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SOME STATISTICAL RELATIONSHIPS AMONG DREDGER PARTICULARS OBSERVED IN THE INDIAN DREDGING FLEET

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SUMMARY

Cutter suction dredgers(CSD), Trailing suction hopper dredgers (TSHD) and Grab dredgers form 88% of the total Indian fleet size, respectively in the order of individual share. Indian yards have achieved 90% indigenization in design and construction of grab hopper dredgers. However, there is a techno-economic backlog in India to manufacture some vital components for CSDs and TSHDs and companies are increasingly looking to buy foreign made dredgers at a high price. Dredging demand in India at ports and in navigable inland water ways is set to grow with the encouragement for water transport. Ministry of Shipping, Govt. of India has sponsored studies at Indian Maritime University – Visakhapatnam (formerly, NSDRC) for indigenization of dredger design and manufacture. The present paper aims to illustrate the existing dredger fleet of India and bring out some interesting correlations or conclusions that aid the design of dredgers. Dredgers are built for a specific function. Due to this design objective, they differ from other marine vessels on the aspects of principle particulars, hopper capacities, powering and other functional data such as cutter power for CSD and dredge pumps power etc. The identified correlations among a few parameters observed from the Indian dredging fleet are discussed. Certain ratios among the main dimensions for a TSHD such as length/breadth, breadth/dredge depth and breadth/draught, also known as ship ratios, are a key to dredger design and are known to vary with market conditions or time. They indicate design trends for future dredgers and require to be kept updated.

NOMENCLATURE

Abbreviations: TSHD, Trailing Suction Hopper Dredger; CSD, Cutter Suction Dredger; GT, Gross Tonnage (ton); C_B (PP), Block Coefficient using length between perpendiculars; DWT, Dead Weight Tonnage (ton)

List of symbols:

 Volume displacement in m^3

1. INTRODUCTION

Dredging industry in India witnessed a steep growth during 1997-2015. A number of new ports were constructed and the existing ports have scaled up their capacity. Increased oil exploration, demand from Navy and the development of inland waterways demanded additional dredging. Maintaining the draughts at ports and existing facilities is a perennial captive demand for dredging. Dredging industry evolved during the period and now we have a few respectable companies that are globally competitive. However, Indian shipbuilding could not capitalize the increasing demand for dredgers and dredging equipment during the period, which can be gauged from the share of Indian built dredgers in the Indian market. Lack of research and development activities in the specialized shipbuilding is another aspect that is impeding native shipbuilding. The total share by numbers of Indian built dredgers in India is about 34% and that for a more specialized dredger TSHD is about 10.8%. A data set for Indian dredgers has been developed at IMU Visakhapatnam covering principal particulars and other relevant data as a first step in identifying a range (size and type of dredgers) for indigenization. A part of this data is vividly documented in the paper under the relevant dredger types using R (statistical programming language) [R Core Team [1]] with ggplot2 (R plotting package) [Wickham [2]].

2. Trailing Suction Hopper Dredgers – TSHD

TSHDs can be discussed in segregated groups based on their vital aspects such as hopper volume or GT, length, total power etc. TSHDs in India can be suitably classed by their hopper volumes as small (below 2850 m^3), medium (2850 – 4671 m^3) and large (4671 m^3). It should be noted that 4671 m^3 is the median value for the data. The division of TSHDs is based on 'summary( )' function in R for hopper volumes and is illustrated in Table 1. It is also interesting to note that the data set of hopper capacities closely fits into a Gaussian bell curve when viewed as a histogram with 500 m^3 interval. Table 2 is a complete statistical summary for TSHDs in Indian market. A few parameters such as hopper capacity, total installed power, etc., show a large standard deviation and were predicted using the linear statistical models for data analysis [John M Chambers [3]]. The length overall to breadth moulded ratio shown in Fig.1, also referred to as a ship number, for more recent dredgers shows an increased trend around 5.5. Linear correlations were observed for datasets of hopper capacity and GT, hopper capacity and total installed power and dredge pump power and total installed power. They are shown in Figs.3 and 7 respectively. Fig.4 shows that most of the TSHDs built after the year 2000 were in the range of 4500 m^3 ~ 7500 m^3 of hopper capacity and are large. More than half of the existing TSHD fleet is built before the year 1990 and it would be interesting to see how these vessels will be replaced in future. Keeping up with the observed trend towards larger vessels, the fleet

