Format for uploading details of completed projects

1. **Project details:**

   a. *Title*: *Development of High Temperature Wear, Erosion and Corrosion Resistant Graphene Nanoplatelates Reinforced Plasma Sprayed Cr_3C_2-NiCr composite Coating for thermal power plant*

   b. *Institute*: *Indian Institute of Technology Patna*

2. **Aim / Objectives:**

The prime objective of the proposal is to enhance the high temperature performance and durability of the most commonly used steel grades (2.25Cr-1Mo steel ASTM-SA213-T22 (T22) in fire tube boilers, fluidized bed combustion boiler etc. This will be done by depositing plasma sprayed graphene nanoplatelates (GNP) (1-2 wt. %) reinforced Cr_3C_2-25(80N20Cr) composite coating over the steel substrate (2.25Cr-1Mo steel ASTM-SA213-T22 (T22). This synthesized coating will be evaluated for its microstructural aspects, mechanical properties, adhesion strength, high-temperature (~800ºC) wear, erosion and corrosion resistance. The above-mentioned objective will be executed by meeting several sub-objectives, which are as follows:

(a) To achieve the uniform dispersion of GNPs in the Cr_3C_2-NiCr matrix by the spray drying technique. Three different spray dried powder i.e. Cr_3C_2-NiCr, Cr_3C_2-NiCr -1 wt. % GNP, Cr_3C_2-NiCr - 2 wt.% GNP will be aimed for depositing the coating.

(b) Optimization of the plasma process parameters i.e. plasma power, primary gas flow rate, feed rate and stand-off distance and depositing all three different composition of coatings at the optimized process parameters.

(c) Investigation of porosity, retention of GNPs in the coating by Raman spectroscopy, fracture surface to confirm the uniform dispersion of GNPs, and the phase characterization of coating.

(d) Evaluation of mechanical properties i.e. hardness, elastic modulus, fracture toughness and adhesion strength of coating using the scratch test.

(e) Determination of thermal conductivity, high temperature (at ~800ºC) wear resistance and coefficient of friction of the coatings using in-situ high-temperature ball-on-disc tribometer.

(f) Examining the erosion test of the developed coating using air jet erosion tester as per the ASTM G 76 standard.

(g) Investigation of high-temperature (at ~800ºC) corrosion resistance of coating in presence of most corrosive salt i.e. Na_2SO_4-V_2O_5.

3. Executive Summary (*One page*):

This project focused on the development of advanced protective coatings to enhance the durability and performance of critical components used in coal-fired thermal power plants. Boiler tubes and related components operating at elevated temperatures are subjected to severe degradation due to wear, erosion, and hot corrosion, which leads to tube thinning, frequent maintenance, and reduced plant efficiency. Conventional Cr_3C_2-NiCr coatings are commonly used for protection. However, their performance is limited due to inherent porosity, crack formation, and penetration of corrosive salts during prolonged service. To address these challenges, the present study investigated the reinforcement of Cr_3C_2-NiCr coatings with graphene nanoplatelets (GNPs), which possess exceptional mechanical strength, thermal conductivity, and chemical stability.

In this work, graphene nanoplatelet reinforced Cr_3C_2-NiCr composite powders were prepared and deposited on boiler-grade steel (ASTM SA213-T22) using plasma spray technology. Spray drying was employed to achieve uniform dispersion of graphene within the matrix. Three coating compositions were developed: conventional Cr_3C_2-NiCr coating, 1 wt.% GNP reinforced coating, and 2 wt.% GNP reinforced coating. Plasma spraying parameters were optimized to obtain dense coatings with good adhesion and minimal porosity. Detailed microstructural and phase characterization was carried out using FESEM, XRD, Raman spectroscopy, and HR-TEM.

The developed coatings were evaluated for mechanical properties, thermal conductivity, high-temperature wear, erosion, and hot corrosion resistance. The results demonstrated significant improvements in coating performance with the addition of graphene nanoplatelets. The hardness of the coating increased from approximately 766 HV for the conventional coating to about 1306 HV for the 2 wt.% GNP reinforced coating, while fracture toughness improved by about 60%. The reinforced coatings also exhibited higher adhesion strength and improved thermal conductivity.

Tribological studies revealed a substantial improvement in wear resistance, with the wear rate reduced by nearly 55% and the coefficient of friction decreasing from about 0.80 to approximately 0.31 with graphene reinforcement. The coatings also showed improved erosion resistance with significantly lower material loss during air-jet erosion tests. Hot corrosion tests conducted in a Na_2SO_4-V_2O_5 molten salt environment at 800 °C demonstrated excellent corrosion resistance of the developed coatings. After 5 days of exposure, the 2 wt.% GNP reinforced coating exhibited a mass gain of only ~0.51 mg/cm^2 compared to ~4.6 mg/cm^2 for the bare steel substrate, indicating strong resistance to high-temperature corrosive environments.

Overall, the developed graphene reinforced Cr_3C_2-NiCr coatings show strong potential for improving the reliability and service life of boiler components in thermal power plants. The technology provides a promising surface engineering solution to reduce maintenance costs, enhance plant efficiency, and extend the operational lifespan of high-temperature components in the power generation sector.

4. Scope for further work:

Further studies can focus on the investigation of anti-fouling and anti-slagging properties of GNP reinforced Cr_3C_2-NiCr coatings under molten ash and high-temperature operating conditions typical of coal-fired boilers. Studies on thermal shock resistance may also be carried out to further understand the durability of the developed coatings under practical operating conditions. In addition, long-term field trials on boiler components such as superheater and water-wall tubes may be conducted to evaluate the coating performance under actual plant environments.

5. Benefits visualized:

The developed GNP reinforced Cr_3C_2-NiCr coatings demonstrated significant improvement in hardness, wear resistance, erosion resistance, and hot corrosion resistance at high temperatures. These improvements can enhance the service life of critical boiler components such as tubes and superheaters in coal-fired thermal power plants. The coating technology can help reduce component degradation, maintenance frequency, and plant downtime, thereby improving the overall reliability and efficiency of power plant operations.