TECHNICAL EDUCATION QUALITY IMPROVEMENT PROGRAMME [TEQIP]

PHASE – II - CoE

Name of the Centre of Excellence: "Challenges of Nanotechnology for 21st Century Generation – Indian Perspective in Global Scenario"

Date of Review Meeting: 5th June 2014

Name of Review Committee members: (i) Prof Ashutosh Sharma, IIT Kanpur,
(ii) Prof Ch. Subrahmanyam, IIT Hyderabad,
(iii) Prof Raman S. Srinivasa , IIT Bombay and
(iv) Prof Sumeer K. Nath, IIT Roorkee

The summary of the observations of the Review Committee members are as below:

- **Achievements:**
  - Progress of the project is satisfactory since its inception.
  - Procurement of equipment and recruitment of staff is in progress.
  - More focussed goals are being identified for research
- **Key Issues/Concerns**
  - Areas of research need to be more focussed taking into account their strength and available infrastructures.
  - Specific component need to be identified for the fuel cell e.g. membrane, catalyst, electrode etc.
  - In composite materials newer approaches/system/materials need to be investigated.
  - The Centre should identify specific components viz. membrane, catalyst, electrode etc. for their fuel Cell.
- **Recommendations:**
  - The Centre should identify/interact with the end user for further utilization in the areas of composites and tribology.
  - Advised to buy FESEM instead of simple SEM due to higher resolution requirement.
  - Projects of MTech students may be based on previous background and training.

"Action Plan for implementation of CoE"

Questions raised by the Review committee members:

(i) Prof Ashutosh Sharma, IIT Kanpur,
(ii) Prof Ch. Subrahmanyam, IIT Hyderabad,
(iii) Prof Raman S. Srinivasa , IIT Bombay and
(iv) Prof Sumeer K. Nath, IIT Roorkee

I. Achievements:

- Progress of the project is satisfactory since its inception.
- Procurement of equipment and recruitment of staff is in progress.
- More focussed goals are being identified for research

Activities undertaken

- National Advisory committee and Technical committee consisting of experts is constituted. Active involvement of CoE team in the discussion with the Advisory committee and it comprising experts from R&D labs like ARCI, DMRL, UOH and faculty from IITs and IISc.
- Specifications for purchasing the equipment finalized for the worth of Rs.1 Crore and Initiated 24 packages for worth of Rs. 2.4 Crore. Procurement Plan of the equipments are finalized and uploaded in the PMSS - detailed specifications for the individual equipment finalized.
- Issued advertisement for admission into master and doctoral program in thematic area, Identified 05 M.Tech students for Teaching Assistantships and 10 students for Research
  Assistantships.
- Retired Professors of IITs - identified as Senior Research Advisor related to expertise in Nanotechnology. Three full-time visiting scientists are also identified for recruitment of Visiting professor, Adjunct faculty and Honorary Professor related to expertise in Nanocomposites, Nano lubricants and PEM Fuel cell.
- BoG Meeting on 12th December 2013 at AUCE (A) for discussing the activities to be taken up under CoE and also on 06th March 2014.

