The 2015 World Congress on
Advances in Structural Engineering and Mechanics (ASEM15)
Incheon, Korea, August 25-29, 2015

The analyses of rocket anchor's penetrating speed in installation and its influencing factors

Wei Yang[1)], *Kai Zhang[2)], Yu Zhang[3)], Run-Hong Tian[4)]
and Meng-Lan Duan[5)]

[1)] *Offshore Oil Engineering Co. Ltd., Tianjin, China*
[2), 3), 4), 5)] *Offshore Oil&Gas Reacher Center, College of Mechanical and Transportation Engineering, China University of Petroleum, Beijing, Beijing, China*

ABSTRACT

With the exploration for oil and gas into deepwater and ultra deepwater, the cost of the deepwater mooring foundation is highly increasing. Therefore, it is necessary to develop a low cost system of deepwater anchors with high holding capacity. The torpedo anchors have many advantages such as low cost, simplified installation and high holding capacity and so on. This new type of anchoring system is a kind of deepwater mooring system of the brightest prospects, which can not only fix the offshore equipment, but also moor the flexible riser in deepwater. The penetration depth of deepwater torpedo anchor is decided by the impact velocity, the anchor's weight and the geologic condition of soil. The penetration depth is usually within 50 meters. Among these factors, the impact velocity of anchor is the decisive factor of the penetration depth of torpedo anchors. Therefore, the study of different influencing factors to the impact velocity is helpful to control the penetration depth by controlling the impact velocity based on the knowledge of seabed soil.

Key Words: Mathematical modeling; Impact velocity; influencing factors.

1. INTRODUCTION

With the development of science and technology and people's understanding of the marine environment, the exploration and exploitation of large-scale offshore oil and gas resources is becoming a reality gradually. At this stage, the exploration and exploitation of marine oil and gas resources has gradually developed from shallow waters (less than 500m) to deep waters (500~1500m) and ultra deep waters (more than 1500m)(Colliat 2002). With the increase of mining depth, a variety of offshore equipment anchoring system is developed in order to fix the mobile offshore platform better. In 1996, Petrobras(Medeiros 2001) proposed the concept of Torpedo Anchor with a series of related experiments. The results of these experiments have shown that Torpedo Anchor can provide a powerful vertical anchorage force for the offshore platform. With the increase of water depth, the cost of the offshore platform anchoring will be doubled and redoubled. This kind of inexpensive offshore anchoring system just relies on its gravity for location and installation, and can provide a reliable anchorage force, and has greatly reduced the cost of offshore platform anchorage in the deep waters. Therefore, this kind of offshore anchoring system provides a good model for the development of inexpensive offshore anchoring system.

In 2006, Antonio Carlos Fernandes, Jairo Bastos de Araujo, osé Carlos Lima de, Almeida, RogérioDiniz Machado (Antonio 2006), Vinicius Matos studied the installation process of rocket anchor and discussed directional stability of rocket anchor when installing it into the water. In 2006, Jean ME Audibert, Maurice N. Movant, Jeong-Yun Won, Robert (Jean 2006) and others in the University of Texas made a series of research and analysis of the process of installing rocket anchor into the seabed. Finally, they made a brief analysis of the impact velocity of the rocket anchor and seabed penetration depth. In 2011, Davood Hasanloo, Hongli Pang, Guoliang Yu (Davood 2011) studied the falling speed and the drag coefficient of the related fluid in acceleration whereabouts phase of the rocket anchor.

This paper mainly analyzes the different forces affecting deepwater torpedo anchor in installation and executes theoretical derivation to each force to make the mathematical modeling of torpedo anchor during launching installation phase. After choosing the calculation parameters, the software of MATLAB can be used to analyze the influencing factors which affect the impact velocity, such as the density (the weight of torpedo anchors), the height of the installation releases, and the lengths of the installation anchor chains and so on.

2. FORCE ANALYSIS AND MATHEMATICAL MODELING OF ROCKET ANCHOR IN THE PHASE OF LAUNCHING INSTALLATION

The installation point of rocket anchor is at H point, a specified height above the seabed surface, which can ensure that there is enough kinetic energy when rocket anchor reaches the seabed surface, and can also ensure that the initial penetration depth of rocket anchor can meet the requirement of pull-out bearing capacity of deep waters drilling platform (in the clay with normal density and pressure, the initial penetration depth of rocket anchor is 2~3 times that of rocket anchor length, and the weight of anchorage force is 3~5 times that of the net weight of rocket anchor). The specified height H point of rocket anchor is also known as the installation height. The foreign researchers set this variable range of H point at 30~150m (Medeiros 2002).

