Carbon emission of dredged marine sediment

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Abstract—**There are 4-6Mt carbon emission resulting from 2,000,000,000 m3 marine sediment.The dredging sediment was removed annually from the waterways around the world.Few efforts have been applied to the evaluation of carbon emission from comparable types of dredger.The carbon emission of four kinds of dredgers which dredged marine sediment was estimated in this paper.Two kinds of representative dredgers have been introduced.They are the Trailling Hydraulic Grab Hopper Dredger and the Sea Going Hopper Suction Dredger.The Dustpan Dredger and the Bucket Wheel Dredger's results also be presentd in the paper.In order to estimate carbon emission clearly,the estimation was divided into 10 portions based on the commonly operation workstage.In the specific dredging situation of the paper,the result shows that the Trailing Hydraulic Grab Hopper Dredger is better suited for 10nm transport distance and has lower carbon emission generated from dredging 1m^3 marine sediment.The result indicates that carbon emission evaluation is not only contribute to control greenhouse effect,but also promote the industry of dredging to strengthen the concept of Low Carbon Development.**

Keywords-carbon emission;evaluation;dredger;offshore;china

I. INTRODUCTION

Maintenance of adequate depths for passage of ships in coastal waterways and inlets requires frequent dredging[1].An average of 300,000,000 m^3 of marine sediments were dredged from china waterways annually.And 2,000,000,000 m^3 were dredged around the world.In recent yeares, An appealing alternative to treating dredged materials as spoils to be discarded is to recognize their value[2]. Sediment dredged from offshore may be retained in the beach system by depositing it on the adjacent ebb-tidal delta. This method of disposal has received recent attention as a potential strategy of sediment management that can nourish beaches[3].So the dreged sediment will be transported to beaches and be discharged to pumping area.

The dredging works of china will lead to millions of tons of CO_2 emission annually.So the assessment of carbon emission of the two kinds of dredgers was estimated in this paper and it will make contribution to reduce carbon emission of dredging industry. The two kinds of dredgers are the traiIling hydraulic grab hopper dredger(D1), Sea going Hopper Suction Dredger (D2) [4].Besides the dustpan dredger(D3) and the trailing bucket wheel dredger(D4) also be estimated.The evaluation process of D3 and D4 was presented in other paper.At present some ways have been used to estimate carbon emission,just like the Model method,Emission coefficient method and Materials accounting method.The first one was commonly used to study Carbon flux of forest and social economic evaluation[5].The coefficient of second method was calssified as air recycling and no air recycling[6].The third could be evaluated by two methods:consumption of apparent energy which was advised by IPCC and detailed classification of fuel[7].

Materials accounting method was selected in this paper.So the carbon emission was generated from fuel consumption of dredgers during dredging operation.

II. EVALUATION METHODS OF CARBON EMISSION OF DREDGERS

Dredgers were widely used to dredge marine sediment.During dredging operation,the carbon emission of dredger is resulted from consumption of diesel fuel of different workstage's dredging equipment.Six workstages of dredging dredged marine sediment(DMS),sailing to the work area,preparing dredging equipment,dredging DMS,loading DMS,inward journey,discharging DMS and daily electricity are considered.Besides,the carbon emission also will be released by some machines,which have been used to provide daily electricity.So the content of dredger's carbon emission is given in Figure 1.

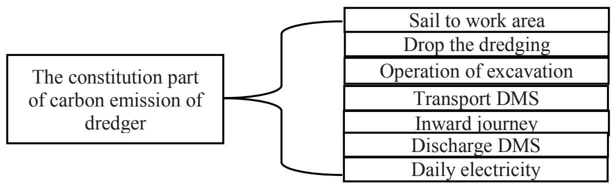

Figure 1. The carbon emission of dredging DMS workstage

According to Figure 1.The total carbon emission($\sum C$) of dredger can be defined as in equation (1):

$$\sum C = CT + CX + CW + CF + CD + CR \quad (1)$$

Where $\sum C$ is the total carbon emission(kg)that derdger dredge 1000 m^3 DMS;*CT* is the carobon emission(kg)of sailing to work area;*CX* is the carbon emission(kg) of dropping dredging equipment;*CW* is the carbon emission(kg) of dredging and transport DMS;*CH* is the carbon emission(kg)of inward journey which include dredger and sandcarrier;*CD* is the carbon emission(kg) of discharging DMS;*CR* is the carbon emission(kg)of daily electricity of dredging DMS

