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INDIA'S NATIONAL A-USC MISSION - PLAN AND PROGRESS

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ABSTRACT

India's current installed power generating capacity is about 225,000 MW, of which about 59% is coal based. It is projected that India would require an installed capacity of over 800,000 MW by 2032. Coal is likely to remain the predominant source of energy in India till the middle of the century. India is also committed to reducing the CO_2 emission intensity of its economy and has drawn up a National Action Plan for Climate Change, which, inter alia, lays emphasis on the deployment of clean coal technologies. With this backdrop, a National Mission for the Development of Advanced Ultra Supercritical Technology has been initiated. The Mission objectives include development of advanced high temperature materials, manufacturing technologies and design of equipment. A corrosion test loop in an existing plant is also proposed. Based on the technology developed, an 800 MW Demonstration A-USC plant will be established. Steam parameters of 310 kg/cm^2, 710 °C / 720 °C have been selected. Work on selection of materials, manufacture of tubes, welding trials and design of components has been initiated. The paper gives details of India's A-USC program and the progress achieved.

INTRODUCTION

India’s current power generating capacity is about 225,000 MW, which is predominantly coal based. About 59% of generation capacity is coal fired, 18% hydro, 2% nuclear, 9% natural gas and 12% renewables. Although the installed capacity has been increasing rapidly in the last few years, there is an overall shortage of electricity in relation to the demand. With expected economic growth of over 6% per annum in the long term, the demand for electric power is likely to shoot up at a much faster rate. According to the Integrated Energy Policy adopted by the Government of India in 2008, the demand for electric power is projected to be about 800,000 MW in 2032. Coal is likely to remain the major source of energy for power generation.

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India has also adopted a National Action Plan for Climate Change (NAPCC) which mandates a reduction in the CO_2 intensity of the Indian economy. This implies that CO_2 emissions resulting from coal combustion in power plants have to be substantially lowered. The bulk of India’s utility power generating capacity comprises pulverized coal fired subcritical thermal power plants of 600 MW, 500 MW, 250 MW and 210/ 200 MW ratings, in addition to older plants of lower ratings. In recent years, supercritical power plants of 660 MW and 800 MW have been established and are in operation. The steam parameters of the supercritical plants being set up currently in India are 247 kg/cm^2, 565 °C/ 593 °C. Future capacity additions will be mainly in the supercritical range. Ultra supercritical plants, with steam temperatures over 600 °C, are also on the anvil.

In the medium to long term, however, India needs to adopt clean coal technologies that promise higher efficiencies, reduced coal consumption per unit of power produced and lower emissions of CO_2 and pollutants such as SOx, NOx, etc. Advanced Ultra Supercritical (A-USC) is one of the most promising of such clean coal technologies, currently under development in several countries. Among major economies, the drivers for adopting A-USC technology are perhaps the strongest in India.

With the above backdrop, the Government of India has initiated a National Mission for Development of Clean Coal (Carbon) Technologies, under which there is a Sub-Mission for the Development of Advanced Ultra Supercritical Technologies for Thermal Power Plants. The National Mission is being executed under the overall leadership of the Principal Scientific Adviser (PSA) to the Government of India. The Mission has a special focus on achieving a high degree of self reliance in technology apart from economic and low cost production through indigenization.

The objective of India's National Mission for the Development of Advanced Ultra Supercritical Technology for Thermal Power Plants is to develop all the technologies required for an A-USC plant and to design, manufacture and establish an 800 MW A-USC Demonstration Power Plant. After successful development and demonstration, there is enormous potential to set up a large number of coal fired power plants based on the A-USC technology developed.

The development work is being executed by a consortium of three organisations: Bharat Heavy Electricals Limited (BHEL), the leading power equipment manufacturer of India; Indira Gandhi Centre for Atomic Research (IGCAR), a premier R&D institution specializing in the development of high temperature materials; and NTPC Limited (NTPC), India's largest power generation utility. Together, the three organizations have the capabilities required to develop and establish an A-USC power plant. In addition, wherever necessary, the help of R&D institutions and other organizations is sought.

The time frame for the development is seven years from the date of approval of the project by the Government of India - comprising 2½ years for development and 4½ years for setting up the demonstration plant. A comprehensive and detailed roadmap of the development activities across the entire spectrum, covering materials selection and development, manufacturing technologies, corrosion test loop, equipment design, thermal cycle design and overall plant design, has been prepared. Well before the formal start of the R&D project, several proactive R&D initiatives have been taken to gain a head start in critical areas of technology and accelerate the pace of development work and significant progress has been achieved.

DEVELOPMENT AREAS TAKEN UP AND PROGRESS ACHIEVED

The following sections give details of the major developmental activities that have been completed or are in progress.

Materials Selection and Development

The materials selected for use in the high temperature zones of the boiler are SS 304HCu and Alloy 617M. The selection is based on the following criteria:

- The materials are included in the ASME code/ code cases
- Fairly good commercial availability
- Experience of use in various applications
- Availability of material properties for design

The specific composition of the materials to be used in the Indian program has been selected to lie in a narrow zone within the overall material specifications of ASME, in order to achieve the desired properties and reduce variability.

