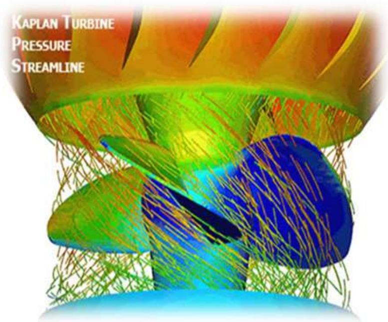
National Workshop on Renovation, Modernization, Uprating & Life Extension of Hydro Power Plants – Diverse Issues & Handling Strategies

Cutting Edge Technologies for Renovation, Modernization and Uprating of Old Hydro Power Stations



16th Dec 2016

CONTENTS

BHARAT HEAVY ELECTRICALS LTD

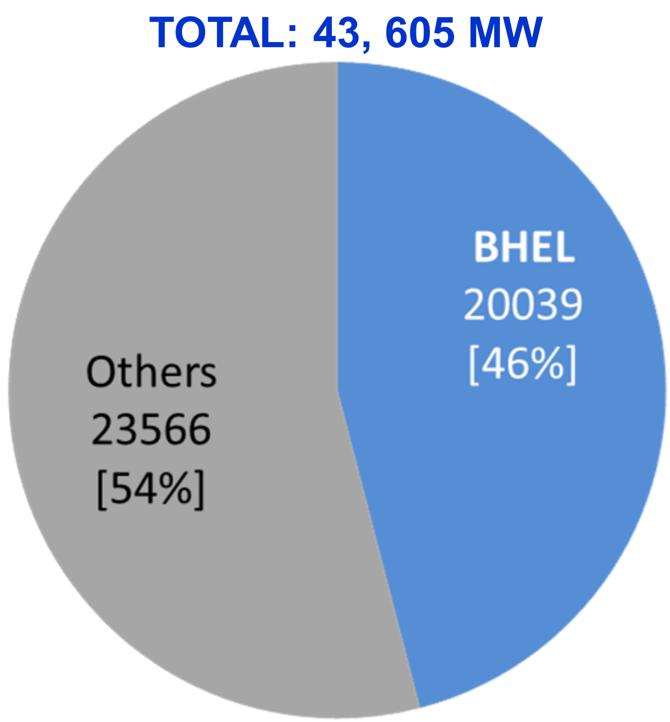
BHEL: JOURNEY TILL DATE

- FIRST Hydro Generating set -- 3x33 MW Obra HEP UP, 1970.
- More than 50 years proven Expertise, Technology & Capability to manufacture, supply and commission.
- Supplied and commissioned 503 + sets having > 23100 MW including export of 49 sets totaling > 2730 MW.
- Augmented the annual manufacturing capacity for Hydro Sets to 2500 MW.
- State of art turbine model testing laboratory.

INSTALLED CAPACITY - HYDRO

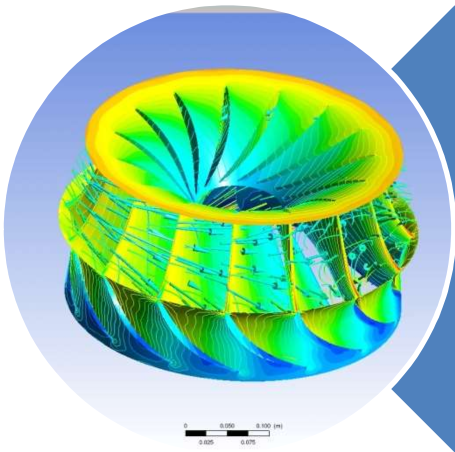
MW
As on 31.03.16

- India has the potential of about 150 GW hydro power
- Approx. 43 GW (upto 31.03.16) has already been installed



R&M Business

Number of 454 Units totaling to 20,039 MW out of which more than 30% of the installed capacity are more than 30 years old .



RMU & LE of Hydro Power Plants

HYDRO POWER PLANT RMU & LE – WHY?

- Life extension & performance restoration
- Plant safety improvement
- Reliability and availability increase
- Operating cost reduction
- Modified hydrology conditions
- Performance improvement
- Uprating

RMU & LE PROJECTS: OBJECTIVES

To cater to change in operating parameters and up-gradation to new technology

To avoid unplanned outage & to replace damaged part due to silt erosion and cavitation

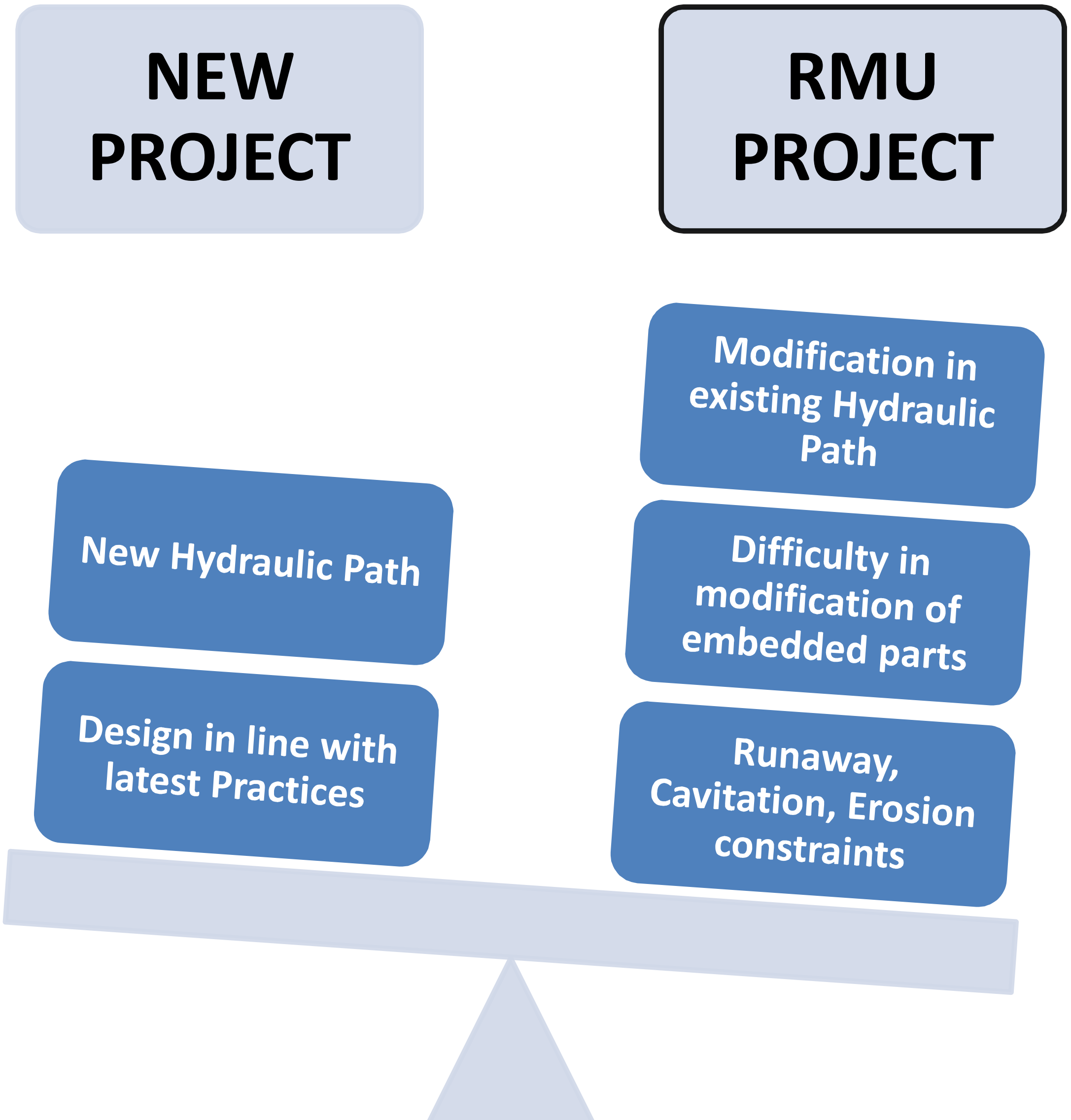
To reduce maintenance and operating cost.

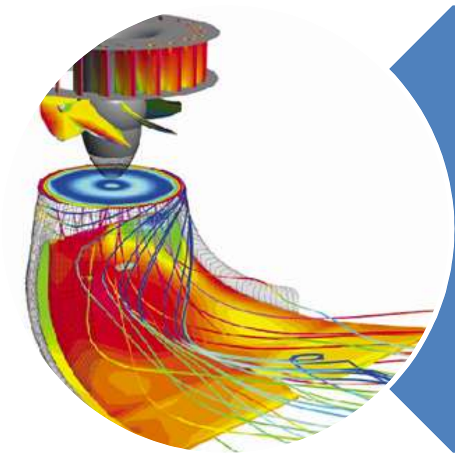
To solve the existing problems(if any) such as cavitation.

To ensure greater availability of Power Houses especially during peaking hours

To enhance the life of power plant and performance restoration/improvement.

