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Design Automation of Marine Propeller Shaft

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Abstract: *The transmission system on a ship transmits power from the engine to the propeller which in turn is convertedinto forward thrust. The entire transmission assembly consisting of engine, gearbox, transmission shaft and propeller is located on the hull part of the marine vessel. Marine vessels are available for various applications with varying types of engine and transmission requirements. A lot of human efforts and time are expended in designing of Marine propeller shaft and its related components. Also, there are chances of human errors during the designing phase. One can overcome the difficulties encountered in designing any product by using automation. The idea is to automate the process of calculation and generation of 2D drawing of Marine propeller shaft and its related components by programming and integrating the software such as Spyder and Rhinoceros using Python language*

Keywords: *Marine Propulsion System, Automation, transmission, hull, thrust block, stern tube*

I. Introduction

The marine vessels can be classified as river going and sea going. It can also be classified on the basis of lubrication as water lubricated or oil lubricated. The marine propeller shaft assembly consists of tailshaft, intermediate shaft, couplings, coupling nuts, sterntube, bosses, bush with liners, gland, gland packing, keys, bolts and sunk screws[1]. In marine propulsion system, the propeller is mounted on shafts which is coupled to the gear box which in turn is connected to the engine. Based upon the requirements the engine is selected and propeller, shaft and associated components are designed. Propeller shafts are exposed to saline water (corrosive environment) thus, are made of stainless steel. Transmission shafts are subjected to cyclic uniform loading which may lead to fatigue failure. Hence, to avoid this, shafts are made by forging process. When the transmission is to be done for larger distances, multiple shafts are connected in series using flanges. Larger shaft length results in more vibrations during transmission. To avoid this and to allow smooth transmission the shafts are supported by intermediate bearing supports or plummer blocks with bearings made of gun metal[1]. The distance between two plummer blocks is to be maintained at 2.5 – 3 metres for transmission speed ranging from 400 rpm to 1800 rpm. The shafts are made to have slightly more thickness i.e. slightly larger outer diameter at all bearing support sections to ensure proper fit of shaft and bearing and to compensate for any material wear occurring during removal of shaft from bearing for maintenance purpose. Fig.1 depicts the Marine Propulsion System mounted on the hull of the ship[1].

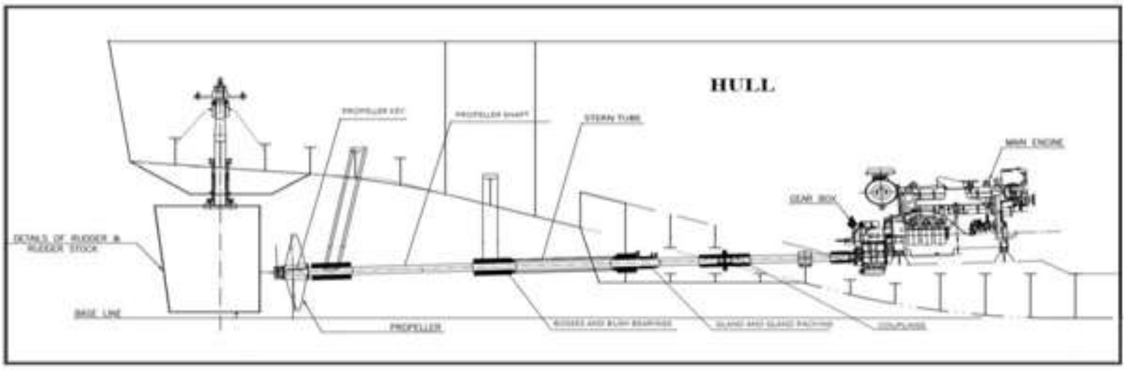


Fig.1 Block diagram of Marine Propeller System [1]

The method of designing a marine propeller shaft is a tedious task due to the variety of combinations possible because of factors such as factor for sea/river going vessel, lubrication type, engine parameters, etc. In the world of automation, industries are searching for ways to save time and lower costs on the engineering process. The objective of this design automation is to significantly reduce the time and efforts required for generating a 2-D drawing of Marine Propeller Shaft and to eliminate the human errors involved in manual calculation and improve the accuracy of propeller shaft design. The work carried out in this paper will enable the marine companies to cater the varying demands of their customers in shorter time and with higher accuracy.