According to the working principle of the rocket anchor, the rocket anchor is released from the specified height of H point, and then penetrates into the seabed at the way of free-falling relying on its self gravity. Therefore, the process of rocket anchor's installation can be divided into two phases: launching installation and penetration the seabed. This paper focuses on the modeling and analysis of installation in waters.

In view of the complexity of Marine environment of offshore oil mining areas, and combination of the unique geometrical shape of the rocket anchor and installations of it, we can ignore the effects of the secondary factors such as ocean current and wave force. Therefore, this paper assumes that the rocket anchor's launching installation had completed in static waters.

From the assumption, we can know that in static waters, the rocket anchor is only subjected to the vertical force acting when it drops vertically. Therefore, thought the force analysis, it is clear that there are four main forces in the phase of installation in waters: the gravity of rocket anchor, the buoyancy of water, the vertical pulling force of anchor chain and the vertical drag force of motion generated when installed in the waters(Antonio 2006)(Hongqi2010)(Mohammad 2009). Among these four forces, the gravity of rocket anchor and the buoyancy of water can be combined together to be the effective gravity. The concrete forces are shown in Fig. 1.

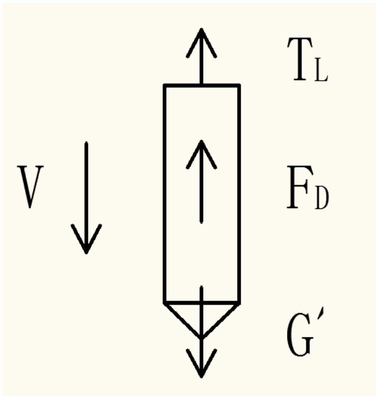


Fig. 1 The force diagram of rocket anchor in waters

In this picture, T_L is the vertical pulling force of anchor chain, F_D is the vertical drag force of sea water to the rocket anchor, $G^{'}$ is the submerged unit weight of rocket anchor.

2.1 The submerged unit weight $G^{'}$ of rocket anchor

During the phase of launching installation, the rocket anchor sustains its own gravity G and the buoyancy of water F_W. In this case, the weight of rocket anchor is known, and the operational area is definable, and the gravity G, the buoyancy of water F_W is a specific figure, so though simplified operation, we can get the submerged unit weight of rocket anchor, which is the effective gravity $G^{'}$. The specific computational process can be seen in Eq. (1).

$$G^{'} = G - F_W = (\rho - \rho_W) g \nabla \qquad (1)$$

In Eq. (1),
G is the own gravity of rocket anchor, $G = \rho g \nabla$, ρ is the density of rocket anchor, g is acceleration of gravity, ∇ is the volume of rocket anchor;

F_W is the buoyancy of water, $F_W = \rho_W g \nabla$, ρ_W is the density of sea water.

2.2 The drag force F_D of sea waters

It is assumed that the whole installation happened in static water, so when the rocket anchor makes "free fall" movement, it will be affected by drag resistance of water. For ease of measurements and calculation, it can calculate according to the drag of flow around the anchor. The specific computational process can be seen in Eq. (2):

$$F_D = \frac{1}{2}\rho_W C_D A_F V^2 \tag{2}$$

In Eq. (2):

ρ_W is the density of sea water (Antonio 2006)that is 1025 kg/m^3;

C_D is the drag coefficient of rocket anchor in sea water, no-dimensional factor;

A_F is the cross-sectional area of rocket anchor, m^2;

V is the falling speed of rocket anchor in sea water, m/s.

2.3 The pulling force T_L of anchor chain

In the process of rocket anchor's installation into the water, the existence of anchor chain plays an important role in the motive force analysis and the stability of direction. Therefore, it is necessary to consider the effect of anchor chain. It is known that when the anchor chain falls down vertically, it is not affected by the lateral anchor chain and ocean current. The simulation analysis of the movement and forces of the anchor chain can be seen in Fig.2.

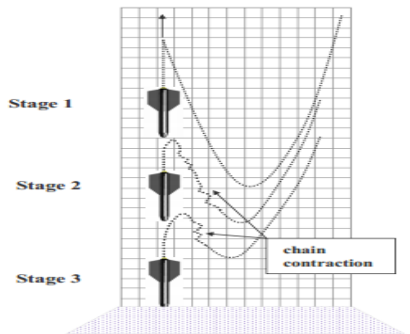


Fig.2 The motion trail of anchor chain in phase of launching installation

If the geometry of the anchor chain is simplified, the anchor chain can be regarded as a wire rope which is made of by a lot of oval steel rings. When the anchor chain tightens to fall with the rocket anchor together, the interaction force of them is pulling force T_L. Fig. 3 is the concrete force diagram.

