



सत्यमेव जयते

Office of the Controller General of Patents, Designs & Trade Marks  
Department for Promotion of Industry and Internal Trade  
Ministry of Commerce & Industry,  
Government of India



### Application Details

APPLICATION NUMBER	202521049571
APPLICATION TYPE	ORDINARY APPLICATION
DATE OF FILING	22/05/2025
APPLICANT NAME	<b>1 . Nilesh Nana Mharsale</b> <b>2 . Archana Satish Shirsat</b> <b>3 . Dr. Dinkar Pitambar Patil</b>
TITLE OF INVENTION	Method and Apparatus for Predicting Material Behavior Using Nonlinear Parabolic and Hyperbolic Boundary Value Problem (BVP) Models
FIELD OF INVENTION	COMPUTER SCIENCE
E-MAIL (As Per Record)	archanashirsat1990@gmail.com
ADDITIONAL-EMAIL (As Per Record)	archnas_ioe@bkc.met.edu
E-MAIL (UPDATED Online)	
PRIORITY DATE	
REQUEST FOR EXAMINATION DATE	22/05/2025
PUBLICATION DATE (U/S 11A)	13/06/2025

(12) PATENT APPLICATION PUBLICATION

(21) Application No.202521049571 A

(19) INDIA

(22) Date of filing of Application :22/05/2025

(43) Publication Date : 13/06/2025

(54) Title of the invention : Method and Apparatus for Predicting Material Behavior Using Nonlinear Parabolic and Hyperbolic Boundary Value Problem (BVP) Models

(51) International classification	:G06F0017130000, G06F0030200000, G06F0030230000, G06F0111100000, G06F0030150000	(71)Name of Applicant : <b>1)Nilesh Nana Mharsale</b> Address of Applicant :Flat No.12, New Jui No.1, Jui Nagar, Kishorsurywanshi Marg, Mhasrul -----
(86) International Application No	:NA	<b>2)Archana Satish Shirsat</b>
Filing Date	:NA	<b>3)Dr. Dinkar Pitambar Patil</b>
(87) International Publication No	: NA	Name of Applicant : NA
(61) Patent of Addition to Application Number	:NA	Address of Applicant : NA
Filing Date	:NA	(72)Name of Inventor :
(62) Divisional to Application Number	:NA	<b>1)Archana Satish Shirsat</b>
Filing Date	:NA	Address of Applicant :Department of Mathematics, Institute of Engineering, MET's Bhujbal Knowledge City, Adgoan, Nashik Nashik -----
		<b>2)Dr. Dinkar Pitambar Patil</b>
		Address of Applicant :Arts and Commerce College, Wadala Nashik, Maharashtra, India Nashik -----

(57) Abstract :

The present invention relates to a method and apparatus for predicting the behavior of engineering materials under various physical conditions using nonlinear parabolic and hyperbolic boundary value problem (BVP) models. The system provides an integrated computational approach that combines nonlinear partial differential equations (PDEs), numerical solvers, and real-time material data to simulate stress, strain, deformation, and heat transfer in solid and composite materials. This invention offers improved accuracy in predicting time-dependent and wave-propagative material responses, applicable in aerospace, civil, automotive, and materials engineering.

No. of Pages : 13 No. of Claims : 5

**FORM 1**  
**THE PATENTS ACT, 1970**  
**(39 of 1970)**  
**&**  
**THE PATENTS RULES, 2003**  
**APPLICATION FOR GRANT OF PATENT**  
**[See sections 7,54 & 135 and rule 20(1)]**

**(FOR OFFICE USE ONLY)**

**Application No.:** .....

**Filing Date:** .....

**Amount of Fee Paid:** .....

**CBR No.:** .....

**Signature:** .....

**1. APPLICANT(S):**

Sr.No.	Name	Nationality	Address	Country	State	Distict	City
1	Nilesh Nana Mharsale	India	Flat No.12, New Jui No.1, Jui Nagar, Kishorsurywanshi Marg, Mhasrul	India	Maharashtra	00	
2	Archana Satish Shirsat	India	Department of Mathematics, Institute of Engineering, MET's Bhujbal Knowledge City, Adgoan, Nashik	India	Maharashtra	Nashik	Nashik
3	Dr. Dinkar Pitambar Patil	India	Arts and Commerce College, Wadala Nashik, Maharashtra, India	India	Maharashtra	Nashik	Nashik

**2. INVENTOR(S):**

Sr.No.	Name	Nationality	Address	Country	State	Distict	City
1	Archana Satish Shirsat	India	Department of Mathematics, Institute of Engineering, MET's Bhujbal Knowledge City, Adgoan, Nashik	India	Maharashtra	Nashik	Nashik
2	Dr. Dinkar Pitambar Patil	India	Arts and Commerce College, Wadala Nashik, Maharashtra, India	India	Maharashtra	Nashik	Nashik