II. Marine Propeller Shaft And Associated Components

2.1. Propeller Shaft:

The Marine Propulsion system is driven by rotating machines such as diesel engines, turbines or electric motors. While designing a Marine propeller shaft one also has to design for for couplings, coupling bolts, keys, keyways, bushes and other associated components. The calculated shaft diameter may require to be modified as per the available range of standard shafts. The specified minimum tensile strength of forgings is to be selected within the following general limits [1]:

- Carbon and carbon-manganese steel 400-760 [N/mm2];
- Alloy steels - 400-800 [N/mm2];

2.2. Couplings:

It includes the gearbox coupling that needs to be designed such that its bolt pitch circle diameter (pcd) matches with that on the other side of the gearbox also taking care of the shaft diameter that will be connected using this coupling. Furthermore, for every intermediate shaft in the assembly, a pair of male and female coupling is required.

The thickness of coupling flanges is taken as equal to or greater than the minimum required diameter of the coupling bolts calculated, with tensile strength of the bolt material being taken as the tensile strength of the corresponding shaft material or 0.2 times the rule diameter of the shaft under consideration, whichever is greater [1].

Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0.25 times the actual diameter of the adjacent part of the tailshaft. The fillet radius at the base of the coupling flange is to be not less than 0.125 times the diameter of the shaft at the coupling [1].

2.3. Sterntube

The shaft is enclosed by the sterntube which supports the shaft and propeller weight. Stern tube can be considered as a shaft covering that is welded to the ship's hull. Thus, sterntube prevents the sea water from entering the machinery space. Seals are provided at both ends of sterntube to prevent the entry of sea water and the loss of lubricating fluid from the stern bearing.

2.4. LINERS

The liners can made up of bronze, gunmetal, white-metal, lignum vitae, rubber composition or staves of approved plastic material[1]. The liners are to be carefully shrunk or forced upon the shaft by hydraulic pressure, and they are not to be secured by pins. Effective means are to be provided for preventing water from reaching the shaft at the part between the aft end of the liner and the propeller boss. If the liner does not fit the shaft tightly between the bearing portions in the stern tube, the space between the shaft and the liner is to be filled with a plastic insoluble non-corrosive compound.

2.5. Bosses And Bush-Bearings

The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

- For water lubricated bearings which are lined with lignum vitae, rubber composition or staves of approved plastic material; the length is to be not less than 4 times the diameter required for the tailshaft under the liner [1];
- For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland the length of the bearing is to be not less than twice the diameter required for the tailshaft[1].

2.6. Gland And Gland Packing

They are arranged to prevent the entry of sea water and the loss of lubricating oil from the stern tube. Gland packing can be made up of rubber. Gland holds the gland packing tightly in place.

2.7. Key And Keyways

Round ended keys are to be used, and the key ways in the propeller boss and cone of the tailshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0.0125 of the diameter of the tailshaft at the top of the cone [1]. The sharp edges at the top of the keyways are to be removed.

2.8. Thurst Block

The thrust block transfers the thrust from the propeller to the hull of ship. It may be an independent unit or an integral part of the main propulsion engine. The construction must be strong enough to withstand normal and shock loads.

2.9. Bolts And Sunk Screws

Bolt size is based on the minimum bolt diameter obtained by calculation and the bolt requirement at the gearbox coupling flange. Sunk screws are normally standard and are selected based on the dimensions of key [1].

III. Methodology

The methodology followed for the automation of the propeller shaft designing process is as follows:

3.1. Manual Calculations

Marine propeller shaft design is to be done based on torsion and bending provided the engine and gearbox parameters. The calculations should be carried out according to the rules mentioned in the IRS Rules and Regulations for the Construction and Classification of Inland Waterways Ships [1]. Calculations are to be done to find the following parameters:

- Diameter of tail shaft(dp) and intermediate shaft(d)
- Diameter of coupling bolts
- Thickness of liners
- Min. c/s area of keys and keyways
- Length of bush

3.2. Coding For Automatic Calculations In Spyder:

- This involves integrating the calculations in the program.
- Optimizing the program by reducing its length by using loops and functions [5].
- Generation of Graphic User Interface (GUI) to accept inputs, display outputs and allow user modifications of certain output parameters as per the availability and preferences. Outputs from this step are to be written to a file.