strength would reduce unless additional demand for dredging is created. Figs. 1-5 show that similar ships are being built off late, may be due to standardization or due to market conditions. Fig.6 shows that the Indian TSHDs have been designed for different hopper densities indicating that only one from the fleet can benefit maximum from full utilization of the dredger hopper volume for specified sediment.

The hopper density for a TSHD is defined as the ratio of DWT to its volume displacement. It shows that a part of the total hopper volume remains underutilized for densities of sediments exceeding this value. The factor may be of help to assess productivity of a dredger at a location or in a project. The volume displacements for TSHDs in the database are extrapolated from their DWTs as shown in the Eq. 1 [W.J.Vlasblom [4]].

$$\square = \frac{DWT}{(1.025 \times 0.6827)} \quad [1]$$

3. Cutter Suction Dredgers - CSD

CSDs involve lesser complexities in design and construction than TSHDs and Indian built CSDs have a share of about 42% of total CSDs in Indian market. A CSD is different from a TSHD in the way that this type of equipment is exclusively used in capital dredging and to an extent in mining industry. A CSD transports the dredged material into a barge or over a pipeline to the spoil area and hence the usual principal particulars such as length, breadth, GT, DWT etc., are not emphasized. The data for CSDs show that about 82% of the fleet is built after the year 1990 and that about 62.5% of dredgers were built after the year 2000. Their steep rate of growth from the year 2000 is in accordance with the port infrastructure development. Some of the important particulars for CSD are cutter power, maximum dredging depth, draft and dredge pump power or throughput. CSDs are usually not self-propelled and require assistance of tugs and anchor handling support boats. A more recent trend in their design is to incorporate spud carriage system that greatly enhances its dredging efficiency and provides for a way to move through the water. A large number of the CSDs added to Indian fleet after the year 2000 were built for a greater dredging depth, about 15 meters and above; it can be deciphered from Fig.10. Fig.9 shows that 25m is the maximum dredging depth upper limit for CSDs in India leaving an exception. The figure also conveys an important picture that bulk (¾ th) of new CSDs have a total installed power of less or equal to 2700 kW. Based on these observations CSDs can be categorized suitably by their total installed power as small (below 920 kW), medium (920 to 2700 kW) and large (exceeding 2700 kW). The division of CSDs is based on Table 3 and it is worked out using the same concepts explained for TSHDs hopper capacity. An elaborate summary of the CSD fleet in India is shown using Table 4. Fig.8 indicates a parabolic relationship between total installed power and length overall. However, this trend is not discussed in the paper. The figure also shows that the cutter power has a strong correlation with total installed power.

4. Conclusion

The statistics indicate a biased market for large sized TSHDs and point towards a potential market for spares, maintenance and repairs for these dredgers. A study to uncover the business opportunities in these avenues may give a direction to Indian industry in TSHD market. Cutter suction dredgers indicate a strong link with water based infrastructural growth and studies to unravel their relationships may yield tools to predict the demand for new CSDs. Two thirds of the existing CSD fleet are small and medium sized and there is ample scope for 100% indigenization in the bracket. The data set for Indian dredgers is presented here using scatter plots for a sample of 65 TSHDs and 45 CSDs. A detailed data analysis comparing a few dredgers practically will yield specific reasons for the wide spread of the scatter and may yield more precise correlations among the parameters. The data also contains a wealth of interesting technical facts on TSHDs and CSDs currently operated in Indian waters much to the benefit of naval architecture community.