Signature Not Verified

Digitally Signed.  
Name: Nilesh Nana Mharsale  
Date: 22-May-2025 21:13:44  
Reason: Patent Filing  
Location: DELHI

**3. TITLE OF THE INVENTION: Method and Apparatus for Predicting Material Behavior Using Nonlinear Parabolic and Hyperbolic Boundary Value Problem (BVP) Models**

**4. ADDRESS FOR CORRESPONDENCE OF APPLICANT / Telephone No.:**  
**AUTHORISED PATENT AGENT IN INDIA:**

Department of Mathematics, Institute of Engineering, MET's  
 Bhujbal Knowledge City, Adgoan, Nashik

Fax No.:

Mobile No: 8390855976

E-mail: archanashirsat1990@gmail.com

**5. PRIORITY PARTICULARS OF THE APPLICATION(S) FILED IN CONVENTION COUNTRY:**

Sr.No.	Country	Application Number	Filing Date	Name of the Applicant	Title of the Invention
--------	---------	--------------------	-------------	-----------------------	------------------------

**6. PARTICULARS FOR FILING PATENT COOPERATION TREATY (PCT) NATIONAL PHASE APPLICATION:**

International Application Number	International Filing Date as Allotted by the Receiving Office
PCT//	

**7. PARTICULARS FOR FILING DIVISIONAL APPLICATION**

Original (first) Application Number	Date of Filing of Original (first) Application
-------------------------------------	--

**8. PARTICULARS FOR FILING PATENT OF ADDITION:**

Main Application / Patent Number:	Date of Filing of Main Application
-----------------------------------	------------------------------------

**9. DECLARATIONS:**

**(i) Declaration by the inventor(s)**

I/We ,Archana Satish Shirsat,Dr. Dinkar Pitambar Patil, is/are the true & first inventor(s) for this invention and declare that the applicant(s) herein is/are my/our assignee or legal representative.

(a) Date: -----

(b) Signature(s) of the inventor(s): .....

(c) Name(s): Archana Satish Shirsat,Dr. Dinkar Pitambar Patil

**(ii) Declaration by the applicant(s) in the convention country**

I/We, the applicant(s) in the convention country declare that the applicant(s) herein is/are my/our assignee or legal representative.

(a) Date: -----

(b) Signature(s) : .....

(c) Name(s) of the singnatory: Nilesh Nana Mharsale,Archana Satish Shirsat,Dr. Dinkar Pitambar Patil

**(iii) Declaration by the applicant(s)**

- **The Complete specification relating to the invention is filed with this application.**
- **I am/We are, in possession of the above mentioned invention.**
- **There is no lawful ground of objection to the grant of the Patent to me/us.**
- **I am/We are, the assignee or legal representative to true first inventors.**
- **The application or each of the applications, particulars of which are given in Para-5 was the first application in convention country/countries in respect of my/our invention.**
- **I/We claim the priority from the above mentioned application(s) filed in convention country/countries and state that no application for protection in respect of the invention had been made in a convention country before that date by me/us or by any person from which I/We derive the title.**

10. FOLLOWING ARE THE ATTACHMENTS WITH THE APPLICATION:

Sr.	Document Description	FileName
-----	----------------------	----------

I/We hereby declare that to the best of my/our knowledge, information and belief the fact and matters stated hereing are correct and I/We request that a patent may be granted to me/us for the said invention.

Dated this(Final Payment Date): -----

Signature: .....

Name: Nilesh Nana Mharsale

To The Controller of Patents

The Patent office at MUMBAI

This form is electronically generated.

# **Title: Method and Apparatus for Predicting Material Behavior Using Nonlinear Parabolic and Hyperbolic Boundary Value Problem (BVP) Models**

**Abstract:** The present invention relates to a method and apparatus for predicting the behavior of engineering materials under various physical conditions using nonlinear parabolic and hyperbolic boundary value problem (BVP) models. The system provides an integrated computational approach that combines nonlinear partial differential equations (PDEs), numerical solvers, and real-time material data to simulate stress, strain, deformation, and heat transfer in solid and composite materials. This invention offers improved accuracy in predicting time-dependent and wave-propagative material responses, applicable in aerospace, civil, automotive, and materials engineering.

## **Field of the Invention:**

This invention pertains to the field of computational material science and applied mechanics. Specifically, it concerns methods and apparatuses for solving nonlinear parabolic and hyperbolic boundary value problems to predict and simulate the physical behavior of engineering materials under stress, thermal load, or dynamic forces.

