

**PROJECT COMPLETION REPORT**  
**UGC MINOR RESEARCH PROJECT**  
**F. No. 37-537/2009(SR)**

TITLE

BIHARMONIC FORMULATION OF INCOMPRESSIBLE VISCOUS FLUID AND  
ITS NUMERICAL SIMULATION BY HIGHER ORDER COMPACT SCHEMES

PRINCIPAL INVESTIGATOR

SHUVAM SEN

SUBMITTED TO  
UNIVERSITY GRANTS COMMISSION  
GOVERNMENT OF INDIA

BY



DEPARTMENT OF MATHEMATICAL SCIENCES  
TEZPUR UNIVERSITY  
TEZPUR-784028, ASSAM, INDIA

**UNIVERSITY GRANTS COMMISSION  
BAHADUR SHAH ZAFAR MARG  
NEW DELHI – 110 002**

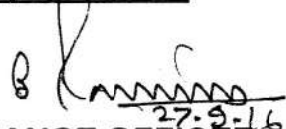
Project Completion Report of the work done on the Minor Research Project

1. Project report No.: 2<sup>nd</sup> (Final)
2. UGC Reference No.: F. No. 37-537/2009(SR) dated 23.12.2009.
3. Period of report: From 01.02.2010 To 31.01.2012
4. Title of research project: “Biharmonic formulation of incompressible viscous fluid and its numerical simulation by higher order compact schemes”
5. (a) Name of the Principal Investigator: Shuvam Sen  
(b) Deptt. and University/College where work has progressed:  
Mathematical Sciences/Tezpur University
6. Effective date of starting of the project: 01.02.2010.
7. Grant approved and expenditure incurred during the period of the report:
 

(a) Total amount approved:	Rs. 1,20,000.00
(b) (i) Total Grant Releases as 1 <sup>st</sup> installment:	Rs. <u>1,00,000.00</u>
(ii) Actual expenditure during the period: (01.02.2010 To 31.03.2011)	Rs. <u>49,951.00</u>
(iii) Total Grant Releases as 2 <sup>nd</sup> installment:	Rs. <u>NIL</u>
(iv) Actual expenditure during the period: (01.04.2011 To 31.01.2012)	Rs. <u>50,049.00</u>
- (c) Report of the work done: Separate Sheet attached, please see.

  
SIGNATURE OF  
THE PRINCIPAL  
INVESTIGATOR

  
REGISTRAR  
*Registrar*  
Tezpur University

  
FINANCE OFFICER  
*Finance*  
Tezpur U.

**Annexure -III**

**UNIVERSITY GRANTS COMMISSION  
BAHADUR SHAH ZAFAR MARG  
NEW DELHI – 110 002.**

**Annual Report of the work done on the Minor Research Project**

**7 (c) Report of the work done:**

**i. Brief objective of the project:**

Objectives of the project work are listed below

- a. To develop an efficient numerical scheme for the solution of unsteady Navier-Stokes equation, specifically on curvilinear co-ordinates.
- b. We are particularly interested in Higher Order Compact formulation which are easier to implement and are faster.
- c. Schemes thus developed will be tested for their stability and convergence both analytically and computationally

**ii. Work done so far and results achieved and publications, if any, resulting from the work (Give details of the papers and names of the journals in which it has been published or accepted for publication):**

Mainly two finite difference numerical schemes have been developed and tested for the above mentioned equation. They are:

- (A) A fourth order accurate semi compact finite difference scheme for the steady Navier-Stokes (N-S) equations in biharmonic pure stream-function form in non-rectangular geometries.
- (B) A second order temporally and spatially accurate finite difference scheme for biharmonic pure stream function form of the transient incompressible 2D Navier-Stokes (N-S) equations for irregular physical domains.

The formulation (A) has been used with great success to simulate steady state results for four different problems. They are:

- (i) A known constructed solution.
- (ii) Fluid flow in a constricted channel.
- (iii) Driven polar cavity.
- (iv) Flow past an impulsively started circular cylinder.

The formulation (B) has been used to study time development of flow field for the following flow fields:

- (i) Flow past circular cylinder for Reynolds number (Re) ranging from 5 to 9500.
- (ii) Flow around oscillating cylinder for different combinations of KC and Re.
- (iii) Flow past a circular cylinder in cross flow.
- (iv) Both uniform and accelerated flow past NACA0012 and NACA0015.



**Finance Officer  
Tezpur University**

The details of the paper published are as given below:

1. *Triggering asymmetry for flow past circular cylinder at low Reynolds numbers; with Jiten C Kalita, Computers & Fluids 59, 44-60, 2012.*
2. *The Biharmonic Approach for Unsteady Flow Past an Impulsively Started Circular Cylinder with Jiten C Kalita, Computers & Fluids 12, 1163-1182, 2012.*

iii. Has the progress been according to original plan of work and towards achieving the objective. If not, state reasons: Yes

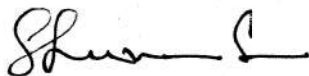
iv. Please indicate the difficulties, if any, experienced in implementing the project: The 2<sup>nd</sup> installment of Rs. 20,000.00 was never released by UGC.

v. If project has not been completed, please indicate the approximate time by which it is likely to be completed. A summary of the work done for the period (Annual basis) may please be sent to the Commission on a separate sheet: Completed

vi. If the project has been completed, please enclose a summary of the findings of the study. Two bound copies of the final report of work done may also be sent to the Commission:

Summary of the findings have been published in two international journals and are attached for your kind perusal.

vii. Any other information which would help in evaluation of work done on the project. At the completion of the project, the first report should indicate the output, such as (a) Manpower trained (b) Ph. D. awarded (c) Publication of results (d) other impact, if any: None