5. ACKNOWLEDGEMENTS

We would like to thank Ministry of Shipping, Govt. of India for funding the project, Prof. S.C Misra for initiating the project on indigenization of dredger design at IMU-Vizag.

6. REFERENCES

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3. John M Chambers, T. (1993). Statistical Models in S. ISBN 0-412-05301-2 © AT & T Bell Laboratories, Chapman & Hall, 2-6 Boundary Row, London SE1 8HN.
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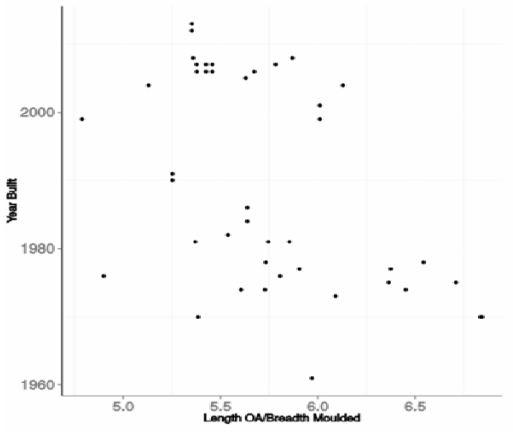
Table 1. Suggested classification of TSHDs in Indian scenario

Parameter	Units	Minimum	1^{st} Quartile	3^{rd} Quartile	Maximum
Hopper Capacity	m^3	209	2850	6725	11,300

Table 2. Statistical snapshot of TSHDs in Indian market

Parameter	Units	Mean	St. Dev.	Min	Max
Maximum dredging depth	m	23.7	7.1	3.2	41.0
Hopper capacity	m^3	4,671.4	2,464.2	209	11,300
Year built		1990	15.7	1961	2013
Length OA	m	103.49	18.18	55.12	139.96
Length BP	m	96.6	18.2	51.60	131.04
Breadth	m	18	2.9	11.25	23.04
Draft loaded	m	6.51	1.63	1.13	9.82
Total installed power	kW	6,815	2,984.7	1,100	13,547
Suction pipe diameter	mm	785.2	165.6	360	1,100
Dredge pump power	kW	1,837	651.4	552	3,470
GT		5,141	2,344.2	785	9,709
DWT		6,901	3,561.6	1,087	16,385
Speed	Knots	12.4	1.7	6.5	14.8
Propulsion power	kW	5,372	2,479	1,084	8,724

Fig. 1. TSHD Length OA / Breadth Moulded Year Built



TSHD Breadth Moulded / Draft Loaded Year Built

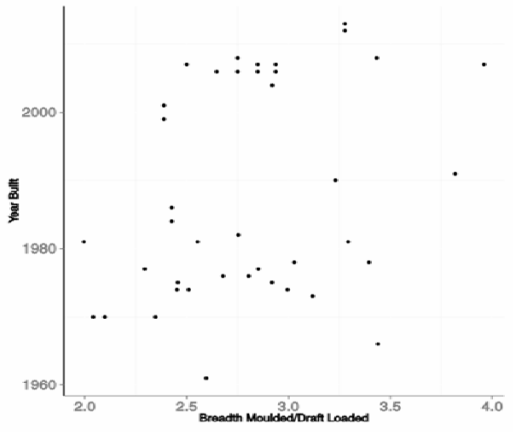
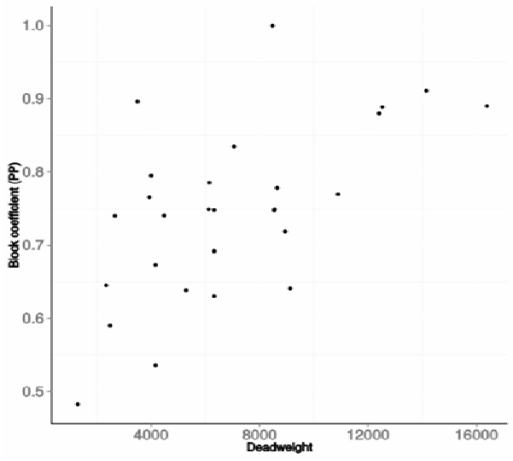