## **Background of the Invention:**

Accurate modeling of material behavior under real-world conditions—such as thermal exposure, mechanical stress, or dynamic loading—is crucial in engineering design. Conventional linear models often fall short in capturing complex material responses like plastic deformation, thermal cracking, and non-homogeneous strain distributions.

Nonlinear partial differential equations (PDEs), especially of parabolic and hyperbolic types, offer a more realistic mathematical foundation for simulating these phenomena. Parabolic PDEs are effective in modeling time-dependent processes like heat conduction and diffusion, while hyperbolic PDEs capture wave-like phenomena such as stress waves and impact dynamics. However, their complexity makes them challenging to solve for practical materials and geometries.

This invention bridges that gap by providing a unified system and method that leverages nonlinear BVPs for accurate, efficient, and adaptable material behavior prediction.

### **Summary of the Invention:**

The invention comprises a method and an apparatus that:

- I. Models material behavior using nonlinear parabolic and hyperbolic PDEs.
- II. Solves these equations under relevant boundary and initial conditions.
- III. Integrates numerical techniques such as the Finite Element Method (FEM), Finite Volume Method (FVM), or spectral methods.
- IV. Includes an adaptive mesh and solver algorithm to ensure computational efficiency.
- V. Incorporates real-time material parameters such as thermal conductivity, elasticity modulus, and damping characteristics.

---

The system outputs detailed predictions on stress distribution, thermal gradients, wave propagation, and potential failure zones, aiding in engineering design and safety evaluation.

### **Detailed Description of the Invention:**

#### **1. Mathematical Modeling:**

- I. **Parabolic BVP Example:** Heat transfer modeled by:

$$\frac{\partial u}{\partial t} = \nabla \cdot (k(u)\nabla u) + Q(x, t)$$

- II. where  $u$  is temperature,  $k(u)$  is temperature-dependent conductivity, and  $Q$  is a heat source.
- III. **Hyperbolic BVP Example:** Stress wave propagation modeled by:

$$\rho \frac{\partial^2 u}{\partial t^2} = \nabla \cdot \sigma(u, \nabla u) + F(x, t)$$

IV. where  $\rho$  is density,  $\sigma$  is nonlinear stress tensor, and  $F$  is external force.

## **2. Solver Implementation:**

- I. Implements nonlinear time-stepping schemes (e.g., Crank-Nicolson, Runge-Kutta).
- II. Utilizes Newton-Raphson or quasi-Newton methods for nonlinear convergence.
- III. Employs error estimation and adaptive refinement of mesh/grid.

## **3. Apparatus Features:**

- I. Input module for material properties and boundary/initial conditions.
- II. Solver engine integrated with high-performance computing capabilities.
- III. Visualization module to render stress fields, deformation contours, and temperature profiles.