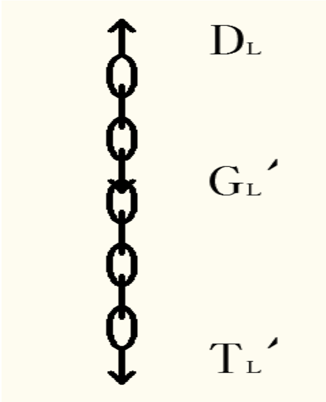


Fig.3 The force diagram of anchor chain in phase of launching installation

In Fig.3, $T_L^{'}$ is the pulling force of rocket anchor to the anchor chain; $G_L^{'}$ is the submerged unit weight of anchor chain; D_L is the drag force of sea water to the anchor chain.

2.3.1 The submerged unit weight $G_L^{'}$ of the anchor chain

During the phase of launching installation, the anchor chain moves together with the rocket anchor. So the submerged unit weight of the anchor chain can be calculated according to Eq. (3):

$$G_L^{'} = (\mathrm{M}_L - \rho_W \nabla_L)\mathrm{g} \tag{3}$$

In Eq. (3):
M_L is the mass of anchor chain, kg ;
∇_L is the volume of displacement of the anchor chain in sea water, m^3 ;
g is the acceleration of gravity, g =9.81 m/s ;
To facilitate the calculation, conversion of anchor chain's mass M_L and displacement mass $\rho_W \nabla_L$ can be written as Eq. (4):

$$M_L = u_L l \text{ , } \rho_W \nabla_L = e_L l \tag{4}$$

In Eq. (4):
u_L is the linear density of the anchor chain, kg/m ;
l is the length of the anchor chain during its entrance into water , m ;
e_L is the linear density of the displaced water column of anchor chain , kg/m ;
Eq. (4) is substituted in Eq. (3), and we can get another Eq. (5) to express the anchor chain:

$$G_L^{'} = (\mathrm{u}_L - e_L)\mathrm{lg} \tag{5}$$

2.3.2 The drag force D_L of water affecting the anchor chain

During the process of launching installation, anchor chain will tighten because of anchor's gravity; therefore, the anchor chain can be regarded as an elongated cylindrical object. Supposing that during the falling of rocket anchor, the drag force of water affecting the anchor chain uniformly distributes along its longitudinal direction, the drag force of water can be calculated according to the drag of flow around the anchors Eq. (6):

$$D_L = \frac{1}{2}\rho_W C_{DL/\mathrm{F}} A_F V^2 \tag{6}$$

In Eq. (6):

$C_{DL/F}$ is the coefficient of seawater' drag force during the process of launching installation.

2.3.3 The equations of Anchor chain's stress condition

Eq. (7) can be got according to anchor chain's stress condition and Newton's second law:

$$T_L^{'} + G_L^{'} - D_L = (\mathrm{M}_L + \mathrm{m}_a^{'})\,\mathrm{a} \tag{7}$$

In Eq. (7):

M_L is anchor chain's mass, kg ;

$m_a^{'}$ is anchor chain's radial additional mass, $m_a^{'}=2m_s^{'} = 2\rho_W \nabla_L$.

Eq. (5) and Eq. (6) are substituted in Eq. (7), and it can be rearranged as Eq. (8):

$$-T_L = T_L^{'} = (\rho_L + 2\rho_W)\nabla_L a + \frac{1}{2}\rho_W C_{DL/F} A_F V^2 - (\mathrm{u}_L - \mathrm{e}_L)\,\mathrm{lg} \tag{8}$$

2.4 The mathematical modeling in the phase of launching installation

Referring to the analysis method of Ture (1974; 1975; 1976) (Mohammad 2009) and according to Newton's second law, we can get the motion Eq. (9) in the phase of launching installation:

$$G^{'} - F_D - T_L = (\mathrm{M} + \mathrm{m}_a)\,\mathrm{a} \tag{9}$$

In Eq. (9);

$G^{'}$ is the submerged unit weight of the rocket anchor;

F_D is rocket anchor's drag force from seawater;

T_L is rocket anchor's pulling force from the anchor chain, $T_L = -T_L^{'}$;

M is the mass of the rocket anchor;

m_a is the radial additional quality of the rocket anchor, $m_a=2m_s = 2\rho_W \nabla$;

a is the fall acceleration, m/s^2 ;

