Development of API for Estimating Torsional Strength of Shaft through Knowledge-Based Engineering Approach

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Abstract— *In recent years, reduction in overall cost of component to survive in competitive market is very essential. This can be done by integrating engineering tools and systems prior to actual prototyping. The common method to do this is making an Application Programming Interface (API) using concept of design automation through knowledge-based engineering. In the presented work an attempt is being made for development of API for scheming of torsional strength of shaft. The development is being done by using commonly available platform such as HTML (Hyper Text Mark-up Language) and JavaScript programming; out of which the UI was designed using HTML and the coding part being done using JavaScript programming. The developed API will help undergraduate students to understand effect of each mechanical parameter torsional strength.*

Keywords - API, Knowledge Based Engineering, HTML, JavaScript, Torsional Strength

1. INTRODUCTION

The use of programming language is increasing day-by-day as organizations believe on concept of mass customization [1]. Every application created has a unique user interface. An application programming interface **(**API**)** is a set of routines, protocols, and tools for building software applications. Basically, an API specifies how software components should interact. Additionally, APIs are used when programming graphical user interface (GUI) components. A good API makes it easier to develop a program by providing all the building blocks. A programmer then puts the blocks together. There are many different types of APIs for operating systems, applications or websites. Windows, for example, has many API sets that are used by system hardware and applications — when you copy and paste text from one application to another, it is the API that allows that to work. The researcher claims that in building applications, an API simplifies programming by abstracting the underlying implementation and only exposing objects or actions the developer needs [2]. While a graphical interface for an email client might provide a user with a button that performs all the steps for fetching and highlighting new emails, an API for file input/output might give the developer a function that copies a file from one location to another without requiring that the developer understand the file system operations occurring behind the scenes. Over the years use of API has got wide spread as stated and summarized by researchers [3-15]; out of which use of API has got wide scope in education sector of India as it will enhance the abilities of fresher graduates to build a bridge between theory and practice [1]. The specific usage of API in education sector are summarizes below;

APIs Make Education More Accessible

Programs like Pearson Academy and Khan Academy use APIs to provide online academic programs. These programs include videos, mind maps, playlists, and more. Since Khan Academy develops open source APIs, schools can incorporate Khan Academy's APIs into their curriculums. This allows these educational facilities to provide resources to their students that they may not have been able to afford otherwise.

APIs Share Academic Research

Academia used to be very exclusive and much information was only available to professors and researchers. With APIs, academics can share their information with the public as well as other researchers. APIs can be used to create apps that provide access to information and collect information from other sources.

APIs Help Standardize Information

Standardized information is especially important in disciplines like the sciences, where new discoveries are constantly being made. APIs allow researchers access to the most recent results from experiments. This allows them to have up to date information for their research allowing them to be more informed and work quickly. In the presented research work, basic concept of strength of machine element i.e. estimation of torsional strength was being evaluated and verified through API. The API integrates the standard design practice though user interface which helps to understand importance and effect of each independent parameter on dependent output parameter. For the development of API, Java scripting was used as backend and HTML was used for developing User interface (UI).

2. DEVELOPMENT OF API

The researcher stated and suggested ample amount of methodologies for customization and automation of design process [1] such as API, MOKA, KNOMAD and DDE. Out of which API, is most common and easy to automate standard design process. A brainstorming was being done on making a design and structure of various applications like a basic calculator, html table creator, etc. and designed an outline of how the interface should look like; and decided to implement and integrate Java Scripting and HTML due to ease of Availability. The work was carried out in such a way that, the code was designed such that the entire information was displayed in the form of a table with proper drop-down box system and radio buttons for better understanding for the user and easy to use. The sample form of API is shown in fig. 1 which shows the design of input parameters screen. Basically, HTML is a computer language devised to allow website creation. These websites can then be viewed by anyone else connected to the Internet. It was relatively easy to learn, with the basics being accessible to most people in one sitting; and quite powerful in what it allows you to create. It was constantly undergoing revision and evolution to meet the demands and requirements of the growing Internet audience [2]. The crucial part of API was related to coding, i.e. encrypting the entire data within some boundary so that the text won't get scattered all over the page. So, there is a need to provide a table so that the text and the values could be clearly understood. The presentation of the app matters a lot [2].