**SIGNATURE OF THE PRINCIPAL  
INVESTIGATOR**



**REGISTRAR**  
*Registrar*  
*Tezpur University*

UNIVERSITY GRANTS COMMISSION  
BAHADUR SHAH ZAFAR MARG  
NEW DELHI – 110 002

Utilization certificate

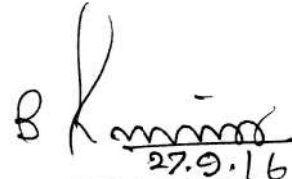
Certified that the grant of Rs. 1,00,000.00 (Rupees One lakh only) (1<sup>st</sup> installment) and NIL (2<sup>nd</sup> installment) received from the University Grants Commission under the scheme of support for Minor Research Project entitled "Biharmonic formulation of incompressible viscous fluid and its numerical simulation by higher order compact schemes" vide UGC letter No. F. No. 37-537/2009(SR) dated 23.12.2009 out of which Rs. 1,00,000.00 (Rupees One lakh only) has been utilized for the purpose for which it was sanctioned and in accordance with the terms and conditions laid down by the University Grants Commission.



SIGNATURE OF  
THE PRINCIPAL  
INVESTIGATOR



REGISTRAR  
*Registrar*  
*Tezpur University*

  
27.9.16

FINANCE OFFICER  
*Finance Officer*  
*Tezpur University*

**UNIVERSITY GRANTS COMMISSION  
BAHADUR SHAH ZAFAR MARG  
NEW DELHI - 110 002**

**STATEMENT OF EXPENDITURE IN RESPECT OF MINOR  
RESEARCH PROJECT**

1. Name of Principal Investigator: **Shuvem Sen**
2. Deptt. of University: **Mathematical Sciences, Tezpur University**
3. UGC approval No. and Date **F. No. 37-537/2009(SR) dated 23.12.2009.**
4. Title of the Research Project: **"Biharmonic formulation of incompressible viscous fluid and its numerical simulation by higher order compact schemes"**
5. Effective date of starting the project: **01.02.2010.**
6. a. Period of Expenditure: From **01.02.2010** to **31.01.2012.**

b. Details of Expenditure:

Sl. No.	Item	Amount Approved Rs.	Grant Released as 1 <sup>st</sup> Installment (2010-11)	Expenditure Incurred Rs. (2010-11)	Grant Released as 2 <sup>nd</sup> Installment (2011-12)	Expenditure Incurred Rs. (2011-12)	Balance
i	Books & Journals	30,000.00	30,000.00	29,951.00	NIL	49.00	NIL
ii	Equipment	50,000.00	50,000.00	NIL	NIL	50,000.00	NIL
iii	Contingency	30,000.00	15,000.00	15,000.00	NIL	NIL	NIL
iv	Field Work/ Travel (Give details in the proforma at Annex-VI).	10,000.00	5,000.00	5,000.00	NIL	NIL	NIL
v	Hiring Services	NIL	NIL	NIL	NIL	NIL	NIL
vi	Chemicals & Glassware	NIL	NIL	NIL	NIL	NIL	NIL
vii	Overhead	NIL	NIL	NIL	NIL	NIL	NIL
viii	Any other items(Please specify)	NIL	NIL	NIL	NIL	NIL	NIL
	Total			49,951.00		50,049.00	
	Actual Balance in the Period					NIL	

  
**Finance Officer  
Tezpur University**

3. Staff

Date of Appointment: Does not arise

S.No.	Expenditure Incurred	From to	Amount Approved (Rs.)	Expenditure Incurred (Rs.)
1	Honorarium to PI (Retired Teachers) Rs.12,000/- p.m.	Does not arise		
2	Post-Doctoral Fellow Fellowship @ Rs. 12,000/- p.m.	Does not arise		
3	Project Associate salary @ Rs.10,000/- p.m.	Does not arise		
4	Project Fellow salary @ Rs.8000/- p.m.	Does not arise		

4. It is certified that the appointment(s) have been made in accordance with the terms and conditions laid down by the Commission.
5. It as a result of check or audit objective, some irregularly is noticed, later date, action will be taken to refund, adjust or regularize the objected amounts.
6. Payment @ revised rates shall be made with arrears on the availability of additional funds.
7. It is certified that the grant of Rs. 1,00,000.00 (Rupees One lakh only) (1<sup>st</sup> installment) and NIL (2<sup>nd</sup> installment) received from the University Grants Commission under the scheme of support for Minor Research Project entitled : "Biharmonic formulation of incompressible viscous fluid and its numerical simulation by higher order compact schemes" vide UGC letter No. F. No. 37-537/2009(SR) dated 23.12.2009. Out of which Rs. 1,00,000.00 (Rupees One lakh only) has been fully utilized for the purpose for which it was sanctioned and in accordance with the terms and conditions laid down by the University Grants Commission.



SIGNATURE OF  
THE PRINCIPAL  
INVESTIGATOR



REGISTRAR  
*Registrar*  
*Tezpur University*



27.9.16

FINANCE OFFICER  
*Finance Officer*  
*Tezpur University*

UNIVERSITY GRANTS COMMISSION  
BAHADUR SHAH ZAFAR MARG  
NEW DELHI – 110 002

## STATEMENT OF EXPENDITURE INCURRED ON FIELD WORK

Name of the Principal Investigator: Shuvam Sen

Name of the Place visited	Duration of the Visit		Mode of Journey	Expenditure Incurred (Rs.)
	From	To		
NONE				

Certified that the above expenditure is in accordance with the UGC norms  
for Minor Research Projects



SIGNATURE OF THE PRINCIPAL  
INVESTIGATOR



REGISTRAR  
*Registrar*  
*Tezpur University*