## **Figures:**

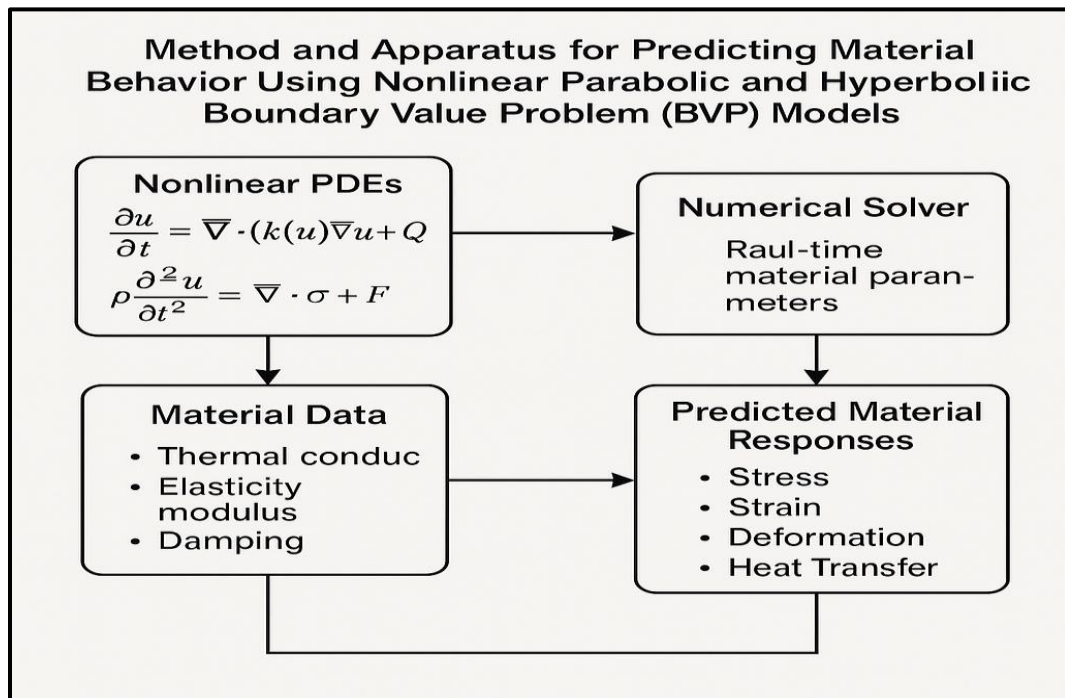
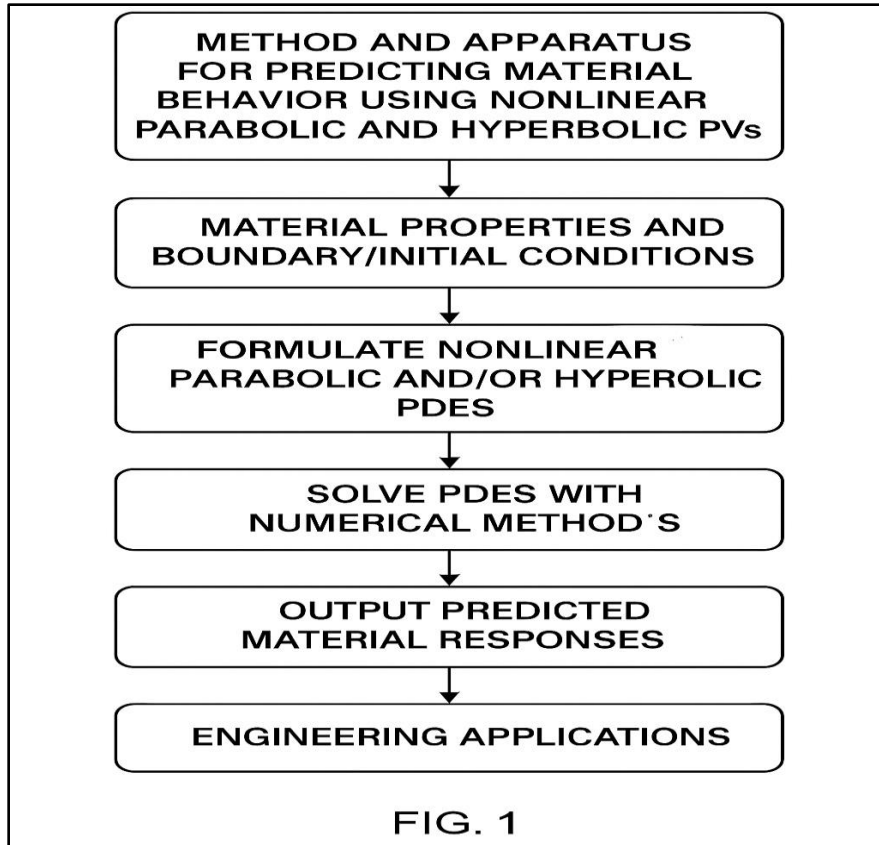
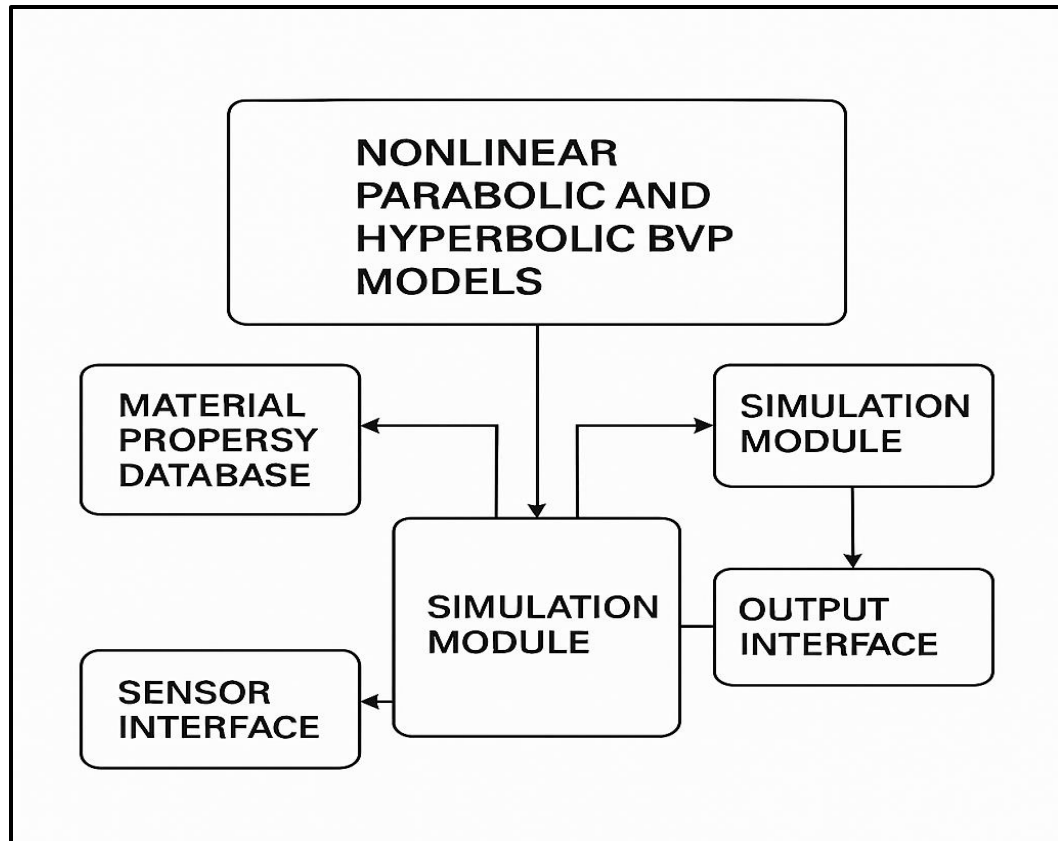