RMU & LE: CHALLENGES





RMU & LE Methodology

RMU & LE: METHODOLOGY

Performance Improvement

- Efficient hydraulic passage
- Design for minimizing losses at micro level

Capacity Uprating

- High discharging runner to cater high discharge
- Utilization of high available head

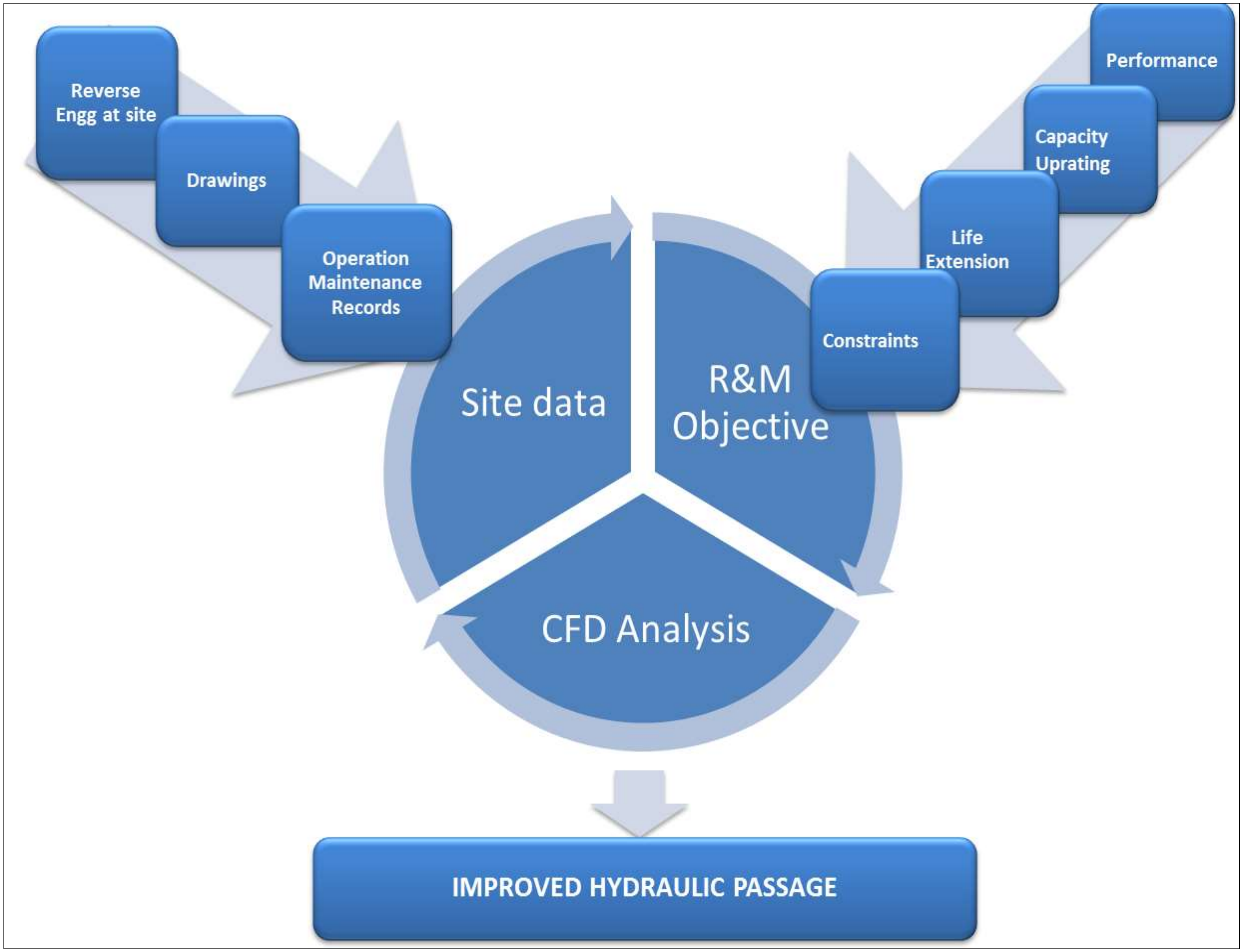
Life Extension

- Replacement of worn out parts
- Innovative design retarding damage due to silt erosion

Environmental Compliance

- Oil leakage to be minimized
- Efficient tapping of natural resource

RMU & LE: METHODOLOGY



RANGE OF SOLUTIONS IN R&M

TURBINES

- Model Testing/CFD Analysis
- Restoring name plate rating
- Uprating with upgraded Runner profiles
- HVOF Coating/ Plasma Coating on underwater parts

GOVERNORS

- High Pressure/ Microprocessor based Digital Governors
- RGMO / FGMO features

GENERATORS

- Re-winding with Class-F insulation
- PTFE pads for Thrust bearings

RANGE OF SOLUTIONS IN R&M

C&I and PROTECTION SYSTEMS

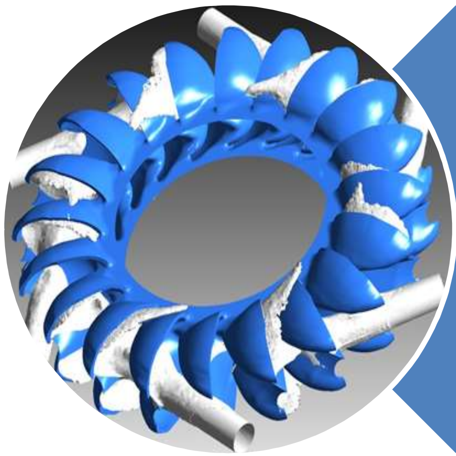
- SCADA/ DCS System
- Smart/Digital Instruments, High speed relays etc.

BOPs

- Retrofitting

ONLINE MONITORING DEVICES

- Vibration monitoring
- Measurement of silt content in water
- Air Gap Monitoring system
- Partial Discharge Measurement system



Advanced Technological Tools for RMU

IMPACT OF MODERN TECHNOLOGY ON RMU&LE PROJECTS

The behavior of each component of a turbine can be studied in a better way & fine tuned to get better performance parameters and higher Efficiency.

Investigate into different facets of the problem and explore possible solutions in a faster & inexpensive way to improve the reliability of the Hydro Product

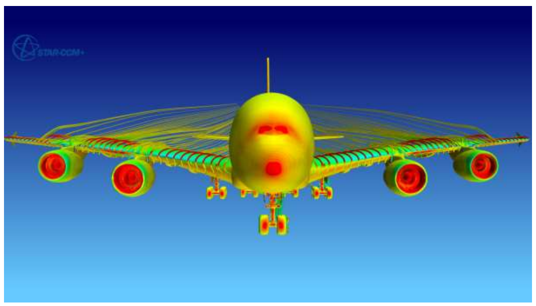
Hydro Turbine is capable of operating in a wider operating range by virtue of smarter design.

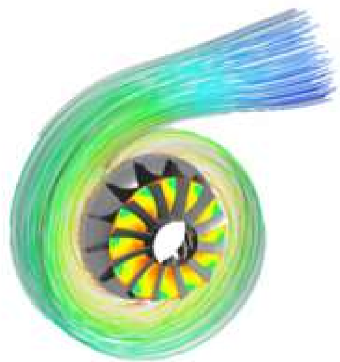
Lesser downtime of machine since the micro phenomenon of cavitation and erosion can be studied & mitigated at the design stage

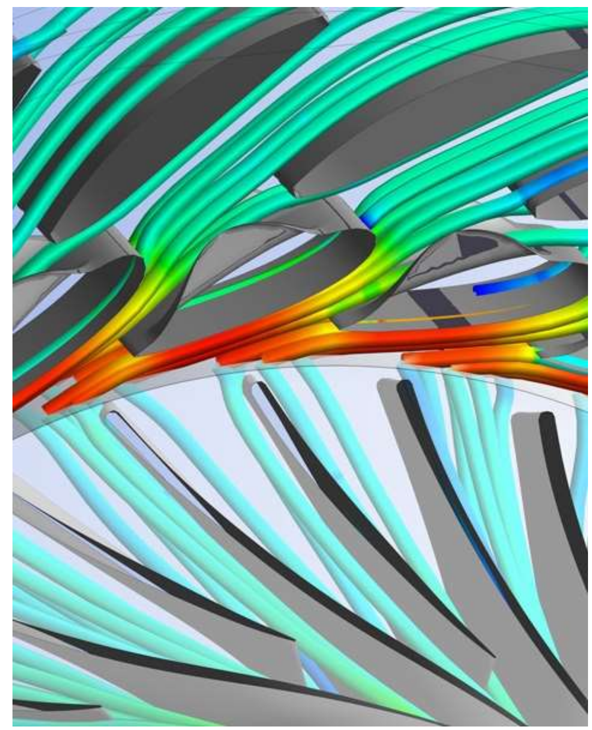
Product cycle time is reduced significantly

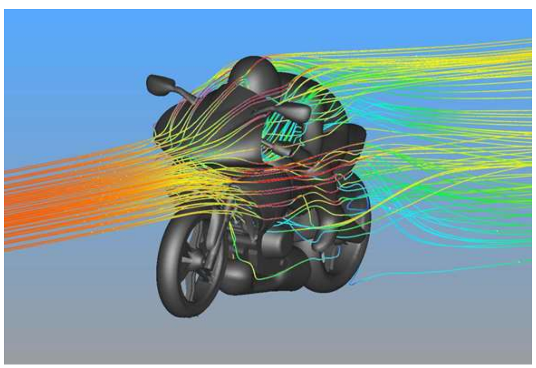
CFD ANALYSIS

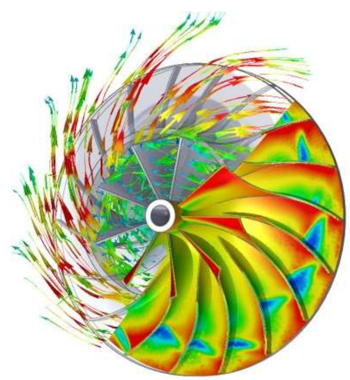
- **Computational Fluid Dynamics** (CFD) is one of the branches of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the millions of calculations required to simulate the interaction of fluids used in engineering.