The Eq. (1), (2), and (8) are substituted into Eq. (9), we can get Eq. (10):

$$(\rho_L + 2\rho_W)\nabla_L a + \frac{1}{2}\rho_W C_{DL/F} A_F V^2 - (\mathrm{u}_L - \mathrm{e}_L)\mathrm{lg} + (\rho - \rho_W)\,\mathrm{g}\,\nabla - \frac{1}{2}\rho_W C_D A_F V^2 = (\rho + 2\rho_W)\nabla a \quad (10)$$

Further calculations can get Eq. (11):

$$A - BV^2 = Ca \quad (11)$$

In Eq. (11);

$A = (\rho - \rho_W)\,\mathrm{g}\,\nabla - (\mathrm{u}_L - \mathrm{e}_L)\mathrm{lg}$;

$B = \frac{1}{2}\rho_W (C_D - C_{DL/F}) A_F$;

$\mathrm{C} = (\rho + 2\rho_W)\nabla - (\rho_L + 2\rho_W)\nabla_L$

3. MOTION ANALYSIS IN PHASE OF LAUNCHING INSTALLATION

According to the conclusion of the recent research on rocket anchor (Antonio 2006) (Davood 2011), when Rocket anchor is released from the specified point H above the seabed surface, it will accelerate downward in different two stages: instantaneous acceleration stage and stable accelerated phase while acceleration decreases. By the way, the drag coefficient C_D is a complicated variable in the instantaneous acceleration phase. However, the duration of this stage is very short which occurs as soon as the rocket anchor is released, the follow-up movement is hardly influenced. Therefore, this paper will skip over this stage. And the downward stage of the rocket anchor can be regarded as the acceleration phase when acceleration decreases. That is to say, the drag coefficient C_D can be regarded as a constant value.

3.1 The maximum impact velocity of the rocket anchor $V_{\max}$.

If the height of releasing point H is high enough, the maximum velocity can be achieved when the rocket anchor arrives at the seabed surface, then we can get the Eq. (12).

$$A - BV_{\max}{}^2 = 0 \quad (12)$$

The maximum impact velocity Eq. (13) of the rocket anchor can be obtained by solving this equation.

$$V_{\max} = \sqrt{\frac{A}{B}} = \sqrt{\frac{(\rho - \rho_W)\,\mathrm{g}\,\nabla - (\mathrm{u}_L - \mathrm{e}_L)\mathrm{lg}}{\frac{1}{2}\rho_W (\mathrm{C}_D - \mathrm{C}_{DL/F})\,\mathrm{A}_F}} \quad (13)$$

3.2 The theoretical impact velocity V of the rocket anchor falling downward the seabed surface

In the engineering practice, for the rocket anchor with certain type and specified installation height of H, the theoretical impact velocity V of the rocket anchor downward to the seabed surface is required to be define, so that the final depth L can be determined while penetrating into the seabed soil. The equation $a=\frac{dv}{dt}=\frac{dv}{ds}\cdot\frac{ds}{dt}=V\frac{dv}{ds}$ is substituted in Eq. (11), we can get Eq. (14).

$$A-BV^2=CV\cdot\frac{dv}{ds} \tag{14}$$

Sorting out the equations above, we can get the relationship Eq. (15) between the specified height H and the theoretical impact velocity V when the rocket anchor arrives at the seabed surface.

$$H=\frac{C}{2B}\ln A-\frac{C}{2B}\ln(\mathrm{A-BV^2})=\frac{C}{2B}\ln\frac{A}{A-BV^2} \tag{15}$$

Here, H represents the distance between the rocket anchor and the seabed surface;

$A=(\rho-\rho_W)\mathrm{g}\nabla-(\mathrm{u}_L-\mathrm{e}_L)\mathrm{lg}$;

$B=\frac{1}{2}\rho_W(C_D-C_{DL/F})A_F$;

$\mathrm{C}=(\rho+2\rho_W)\nabla-(\rho_L+2\rho_W)\nabla_L$;

4. ANALYSES OF THE PARAMETERS

From the above mathematical modeling analysis, we have obtained the relationship Eq. (15) between the specified height H and the theoretical impact velocity V when the rocket anchor arrives at the seabed surface. Through the analysis to the obtained equations, we can get nine parameters influencing the theoretical impact velocity of the rocket anchor: the height of releasing point H, rocket anchor's density ρ, installation anchor chain's density ρ_L, seawater's density ρ_W, installation anchor chain's length l, the anchor chain's linear density u_L, equivalent fluid line density e_L, the rocket anchor's drag force coefficient C_D and the anchor chain's drag force coefficient $C_{DL/\mathrm{F}}$.

