https://dx.doi.org/10.22161/ijaers.4.3.6 *ISSN: 2349-6495(P) | 2456-1908(O)*

Performance tests on Screw Feeder Conveyor for Nodule Transfer Deep Sea Applications

Amudha.K, Ramesh N.R., Sundaramoorthi.V , Dineshkumar .D ,Muthuswamy.V, Rethnaraj.T , G.A.Ramadass

National Institute of Ocean Technology, Chennai, India

Abstract*—*A screw conveyor is a versatile conveyor used in many process plants for the transfer of bulk solids and powders. The following article has written to understand screw conveyor design and selection of the right screw conveyor for underwater applications to convey crushed manganese nodules to the pump system for nodule transfer.

The nodules from the sea bed will be collected by a pickup device and crushed into less than 30mm pieces by using a crusher and pumped by a positive displacement pump to the mother vessel. Screw feeder is used to transfer curshed Polymetallic Nodules from hopper to pump system with controlled feed rate. A land based screw feeder is modified to suit the under water applications.

Studies on screw conveyors were conducted to examine performance in land as well as underwater. Most of these studies were experimental in nature. This paper presents a critical review on the design and validation of a screw conveyor.

Keywords*— *Mining, Manganese nodules,* Polymetallic nodules, *Screw conveyor.

I. INTRODUCTION

Deep sea mining of polymetallic nodules is of increasing importance to many countries, due to the potential of abundant supply of manganese, nickel, copper and cobalt. The nodules are available in all sizes up to 100mm in diameter; but usually range from 20 to 70mm. The nodules occur in ocean depths up to 6000m; hence various countries have been developing technologies for mining them from such depths. Shematic of deep subsea technology for mining these resources as shown in Fig.1. It is a major challenge considering the ultra-high pressure environment of 550 bar (about 250 times the pressure in automobile tyres), very soft soils of shear strength 2.5 kPa (similar to heavy grease) and other factors.

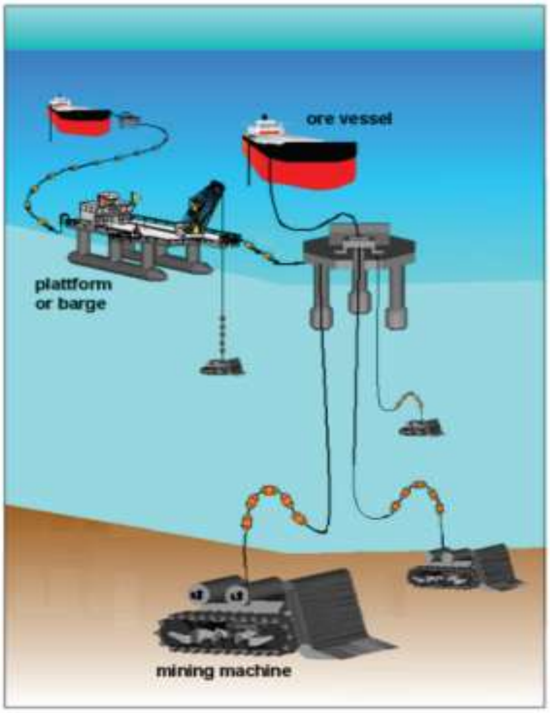

Fig. 1: Integrated deep-sea mining system using Flexible Riser configuration.

A study was taken in developing a deep sea mining system using flexible riser concept (Grebe, 1997). The concept has been realized and tested upto 512 m depth in the Indian seas. Initially, the system was tested for sand and silt mining operations-short term operations at 451m depth in 2001 and long term operations at 521m depth in 2006. The developed mining machine was augmented with polymetallic nodule collector and crusher, large solids handling pump and tested for operations at 512 m depth using artificial nodules. For laying artificial nodules, initially a remotely operable artificial nodule laying system was developed and tested at 518 m depth in 2007.Now the effort is towards the development of mining systems for 6000 m depth.

The traction force required to manoeuvre the mining machine along with reciprocating pump is a difficult task and the pump system from the miner is being separated and positioned in a the pump frame system.

https://dx.doi.org/10.22161/ijaers.4.3.6 *ISSN: 2349-6495(P) | 2456-1908(O)*

In the proposed integrated mining system configuration the Pump frame is proposed to be vertically hanging from the mother vessel and the crawler based mining system would be with a pump, collector, pickup and crusher systems on the seabed.