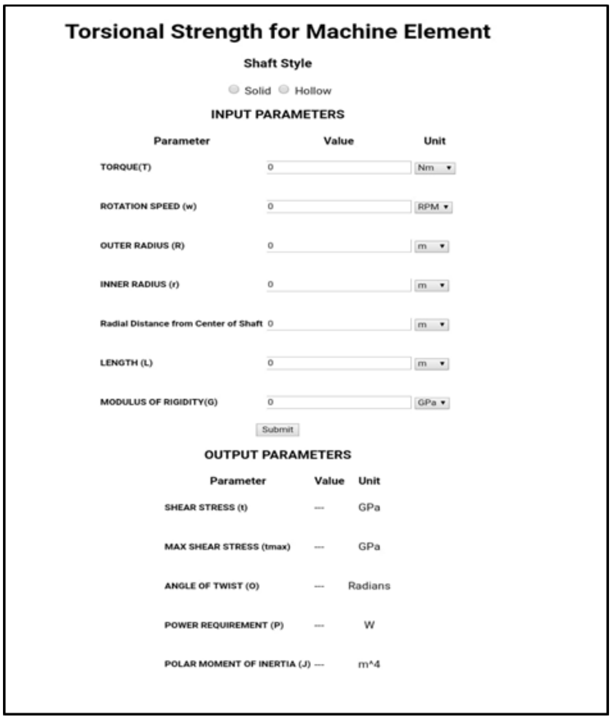


Fig.1: API Structure

The basic standard procedure stated in user manuals and available literature was used to develop the API [16-17]. The subsequent step was to allow user to feed input to the system so basic independent input variables such as Torque, Rotation speed, Radii, Rigidity modulus and other specific geometry parameters geometry was encrypted in the form of tables. Later on, it was integrated with dependent output parameters such as Stress, Angle of Twist, Polar moment of Inertia and Power through standard empirical relations and allows users to see results by clicking submit button given at the end. The table I summarizes the standard equations used for scripting.

Table I: Equations used for API Scripting

Parameter	Symbol	Equation
Shear stress	τ	$\tau = T_p/J$
Angle of twist	θ	$\theta = TL/GJ$
Max. shear stress	τ_{max}	$\tau_{max} = Tc_2/J$
Polar moment of inertia of solid shaft	J (solid)	$J = (\pi/2)(c_2{}^\wedge 4)$
Polar moment of inertia of hollow shaft	J (hollow)	$J = (\pi/2)(c_2{}^\wedge 4 - c_1{}^\wedge 4)$
Power	P	P=T*w

The Flow chart of entire API development is shown in Fig.2.