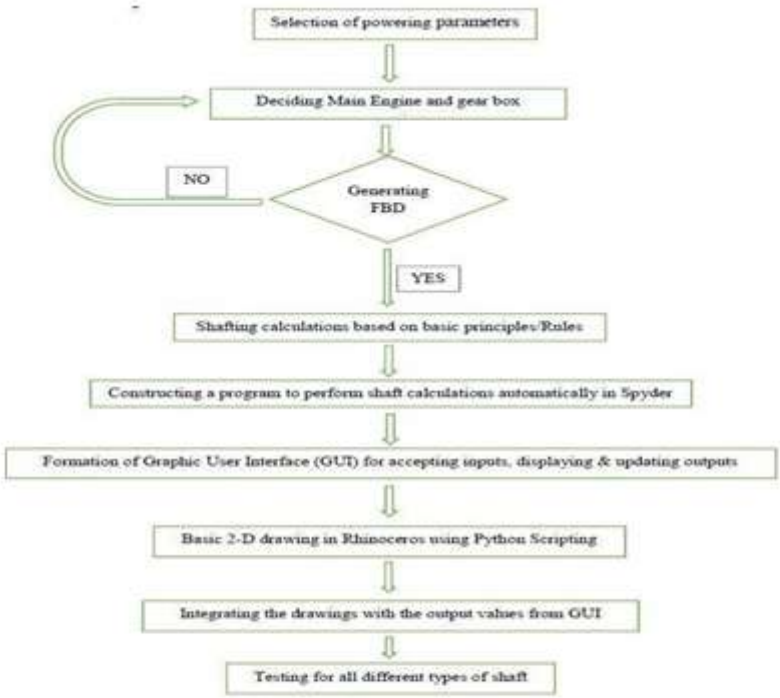
3.3. Coding For Basic Drawings In Rhinoceros:

This involves coding in Rhinoceros using Python Scripting to generate basic drawings of all the components in the Marine Propeller Shaft Assembly. All the parts are to be coded by forming relations with the dimensions that should be imported from the output file of the automatic calculation [5].

3.4. Integrating The Output Values From Automatic Calculations With 2-D Drawings:

- This involves exporting the output values from Spyder to a data file.
- Creating a batch file that holds the commands for running Rhinoceros code from Spyder.
- Importing the output data file in Rhinoceros

Below shown is the flowchart for the entire process followed in Design Automation of Marine Propeller Shaft:



IV. Marine Propeller Shaft Calculations

Propeller Shaft designing requires inputs such as engine power, engine speed, output power and speed range to be attained, gearbox parameters, etc. The designing shall be done after determining all the input parameters. Designing involves finding diameter of the propeller shaft (both tail shaft and intermediate shaft), diameter of coupling bolts, thickness of tail shaft liners, minimum cross-sectional area of keys and keyways required and sternbush bearing length.

The diameter, dp, of the tailshaft can be determined by the following formula [1]:

$$d_p = 103.5\, k\, a \sqrt[3]{\frac{410P}{(U+160)R}} \text{ [mm]}$$

where,
k = shaft design factors [3]
σB = specified minimum tensile strength of the material [N/mm2].
For calculation purposes, this value is not to be taken greater than 600 [N/mm2] (for carbon, carbon manganese and alloy steels)

The diameter, dp of the tailshaft determined in accordance with the formula is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2.5 dp whichever is the greater.

V. Outcomes

5.1. Gui Generation And Accepting Inputs

Initially, GUI (Graphics user interface) is developed in Spyder 3.6 IDE using Python for performing calculations and generating output that shall be used for Marine Propeller Shaft drawing [6].