In order to simplify the calculation, according to the experience, we regard some parameters as constants which have little effects, including the density of seawater ρ_W=1025 kg/m^3, the density of installation anchor chain ρ_L=7850 kg/m^3 (construction steel density), linear density of equivalent fluid $e_L=\frac{\rho_W}{\rho_L}u_L\approx 0.131u_L$, and the related drag resistance coefficient $C_D-C_{DL/F}=0.3$ (according to the results of the marine basin experiment).

For some important parameters, their values are defined according to the real objects. Therefore, the overall density of the rocket anchor varies from 2500 kg/m^3 (concrete density) to 7850 kg/m^3 (iron density) because of different fillers. The height of releasing point H can be valued arbitrarily (generally the value is between 30m to 150m in some research literatures about rocket anchor). As for the sizes and the shapes of the rocket anchors and anchor chains, we select three typical rocket anchors and installation anchor chains. And the sizes parameters are as shown in Table. 1 (Hongqi 2010):

Table.1 parameters table of the rocket anchor's and the anchor chain's sizes

	diameter (m)	Length (m)	Diameter of anchor chain(m)	Linear density of the anchor chain(kg/m)	equivalent fluid line density(kg/m)
Torpedo anchor	0.762	12	0.06	15	1.965
	0.762	12	0.08	26	3.406
	1.067	15	0.10	40	5.240

In order to make it easy for the follow-up analysis, it is supposed that the height of the cone top of the rocket anchor is equivalent to the diameter of the rocket anchor. And according to the above tables, the cross-sectional are, A_{F1}=A_{F2}=$0.456m^2$, $A_{F3}=0.894m^2$,the volume of the rocket anchor ∇_1=∇_2=$5.241m^3$, ∇_3=$12.777m^3$ and the volume of the installation anchor chain ∇_{L1}=$0.003lm^3$, ∇_{L2}=$0.005lm^3$,. ∇_{L3}=$0.008lm^3$.

5. CALCULATIONS OF THE ROCKET ANCHOR IN THE PHASE OF LAUNCHING INSTALLATION STAGE

In the engineering practice, with the influence of the anchor chain ($T_L \neq 0$, $l \neq 0$), If the height of releasing point H is high enough, the maximum impact velocity of rocket anchor can be achieved when it arrives at the seabed surface, then the maximum impact velocity $V_{\max}$ of the rocket anchor can be expressed as the following Eq. (13):

$$V_{\max} = \sqrt{\frac{A}{B}} = \sqrt{\frac{(\rho-\rho_W)\,\mathrm{g}\,\nabla-(\mathrm{u}_L-\mathrm{e}_L)\,\mathrm{lg}}{\frac{1}{2}\rho_W(\mathrm{C}_D-\mathrm{C}_{DL/F})\,\mathrm{A}_F}} \tag{13}$$

Here, $A=(\rho-\rho_W)\,\mathrm{g}\nabla-(\mathrm{u}_L-\mathrm{e}_L)\,\mathrm{lg}$=$(\rho-1025)9.81\nabla-(\mathrm{u}_{Li}-\mathrm{e}_{Li})\mathrm{l}9.81$

$B=\frac{1}{2}\rho_W(C_D-C_{DL/F})A_F$=$153.75A_F$

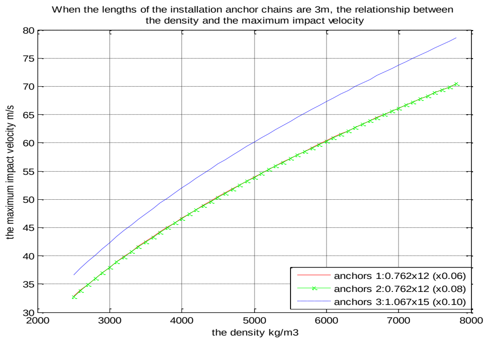
∇_1=∇_2=$5.241m^3$, ∇_3=$12.777m^3$

A_{F1}=A_{F2}=$0.456m^2$, $A_{F3}=0.894m^2$

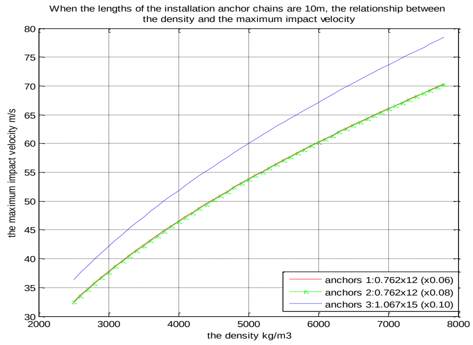
$u_{L1}=15kg/m$, $u_{L2}=26kg/m$, $u_{L3}=40kg/m$