Fig.2



**Fig.3**

**Fig. 1: Flowchart – Process flow from inputs to simulation outputs.**

This flowchart outlines the **step-by-step methodology** used in the invention:

**1. Start: Method and Apparatus**

Indicates the overall system designed to simulate material behavior using advanced mathematical models.

**2. Material Properties and Boundary/Initial Conditions**

Inputs include properties like thermal conductivity, elasticity modulus, damping coefficient, and the conditions under which the material operates (e.g., fixed ends, initial temperature, etc.).

**3. Formulate Nonlinear Parabolic and/or Hyperbolic PDEs**

Based on the inputs, the system generates mathematical models in the form of nonlinear partial differential equations (PDEs).

- *Parabolic PDEs*: For processes like heat diffusion.

- *Hyperbolic PDEs*: For stress wave propagation or dynamic loading.
4. **Solve PDEs with Numerical Methods**  
The system uses solvers like finite element or finite volume methods to compute the solution to these complex PDEs.
  5. **Output Predicted Material Responses**  
The computed results show how the material behaves — such as deformation, stress concentration, or heat flow.
  6. **Engineering Applications**  
These predictions can be applied in real-world engineering design, safety checks, and failure prevention.

**Fig. 2: Simulation Diagram – Mathematical and Computational Workflow**

This figure shows how the system combines physics, computation, and data:

1. **Nonlinear PDEs Block**

Two types of PDEs are represented:

$$\frac{\partial u}{\partial t} = \nabla \cdot (k(u)\nabla u) + Q$$

(Heat conduction)

$$\rho \frac{\partial^2 u}{\partial t^2} = \nabla \cdot \sigma + F$$

(Wave/stress propagation)

2. **Numerical Solver**

Uses real-time parameters to solve these equations efficiently.

3. **Material Data**

Input includes thermal conductivity, elasticity, and damping — these govern how the material behaves under loads.

4. **Predicted Material Responses**

Outputs include:

- I. Stress
- II. Strain

- III. Deformation
- IV. Heat transfer

### **Fig. 3: System Architecture Diagram**

This block diagram represents the **software and hardware architecture** of the predictive system:

- I. **Nonlinear BVP Models**  
Core mathematical engine driving the predictions.
- II. **Material Property Database**  
Stores predefined or measured material characteristics.
- III. **Simulation Modules**
  - a. One module handles equation solving.
  - b. Another interfaces with external sensors to receive real-time data.
  - c. Outputs are sent to a user interface.
- IV. **Sensor Interface**  
Allows real-time data input — e.g., temperature, pressure sensors.
- V. **Output Interface**  
Provides graphical or numerical results (stress contours, heat maps, etc.) to engineers or users.

### **4. Applications:**

- I. **Aerospace:** Thermal fatigue analysis of turbine blades.
- II. **Automotive:** Crashworthiness and impact modeling of vehicle components.
- III. **Civil:** Seismic response modeling in buildings and bridges.
- IV. **Manufacturing:** Thermal stress analysis in welding and additive manufacturing.

