김일성종합대학학보 JOURNAL OF KIM IL SUNG UNIVERSITY
(자연과학) (NATURAL SCIENCE)
주체103(2014)년 제60권 제6호 Vol. 60 No. 6 JUCHE 103(2014).

Sorting Process and Gravity Concentration Characteristics of Placer Minerals in Coastal Areas

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The great leader Kim Jong Il said:

"In order to meet the rapidly increasing demand of the national economy for fuel and raw material resources we must put geological prospecting on a modern footing."

In general, placer minerals in coastal areas are formed when initial material sources undergo weathering, erosion, transport and sedimentation.

Sediments carried into the sea go through constant movement and sedimentation in time and spaces and then they are sorted into grain sizes according to their density differences. [3]

We studied the relationship between the sorting process of placer minerals in the seawater vehicle and the gravity concentration character.

1. Sorting Process of Placer Minerals in Coastal Areas

In seawater vehicle, when sediment grains of different sizes and of different densities precipitate, heavy grains which precipitated earlier sink in the place while suspended light ones sink as they travel long distances. In this way placer minerals in coastal areas are sorted and sink according to their density and their grain size.

On the other hand, sediment grains deposited in a certain place turn into a moving state when hydraulic conditions change, and this critic hydraulic condition is called the starting velocity of sediment grains.

There are a number of formulas to calculate the starting velocity of sediment grains, but the most appropriate one is the following [1].

$$\mathrm{v}_e = 0.22\left(\frac{\rho_s-\rho_0}{\rho_0},\ \frac{gd}{f_{\mathrm{cw}}}\right)^{1/2}, \quad d \ge 0.217\mathrm{mm} \tag{1}$$

$$\mathrm{v}_e = \frac{0.55}{\sqrt{f_{\mathrm{cw}}}}\nu^{0.36}\left(\frac{\rho_s-\rho_0}{\rho_0}g\right)^{0.32} d^{-0.04}, \quad d < 0.217\mathrm{mm} \tag{2}$$

where d is the grain class of sediment; ρ_s and ρ_0 are densities of sediment grain and vehicle; g is gravity acceleration; ν is a kinetic coefficient of viscosity of the vehicle; f_{cw} is a coefficient of total friction of wave and is related to bed shear stress.

The starting grain size is the size of sediment grain which can move with the starting velocity. Calculation of the starting grain class is slightly complicated but its final formula is as follows:

$$d_e = \tau_{cw} / [0.05(\rho_s - \rho_0)g] \tag{3}$$

where τ_{cw} is the bed shear stress.

Table 1, 2 show velocities of precipitation corresponding to the density and the grain size of the sediments which affect the grain size distribution of placer minerals in coastal areas and the starting velocity according to the depth of water and the starting grain size.

Table 1. Settling velocity corresponding to the size and density of the sediment grains(cm/s)

Grain size /mm	Density/($\times 10^3$kg m^{-3})					
	3	4	5	6	7	18
0.005	0.003	0.004	0.005	0.006	0.008	0.023
0.05	0.270	0.410	0.540	0.680	0.820	2.310
0.1	3.240	3.710	4.090	4.400	4.680	6.620
0.5	16.220	18.570	20.400	22.010	23.400	33.100
1.0	32.400	37.200	40.880	44.000	46.800	66.200
2.0	64.900	74.280	81.750	88.060	93.600	132.400
3.0	97.300	111.000	123.000	132.000	140.000	198.600
5.0	162.200	185.700	204.000	220.000	234.000	331.000

Table 2. starting velocity according to water-depth and starting grain class of the sediment grains(m/s)

Depth/m	Starting grain size/mm				
	0.05	0.2	0.4	0.6	3
1	0.18	0.23	0.24	0.29	0.64
5	0.24	0.23	0.31	0.38	0.84
10	0.27	0.26	0.35	0.42	0.95
20	0.30	0.29	0.39	0.48	1.06
40	0.34	0.32	0.44	0.53	1.19
60	0.37	0.35	0.46	0.57	0.28

As shown in table 1, 2, zones of the coarse, middle, fine placer deposits are created according to intensity of the action of the hydra-dynamic factors that controls mineral composition, grain class and separation process. In other words, at a certain point at the bottom of the sea, the sediment grains can be distributed according to the fomula of the sedimentation velocity at one time but can also be distributed according to the formula of the starting velocity the other time. This results in the creation of different placer deposits with different mineral composition and size.