For generating GUI, the first step is to make a window to which the frames are added such as input frame, changes frame and output frame. After that labels are added to the frame. Labels are used to ask for the input data. Corresponding to the labels textboxes and combo boxes are created to accept input data. Combo box is used to allow the user to select one of the standard values available. Further buttons are created to which functions like calculate, update, run etc. are assigned. Functions are parts of the coding that contain the exact activity to be performed [5]. Fig 3. Shows the output of the GUI formed using python language.

5.2. Drawing In Rhinoceros

A 2-D drawing cannot be generated directly from the output values. First, some basic 2-D drawings are to be made in Rhinoceros using Python Script [6] and then it is to be integrated with the output values to obtain the desired drawing. The drawings are made by forming relations with the standard values of diameters and lengths. These standard values are imported from the calculated output from previous step to produce a final drawing. The basic Rhinoceros window before generation of the output is shown in Fig 3.

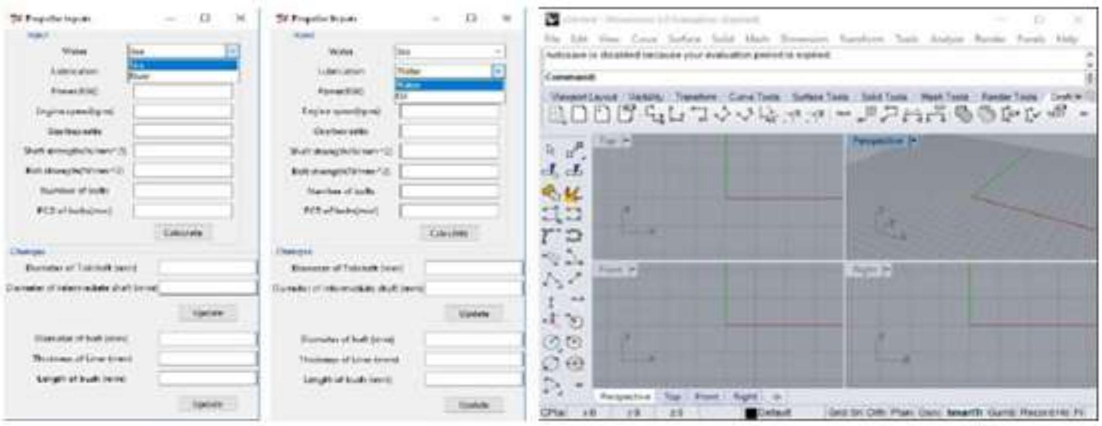


Fig 3. Formation of GUI – Spyder (Python 2.7) and Rhinoceros Window (Rhinoceros 5.0)

5.3. Integrating The Output Values From Gui With Drawing In Rhinoceros

The output values from the automatic calculations in Spyder are exported to a data file. This is done by writing a code in Spyder itself. A batch file is created in which the command for opening Rhinoceros and running the python script file for drawings is written. This batch file is also called from within the Spyder program. The values from the data file are imported in Rhinoceros to be assigned to the design variables after which drawings are generated using these variable values [6].

VI. Results

Following are the images of the outputs at various stages. Fig. 4 shows the final values obtained after calculations that will be used as standard values for generating drawing while fig. 5 to fig.6 show the drawings automatically obtained in rhinoceros.

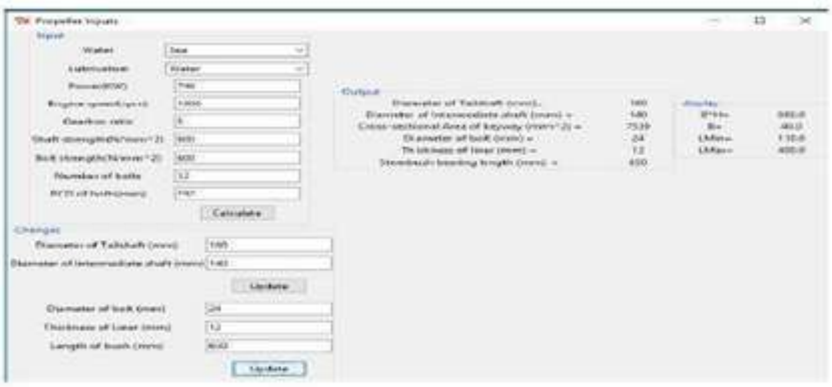


Fig 4. Obtaining output from input parameters – Spyder (Python 2.7)

