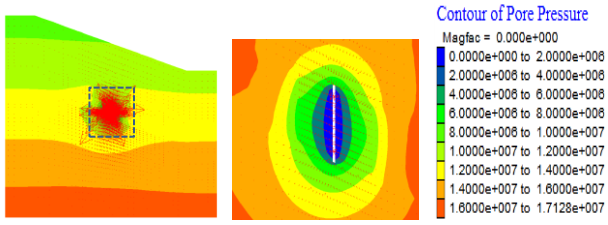

Fig. 3 Fluid flow vector contour

The parameters of the model were determined by field investigations and laboratory tests conducted in previous studies[1]. This model considered the inclination angles of seabed and MH layer, which is more realistic to the real situation. The dissociation of MH is represented by decreasing the value of deformation modulus to 1/100 of the original value and decreasing that of the coefficient of permeability to 10 times of the original value. Five cases (Case 1 – Case 5) were simulated with inclination angels of 0 º, 5 º, 10 º, 15 º, and 20 º, respectively.

3. Results and analysis

The results of Case 5 with inclination angle of 20 ºafter the start of dissociation of 100 hours were taken as an example to analyze the evolutions of deformation, flow and pore pressure. As shown in Fig. 2, the settlement appears in both upper rock layer and MH layer with the largest value of about 2.34m in the surroundings of production well.

Keywords: Methane Hydrate, Deformation behavior, Inclined seabed, Numerical simulation
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With the increment of time, the settlement region expands in the upper rock layer. As shown in Fig. 3, water flows into the production well with the pore pressure uniformly distributed surrounding the well. As shown in Fig. 4, the changes of pore pressure mainly appear around the production well. With the increase of time, the influential region expands, resulting in the decrease of pore pressures.

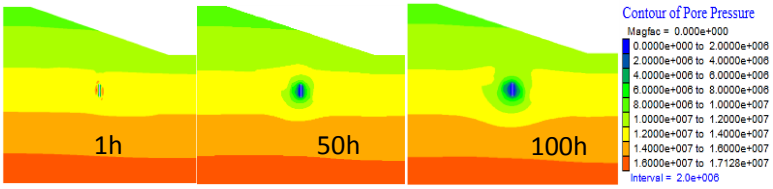
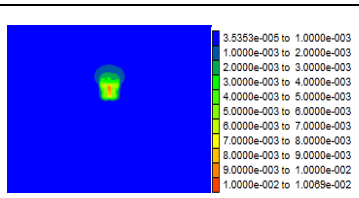
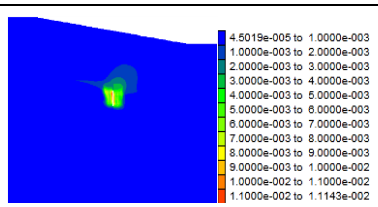
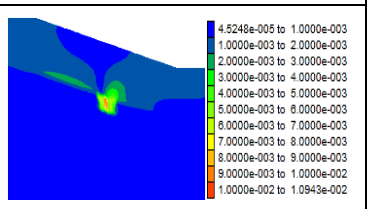
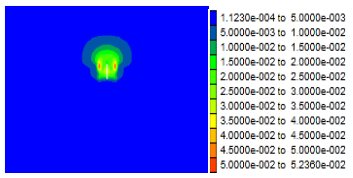
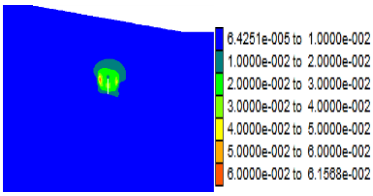
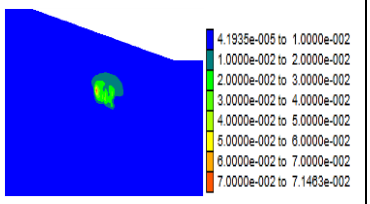
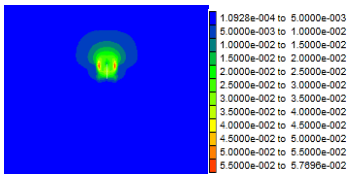
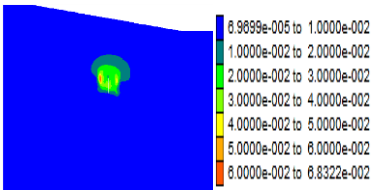
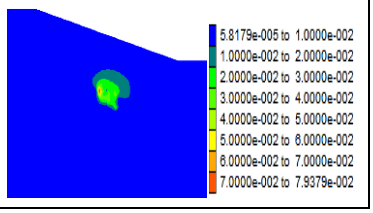


Fig. 4 Changes of pore pressure with time (case5)

Table 1 Changes of shear strain with time

Fluid time	Case 1 (0 °)	Case 3 (10 °)	Case 5 (20 °)
T=1h			
T=50h			
T=100h			

As illustrated in Table 1, the value of shear strain increases with the increase of inclination angle and dissociation time. The critical value of shear strain is calculated as 1.8%, showing that the regions around the wellbore are damaged in all cases after 100h. The shear strain increases dramatically from 1h to 50h, and approximately remains stable after 50h.

Fig. 5 depicts the settlement curves of the seabed. The maximum value of settlement increases with the increase of the inclination angle and the largest settlement is around 92cm. The largest settlements appear on the right side of the centerline, due to the influence of the inclination. Fig. 6 presents the settlement curves of MH layer, in which the largest settlements are almost identical and the value is about 230cm.

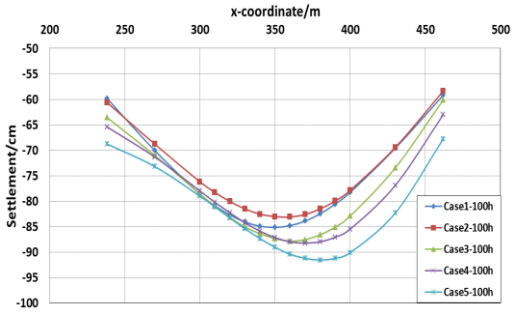


Fig. 5 The settlement of seabed

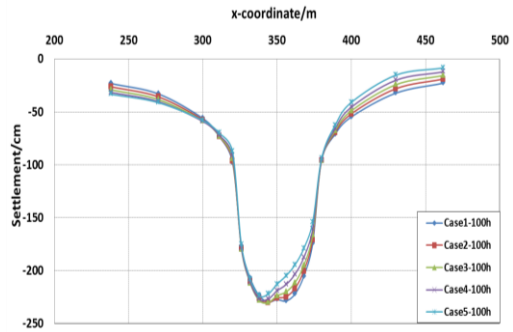


Fig. 6 The settlement of MH layer

4. Conclusions

With the production of MH, the settlement expands from MH layer to a wider parts of the upper rock layer. The larger the inclination angle is, the more unstable the seabed becomes. The areas around the production well are the most possible parts that failures may occur, therefore attention is required during productions.

References

[1]Sayuri K,Yukihiro H,Yujing J: The consolidation settlement behavior of the submarine foundation by methane hydrate decomposition and the dynamic stability of an ore chute. The 4th Comprehensive Symposium on Methane Hydrate(CSMH-4) in Japan, pp63～67,2012(in Japanese)..