- Investigators (Faculty members) submitted the revised research proposals and clear action plan regarding main themes of CoE.
- Four thematic areas of Research namely Nanocomposites, Multiscale composites, Nano Lubricants and PEM Fuel cell. In addition to this 08 Faculty, 10 PhD scholars and 21 M.Tech students doing research in the thematic areas.
- Discussions are in progress for the collaboration with Industries. Expert speakers from industry and academia invited for talk.
- Support to Faculty and student members for Paper presentation is started.
- Industry Academia Collaboration: Prof. K. Ramji of Department of Mechanical Engineering, visited various Universities (University of Illionois, Sanford University, University of Berkely, Chikago State University) and Industries (Google, CISCO etc.) in USA during Sept -Oct. 2013, to establish industry academic collaborations.
- Industry Academia Collaboration: Prof. S.V. Naidu and Prof. N. Chitti Babu of Department of Chemical Engineering, visited Greece, Europe for attending training programme on Fuel cell in the month of July - August 2014.
- 12 Participation of Investigators in various International workshop, conference, Seminar and symposium.
- National level collaboration with IITs, IISc, DRDO Labs, Central University-Hyderabad, CSIR Labs and industries.
- International collaboration with various Universities (University of Illionois, Sanford University, University of Berkely, Chikago State University, National University of Singapore) and Industries (Google, CISCO etc.) in USA.
- Industry Institute interaction is initiated with local industries related to the fields of Nanocomposites, Multiscale Composites, Nano lubricants and PEM Fuel cell. Industry sponsored research and consultancy works are under progress
- New Proposals invited for Innovative projects from UG/PG students related to the fields of Nanocomposites, Multiscale Composites, Nano lubricants and PEM Fuel cell.
- Meetings for planning and over all activities of the centre and Identification of site for the CoE and planning for the laboratory space, office space and other related logistics finalized.

- Team will meet once in every forth night to discuss the progress of management issues and research activities of the COE.
- Thesis work of ME/PhD students is being undertaken in the thematic areas of Nanocomposites, Multiscale Composites, Nano lubricants and PEM Fuel cell.
- Planning of Special Hands on training sessions for the research scholars, Faculty members and PG students

(i) To resolve the issues & concerns raised by the committee and

(ii) The implementation of recommendations made in the review meeting.

Areas of research need to be more focussed taking into account their strength and available infrastructures.

The identified focussed areas in this theme are

- **Multiscale Composites**
- **Nanocomposites**
- **Nanolubricants & Machining**
- **PEM Fuel cell**

Theme 1.

1. Areas of research need to be more focussed taking into account their strength and available infrastructures.
2. In composite materials newer approaches/system/materials need to be investigated.

i) Nanolubricants & Machining:

a. Definition of the problem

- Aims to study the influence of variation of solid lubricant particle size by varying it in the nano level in the machining of hardened steel.
- It also aims to investigate the influence of variation solid volume fraction on the proposed lubricant performance in machining of hardened steel.

b. **Importance of the proposed model**

- Effect of solid lubricant particle size in the nano level can be uncovered.

- Difference between role of nano layered sputtered coatings and solid lubricant powder emulsions can be evaluated under real machining conditions.

c. Objectives

- To test the effect of variation of particle size in its nano level in the form of **Solid lubricants like** Graphite, MoS2, Boric acid etc. while machining hardened steel.
- To test the effect of variation of weight percentage of boric acid in canola oil.
- To differentiate the role of sputtered and solid lubricant emulsions used in machining applications.
- To validate with finite element model.
- To fit an equation using regression analysis.
- To develop a fuzzy model to generalize the particle size phenomena.

d. Technical details

- Range of particle sizes under study: 10-100 nm and 100-500 µm.
- Machining tests are proposed to evaluate the effect of boric acid particle size
- Evaluation parameters: Cutting forces, tool temperature and Surface roughness

e. Methodology

- To synthesize the solid lubricant nano particles.
- To develop an experimental setup
- To conduct experiments to test the effect of variation of particle size.
- To coat the solid lubricant using sputtering process.
- To conduct the experiments to compare the results with that of I phase.
- Analysis of data.
- To validate the experimental results with FEA model
- To develop a fuzzy model

f. Action Plan

Months	**Activity**
1-3	Problem specification and survey of literature

4-6	Procurement of Quotations Consumables and Boric acid, Graphite and MoS_2 Geometric tests on M/c tool
7-9	Procurement of Quotations Consumables and Boric acid Geometric tests on M/c tool
10-12	Characterization of raw boric acid Synthesis of Nano boric acid powders
13-15	Characterization of raw boric acid Synthesis of Nano boric acid powders
16-18	Fabrication of an Emulsification system Development of Experimental setup Procurement and calibration of dynamometer and Roughness tester

ii. Nanocomposites & Multiscale Composites

- In composite materials newer approaches/system/materials need to be investigated.