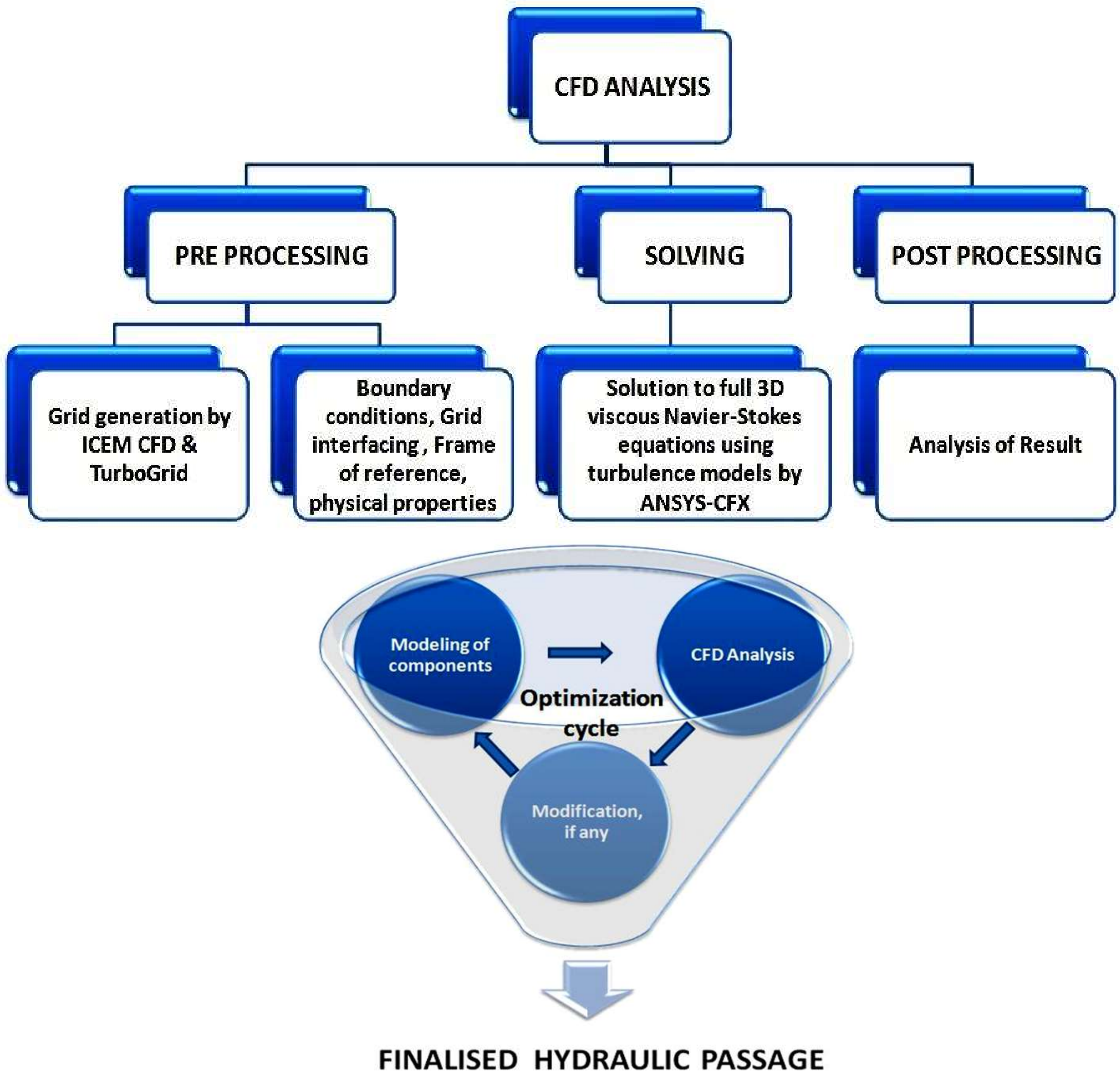




WHY CFD ?

- Advent of high capability computer resources.
- Advancement in mathematical modeling of real life physical phenomenon.
- Using the modern CFD Techniques, the designer can analyze the behavior of each component of a turbine in a better way and fine tune them to get better performance parameters.
- Cycle time of design optimization using CFD is extremely less as compared to the experimental methods.
- Only the best variant is experimentally tested for the validation of results.

PROCESS OF CFD ANALYSIS



CFD ANALYSIS AT BHEL

BHEL Bhopal uses one of the most powerful & popular CFD packages for turbo-machinery applications (Ansys-CFX).

It is based on full 3-D Navier-Stokes equations.

Multiple frames of reference for simultaneously solving rotating and stationary components.

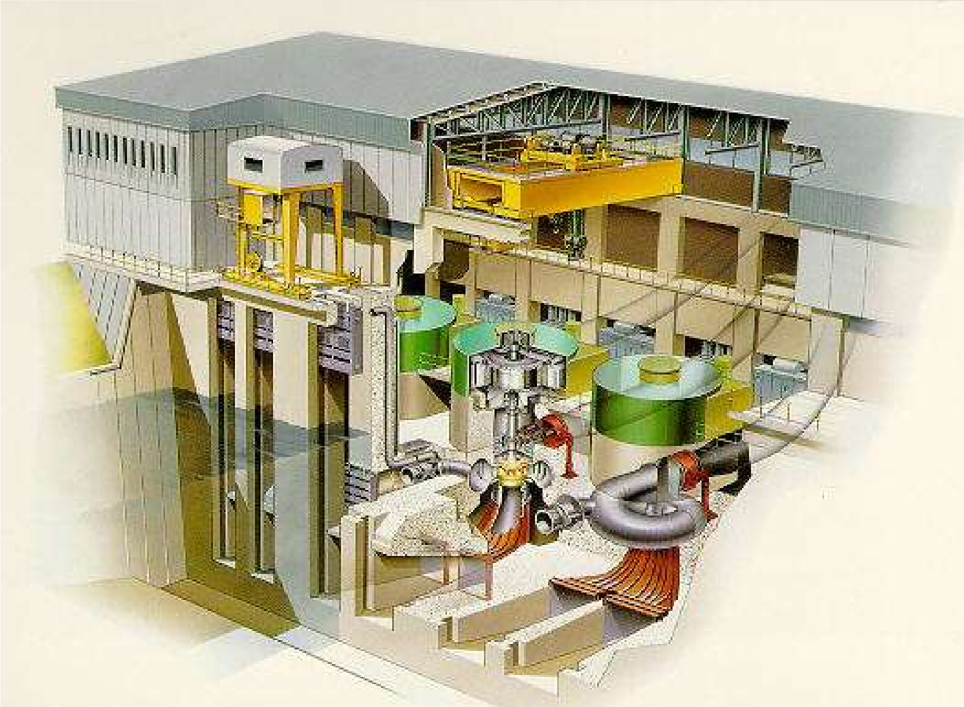
Turbulence effects are taken care using a variety of turbulence models.

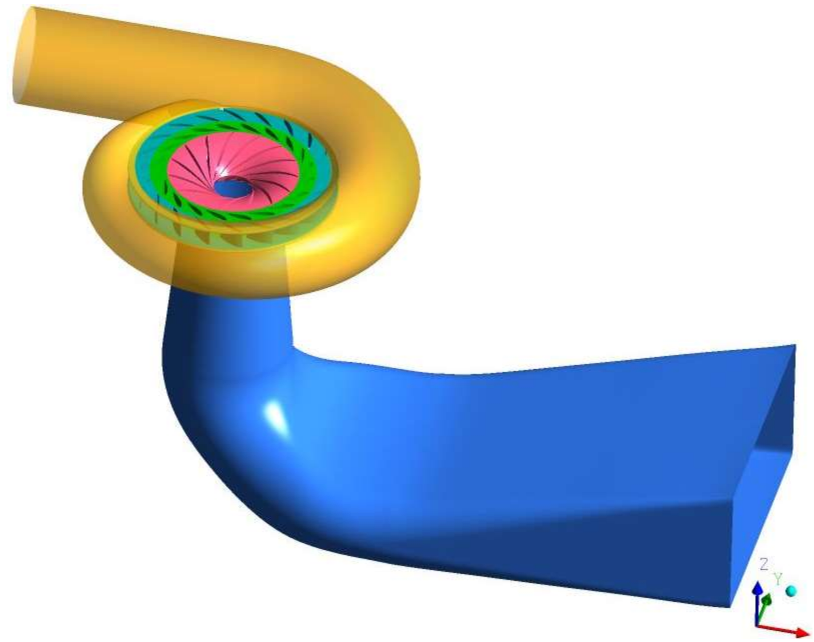
Grid generation is done using ICEM-CFD, Ansys Turbogrid & blade geometry synthesis is done by Ansys Bladegen.