2. Characteristic of the gravity concentration

In laminar and turbulent flow, free settling velocity of the precipitating grain can be calculated with the following formula: [2,4]

$$v_S = \frac{gd^2(D_S - D_f)}{18\eta} \tag{4}$$

$$v_N = \left[\frac{3gd\ (D_S - D_f)}{D_f}\right]^{1/2} \tag{5}$$

where v_S and v_N are free settling velocities of the precipitating grain in the laminar and turbulent flow, D_S is density of the precipitating grain, D_f is density of the vehicle, η is viscosity of the vehicle, g is the gravity acceleration, d is size of a precipitating grain(density).

We can simply put it into formulas (4) and (5).

$$v_S = k_1 d^2 (D_S - D_f) \tag{6}$$

$$v_N = k_2 [d \ (D_S - D_f)]^{1/2} \tag{7}$$

where k_1 and k_2 are invariables, ($D_S - D_f$) is effective density of the precipitating grain whose density in the solution of D_f is D_S.

Formulas (6) and (7) show that the settling velocity of the precipitating grain depends on the size and density of the vehicle. Therefore, the ratio of free settling can be worked out with the following formula:

$$\frac{d_a}{d_b} = \left(\frac{D_b - D_f}{D_a - D_f} \right)^n \tag{8}$$

where d_a and d_b are sizes of the precipitating grains *a* and *b*, D_a and D_b are densities of the precipitating grain *a* and *b*.

In this formula (8), with Stock's rule, *n* refers to fine grains and is 0.5, but with Newton's rule, *n*, being the coarse grain, is 1. And if *n* is of a middle size of 50μm～0.5cm, it is 0.5～1.

In practice, sediment grains are more influenced by hindered settling than free settling. When the amount of grains increases in the pulp, the settling velocity of the grain decreases as the interference between the grains increases.

Therefore, we can draw out a new settling velocity formula from the formula (7).

$$v = k[d(D_S - D_P)]^{1/2} \tag{9}$$

where D_P is the density of the pulp.

As shown in the formula (9) effective density decreases as the density of the pulp increases. And as effective density decreases, the settling velocity decreases.

If we change the D_f into D_P in the formula (8), we can draw a new formula to calculate the ratio of the sizes of the grains in hindered settling.

$$\frac{d_a}{d_b} = \left(\frac{D_b - D_P}{D_a - D_p} \right) \tag{10}$$

Formula (10) shows that the ratio of the sizes of the grains in hindered settling is related to the density of the pulp. In other words, the greater the density of pulp, the greater the ratio of the sizes of the grains in hindered settling.

Calculation of the ratio of the grain sizes of the coastal placer minerals of different densities in hindered settling is shown in table 3.

Table 3. Ratio of the grain sizes of the coastal placer minerals of different densities in hindered settling(quartz is the standard here)

Section	Density of the pulp /($\times 10^3$kg m^{-3})	Density of minerals/($\times 10^3$kg m^{-3})					
		3	4	5	6	7	18
Stocksgrain	1	1.100	1.348	1.557	1.740	1.907	3.210
	1.5	1.391	1.615	1.865	2.085	2.284	3.845
Allengrain	1	1.137	1.490	1.805	2.094	2.365	4.735
	1.5	1.194	1.678	2.100	2.483	2.839	5.905
Newtongrain	1	1.212	1.818	2.424	3.030	3.636	10.303
	1.5	1.739	2.609	3.478	4.348	5.217	14.780

As shown above, if the ratio of the grain size of the coastal placer minerals and the density of the pulp increase, the effectiveness of the gravity concentration increase.

Conclusion

1) In the coastal areas with placer minerals there exist coarse, middle and fine deposits with different mineral compositions which depend on the extent of the action of hydrodynamic factors which control the process of creating and sorting sediments

2) The greater the ratio of the grain sizes of the coastal placer minerals and the density of the pulp, the greater the effectiveness of gravity concentration in the placer minerals.

References

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