Because the carbon emission of every dredging workstage is resulted from the combustion of diesel fuel in Equation (1).Carbon emission of every workstage can be written as:

$$C_i = \eta * MiH \quad (2)$$

Where C_i is the carbon emission(kg)of dredging workstage *i,i=T,X,W,F,H,X,R*;η is the carbon emission(kg) of combustion 1kg fuel;*MiH* is fuel consumption(kg)of dredging workstage *i,i=T,X,W,F,H,X,R*.

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In this passage, the power resource is diesel fuel,so η was acted as the carbon emission of consumption 1kg diesel fuel.Consumption 1kg diesel fuel will release 3.14kg CO_2,0.00021 kg CH_4 and 0.000254kg NO_2.Then the CH_4 and NO_2 will be transformed into CO_2 by GWPs[8].So consumption 1kg diesel fuel will actually released 3.2kg CO_2.In other words η=3.2.

MiH was generated from some driving machines,which were used to drive equipment of dredging workstage *i*. Corresponding to the power of driving machine is a specific fuel consumption.So MiH can be calculated using the equation

$$MiH = \sum_{k=1}^{n} P_k * VkH * t_k * (P_k / P_m) \tag{3}$$

Where P_k is the output power(kw)of a driving machine which was used to drive equipment of dredging workstage *i*;*VkH* is the specific fuel consumption(g/kw*h)of driving machine under rated power operation;t_k is the running time(h)of driving machine;P_m is the rated power(kw)of driving machine.

III. DREDGER SAMPLING AND EVALUATION

In order to get accurate results,the carbon emission of dredgers was estimated in a special situation. The situation is that the distance from work area to port is 10nm,depth of marine is 10m;Temperature is 0 to 30℃;the height of waves is 1.0 to 1.2m and the dredging operations covered sea area.During dredging operation,The carbon emission that is generated from dredger's moving which through spuds and anchors will not be estimated.Loose non-cohesive soil,particle size is 16 to 50 μm .Towboat(BC) which was used to tow some dredgers(D1,D4).The towboat are Wuxi manufacturing,the powr is 1000HP,the Speed is 10.5kn,the power of main enging is 373kw(The specific fuel consumption is replaced by 360kw 12v135AZLD-1 diesel generator.The specific fuel consumption is 206g/kw.h).

A. Trailing Hydraulic Grab Hopper Dredger(D1)

1) Principle of operation and power device parameters of (D1).

The carbon emisison of "CHANGYING 50"trailing hydraulic grab hopper dredger was evaluated.During dredging operation,two spuds of dredger are used to fix position of D1[9].The DMS was dredged by D1's grab.The grab was controlled by crane boom[10].Productivity of D1 is 1500 m^3/h,the speed of dropping spud is 0-4m/s,the depth that spud insert into soil is 2m. Dropping speed of grab is 1.67m/s,rising speed of grab is 1m/s.Power device parameters of D1 are shown in table 1

TABLE I. POWER DEVICE PARAMETERS OF D1

POWER DEVICE	Amount	Power (kw)	Substitude for	Fuel consumption(g/kw*g)	function
Diesel generator sets	1	3530		209	dredging
Diesel generator	1	956	1000KW U.S.A cummins diesel generator	208	Rise spuds
Diesel generator	1	220	220KW Shang Hai diesel generator sets	206	Rise anchor
Diesel generator	1	80	80kw U.S.A cummins KH88 diesel generator	210	Daily electricity