The objective of paper is to study the screw feeder performance to feed the crushed manganese nodules to the pump which will pump to the mother ship. The crushed manganese nodules stored in the hopper system has to be transferred for the corresponding flow rates.

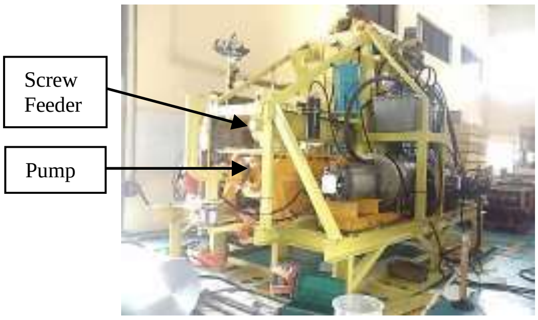

Fig. 2: Assembled view of pump system

As a first phase it was planned to conduct a sea trial at lower depth. The above Fig.2 shows the assembled view of the screw feeder with pump system.

II. DESIGN REQUIREMENT

For the applications as shown in the Fig.3 the horizontal screw feeder has been chosen to transport nodules as per Conveyor Equipment Manufacturers' Association (CEMA) standards. The screw feeder should be suitable for working in sub-sea high pressure low temperature environment & operating conditions. A land based screw feeder system was designed to suit underwater requirement by incorporating suitable sealing, bearing etc.,for the required feed rate and loading conditions, and it was tested in a test set up for evaluating its performance.

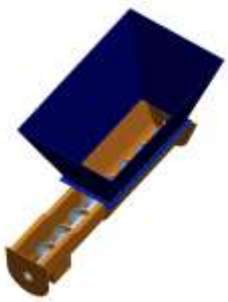

Fig. 3: Screw Feeder with Hopper

The conveyor screw imparts a smooth positive motion to the material as it within the trough. The Fig.4 shows that it consists of a tube (shaft) containing a spiral blade coiled around a shaft, driven at one end and held at the other. As per table 1,the rate of volume transfer is proportional to the rotation rate of the shaft. Advantages of the horizontal screw feeder are: reduced risk of environment pollution, the transported material is protected from exterior contamination, flexibility of use, functional reliability, can control the flow of material very well.

Table.1			
Bulk Density of material	2000 kg/m^3		
Required Capacity (m^3/hr)	2	3	4
Revolutions of Screw per minute	8	12	16

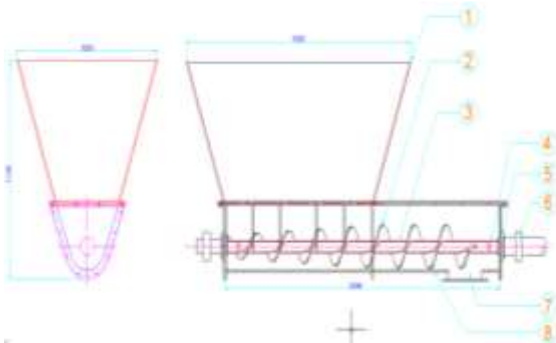

Fig.4: View of Screw Feeder With Hopper

1. Hopper 2. Tappered Screw 3. Pipe 4. Shaft 5. Seals 6. Plummer Block 7. Discharge Outlet 8. Trough

III. SELECTION OF PARAMETERS

The capacity of the screw conveyor in cubic feet per hour per revolution per minute is:

$$\frac{C}{rpm} = \frac{0.7854 \times (Ds^2 - Dp^2) \times P \times K \times 60}{1728}$$

The diameter of conveyor would be selected from corresponding percentage loading to achieve the equivalent capacity within the recommended rpm range. From the therotical calculation the trough loading was calculated as 45%.Based on the experiments conducted the trough loading arrived was 53% .

The diameter of screw and pitch of the screw was chosen was 228.6 mm and diameter of pipe 63.5 mm.

For the present case the ball bearimg was chosen and hence hanger bearing factor considered was 31.

V. TEST AT LAND

The test set up at land as shown in Fig.5 consists of 44 cc hydraulic motor which provides a torque 0.63 Nm/bar was utilized for the present study. The Gear box was coupled to the drive motor and the screw feeder shaft. A 8 station servo valve pack was utilized to control the flow of hydraulic motor.The results are tabulated in the table 3 confirms that nodule output rate was 8.6 kg per rotation.