## **Claims:**

### **Claim 1:**

A method for predicting the behavior of materials using nonlinear parabolic and hyperbolic boundary value problem models, comprising:

- I. receiving material properties and boundary/initial conditions;
- II. formulating nonlinear parabolic and/or hyperbolic PDEs representing heat transfer, stress propagation, or deformation;
- III. solving said equations using numerical methods; and
- IV. outputting predicted material responses.

### **Claim 2:**

The method of claim 1, wherein the numerical method comprises a finite element solver with adaptive meshing and nonlinear iteration schemes.

### **Claim 3:**

The method of claim 1, wherein real-time sensor data is integrated to update boundary conditions or material parameters dynamically.

### **Claim 4:**

An apparatus for modeling and visualizing material behavior under thermal or mechanical loading, comprising:

- I. a processor configured to implement nonlinear BVP solvers;
- II. a data input module for material parameters;
- III. a computational mesh generator; and
- IV. a user interface for visualizing simulation outputs.

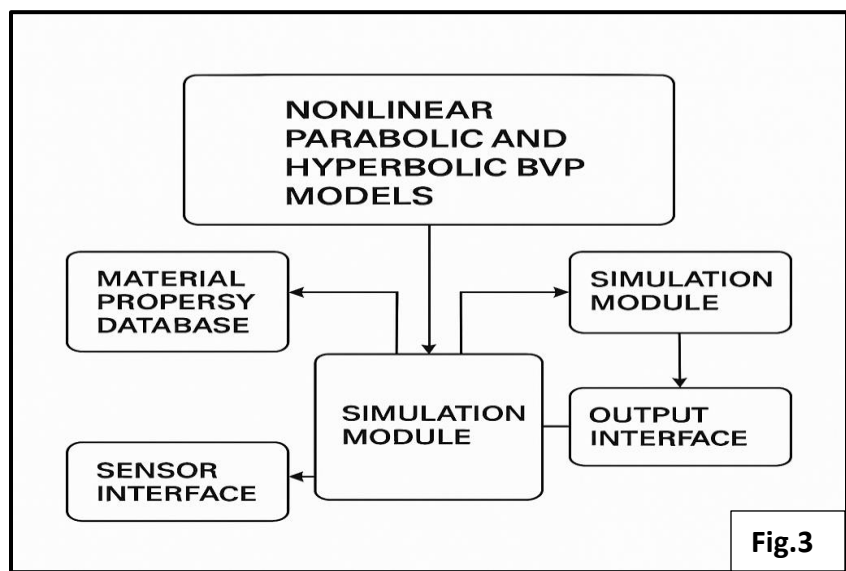
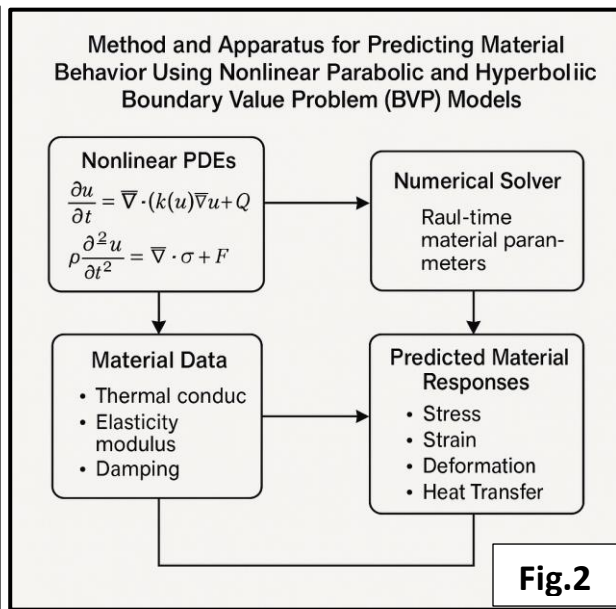
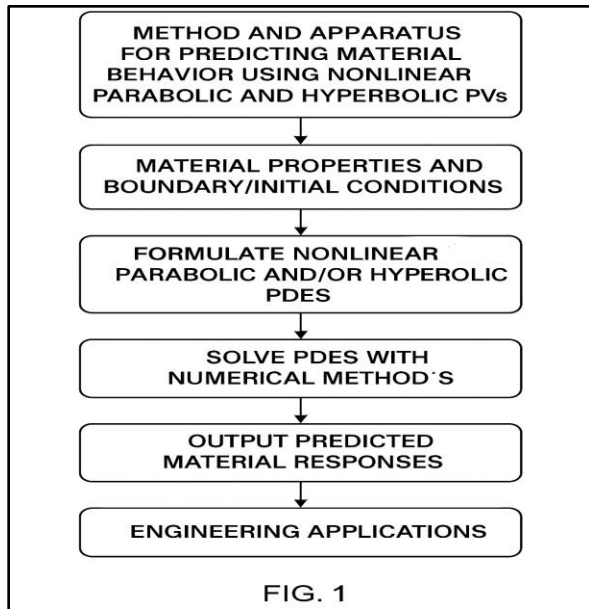
### **Claim 5:**

The apparatus of claim 4, wherein the system is configured for integration with CAD/CAE environments for design optimization.