Development of Processing Technologies

In order to gain experience in processing and using these materials, forged ingots of SS 304HCu and Alloy 617M, starting from the basic ingredients, have been manufactured on a pilot scale. The materials were characterized at each stage of the production process and the process was optimized to achieve the specifications and the desired properties. The manufacturing process has been stabilized and is capable of being scaled up.

Boiler tubes of SS 304HCu and Alloy 617M have also been manufactured on a pilot scale, starting from the forged ingots developed earlier. A detailed stage wise characterisation approach was adopted for the development of tubes of SS 304HCu and Alloy 617M in order to ensure that the process of manufacture was optimized to obtain the specified characteristics. This approach helped to overcome problems faced during the initial trials. The series of heat treatments and characterizations at various stages of tube manufacture helped in understanding the materials behavior towards mechanical working and heat treatment. Based on these metallurgical inputs, the process flow sheets were evolved and optimized.

Materials Testing

A comprehensive materials testing program covering long term creep tests and hot corrosion for the parent metal, tubes and welded joints, both similar and dis-similar, has been put in place. The tests being carried out are briefly described below:

Creep Tests

Long term creep tests on Alloy 617M at 650, 700, 750, 800 °C, with stress 100 MPa to 360 MPa, and test durations ranging from 100 hours to 10,000 hours are in progress. Creep tests on Alloy 617M welded with Alloy 617 filler material are being carried out at 650, 700, 750, 800 °C, with stress 100 MPa to 360 MPa, and test durations ranging from 100 hours to 1200 hours. Tensile and hot tensile (600-800 °C) impact tests are also being carried out.

Creep tests on Super 304HCu tubes welded with Alloy 617M and Alloy 625 filler material at 600, 700, 750 °C, and stress 125 MPa to 275 MPa, with test durations ranging from 100 hours to 1,500 hours are in progress. Creep tests on parent metal at 600, 650, 700°C, with stress 100 MPa to 360 MPa, and test durations ranging from 100 hours to 2,000 hours are being carried out.

Creep tests are also being carried out on dissimilar welds of Alloy 617M with SS 304HCu using Alloy 617 filler material welds at 600, 650 and 700 °C, and stress 180 MPa to 280 MPa, with test durations ranging from 100 hours to 3,000 hours.

Hot Corrosion Tests

Hot corrosion tests in a simulated flue gas environment have been carried out on Alloy 617M and SS 304HCu tubes in the laboratory at 600, 700, 800 °C for up to 1000 hours duration.

Hot Corrosion Test Loop

The materials chosen have been extensively tested elsewhere for hot corrosion. To check for hot corrosion with firing of Indian coal, a corrosion test loop is planned to be installed at an existing power plant in India.

The test loop comprises tubes of T91, SS 304HCu and Alloy 617M. The steam flow is taken from the main steam line at a temperature of about 540 °C. In the test loop, the steam is heated to a temperature of 720 °C. After the test loop, the steam pressure is reduced to hot reheat pressure in a multistage steam regulation valve, which regulates the steam quantity to achieve the steam temperature of 720°. The steam from the regulating valve is mixed in a mixing piece with relatively cold steam at about 390 °C, taken from the Low Temperature Superheater (LTSH) outlet link, to get steam at a temperature of approximately 540 °C, in order to return the steam flow into the hot reheat pipeline. The test loop is likely to be installed in 2014 and is planned to be in operation for at least two years.

Manufacturing Technologies

To gain hands-on experience in manufacturing with high temperature materials, trials for all the operations required during the manufacture of boilers, steam turbines and other power plant equipment, are being carried out. Some of these are briefly mentioned below.

Welding of Tubes and Plates

Welding was carried out on tubes and plates using various processes like Gas Tungsten Arc Welding (GTAW), Hot Wire GTAW, semi-automated GTAW on Alloy 617M. The trials were successful and it was possible to get consistent quality of the butt welds in all the cases. The process parameters have been finalized for the welding with the available materials. Some dissimilar welding combinations were also tried out and the outcome was satisfactory. Figure 1 shows a sample tube to tube butt weld joint.

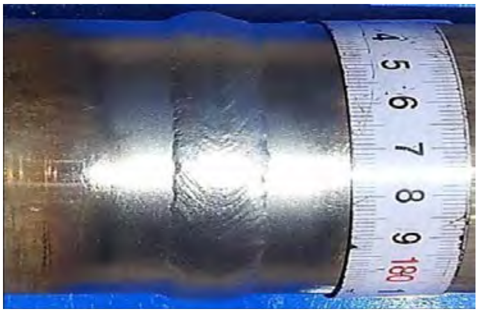

Figure 1: Tube to Tube Butt Weld with Hot Wire GTAW

Forming

Tube bending is another area of interest, especially for the fabrication of high temperature superheater coils. The forming trials on the tubes involved bending the tubes to different radii. The bends gave good results, with a controlled level of ovality and thinning. There were no cracks or any significant indications on the entire bend. The bending trials were conducted on a Pine 150 CNC tube bending machine. Figure 2 shows Alloy 617M tubes cold bent to R/D 1,2 and 3.