Fig. 5: Test set up at Land

Table.3 -Test at Land

Flow (m^3/hr)	Speed (rpm)	Output (kg)	Time (Mins)
40	1.9	16.4	1
90	4.9	41.6	1
90	4.9	41.1	1

VI. TEST AT UNDERWATER

Preliminary trials were conducted on land with the system kept inside a water tank of size 8m x 4m x2 m as shown in Fig 6.

Fig.6: Test set up at in Tank

The inner diameter of the transport hose used for the present study is 102 mm. For the hydraulic transport of grain type solids, the particle diameter should be one-third of the hose diameter to avoid clogging. Therefore, the maximum allowed particle size should be less than 30 mm. The nodule was pumped using reciprocating pump through a hose of Ø102 mm, vertically to a height of 30 meters.

Table.4-Testing in test tank

Flow(m^3/hr)	Speed (rpm)	Output (kg)	Time (Mins)
30	17.8	223	1.5
30	18.3	150	1
40	8.4	142	2
40	8.4	149	2
40	15.5	141	1

From the above table 4 it confirms for different flow rates and feed rate the nodule output rate found to be 8.6 kg per rotation which was measured in the load cell.

VII. TEST AT SEA

The Fig.7 shows the system was tested at a depth of 150 m at sea and the screw feeder was operated to provide feed at 4 Tn/hr and 8 Tn/hr.The slurry was collected at ship and nodules were drained and the output weight was calculated.

Fig. 7: Test at sea

It was observed the collected quantity was 14 % less than the calculated value as shown in the table 5. From the operation it was observed that while collection of nodules in the hopper placed at mother ship finer particles got washed away.It was observed feeder continued supplying for some more time in the 2 minutes of operation which was collected 149 kg/min

https://dx.doi.org/10.22161/ijaers.4.3.6 **ISSN: 2349-6495(P) | 2456-1908(O)**

Table.5-Test at Sea

Flow(m^3/hr)	Speed (rpm)	Output (kg)	Time (Mins)
30	8	59.4	1
30	8	149.5	2

VII. DATA ACQUISITION AND CONTROL SYSTEM

The Data Acquisition and Control System (DACS) for the this test was formulated using stand alone real time controller namely compact Reconfigurable Input Output (cRIO) along with associated input and output modules, signal conditioning circuits, video and data telemetry system. The configuration details for each I/O modules along with main cRIO-9025 controller for various final control elements / sensors are listed in the below Fig.8.

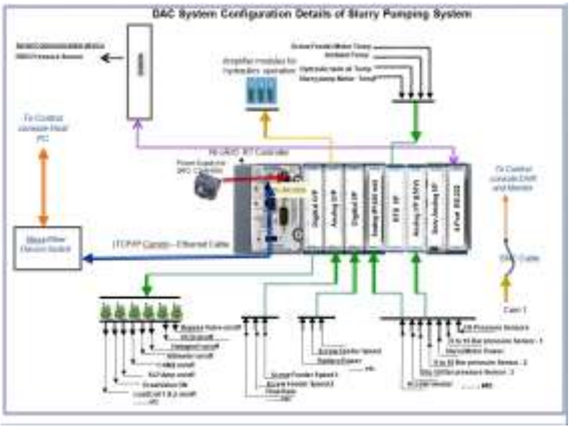

Fig.8: Data Acquisition and Control System (DACS)

VIII. SENSORS AND AMPLIFIERS

The speed of the screw feeder has been measured by using an inductive type proximity sensor with an accuracy of 0.1% Full scale.An inductance pick up device fixed on the shaft of the screw feeder, senses the rotation of switching distance of 1 mm and provides a pulse sequence proportional to the number of rotations.

The speed of the screw feeder is controlled hydraulically by two proportional control valves. The proportional control valves can be controlled by a voltage controlled amplifier module, which is commanded from the analog output module of the DAC system. Hydraulic coils are connected to the amplifier module and input to the amplifier module is a differential output voltage (+/−10 V DC) from the analog output module. By varying the differential voltages to the amplifier, proportional control valve can be operated in the forward and reverse direction of the screw feeder.The screw feeder pump pressure also been measured by using 900 bar rated pressure sensor, the accuracy of this sensor is about < ± 0.25 % Full scale range.

IX. UNDERWATER VISION SYSTEM

One set of Underwater camera and lamps were used for monitoring the operation of screw feeder. The camera and lamp was mounted on the Pan& Tilt unit to enhance the view angle of the camera. The screw feeder operation videos have been recorded by using a Digital Video Recorder (DVR) at ship side as shown in Fig 9.