## **Advantages of the Invention:**

- I. Captures nonlinear and time-dependent material behaviors.
- II. Applicable to a wide range of engineering domains.
- III. Improves predictive capability and reduces reliance on physical prototypes.
- IV. Enables early-stage failure analysis and design correction

**Abstract:** The present invention relates to a method and apparatus for predicting the behavior of engineering materials under various physical conditions using nonlinear parabolic and hyperbolic boundary value problem (BVP) models. The system provides an integrated computational approach that combines nonlinear partial differential equations (PDEs), numerical solvers, and real-time material data to simulate stress, strain, deformation, and heat transfer in solid and composite materials. This invention offers improved accuracy in predicting time-dependent and wave-propagative material responses, applicable in aerospace, civil, automotive, and materials engineering.



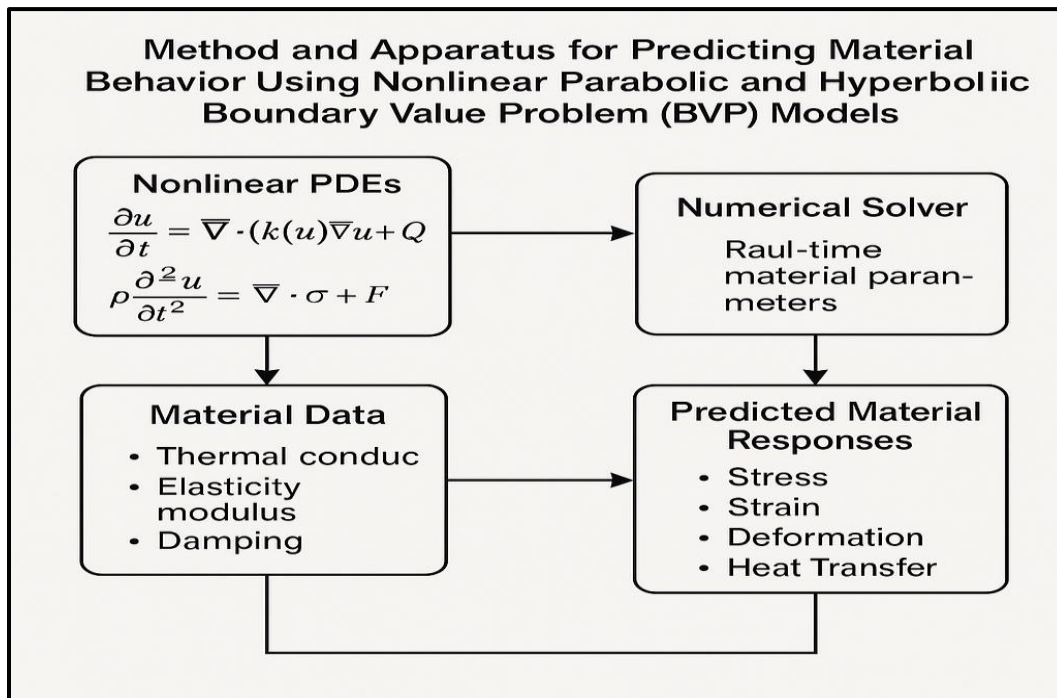
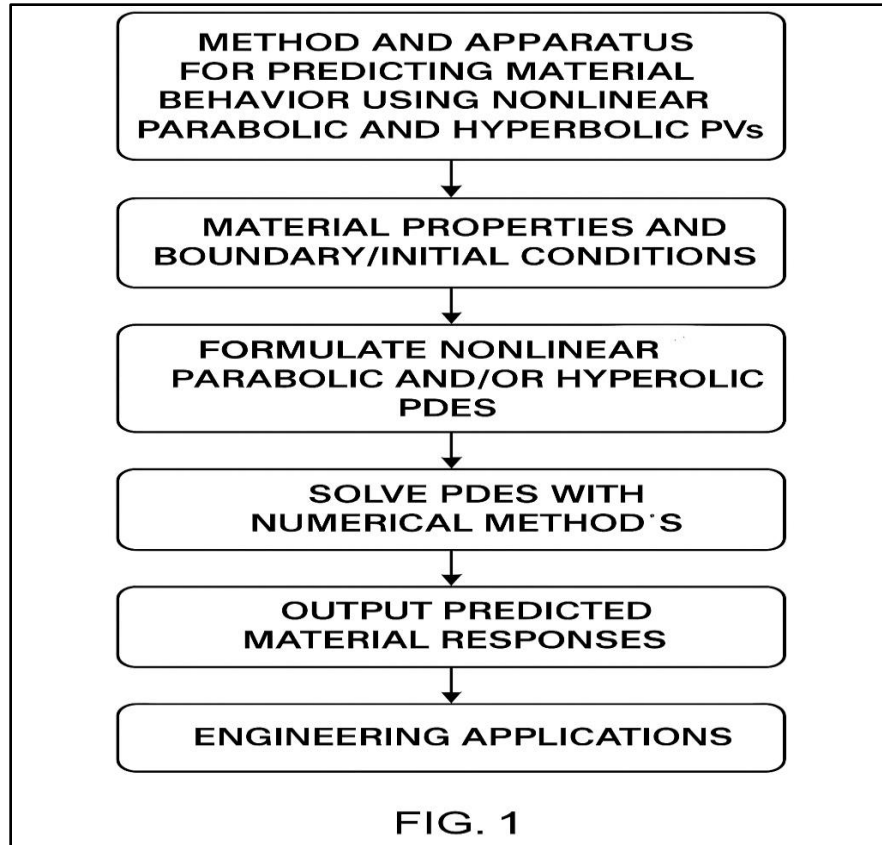