Structured grid is generally used in all the components for more accurate simulation.

Using suitable macros validated by experiments, various performance parameters are evaluated.

NUMERICAL SIMULATION OF REACTION TURBINES





Coordinates: (x,y,z)

Velocity Components: (u,v,w)

Time : t

Density: ρ

Pressure: p

Stress: τ

Reynolds Number: Re

GOVERNING EQUATIONS

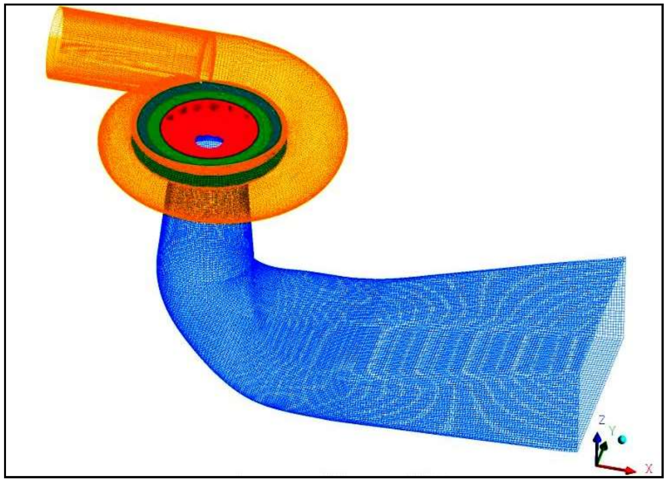
Continuity: $$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

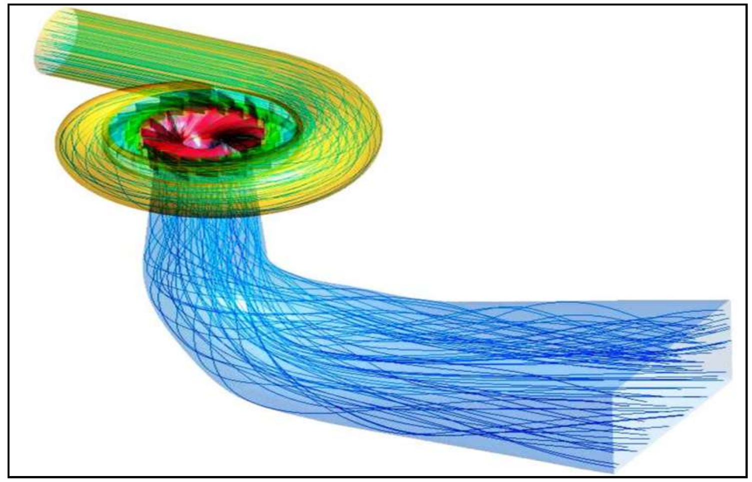
X – Momentum: $$\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}\right]$$

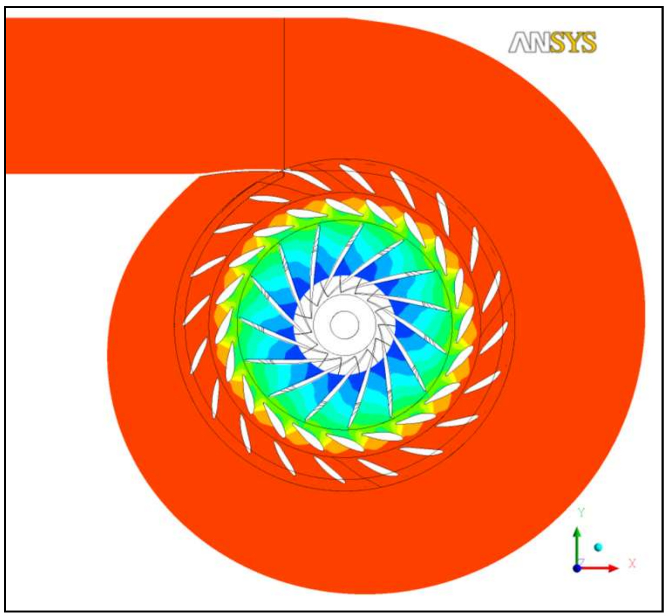
Y – Momentum: $$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z}\right]$$

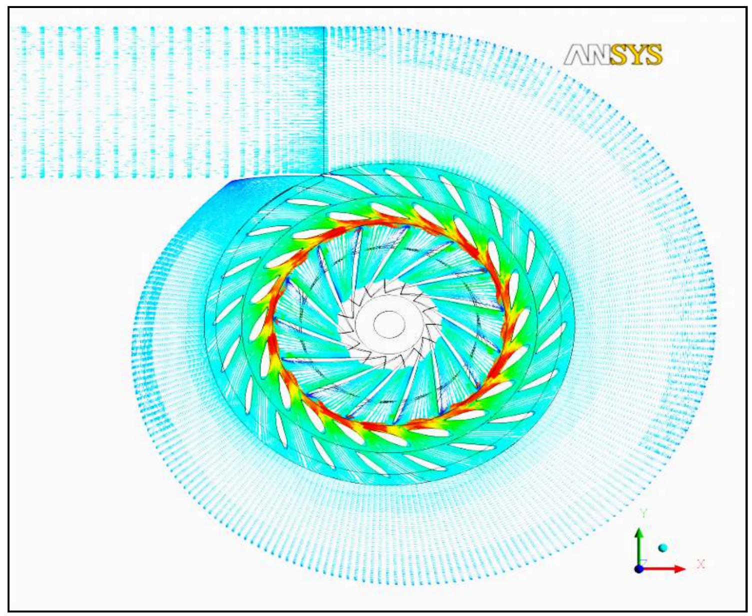
Z – Momentum $$\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right]$$