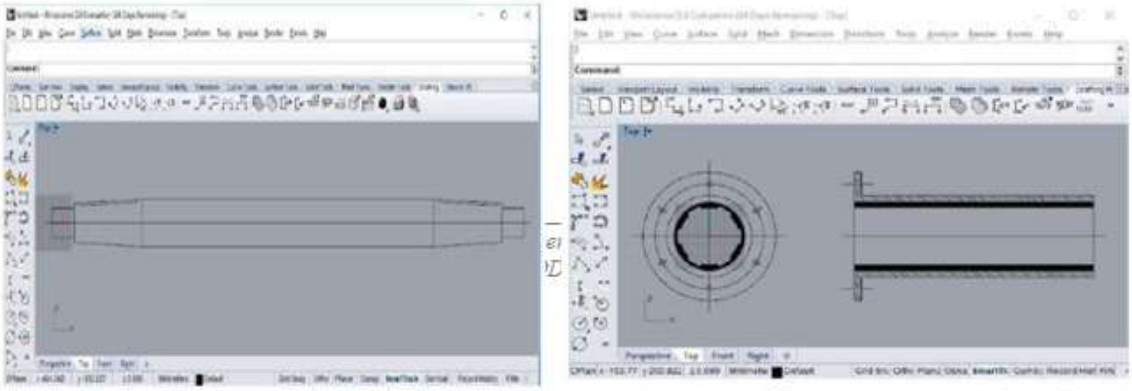


Fig 5. Tail shaft, Intermediate shaft and AFT bush with liner (Rhinoceros 5.0)

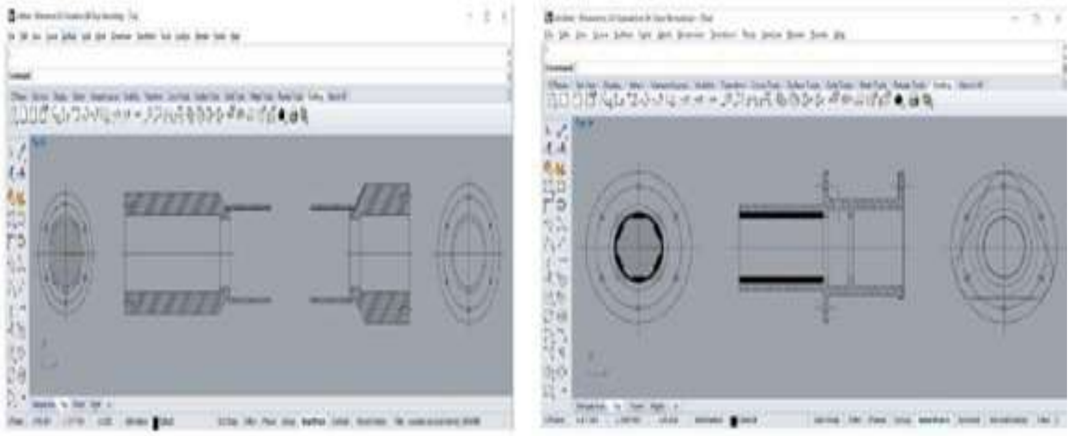


Fig 6. Stern tube and Forward bush with Liner (Rhinoceros 5.0)

VII. Conclusion

This paper presents an automated approach to develop 2-D drawings of Marine Propeller Shaft and its associated components without having to do tedious calculations nor spend hours making specialized drawings every time for any variation in demand. The entire process being automated leaves no gap for human errors.

The program so developed provides a friendly graphical user interface which can be accessed through Spyder wherein the user has to simply insert input data and the output provides a detailed 2D drawing obtained in Rhinoceros. The present work explains how the marine industry can benefit from this design automation and save its time and money.

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