Fig. 9: Real Time Acquired Screw feeder Snap

X. GRAPHICAL USER INTERFACE

The user interface software as shown in Fig10 (Graphical User Interface (GUI)) is developed using LabVIEW. The following parameters were acquired through DAC system @ 10 Hz sampling rate and displayed in the front panel in the host PC with appropriate engineering units and also logged these parameters with date and time stamp. The data telemetry between DAC System and Host PC has been formulated by using TCP/IP (Transmission Control Protocol / Internet Protocol)communication.

Real-time measured parameters for screw feeder operations are,

- Screw Feeder Pump Pressure (bar)
- Screw Feeder Motor Temperature (^{0}C)
- Screw Feeder speed(rpm)

Fig. 10: Graphical User Interface of Operator Screen

XI. ELECTRICAL UNIT

The screw feeder is driven by a hydraulic motor and is powered from a separate sub-sea Hydraulic power unit (HPU) . Since the screw feeder is designed for subsea operation a sub sea HPU unit is used. The speed of the screw feeder is variable through the control of proportional flow control valves.

The HPU is powered by a 55kW 3 phase sub-sea electric motor operating at 3000V AC. Higher operating voltage is chosen to overcome the voltage drop in the subsea cable through which the electric power is transmitted. The electric motor (HPU) is oil filled and pressure sensor compensated type and is started through a Medium voltage soft starter system to avoid high inrush current during motor starting.

XII. CONCLUSION

From the experiments it is evident that the there is no loss in mass flow rate with different flow rates and feed rate.The nodule output rate found to be 8.6 kg per rotation.The screw feeder operated at 150 m depth there was mass loss of 14 % due to wash away of finer particles and feeder continued to supply some more time which has to be studied further. The above design will be validated in the sea trials for higher depth and the input would be useful for 6000m design of screw feeder systems.

ACKNOWLEDGEMENTS

We sincerely thank Ministry of Earth and Science and Deep sea Technology and Ocean Mining group, NIOT for its support and development of the system.

REFERENCES

[1] Classification and definition of Bulk materials CEMA standard 550-2003
[2] Screw conveyor dimensional standards CEMA standard 300-2003
[3] S.Rajesh, A.A. Gnanaraj, A. Velmurugan, R. Ramesh, P. Muthuvel, M.K. Babu, N.R. Ramesh, C.R. Deepak, M.A. Atmanand (2011) Qualification tests on Underwater Mining System with Manganese Nodule Collection and Crushing Devices Proceedings of the Ninth (2011) ISOPE Ocean Mining Symposium,Maui, Hawaii, USA, June 19-24
[4] Amudha, K, Rajesh, S, Ramesh, N R, Muthukrishna Babu, Raju Abraham, Deepak.C R, Atmanand, M.A (2009). “Development and Testing of Remotely Operated Artificial Nodule Laying System at 500 m water depth” Proc. 8th ISOPE Ocean Mining Symposium,Chennai, India, ISOPE, pp 233-238.
[5] Uematsu,T., Nakamura,S., Hino, Y. and Suyama, H.‘‘A study of the screw conveyor.’’ Trans. JSME,26(162), 180–186. (1960).
[6] Don McGlinchey “Bulk Solids Handling: Equipment Selection and Operation” Page No. 197-219 Blackwell Publishing Ltd. ISBN: 978-1-405-15825-1 , 2008
[7] Chris Rorres “THE TURN OF THE SCREW:OPTIMAL DESIGN OF AN ARCHIMEDES SCREW”, Page : 72-80 ,JOURNAL OF HYDRAULIC ENGINEERING / JANUARY 2000
[8] Alma Kurjak, "The vertical screw conveyor- powder properties and Screw conveyor design", SE-221 00 Lund, Sweden, January 2005
[9] Atmanand, MA, Shajahan,MA, Deepak CR, Jeyamani, R, Ravindran, M, Schulte, E, Panthel, J, Grebe, H and Schwarz, W (2000). “Instrumentation for underwater crawler for mining in shallow waters,” Proc. International symposium of Autonomous Robots and Agents, Singapore, May 26, 2000.
[10] Atmanand, MA, Deepak CR, Jeyamani, R, Ravindran, M, Schulte, E, Panthel, J, Grebe, H and Schwarz, W (2000). “Instrumentation and Control System of a Sand Mining System for Shallow Water”, Proc. International symposium The Fourth (2001) Ocean Mining Symposium Szczecin, Poland, September 23-27, 2001.