International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 03, March-2015

Indian AUSC Steam Turbine Program – Current Status and Future Program

N. C. Bhatt, Maneesh Batrani, Jatinder Mohan, V. Gopalakrishnan & M. K. Verma
Steam Turbine Engineering, Bharat Heavy Electricals Limited,
Haridwar – 249403, India

***Abstract* – Even after 68 years of independence electricity generation in India is lagging behind the increasing demand of power from domestic as well as industry sector. This gap between demand and supply of power alongside continual pressure to reduce carbon emissions has pushed India to plan for design and development of power plant with ever higher efficiency. Efficient and clean power is the 'Need of Hour' across the globe. In this regard power utilities across the world are trying to achieve Advanced Ultra Supercritical (AUSC) Parameters in their fossil power plants.**

Raising steam parameters for improving the efficiency of a fossil fueled power plant is a traditional method used by power plant designers. But, elevating steam parameters in a steam turbine is limited by the capability of materials to sustain high temperature and pressure. High Chrome steels currently used in steam turbines can be used for operation with steam parameters in supercritical/Ultra supercritical (USC) range (up to 600 deg C). But, these steels exhaust their capability when temperature is further increased to the range of AUSC parameters i.e. more than 700 deg C. This has led to consider the use of Nickel based alloys in AUSC steam turbines. Hence, Nickel based alloys, having ability to sustain temperatures above 700 deg C, have been considered for replacing high Chrome steels for AUSC steam turbine applications by most of such programs worldwide.

Although these Nickel alloys are suitable for the range of operating temperatures of AUSC application, their high cost implications require much more optimally designed components in comparison to High Chrome Steels. Best efforts are put to make the design of components slim and smart to keep the cost under control and offer a techno-economic design of steam turbine. This paper brings out the current status and developmental roadmap of Indian AUSC steam turbine project.

Keywords: Advanced Ultra Supercritical, AUSC, steam turbine, Alloy617, Ni-based alloys.

I. INTRODUCTION

Many parts of rural India are still deprived of electricity. Need for electrification of all the areas, improvement in lifestyle and increasing industrialization are raising the electricity demand in India steadily and it is expected to increase more sharply in future. India's current installed power generating capacity is about 225,000 MW, of which about 59% is coal based. 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.

In India, fossil power is expected to remain the primary source of electricity generation for the next few decades. Emission from fossil fueled thermal power plants is a major source of global warming and CO_2 emissions in atmosphere. To contribute in the global efforts to limit global warming, India is steadily shifting from subcritical power plants to supercritical / ultra supercritical, which are more efficient in nature thereby assisting the goal of reduced carbon emissions. Author's organization, which is a Public Sector Undertaking (PSU), achieved a milestone with successful installation and commissioning of its first 660 MW supercritical set of Barh Thermal Power Project in year 2013.

As a responsible global partner committed to a green environment for future generations, India has embarked upon the development of AUSC power plant to create a highly efficient and clean energy source for electricity generation and to create a competitive indigenous technology catering the ever rising power demand of the country.

II. INDIAN AUSC PROGRAM

To achieve the goal of reduction in global warming, a national mission for the development of AUSC technology has been initiated by Government of India (GoI).The Mission objectives include development of advanced high temperature materials, manufacturing technology and design of equipment. The final objective is to successfully install and operate a reliable 800 MW demonstration AUSC power plant as early as possible. A significant work has already been done in this direction.

A. *Current status of Indian AUSC steam turbine program*

a. *Material selection*

The utility of materials is limited by their capacity to sustain elevated temperatures without undergoing loss of strength over prolonged exposure. Higher the temperature of operation, lesser is the resistance of material to creep and relaxation. 9-10% Chrome Steels currently used in supercritical/USC steam turbines exhaust their load carrying capability at around 600 deg C. The steam parameters of Indian AUSC program are 310 bar/ 710 deg C/ 720 deg C make these high Chrome Steels unsuitable for these conditions. Hence, Super 304 H and nickel based alloys Alloy617 (M) & Alloy625 are identified for operating at these temperatures for boiler and turbine components. These materials are developed and tested extensively for characterization of material properties. In the initial phase of project focus was mainly on the boiler components and after a certain level of achievement, the turbine components, which are also subjected to very high temperature and pressure, are currently under scanner.

Alloy 617 (M) is identified for forged parts (rotors) of steam turbines, while Alloy 625 is to be used in castings of turbines and valves. The selection is based primarily on the basis of their application range of temperatures, their characterization in the ASME code/ code cases, fairly good commercial availability, experience of use in various applications and 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.

b. *Approach for mechanical design of turbine components*

Design of components for high temperature involves lot of complexities and repercussion of failures could be severe and can even result in loss of life. Materials that are used in creep zone need long term expensive material testing for generating reliable material properties data for design. At the same time, design of many components needs to satisfy requirements of certain regulatory bodies set-up by government agencies. Such requirements have led the generation of different design codes/standards. ASME boiler and pressure vessel code, French nuclear code RCC-MR and British PD5500 are some of the codes for high temperature design that are having good reputation in engineering community. Most of these codes are component specific and mainly deal with design of pressure vessel, pipes, power boilers, nuclear components etc. and are not directly applicable for steam turbine components.