2) The carbon emission's equation of D1

In order to evaluate the carbon emission of D1.The daily electrecity and dredging workstage of "CHANGYING 50" were considered.The workstages were composed of towing to work area by towboat,dropping spuds,excavation,rising spuds and inward journey.So the equation of D1 to the above content is:

$$\sum C = CT + CX + CW + CQ + CF + CR + 612 \tag{4}$$

Where $\sum C$ is the total carbon emission(kg)of dredging workstage and daily electricity,*CT* is the carbon emission(kg) of towing to work area by towboat,*CX* is carbon emission(kg) of dropping spuds,*CW* is carbon emission(kg) of dredging DMS,*CQ* is the carbon emission(kg) of rising spuds,*CF* is the carbon emission(kg) of inward journey,*CR* is the carbon emission(kg) of daily electricity,612kg is the carbon emission of sandcarrier which carrise 1000m^3 DMS and transport 10nm.

$CT = 3.2 * MTC$,*MTC* is the diesel consumption of towing to work area by towboat(kg).

During the workstege,the speed of sailing was considered as top speed,the power was considered as rated power.So the diesel consumption of MTC can be writen as:

$$MTC = (VTH / 1000) * t * PT * n = (VTH / 1000) * (S / V) * PT \tag{5}$$

VTH is the specific fuel consumption of *MTC*'s rated power(g/kw*h),t is the spending time(h)of towing;*PT* is the rated power(kw)of propulsion system;n is the number of propulsion system;*SX* is the depth of dropping spuds(m),*VX* is the speed of dropping spuds(m/h).

$CX = 3.2 * MXC$,*MXC* is the diesel consumption of D1's dropping spuds(kg).

$$MXC = (VXH / 1000) * tX * PX * n \tag{6}$$

$$tX = SX / VX \tag{7}$$

VXH is the specific fuel consumption of dropping spuds(kg),*tX* is the spending time of dropping spuds(h),*PX* is the driving power of dropping spuds(kw),n is the number of dropping spuds,*SX* is the depth of dropping spuds(m),*VX* is the speed of droping spuds(m/h).

Excavation of D1 was composed of dropping grab,dredging DMS and rising grab.Owing to dredging DMS spend relatively less time,the carbon emission of it can be ignored.

$$CW = 3.2 * (HWF + HWT) * CWn \tag{8}$$

HWF is the diesel consumption(kg)of dropping grab at a time,*CWn* is cycling times.One time include dropping,dredging DMS and rising.

$$HWF = (VHF / 1000) * WFt * PWF \tag{9}$$

$$WFt = SWF / VWF \tag{10}$$

VHF is the D1's specific fuel consumption(g/kw*h) of dropping grab;*WFt* is the spending time(h) of rising grab;*PWF* is the power(kw) of dropping grab;*SWF* is the depth(m) of dropping grab;*VWF* is the speed(m/h) of dropping grab.

$$CQ = 3.2 * HQ \tag{11}$$

$$HQ = tQ * (VHQ / 1000) * PQ \tag{12}$$

$$tQ = SQ / VQ \tag{13}$$

HQ is the D1's diesel consumption(kg) of rising spuds.*tQ* is D1's spending time(h) of rising spuds,*VHQ* is the specific fuel consumption(g/kw*h) of rising spuds,*PQ* is the power(kw) of driving machine of rising spuds,*SQ* is the height(m) of rising spuds,*VQ* is the speed(m/h) of rising spud.

As the fuel consumption of unload is close to fully laden for one sandcarrier in the same distance's navigation,*CF=CT*.

$$CR = 3.2 * (VHR / 1000 * RT * PR) \tag{14}$$

VHR is D1's specific fuel consumption(g/kw*h) of daily electricity,*RT* is the spending time(h) of daily electricity,*PR* is the power of daily electricity.Figure 2 shows the proportion of carbon emission of D1's workstage.