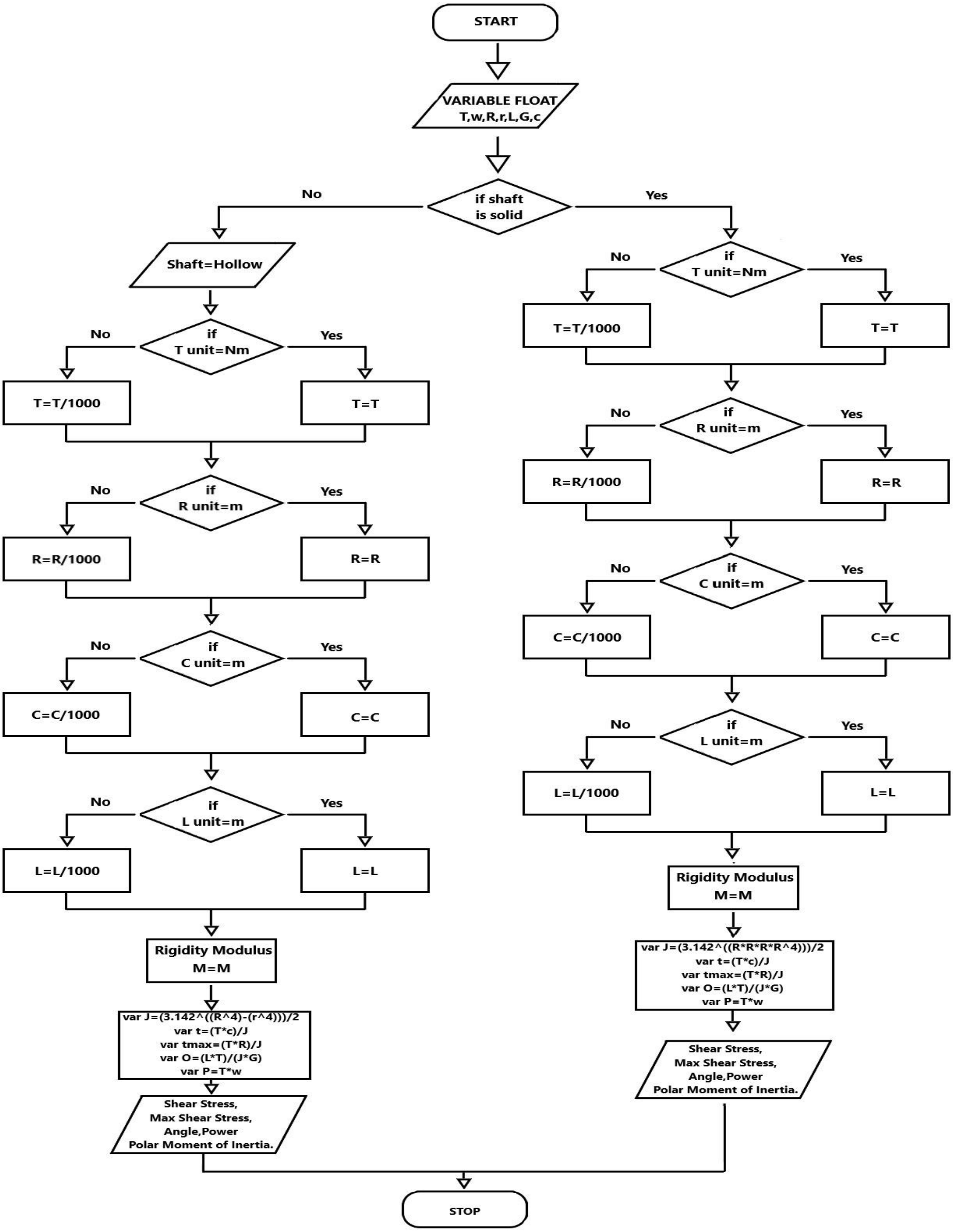


Fig.2: Process flowchart of API

3. Theorotical Casestudies

The theoretical relation as stated in reference book [18], when a shaft is subjected to torque or twisting a shearing stress is produced in the shaft. The shear stress varies from zero in axis to maximum at the outer surface of shaft.

$t = T\, r / J$ (1)

Where, t = shear stress (Pa, lb_f/ft^2 (psf))
T = twisting moment (Nm, lb_f ft)
r = distance from center to stressed surface in the given position (m, ft)
J = Polar Moment of Inertia of Area (m^4, ft^4)

Similarly, for estimating Circular shaft and maximum moment or Torque the empirical relation can be stated as

$T_{max} = t_{max}\, J / R$ (2a)

$T_{max} = (\pi / 16)\, t_{max}\, D^3$ (2b)

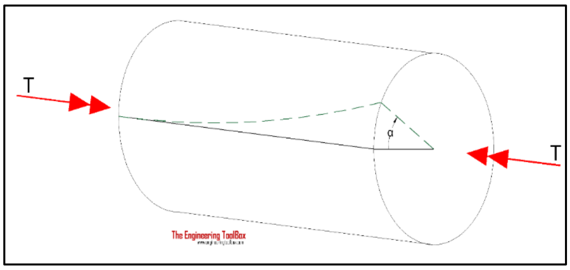
$T_{max} = (\pi / 16)\, t_{max}\, (D^4 - d^4) / D$ (2c)

Where, T_{max} = maximum twisting moment (Nm, lb_f ft)
t_{max} = maximum shear stress (Pa, lb_f/ft^2)
R = radius of shaft (m, ft)
And thus, Polar Moment of Inertia of a circular solid shaft and hollow shaft can be expressed as;

$J = \pi\, D^4 / 32$ (3a)

$J = \pi\, (D^4 - d^4) / 32$ (3b)

Where, D = shaft outside diameter (m, in)
d = shaft inside diameter (m, in)
The torsional deflection of shaft can be determined



by

$\alpha = L\, T / (J\, G)$ (4)

Where, α = angular shaft deflection (radians)
L = length of shaft (m, ft)
G = Shear Modulus of Rigidity (Pa, psf)

The above relations were tested for proven numerical and developed API and results were found to be exact. Thus, validation of API being done successfully which is described and discussed in subsequent subsections.

For solid Shaft:

For testing API, sample problem statement was taken into consideration and results were obtained through both and compared in table II,

Sample Problem Statement: A moment of 1000Nm is acting upon the solid shaft, which is rotating at 2000RPM. The radius is 50mm. The length of shaft is 1m. The modulus of rigidity is 79GPa.

Table II: Comparison of Result for Solid Shaft

Sr. No.	Parameter	API Results	Analytical results
1	Max Shear stress	0.0050922 GPa	0.005092 GPa
2	Angle of twist	0.001289 rad	0.001289 rad
3	Power requirement	2000000 W	2000000 W
4	Polar moment of inertia	9.81875 x 10^-6 m^4	9.81747 x 10^-6 m^4

For Hollow Shaft:
Similarly, like solid shaft, Hollow shaft API was also tested through sample problem statement and results were tabulated in table III,

Sample Problem Statement: A shaft with 50mm outer diameter and 30mm inner diameter is subjected to torque of 1200 Nm with input as G = 90GPa, Length L = 0.7m, Rotation speed w = 2000RPM

Table III: Comparison of Result for Hollow Shaft

Sr. No.	Parameter	API Results	Analytical results
1	Max Shear stress	0.05616 GPa	0.05617 GPa
2	Angle of twist	0.0174 rad	0.0175 rad
3	Power requirement	2400000 W	2400000 W
4	Polar moment of inertia	5.3414 x 10^-7 m^4	5.3410 x 10^-7 m^4

4. Discussion

The results tabulated in earlier section clearly states that the API validation was successful through numerical case studies. Along with successful validation it also proved to be beneficial mainly in design time. It was found that through API, around 90% time was saved when compared with analytical calculation time; tabulated in table IV.

Table IV: Time Taken through API and Analytical

Sr. No.	Shaft type	Time Taken	
		API	Analytical Method
1	Solid Shaft	5 sec	270 sec
2	Hollow Shaft	6.3 sec	300 sec

The use of API allows user to interact with the GUI and understand the effect of each parameter on the system. The API was just a Case study model with proven examples but it can be implemented to live problems also.

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