For Indigenous AUSC application the first step taken towards the design of steam turbine components was identification of failure modes. Major components subjected to high temperature in TG Island can be broadly divided in two main categories. First are pressure retaining components and second are rotating components. Although none of the above mentioned codes are directly applicable for steam turbine components but inspiration was taken from them especially in terms of failure modes. All the failure modes applicable for a pressure vessel operating in creep range are equally applicable for steam turbine valves and casings. Major failure modes identified for the preliminary design of AUSC steam turbine components are:

- Ductile failure
- Brittle failure
- Creep rupture
- Detrimental deformation due to creep
- Fatigue failure due to variable load
- Creep-fatigue interaction
- Failure due to short term load excursion
- Large creep deformation due to long term load excursion
- Excessive deformation due to Ratcheting
- Loss of function due to large deformation
- Environment Conditional failure
- Rotor-dynamics related issues (for rotors)

Next step was deciding the design loads. All the expected loads and load combinations were discussed in length, categorized based on probability of occurrence and factor of safety were assigned to them. As rotors are subjected to dynamic loadings, addition failure modes and different factor of safety compared to casings were planned for them. Magnitude of loads, their combinations and design factors were then finalized. All these findings were presented to the respective review committee and cleared by them.

"Design by Analysis (DBA)" procedure of ASME-BPVC is a generalized way of designing any component and it addresses most of the identified failure modes in components. This procedure also elaborates the procedure of using commercially available finite element software for mechanical design of components. With the help of DBA philosophy, stress field obtained from FE stress analysis under a given loading and boundary conditions can be categorized, linearized and interpreted. Hence, Design by analysis philosophy is adopted as mechanical design procedure for turbine components.

Due to dynamic interface among components (rotor and casing), functional failure modes are also very important. Any mismatch or contact between moving parts of rotor and stationary parts of casings could lead to serious damage to turbine. Quantification of clearances need better estimation of field variables; hence it needs a relatively involved analysis and will be done in the next level.

Decades old design of subcritical sets is based on very basic methods compared to advance methods known today. Those methods, which were mainly classical calculations based, still hold good, but can be supplemented by advanced methods involving inelastic analysis, strong analysis capabilities of FE software, damage analysis techniques and integrity/life assessment methods. All the above mentioned procedures together not only improve the quality and accuracy of assessment but also may lead to lesser weight of components due to accurate simulation of stress field under given load and boundary conditions. It is very much required to implement these advanced and reliable analytical techniques due to more severe loading conditions and higher cost involved.

Advanced commercial codes available in the market are used in the design process for Heat balance diagram, turbine blade flow path, finite element analysis, rotor-dynamics analysis, CFD analysis etc. Self-written programming codes are also generated as per requirements. Programs and procedure were validated rigorously.

B. *Future plans*

Future plans of development are decided keeping in mind that the optimization of various techno-economical parameters is only possible if plant can be designed to give high availability and good results for the desired service period.

a. *Realization of welded configurations*

To reduce the cost of turbine components, use of Ni-based alloys is planned only in the zones of high temperatures which are beyond the capability of currently used high chrome steels. For this purpose, Indian AUSC consortium is planning for a dissimilar weld configuration (Ni-based alloys to chrome steels) of rotors and casings. This adds the task of design and integrity assessment of welds also. Till now weld design realization is in pilot study mode. Research is going on at different labs of consortium members for the same. Welding trials on dissimilar metal thick components will be conducted by the end of this year.

b. *Testing of scaled rotor*

The component for which design engineers are having main concerns is HP and IP rotors of steam turbine. To increase the confidence in development procedures, there are plans to test a full scale diameter rotor of Alloy 617 at elevated temperature. To simulate the damage during design life of rotor in short term testing, test temperature will be increased accordingly. Damage due to cycling will also be simulated in the same test in accelerated manner.

c. *Indigenization of material*

The cost of an AUSC power plant will be tremendously high in comparison to current sets because of the use of nickel based alloys. To meet the time deadline of first demonstrative project, material will be procured from international market. Later to reduce the material cost during commercialization, it is planned to indigenize advanced high temperature materials.

d. *Others*

Structural integrity aspects of these plants will be a major subject of discussion in the coming time among scientific and engineering community. Basic life assessment analyses will be performed during the design phase itself.

Currently studies are going on optimizing startup curves, reduction of machining time of Ni-based alloys, allowable level of residual stresses in Ni-based alloys, the effect of multiaxiality in design, ratcheting assessment, improved NDT methods for Ni-based alloys, repair of defects etc.

III. DEVELOPMENTAL ROADMAP

The need of AUSC power plant in India arises from reasons that are not similar to the remaining world. Higher rating more efficient fossil fuel power plants are needed as the country is still having power shortage. Hence schedules of Indian AUSC program are very aggressive. A demonstration plant is planned in the beginning of next decade. Construction of a safe and reliable AUSC power plant with such an aggressive schedule requires a lot of efforts. To achieve this, all the material selected are having carefully controlled chemistry in the broader band of chemical composition of already existing materials. Most of the material properties are coded in standards for these materials and hence relatively less material testing is required. To gain confidence in the designed components, rigorous component level testing is planned. Extensive use of advanced finite element analysis practices for simulation of different conditions during component testing is envisaged to gain confidence in design. A demonstration plant will come in existence first and all the learning from it will be used during commercialization phase.

IV. SUMMARY

Fossil fuel is the main source of electricity generation in India and to cater the power requirement of country in most efficient way, going for the AUSC technology is must. Indian AUSC consortium has decided the goals of program based on the requirements specific to the country, which are different from the rest of the world. Time, money and manpower are devoted to achieve a safe, reliable and state-of-art power plant with ever high efficiency. Use of advance computation/simulation methods, rigorous component testing, complete indigenization of material and developmental processes are the key factors to success.

India's existing scientific, engineering and manufacturing potential is being streamlined for a completely indigenous state-of-art AUSC power plant. The program is moving steadily towards its objectives and consortium is committed to demonstrate an AUSC power plant in projected time.

REFERENCES

- Alok Mathur, O.P. Bhutani, Dr. T. Jayakumar, D.K. Dubey, S.C. Chetal "India's National A-Usc Mission - Plan And Progress".
- ASME Boiler and Pressure Vessel Code.