Fig. 2. TSHD - DWT / C_B (PP)



TSHD - Year Built / C_B (PP)

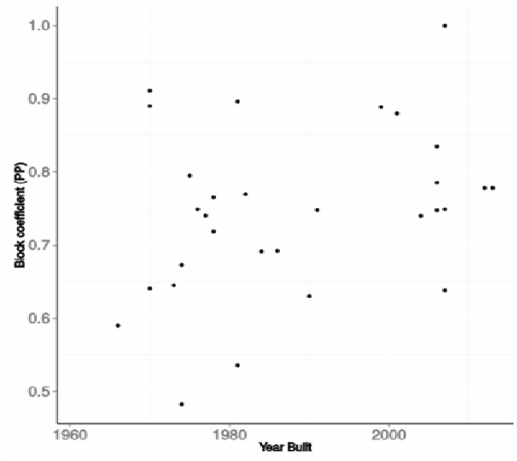
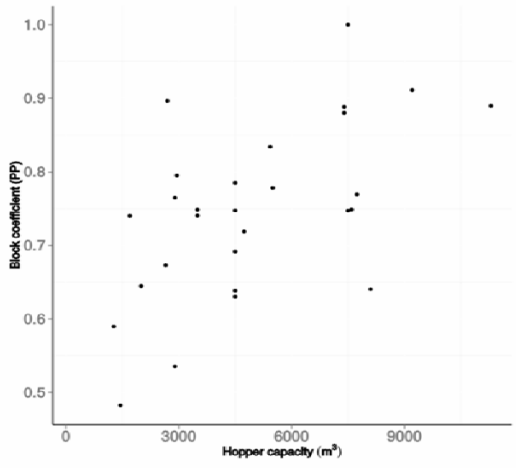


Fig. 3. TSHD - Hopper capacity / C_B (PP)



TSHD - Hopper capacity / Gross Tonnage

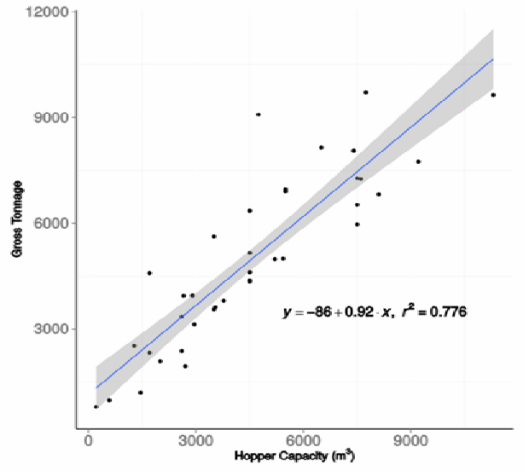
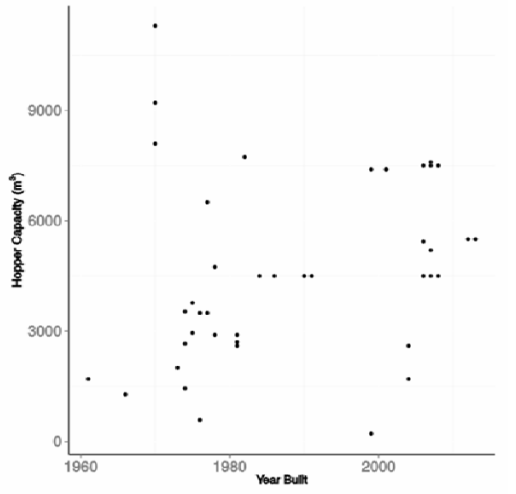