TYPICAL COMPUTATIONAL DOMAIN & RESULTS

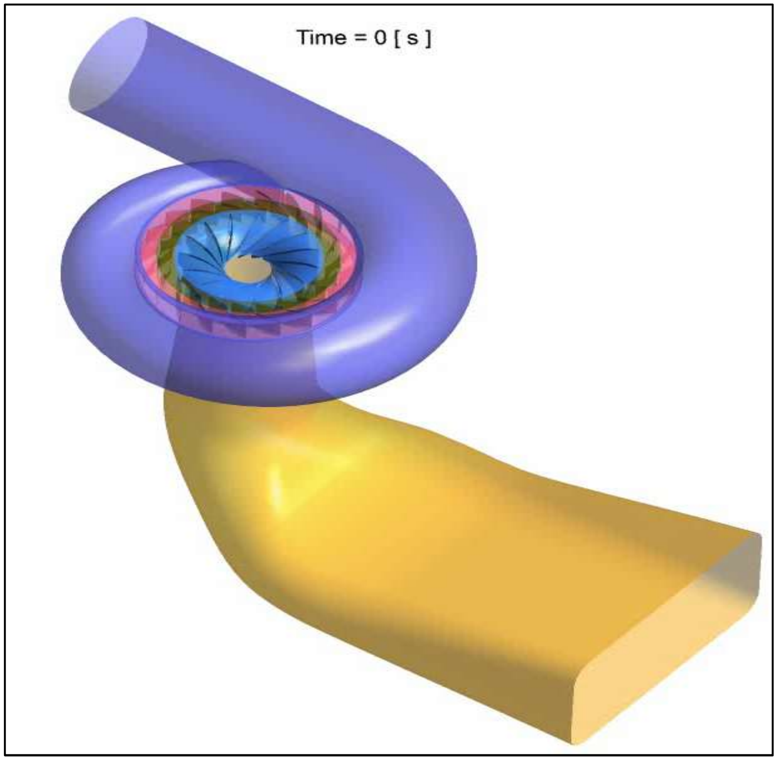


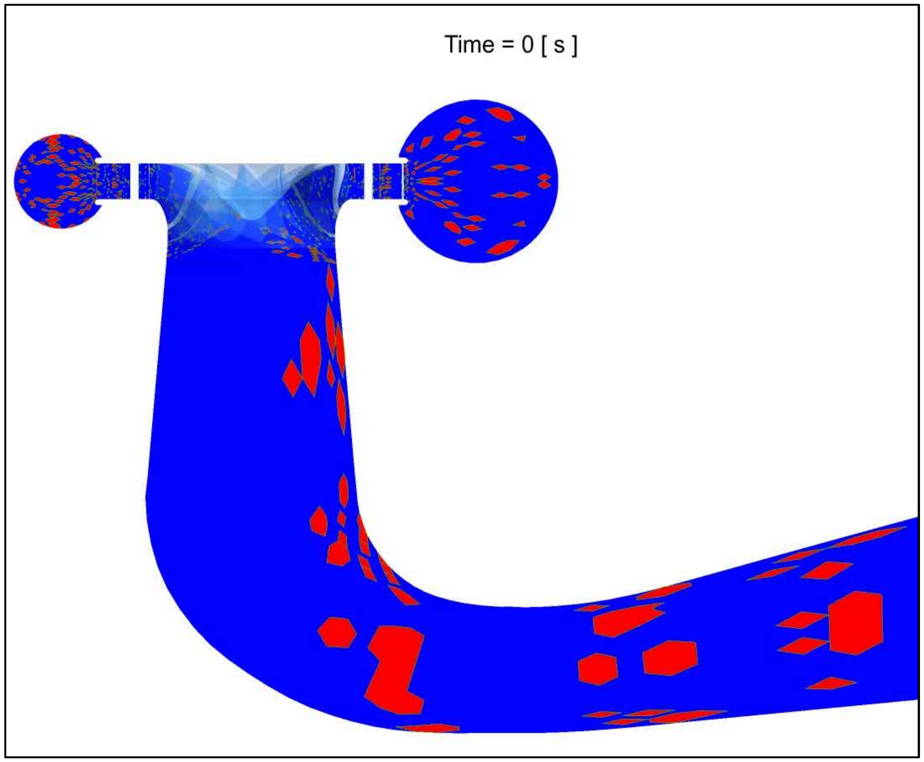






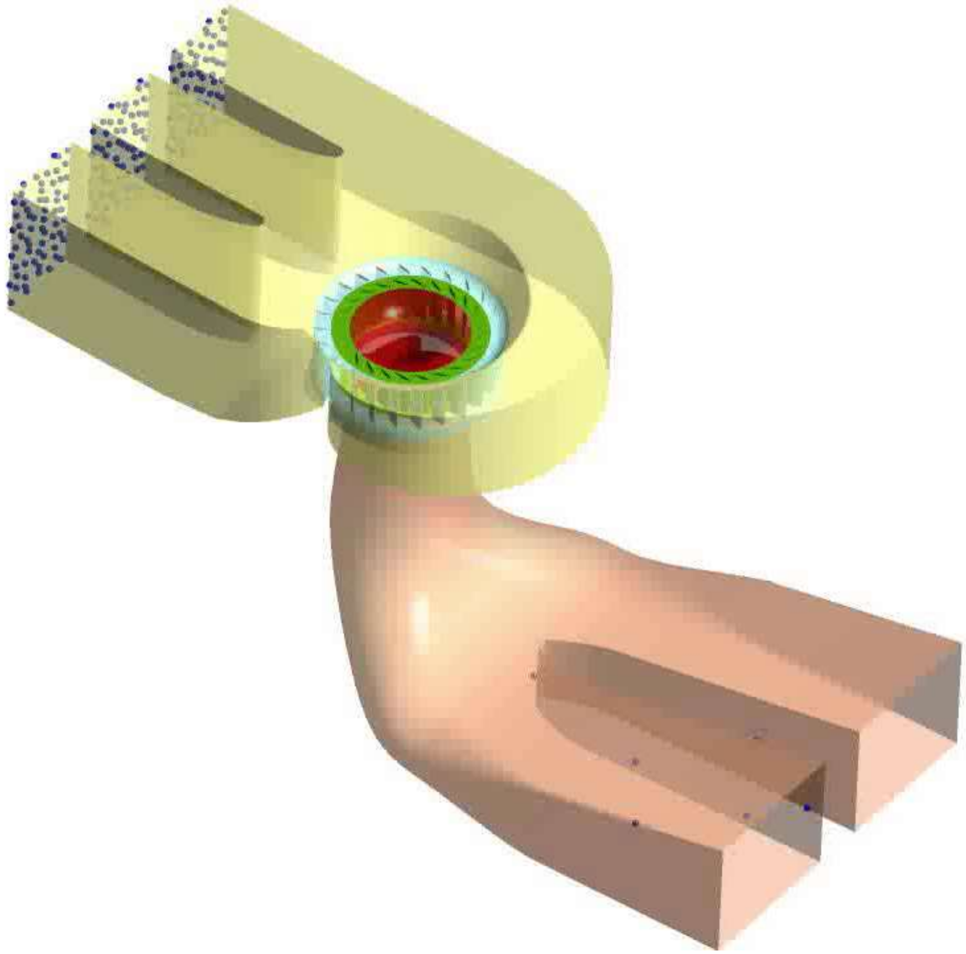
NUMERICAL SIMULATION BY CFD ANALYSIS





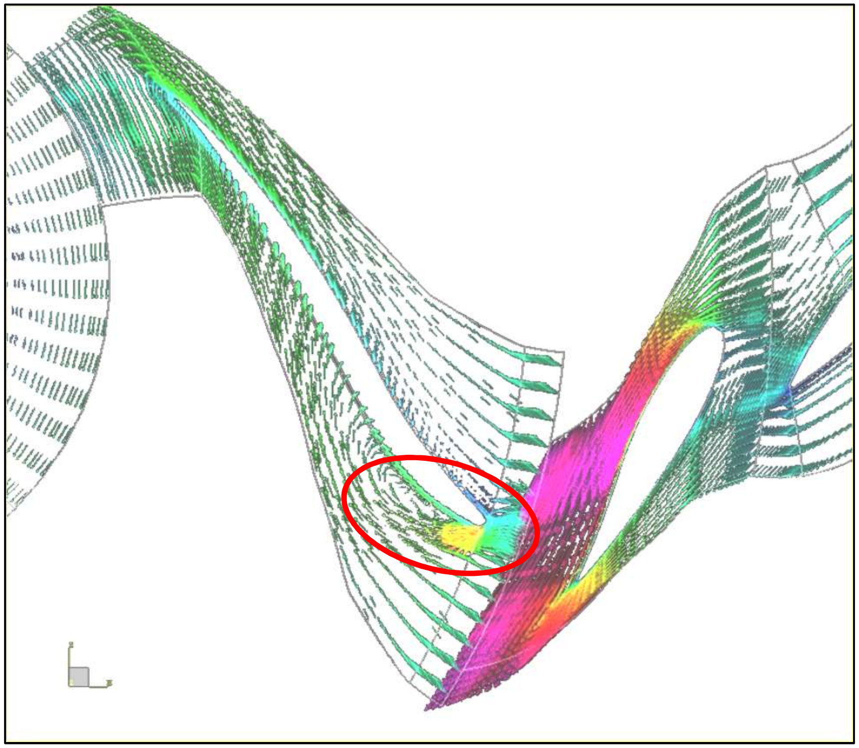
CFD Analysis of Francis turbine

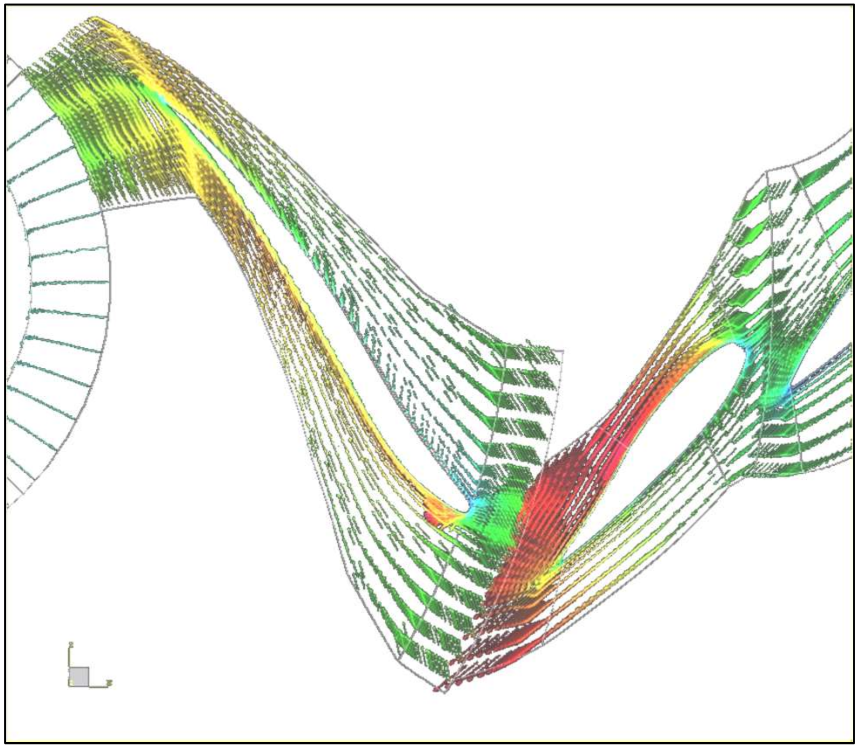
NUMERICAL SIMULATION BY CFD ANALYSIS



CFD Analysis of Kaplan turbine

OPTIMIZATION USING CFD ANALYSIS



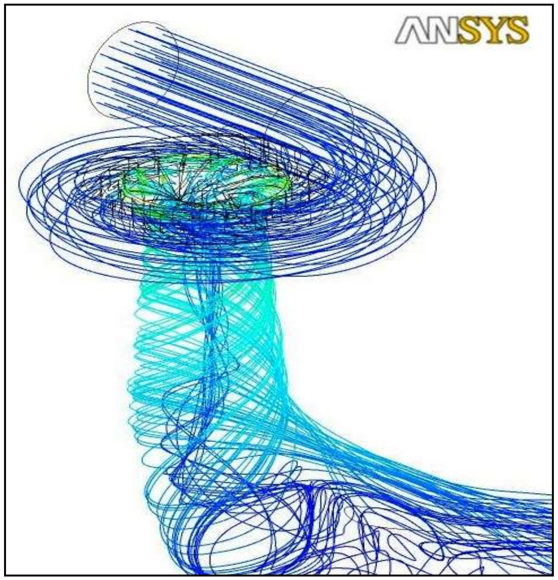


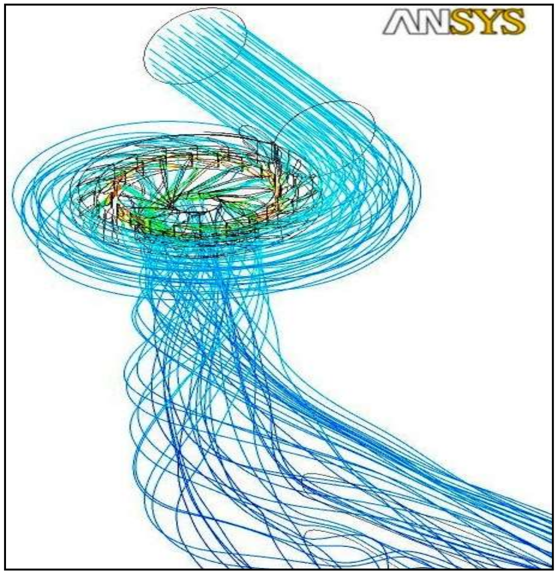
Mismatch between Runner Blade & Guide Vane :