$e_{L1}=1.965kg/m$, $e_{L2}=3.406kg/m$, $e_{L3}=5.240kg/m$

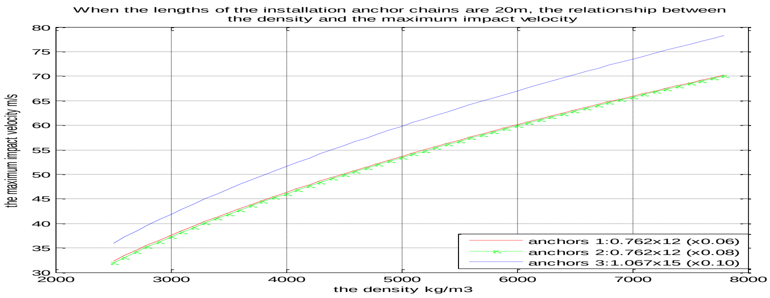
Setting the lengths of the anchor chains respectively l_1=$3m$, l_2=$10m$, l_3=$20m$, the relationship between the density and the maximum impact velocity is shown in Fig.4 (a),(b),(c):



(a)



(b)



(c)

Fig. 4 The relationship between the density and the maximum impact velocity when the lengths of the installation anchor chains are (a) l_1=3m ,(b) l_2=10m ,(c) l_3=20m .

Considering the influence of the installation anchor chain ($T_L \neq 0$、$l \neq 0$) and according to the motion of rocket anchor Eq. (15), we define the overall density of rocket anchor as ρ=5000kg/m^3

$$H=\frac{C}{2B}\ln A-\frac{C}{2B}\ln(\mathrm{A}-\mathrm{BV}^2)=\frac{C}{2B}\ln\frac{A}{A-BV^2} \tag{15}$$

Here: $A=(\rho-\rho_W)\mathrm{g}\nabla-(\mathrm{u}_L-\mathrm{e}_L)\mathrm{lg}=38994.75\nabla-(\mathrm{u}_{Li}-\mathrm{e}_{Li})19.81$

$B=\frac{1}{2}\rho_W(C_D-C_{DL/F})A_F=153.75A_F$

$\mathrm{C}=(\rho+2\rho_W)\nabla-(\rho_L+2\rho_W)\nabla_L=7050\nabla-(\rho_L+2050)\nabla_L$

$\nabla_1=\nabla_2=5.241m^3$, $\nabla_3=12.777m^3$

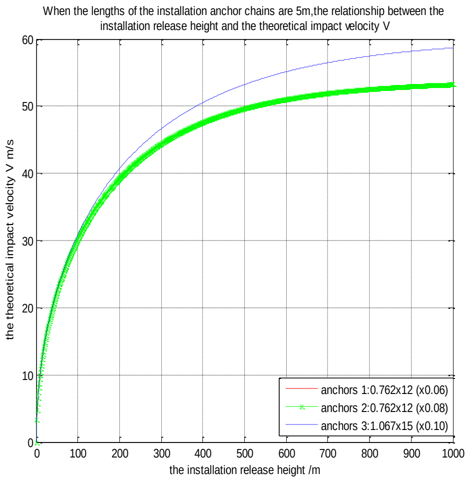
$\nabla_{L1}=0.003lm^3$, $\nabla_{L2}=0.005lm^3$, $\nabla_{L3}=0.008lm^3$

$A_{F1}=A_{F2}=0.456m^2$, $A_{F3}=0.894m^2$

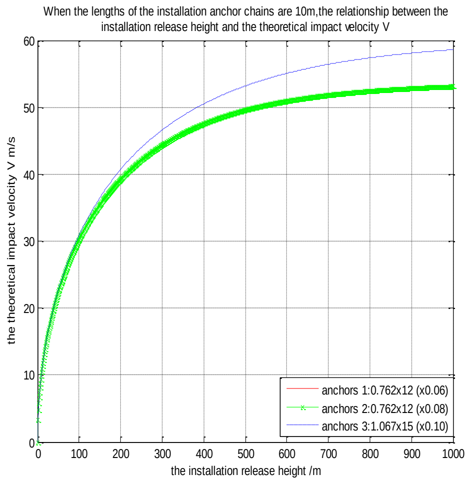
$u_{L1}=15kg/m$, $u_{L2}=26kg/m$, $u_{L3}=40kg/m$