Fig. 4. TSHD - Year Built , Hopper capacity



TSHD - Speed / Hopper capacity

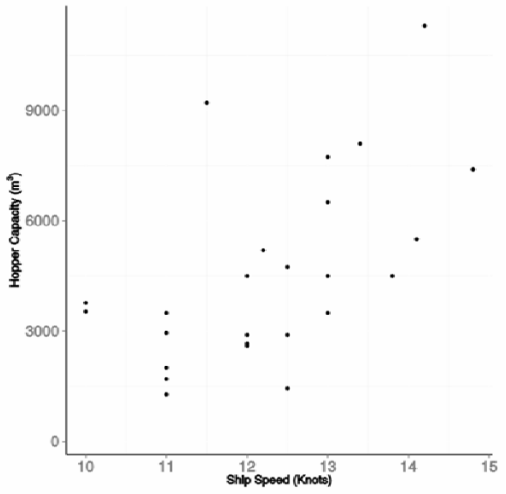
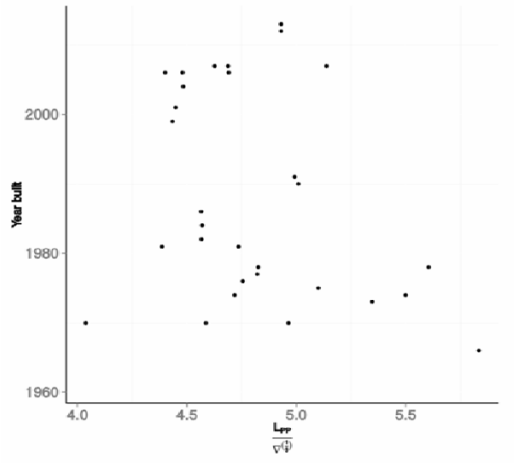


Fig. 5. TSHD - $\frac{L_{PP}}{\nabla^{\frac{1}{3}}}$ / Year Built



TSHD - $\frac{V}{\sqrt{L}}$ / Year Built

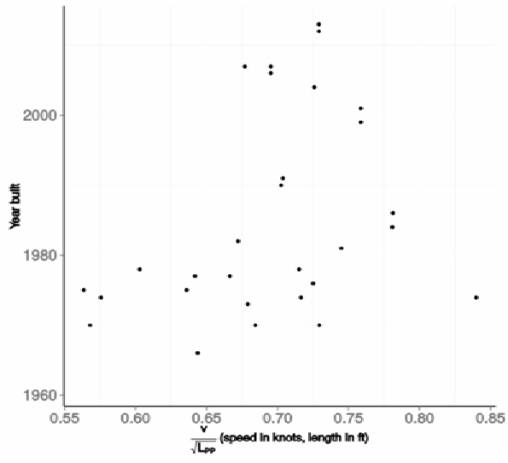


Fig. 6. TSHD - Year Built Hopper density ($\frac{t}{m^3}$)

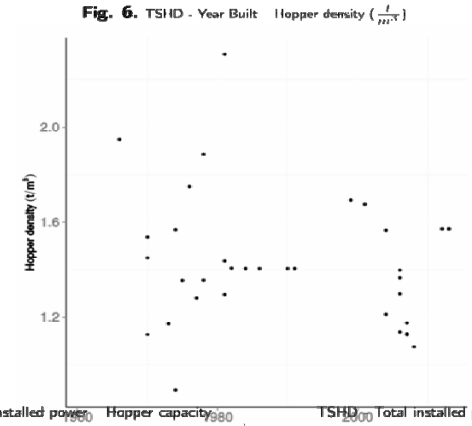


Fig. 7. TSHD - Total installed power Hopper capacity TSHD - Total installed power / Dredge pump power