- **Entry Shock Loss**
- **Secondary Flow Losses**

Optimized Geometry: Minimized Losses

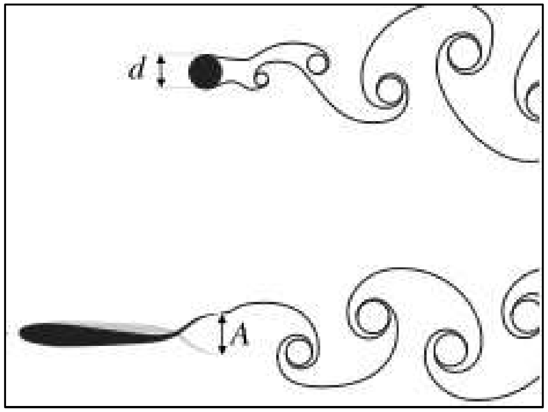
OPTIMIZATION USING CFD ANALYSIS





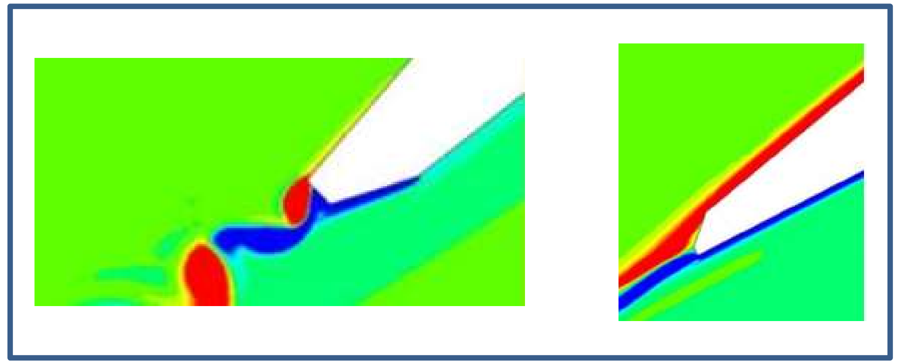
- **Hydraulic Losses**
- **Flow Induced Vibrations**

OPTIMIZATION USING CFD ANALYSIS



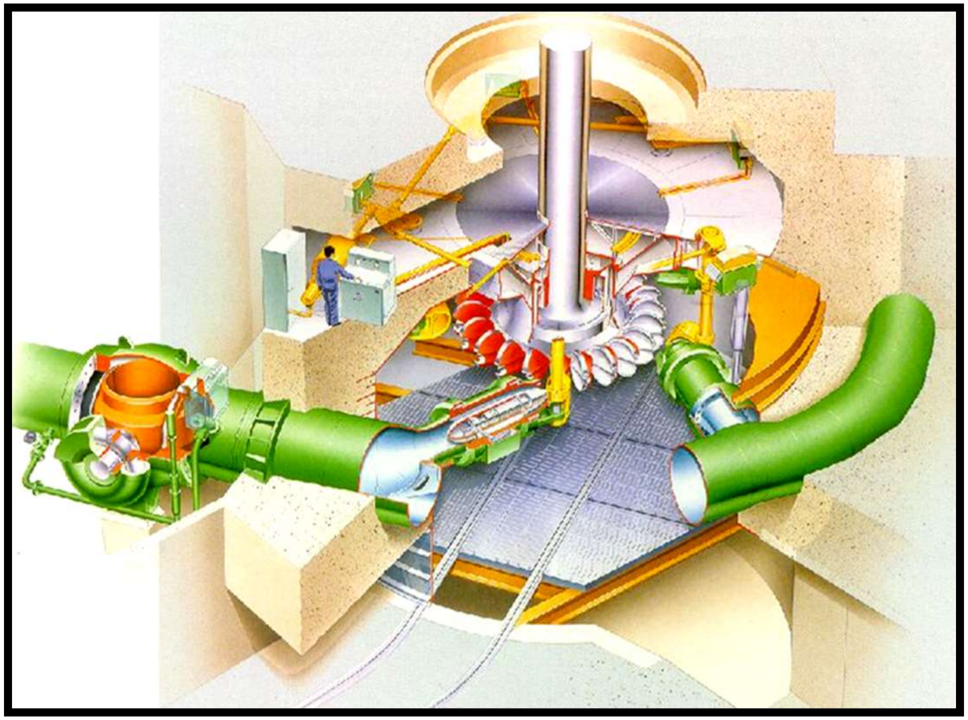
$$f = \frac{S * v}{a}$$

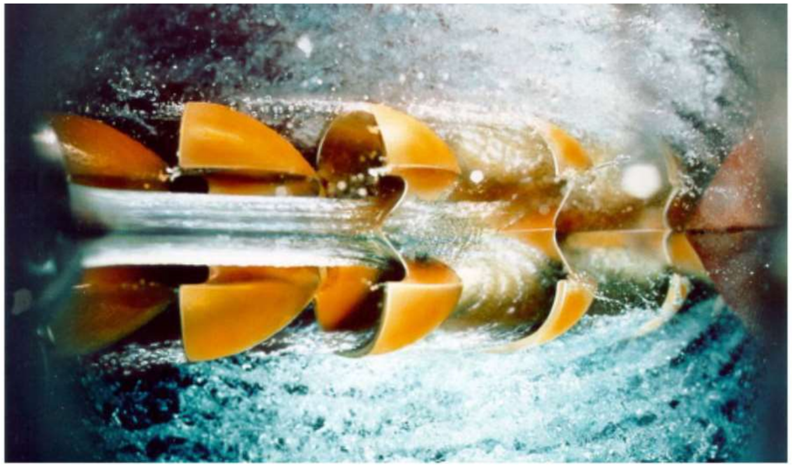
S = Strouhal number
v = flow velocity
a = effective trailing edge thickness



- **Von Karman vortex-shedding**
- **Flow Induced Vibrations**

NUMERICAL SIMULATION OF IMPULSE TURBINES



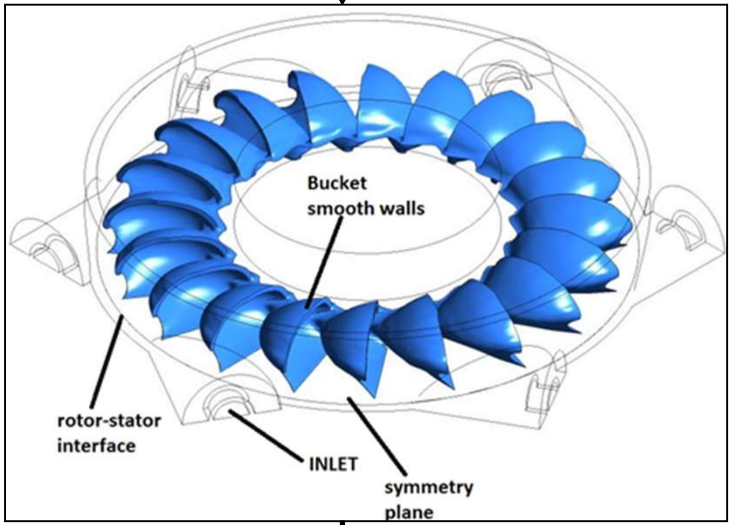


- Extension of CFD analysis to Pelton Turbine poses a complex set of problems in regard with numerical stability and accuracy.