$e_{L1}=1.965kg/m$, $e_{L2}=3.406kg/m$, $e_{L3}=5.240kg/m$

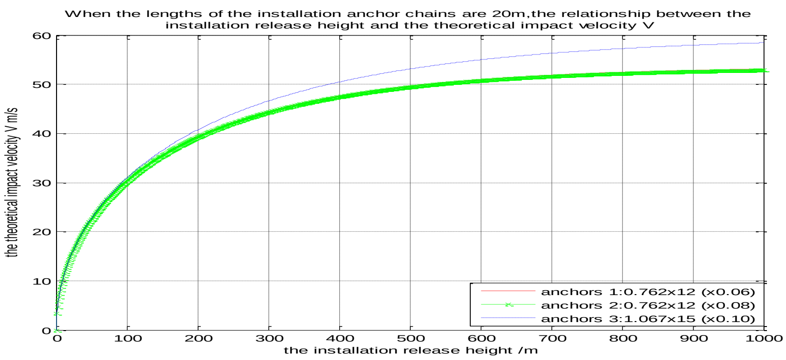
Setting the lengths of the anchor chains respectively l_1=5m , l_2=10m , l_3=20m , under circumstance with anchor chain, the relationship between the height of releasing point and the theoretical impact velocity is shown in Fig. 5 (a),(b),(c):



(a)



(b)



(c)

Fig. 5 The relationship between the installation release height and the theoretical impact velocity when the lengths of the installation anchor chains are (a) $l_1=5m$,(b) $l_2=10m$,(c) $l_3=20m$.

In order to verify the effects of anchor chain's lengths on the theoretical impact velocity, we define the overall density of rocket anchor $\rho=5000kg/m^3$, according to the Eq. (15) for the motion of rocket anchor

$$H=\frac{C}{2B}\ln A-\frac{C}{2B}\ln(\mathrm{A}-\mathrm{BV}^2)=\frac{C}{2B}\ln\frac{A}{A-BV^2} \tag{15}$$

Here: $A=(\rho-\rho_W)\mathrm{g}\nabla-(\mathrm{u}_L-\mathrm{e}_L)\mathrm{lg}=38994.75\nabla-(\mathrm{u}_{Li}-\mathrm{e}_{Li})19.81$

$$B=\frac{1}{2}\rho_W(C_D- C_{D/L})A_F=153.7A_F$$

$$\mathrm{C}=(\rho+2\rho_W)\nabla-(\rho_L+2\rho_W)\nabla_L=7050\nabla-9900\nabla_L$$

$\nabla_1=\nabla_2=5.241m^3$, $\nabla_3=12.777m^3$

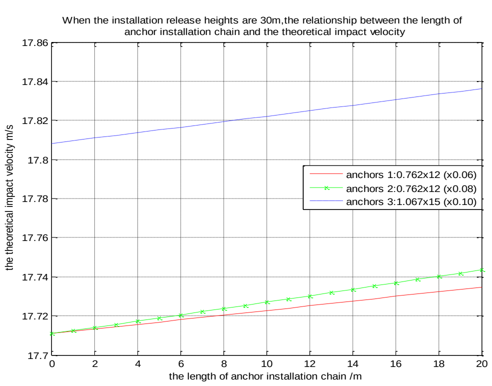
$\nabla_{L1}=0.00lm^3$, $\nabla_{L2}=0.005lm^3$, $\nabla_{L3}=0.008lm^3$

$A_{F1}=A_{F2}=0.456m^2$, $A_{F3}=0.894m^2$

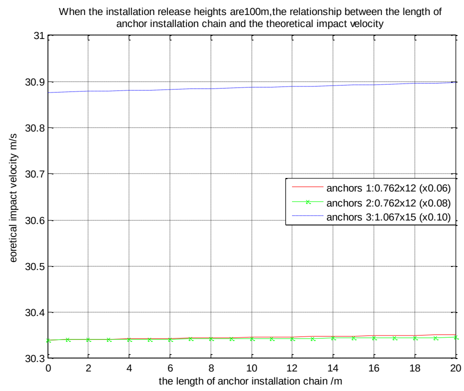
$u_{L1}=15kg/m$, $u_{L2}=26kg/m$, $u_{L3}=40kg/m$