  The following materials are identified and related to this newer approaches/systems need to be investigated.

  - Nanoclay reinforced Nanocomposites
  - SWNT, MWNT, Graphene, Carbon block, Carbon nano fiber reinforced composites
  - Nickel Ferrite reinforced Nanocomposites

a. Definition of the problem

- Modeling of Nanocomposites and Multiscale Composites
- Effect of Fiber Orientation on Elastic Properties of Multiscale Composites
- Analysis of Stress Concentration
- Free Vibration Analysis of Multiscale Composite Panels
- Non-linear Structural Response of Multiscale Composite Panels

b. The Objectives of this Research are

- Develop, 3-D representative volume element (RVE) based on the continuum mechanics
- Evaluate the elastic properties of nanocomposites using finite element method (FEM)
- Study the integration effect of CNT's in polymer composites.
- Develop numerical models for predicting the elastic properties of multiscale composites.
- Investigate the effect of fiber orientation on elastic properties of CNT based multiscale composites.
- Study the effect of CNT reinforcement on the stress concentration of multiscale composites
- Perform Free vibration analysis for three types of CNT based composite panels.
- Find the non-linear response of CNT based composites subjected to air blast loading.

d. Technical details

- Nanocomposites are made by introducing a nanoparticles into a composite matrix
- Common nano particles are nanotubes, nanofibers, nanoclays, Graphene etc.
- Improvement in composite properties with the addition of small amount of nanoinclusions.
- The percentage weight of nanoparticles in the composite matrix is in the range of 0.1% to 5%
- One of the nanoinclusions receiving much attention from the past two decades are CNTs

Theme 2.

Key Issues/Concerns

(i) Areas of research need to be more focussed taking into account their strength and available infrastructures.

(ii) Specific component need to be identified for the fuel cell e.g. membrane, catalyst, electrode etc.

(iii) The Centre should identify specific components viz. membrane, catalyst, electrode etc. for their fuel Cell.

DEFINITION OF THE PROBLEM AND FOCUSED AREA

PEM Fuel Cell: Fuel cells are electrochemical devices that convert chemical energy directly into electrical energy. Fuel cells can provide power where no electric grid is available. They are quiet during operation unlike the loud, polluting electric generator. Portable fuel cells are used for emergency power back-up and in military applications. PEM fuel cells operate at low temperatures, have high power density, respond quickly and have fast start up capability. The PEM fuel cells can start within 30 seconds after the fuel supply to the cell. Thus they have a low start up time. At temperatures of the order 25^{o}C PEM fuel cells start within 15 seconds. At sub-freeze temperatures, such as -20^{o}C they require up to 45 seconds to start. Hence the PEM fuel cell system is considered to be one of the most promising future power vehicular power systems. We intend to develop PEM fuel cells with certain catalyst materials which were not used by NMRL with the motives of improving their performance and reducing the cost. The different catalysts and alloys which we propose to use are listed in our project proposal. In all these catalysts an attempt is made to reduce the quantity of platinum with a purpose of reducing the cost. We intend to achieve thin film coating of the catalyst on gas diffusion layer (i.e., the carbon paper or cloth) by using certain new methods. It is understood from literature that the thin films would give a better performance due to an increase in active surface area per unit weight of catalyst. The catalyst material consumption is reduced when the coating is applied as a thin film.

Catalyst Preparation: Platinum based catalysts are used in PEM fuel cells. Platinum is a major limiting factor in the overall cost. It is necessary to decrease the amount of precious metal as the electro-catalyst without sacrificing the performance of the fuel cell. Extensive research is carried out all over the world to produce PEM fuel cells commercially by reducing their cost of manufacture and by improving their reliability

during long hours of power production. The two major approaches to reducing Pt loading in the catalyst layer are by using alloys and carbon supports. Alloy catalysts have several benefits, such as specific activity improvement as well as enhancement of contaminant tolerance. Carbon supported catalysts help in improving catalyst utilization. Active research is on by the use of different combinations of platinum, other metals and various forms of carbon in catalyst preparation.