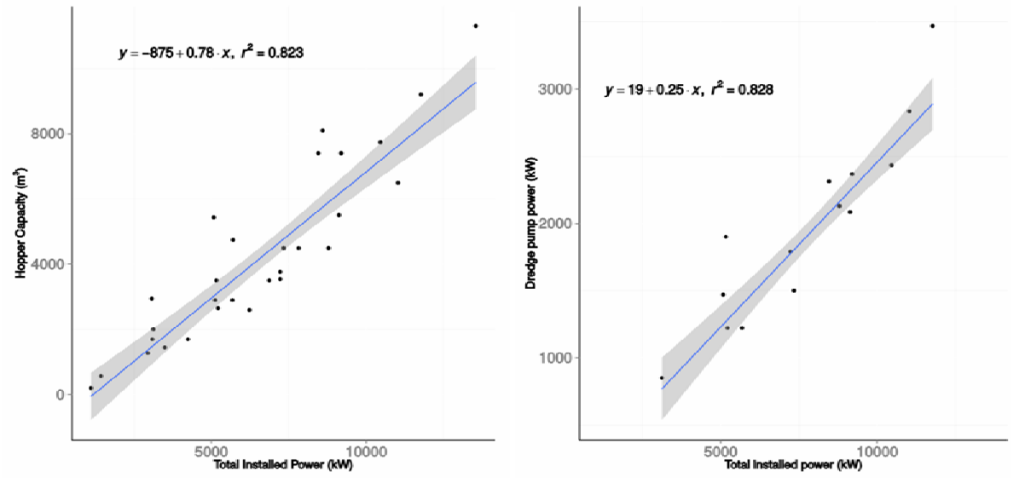


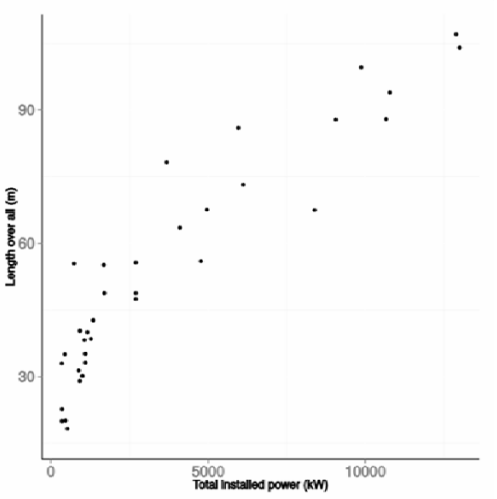
Table 3. Suggested classification of CSDs in Indian scenario

Parameter	Units	Minimum	1^{st} Quartile	3^{rd} Quartile	Maximum
Total installed power	kW	343	920	2700	13000

Table 4. Statistical snapshot of CSDs in Indian market

Parameter	Unit	Mean	St. Dev.	Min	Max
Maximum dredging depth	m	17.0	6.52	6.0	29.0
Year built		2000	11.2	1971	2012
Length OA	m	48.62	23.12	16.0	107.0
Length BP	m	33.34	16.92	11.0	80.0
Breadth	m	10.25	4.09	3.5	20.0
Total power	kW	2,888	3,382	343	13,000
Suction pipe diameter	mm	564	185	300	900
Cutter power	kW	438	522	30.0	2,940
Dredge pump power	kW	1,360	1,400	138	6,990