$e_{L1}=1.965kg/m$, $e_{L2}=3.406kg/m$, $e_{L3}=5.240kg/m$

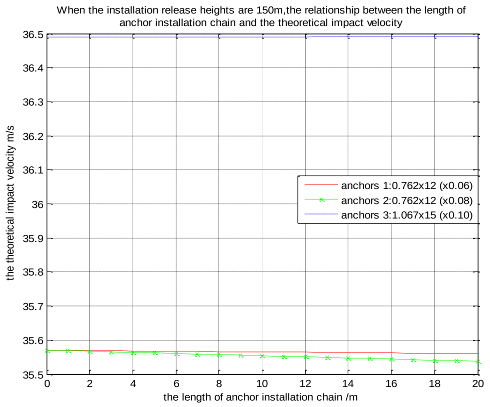
Setting the height of releasing point as $H_1=30m$, $H_2=100m$, $H_3=150m$, $H_4=300m$, the relationship between the lengths of anchor chain and the theoretical impact velocity at the specified height is shown in Fig.6 (a),(b),(c),(d):



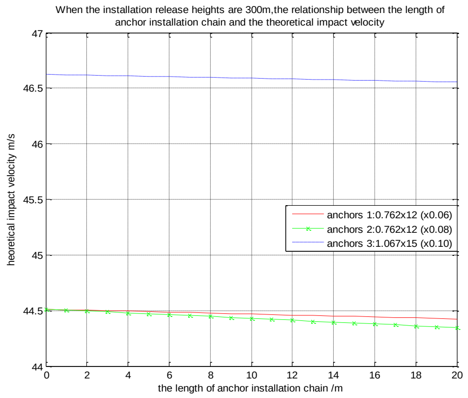
(a)



(b)



(c)



(d)

Fig. 6 The relationship between the length of anchor installation chain and the theoretical impact velocity when the installation release heights are (a) $H_1=30m$,(b) $H_2=100m$,(c) $H_3=150m$ (d) $H_4=300m$.

6. CONCLUSIONS

1) The rocket anchor accelerates while the acceleration decreases gradually after

the installation and release. If the height of the installation is high enough, the maximum impact velocity of the rocket anchor may be achieved when it arrives at the seabed surface.

2) The theoretical impact velocity of the rocket anchor arriving at the seabed surface is positively related to the installation height of the rocket anchor at a certain range of installation height, The theoretical impact velocity of the rocket anchor achieves maximum value if the installation height is higher than this range, which is the maximum impact velocity.
3) The theoretical impact velocity of the rocket anchor reaching the seabed surface is related not only to the rocket anchor's type, but also to its overall density (or the rocket anchor's mass) and the releasing height for installation.
4) The maximum impact velocity of rocket anchor is not only related to the rocket anchor's type, but also positively related to the overall density (or the rocket anchor's mass) of the rocket anchor.
5) The length of anchor chain may have effect on the theoretical impact velocity of rocket anchor when it arrives at the seabed surface, whilethe height of releasing point for the installation of the rocket anchor is determined.

ACKNOLEDEGEMENT

This research is supported by Supported by Science Foundation of China University of Petroleum, Beijing (No.2462015YQ0403).

REFERENCES

Antonio, C.F., Jairo, B.A., Carlos, L.D., Almeida, Rogério, D.M. andVinicius, M. (2006),"Torpedo Anchor Installation Hydrodynamics"[J]. Journal of Offshore Mechanics and Arctic Engineering.1-8.

Colliat, J.L. (2002),"Anchors for Deepwater to Ultra-deepwater Mooring"[C]. Offshore Technology Conference, 1-5

Davood, H.,Hongli, P. andGuoliang, Y. (2010),"On the estimation of the falling velocity and drag coefficient of torpedo anchor during acceleration"[J].Ocean Engineering, **42**, 135-146.

Hongqi, M. (2010),"Research on Initial Penetration of Torpedo Anchor into Seabed Soil"[D]. TianjinUniversity: School of Civil Engineering.31-34.

Jean, M.E.,Audibert, M.N., Movant, J.Y.W. and Robert, B.G. (2006),"Torpedo Piles: Laboratory and Field Research"[C]. International Offshore and Polar Engineering Conference,**16**,462-468.

Medeiros,C.J.Jr. (2001),"Torpedo Anchor for Deep Water"[C].DOT, Rio de Janeiro.

Medeiros,C.J.Jr.(2002),"Low Cost Anchor System for Flexible Risers in Deep Waters"[C]. OTC,14151, 1-3.

Mohammad, S.R. (2009),"B.S.M.S.A computational Procedure of Simulation of Torpedo Anchor Installation, Set-up and Pull-out"[D].the University of Texas, 10-16.