Membrane Electrode Assembly: The structure and composition of Membrane Electrode Assembly (MEA) are of vital importance. Recent impetus is on finding methods to improve the organization of the MEA by increasing the catalyst utilization and by improving the physical and electrochemical properties of the carbon support in the catalyst layer. The surface properties of the carbon supports have a significant effect on the degree of catalyst dispersion. Carbon materials with high surface area and good crystallinity provide a high dispersion of Pt nanoparticles, and also facilitate electron transfer, resulting in better device performance. The most popular carbon supports are Vulcan XC 72 and Black Pearls.

Flow field plates: The bipolar (or flow field) plates used in PEM fuel cell stacks are usually made of resin impregnated graphite. They separate individual cells in the stack, distribute fuel and oxidant in the cell, and help in humidifying the gases and keeping the cells cool. Different designs of flow fields are available in bipolar plates, such as parallel, serpentine and interdigitated. Research on these and some other flow fields is pursued by several investigators with objectives of minimizing the pressure drop and providing even distribution of mass transfer through carbon diffusion layer to the catalyst surface for reaction.

Our focused area of interest to improve the performance of PEM fuel Cell:

a) Different compositions of constituents in certain selected catalysts will be tried and tested. The following catalysts are considered for experimental study.

   Single metal catalyst : Pt/C

   Binary catalyst: Pt-Ru/C, Pt-Mo/C, Pt-Pd/C

Tertiary catalyst : Pt-Ru-Mo/C, Pt-Ru/W, Pt-Ru/Al_4 and

Non-noble catalysts: Fe and Co-N/C

Gas diffusion layer: Graphite paper wet - proofed with poly tetra fluoro ethylene.

Carbon support: Carbon nanomaterials, nanotubes and nanofibers for improved catalyst performance and durability.

b) Different catalyst loadings with supporting nano-materials will be made and the performances will be tested in fuel cells.

c) Since the power obtained by a single fuel cell is low, stacks are made with many fuel cells to obtain the required amount of power. To get the maximum utilization of fuel and Oxidant it is essential to improve the flow fields flow pattern. Experiments will be conducted by using plates of different types of flow fields such as parallel, serpentine and other special types. The effect of each type of flow field on performance of the fuel cell will be obtained.

d) The objective aimed in this project is to manufacture a fuel cell stack to deliver 1 kW of power supply and to maximize the performance of the fuel cell stack so as to obtain a current density up to 0.4 A/cm^2 at 0.75 voltage.

ACTION PLAN

The time-wise action plan is indicated below. The figures shown within brackets refer to time period in months.

- Procurement of equipments and materials like membranes, carbon cloth/paper, Teflon solution, Nafion solutions, flow field plates and other accessories for experimental study. (1-3)
- Released purchase orders for equipment except Fuel Cell Test Station.
- Catalyst loading and characterization (4-6)
- Preparation of 25 cm^2 MEA with different membranes, catalysts, catalyst loadings and gas diffusion layer thicknesses. (7–10)
- Experiments to be carried out on 25 cm^2 single cell with different MEAs, different flow field plates to achieve a performance of 0.5 A/cm^2 at 0.6V. (11-16)

- Develop a 100 cm^2 single PEM fuel cell with a performance of 0.40-0.45 A/cm^2 at 0.70 V. (17-20)
- Preparation of a stack for 1.0 KW with MEA area of 100 cm^2 and testing of its life time (21-23)
- To carry out thermal studies for 1.0 KW stack (24)

Aim:

- Test the 1.0 KW stack for AUV at NSTL, Visakhapatnam.