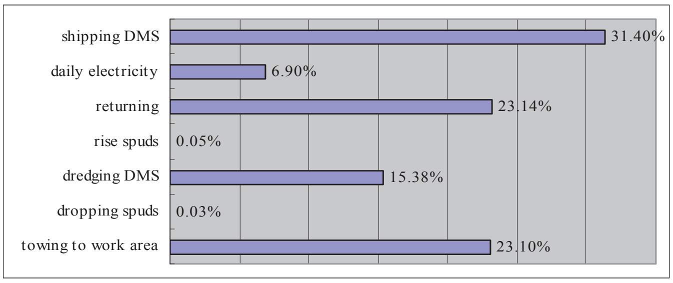

Figure 2. The proportion of carbon emission of D1's workstage

B. Sea going Hopper Suction Dredger(D2)

1) The principle of operation and power device parameters of D2

The carbon emission of "Chang Jing NO2"was estimated.The workstage of excavation,loading DMS and unloading DMS were operated by itself.During excavation,the DMS was dredged by the drag and suction device rely on the moving of dredger with the speed of 2.5kn.Then the DMS which has been dredged was pumped into cabin until the cabin filled with DMS.At last,DMS was discharged into dumping area[11].

The dredger producitivity is 8000m^3/h,navigational speed is 14.6kn(the capacity factor of propulsion system is 85%).During exvacation,the speed of D2 is 2.5kn(the capacity factor of propulsion system is 90%).Spending time of discharging DMS is 70min.During the workstage, The capacity factor of propulsion system is 5%,because the system was only used to drive mud pump.The propulsion system parametres were shown in table2[12].

TABLE II. PROPULSION SYSTEM PARAMETERS OF D3

POWER DEVICE	*Amount*	*Power(kw)*	*Substitude for*	*Fuel consumption(g/kw*g)*	*function*
Propulsion system	2	6300		210	Navigate and drive chaft gnerator
Shaft engine	2	1600			High pressure and Sealing pump
Diesel generator sets	1	345			Emergency parking
Major diesel generator	2	680	700kw U.S.A cummins	206	Others consumption

2) Carbon emission's equation of D2

The daily electricity and dredging workstage of D2 have been considered to estimate the carbon emission of D2.The dredging workstages of D2 was composed of navigating to work area,excavation,inward journey and discharging DMS .So the carbon emission's equation of D2 can be written as:

$$\sum C = CZ + CW + CF + CX + CR \tag{15}$$

$\sum C$ is total carbon emission(kg) of the dredger;*CZ* is carbon emission(kg) that D2 navigate to work area,*CW* is carbon emission(kg) of dredging,*CF* is the carbon emission(kg) of returning,*CX* is carbon emission(kg) of discharging DMS,*CR* is carbon emission(kg) of daily electricity.

The power resource of D3 is diesel,so η =3.2.Every dredging workstage of D3 can be writen based on equation 2 and 3 as:

$$CZ = 3.2 * MZH \tag{16}$$

$$MZH = (SZ / VZ) * 3600 * PZT * p * n * (VZH / 1000) \tag{17}$$

MZH is diesel consumption(kg) that dredger navigate to work area.*SZ* is the diatance(nm) of self navigating,*VZ* is the navigational speed(kn),*PZT* is the power(kw) of propulsion sysytem,*p* is capacity factor of propulsion system(kw),*n* is number of propulsion system,*VZH* is the specific fuel consumption(g/kw*h) of self navigating.

$$CW = 3.2 * MWH = 3.2 * (MWPH + MWBH) \tag{18}$$

$$MWPH = PPQ * Pn * (VWPH / 1000) * Pt \tag{19}$$

$$MWBH = pB * PBQ * Bn * (VWPH / 1000) * Bt \tag{20}$$

MWH is the diesel consumption of dredging(kg);*MWPH* is the diesel consumption(kg) of dredging equipment;*MWBH* is the diesel consumption(kg) of driving generator,which be used to drive mud pump;*PPQ* is the power(kw) of driving generator was used to drive rake;*Bn* is the number of driving generator;*VWPH* is specific fuel consumption(g/kw*h) of driving generator been used to drive mud pump;*Bt* is the running time(h) of mud pump.

As the fuel consumption of unload is close to fully laden for one sandcarrier,in the same distance of navigation, $CF = CZ$.

$$CX = 3.2 * MXH \tag{21}$$

$$MXH = Xt * n * XP * PXQ * (VXH / 1000) * XP * n \tag{22}$$

MXH is diesel consumption(kg) of discharging DMS;*Xt* is spending time(h) of discharging DMS,n is the number of mud pumps,*Xp* is capacity factor of full power of driving machine been used to drive mud pump.*PXQ* is the full power(kw) of propulsion system,*VXH* is specific fuel consumption(g/kw*h) of propulsion system.