Fig.2

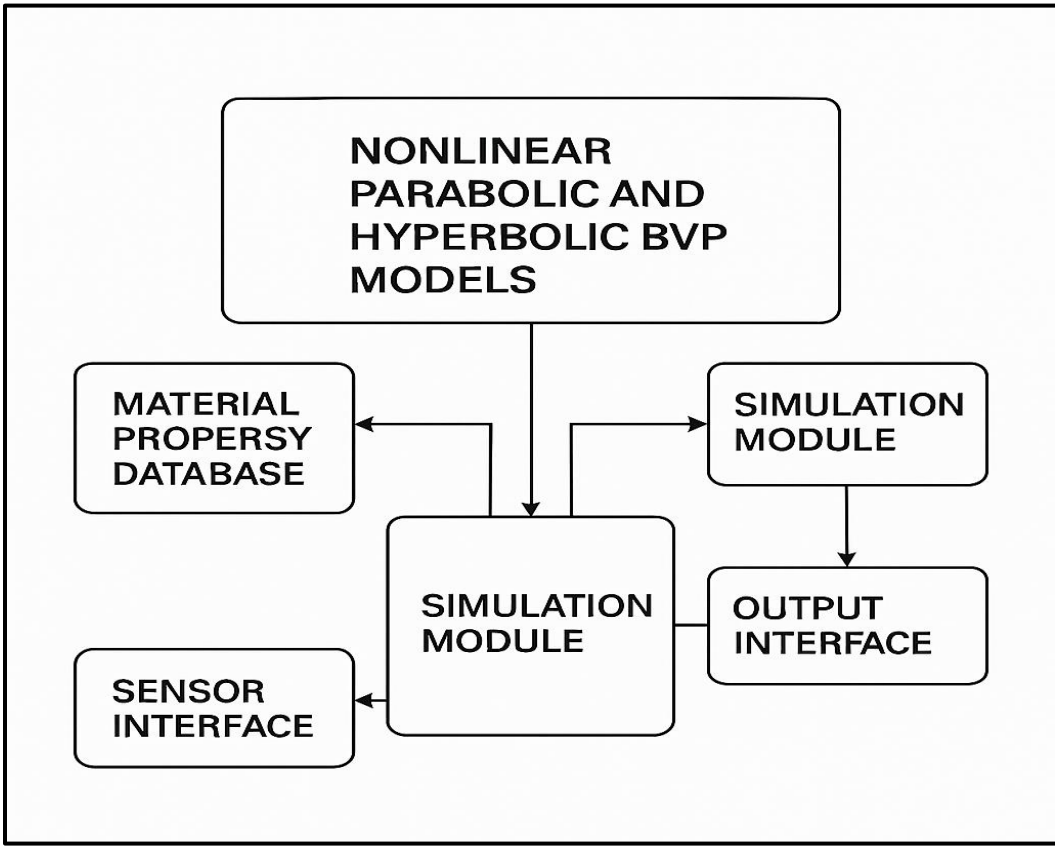


Fig.3