Figure 2: Alloy 617M Tubes Cold Bent to R/D 1, 2 and 3

Studies on Critical Aspects of Technology

Studies on various critical aspects of the technology have been initiated. These include the following:

Thick Walled Superheater Header

Manufacture of thick walled headers, such as superheater headers, involves challenges in manufacturing, especially in welding, as failures in welding of thick sections have been reported in the literature. It is, therefore, important to study in detail and optimize the welding technologies for thick walled headers.

A mock up superheater header made of Alloy 617M is being fabricated. The header will be similar to the final superheater header assembly in terms of diameter and thickness but of shorter length. Several developmental tasks will be undertaken, including development of end covers, establishment of circumferential seam welding procedures between end cover and pipe, establishment of fillet welding process for stub to pipe welding and establishment of advanced ultrasonic testing techniques for the detection of discontinuities in butt and fillet welds.

HP Bypass Valve

Development of valves to suit the pressures and temperatures encountered in A-USC boilers has been identified as a critical area, due to the complexity of valve design. The High Pressure Bypass valve for high pressure steam turbine is one such valve, which is subjected to A-USC steam parameters at the inlet to the HP turbine. The design and manufacture of an HP Bypass valve for A-USC parameters is therefore being taken up. Several developmental tasks will be undertaken, including development of materials for body and other components, stem, hard facing, fasteners, and packings of the valve, establishment of body spherical and other machining, stem milling, deep hole drilling, destructive and non-destructive testing procedures, establishment of body-nozzle welding, seat hard facing, body assembly-seat welding procedures, and establishment of advanced ultrasonic techniques for detection of discontinuities in welds.

Dis-similar Weld Joint of Turbine Rotor

Development of steam turbine rotor forgings of advanced high temperature nickel base materials is an important area to be addressed while considering the 710°C / 720°C steam cycle. Considering that a monolithic rotor of Alloy 617M would be expensive, a welded rotor is being considered. The rotor would have an Alloy 617M forging for the high temperature portion of the HP/IP rotor, with a dis-similar metal weld joint between the cylindrical forgings of Alloy 617M and 10% Cr steel. Operating experience on dis-similar metal weld joints is not very satisfactory. The joining technique therefore needs to be developed and tested thoroughly. To address the main issues related to welded turbine rotor manufacture, laboratory scale studies to demonstrate the weldability of large size forgings of Alloy 617M to 10% Cr steel and optimization of weld procedures and welding consumables, while maintaining the properties of the forgings, are being undertaken.

Technical specifications for the Alloy 617M rotor forgings suitable for use in the 800 MW A-USC plant, developing the supply base for manufacture of scaled down Alloy 617M cylindrical forgings, procedure development for narrow-gap tungsten inert gas (NG-TIG) welding of dissimilar metal weld joints, finalizing the associated non-destructive testing methodologies, and characterization of the short-term and long-term mechanical properties of the Alloy 617M/ 10%Cr steel joint are some of the outcomes of the work.

Blade Profiles for HP Turbine

Design of steam flow path and blade profiles for A-USC parameters are important aspects of steam turbine design as blades using advanced high temperature alloys are being designed for the first time. A project to develop the blade profiles for A-USC parameters is under way and is nearing completion. Trial manufacture of steam turbine blades with Alloy 617M is also being undertaken as part of the project, to ensure that the manufactured blades satisfy all the specifications. The profile design is also being verified through Computational Fluid Dynamic (CFD) analysis and also through physical cascade testing in the laboratory.

Thermal Cycle

The target efficiency of the A-USC plant has been set as 46% on HHV basis, under Indian environmental conditions (cooling water temperature of 33 °C), and with Indian coal firing. This gives a reduction in CO_2 emissions of about 11% compared with a supercritical plant of the same rating. The thermal cycle of the plant has been designed after a series of techno economic studies to achieve the most economical and efficient configuration.

Conceptual Design of Boiler

Several techno-economic studies were carried out to decide the optimum configuration of the boiler. A two pass, single reheat boiler configuration with tilting tangential firing has been selected.

Tubes of SS304HCu and Alloy 617M are used in the high temperature zones in the superheater and reheater. Some new features to maximize the utilization of heat are also included.

CONCLUSION

A National Mission for the development of A-USC technology for thermal power plants has been initiated by the Government of India, with BHEL, IGCAR and NTPC constituting the core team. The objective is to establish an 800 MW A-USC demonstration power plant in a time frame of seven years. A comprehensive plan of action has been prepared for developing the entire range of technologies necessary. Several proactive initiatives have been taken to gain a lead time and accelerate the work before the formal start of the project. There is a strong focus on achieving self reliance in technology and low cost manufacturing through indigenization.

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