The carbon emission's estimate of daily electricity is only limited in navigating.

$$CR = 3.2 * MRH = 3.2 * (PRQ * Zt * VHQ / 1000) \quad (23)$$

MRH is diesel consumption(kg) of daily electricity during navigation;*PRQ* is the power(kw) of disel generator which was used to drive daily electricity;*Zt* is the spending time of navigation(h);*VHQ* is the specific fuel consumption(g/kw*h) of diesel generator which was used to drive daily electricity. Figure 4 shows the proption of carbon emission of D2's workstage.

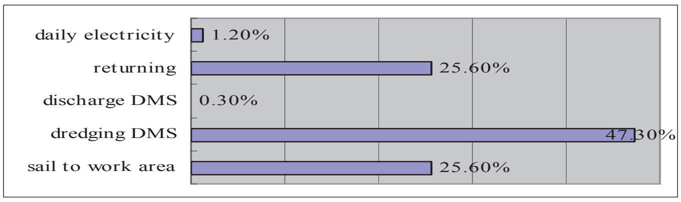

Figure 3. The proption of carbon emission of D2's workstage

C. Results

Besides the two kinds of dredgers,the carbon emission's results of the dustpan dredger(D3) and the trailing bucket wheel dredger(D4) also be presented in the paper.The carbon emission's result of the four kinds of dredgers was shown in table 4. The carbon emission that the four kinds of dredgers dredged per cubic metre DMS was shown in Figure 4.

TABLE III. THE CARBON EMISSION OF EVERY DREDGING WORKSTAGE OF THE FOUR KINDS OF DREDGERS

Workstage	D1(kg)	D2(kg)	D3(kg)	D4(kg)
Navigate(towing) to work area	450.6	4187.1	888.15	450.6
Fix position	0.73			0
Dropping dredging equipment	138.4		0.003	4.6
Dredging DMS		7749.1	1215.4	671.4
Rising dredging equipment	161.6		0.003	4.6
moving	1.013			1.2
returning	450.6	4187.1	888.15	450.6
Shipping DMS	612		612	612
Daily electricity		199.1	400	19.1
Discharging DMS	135.4	49.2		
Total carbon emisison	1950.34	16372	4003.7	2214.1

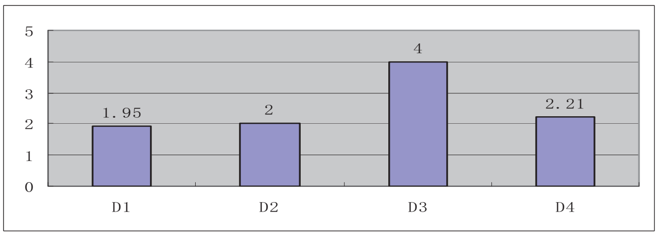

Figure 4. The carbon emission of dredgers dredged DMS per cubic metre

IV. ESTIMATE RESULETS

During dredging operation,four kinds of dredgers were estimated for carbon emission using an material accounting method.The fuel consumption of dreding workstage and daily electricity of dredgers were estiamted.The purpose of estimating fuel consumption of dredging workstage is to evaluate the carbon emission of dregers.

Assume the dredging situation in this paper.During dredgeing operation,Figure 4 shows that the carbon emission of the four kinds of dredgers is different.

CONCLUSION

The evaluation in this manuscript lead to some conclusions are exposed:

According to the material accounting method,carbon emission of dredger was generated from fuel consumption.During dredging operation,Figure.4 shows that the carbon emission was dicharged from different kinds of dredgers is different.Hydraulic grab dredger with sandcarrier is much more suitable for 10nm transport distance.The resulets were estimated by extract some date of dredging equipment.If the method has some deficiencies,please providing valuable opinion to me.The potential of carbon emission evaluation of dredgers to contribute significantly to control greenhouse effect.

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