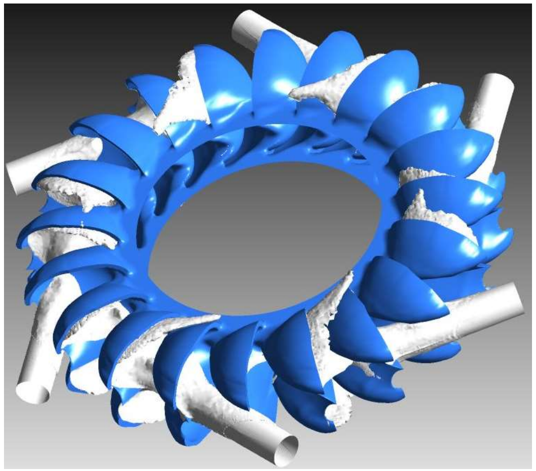
- Simulating Free water jet, Water sheet over buckets still poses a challenge

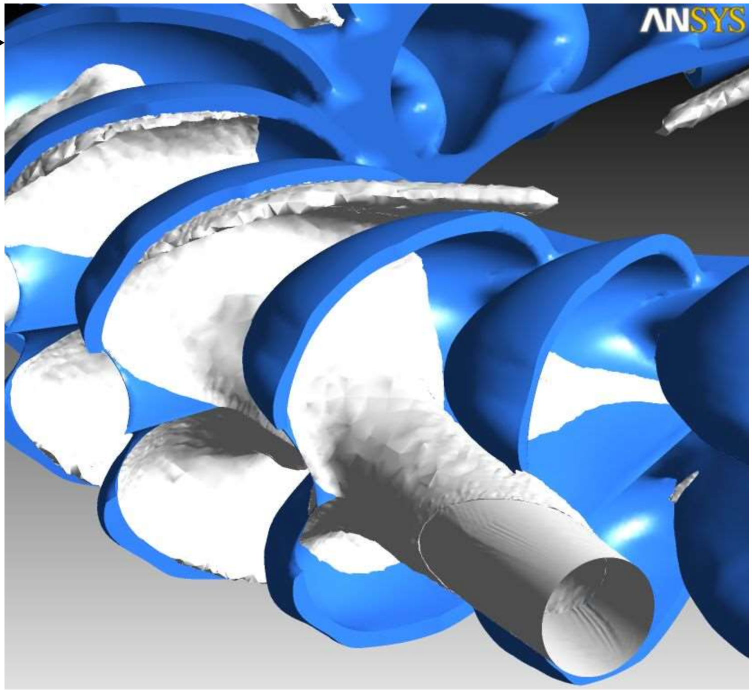
NUMERICAL SIMULATION OF IMPULSE TURBINES