Fig. 8. CSD - Total installed power / Length overall



CSD - Cutter power / Total installed power

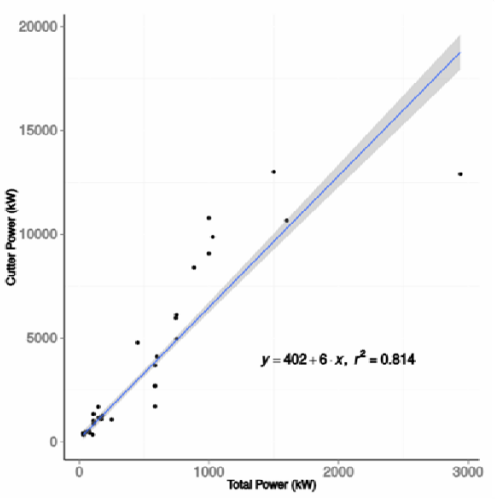
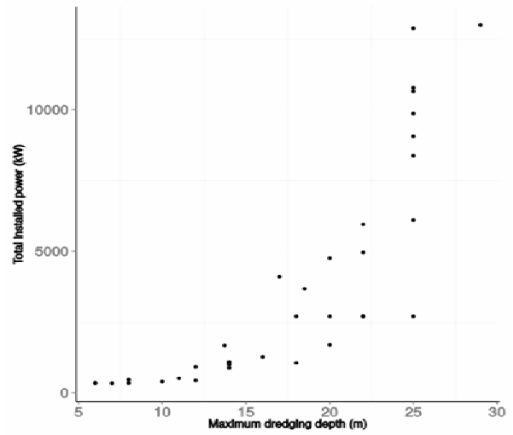


Fig. 9. CSD - Maximum dredging depth / Total installed power



CSD - Year built / Total installed power

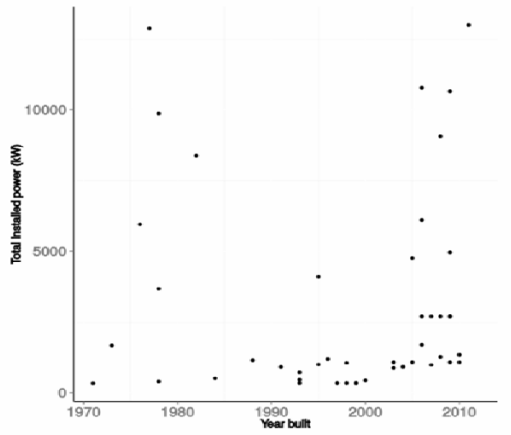
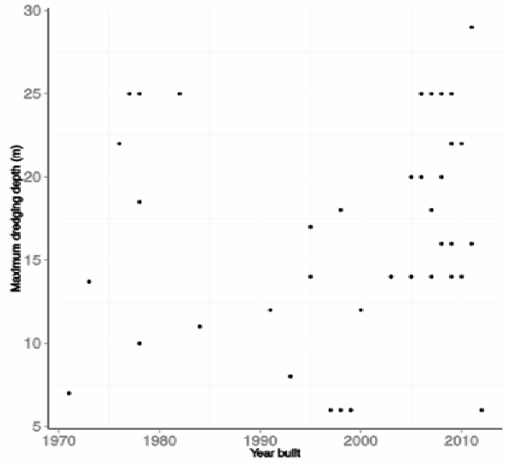
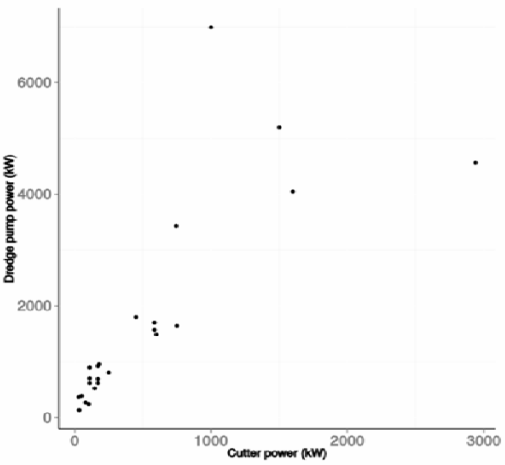


Fig. 10. CSD - Year built / Maximum dredging depth



CSD - Cutter power / Dredge pump power



7. AUTHORS BIOGRAPHY

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Ramesh Upadhyayula S holds the current position of Chief Manager at Indian Maritime University - Visakhapatnam. He is the head of School of Maritime Design and Research (SMDR), which is carrying forward the activities of the NSDRC (National Shipbuilding & Research Center). He has undertaken a lot of design and consultancy projects under NSDRC since 1993. He is a marine engineer and worked as a sea going chief engineer including on dredgers.