CFD MODEL



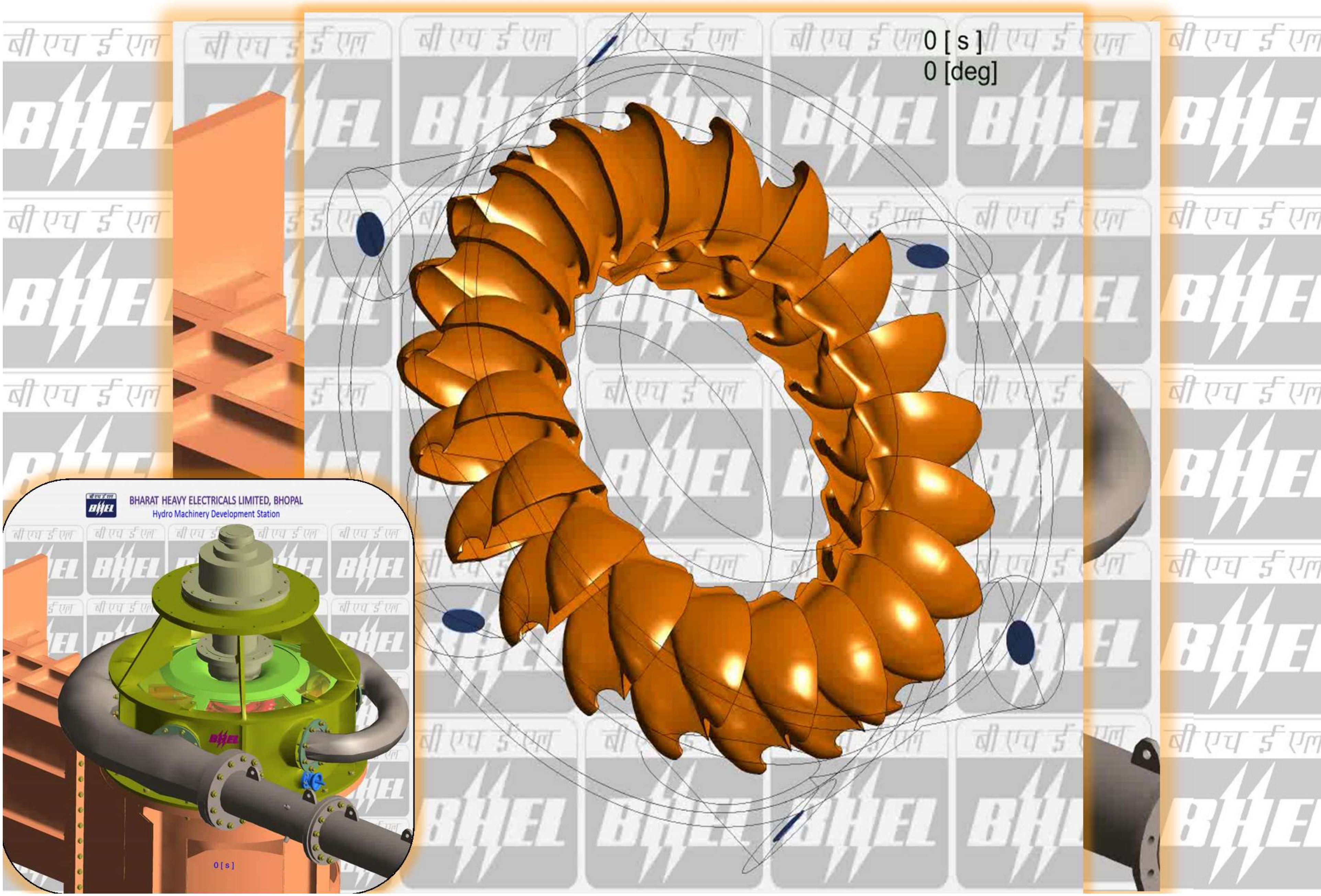
CFD ANALYSIS RESULTS



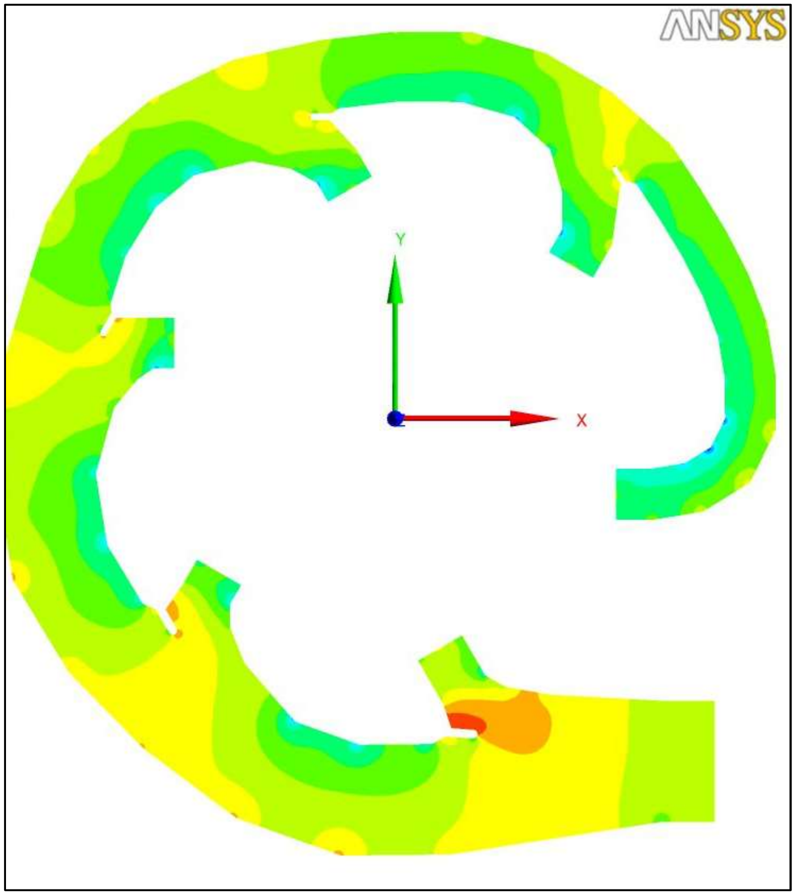


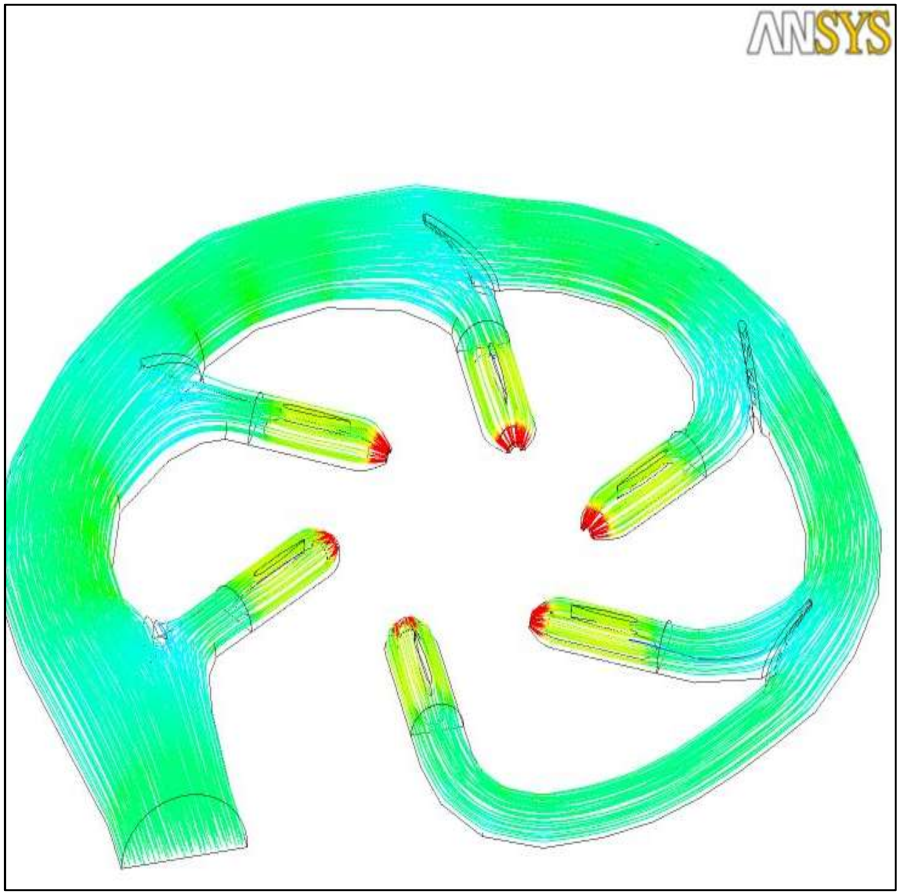
CFD Analysis of Pelton turbine

NUMERICAL SIMULATION OF IMPULSE TURBINES

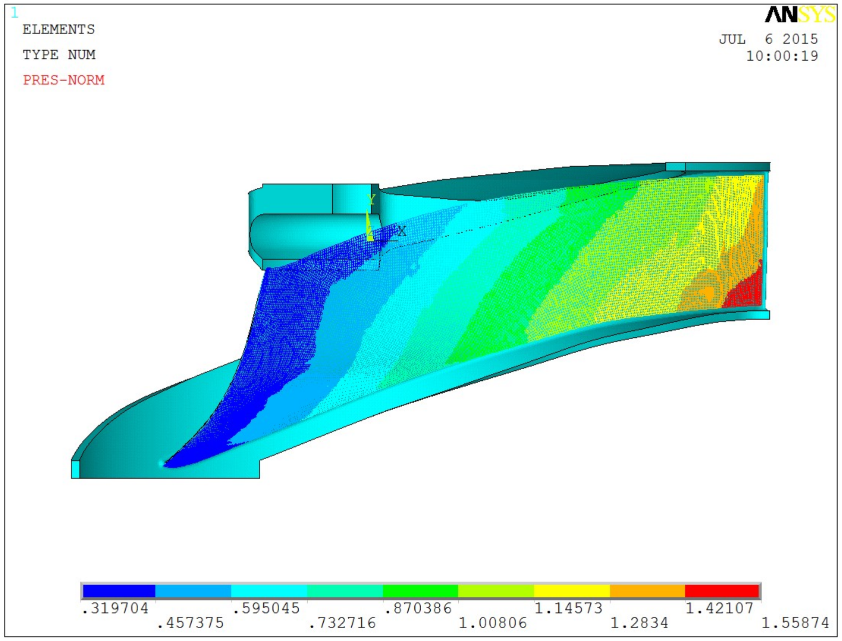


NUMERICAL SIMULATION OF IMPULSE TURBINES

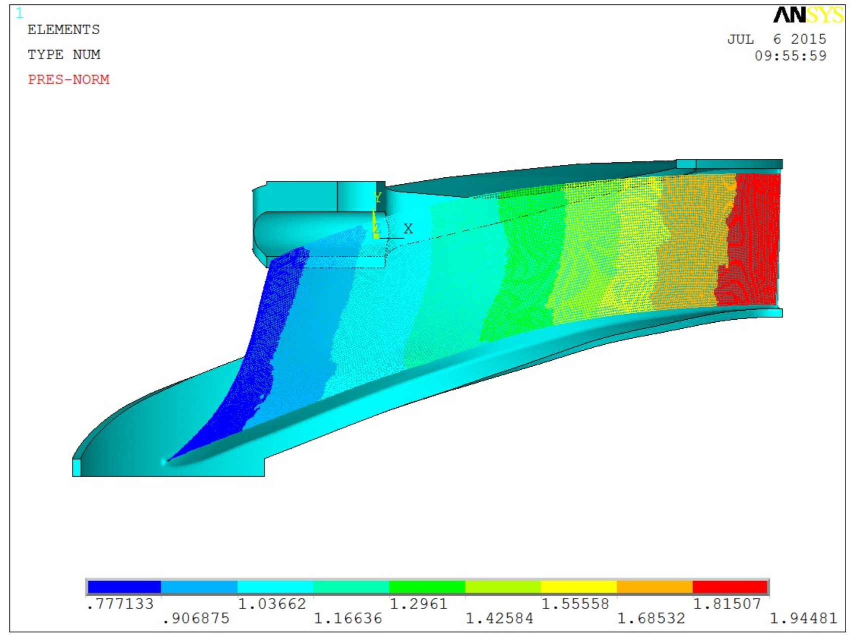




RUNNER BLADE STRUCTURAL ANALYSIS

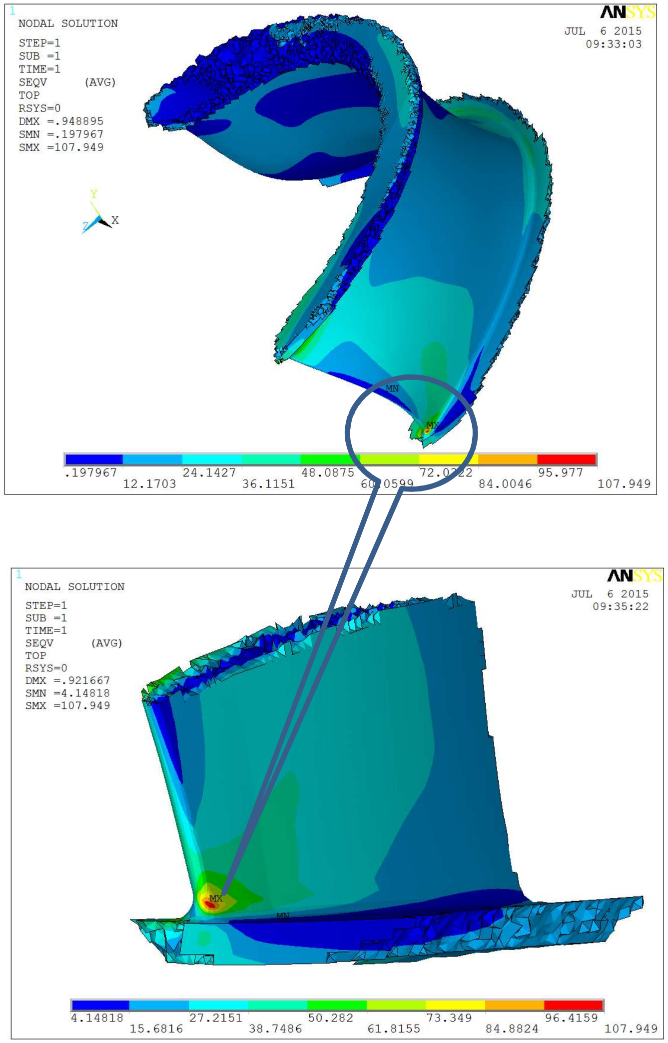


Applied Pressure Profile on Suction-side

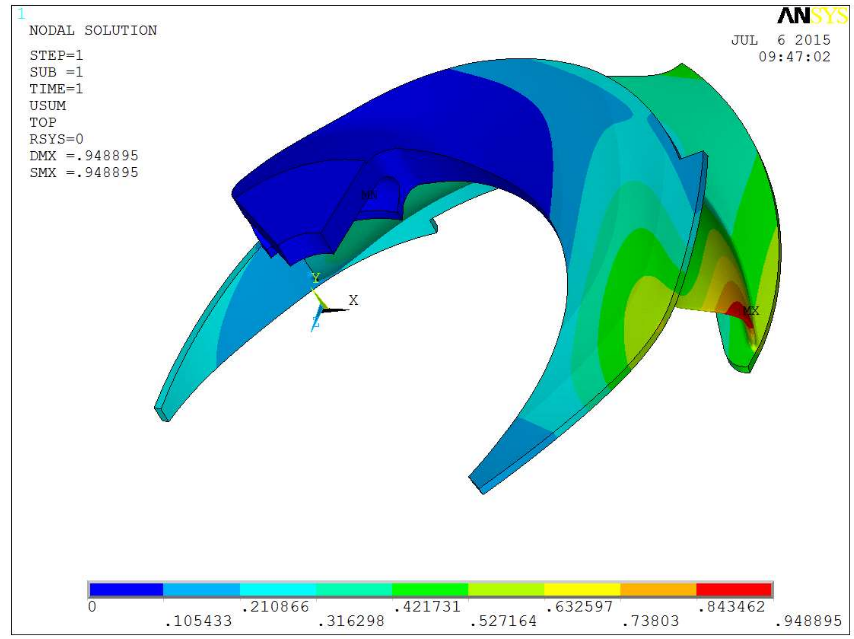


Applied Pressure Profile on Pressure-side

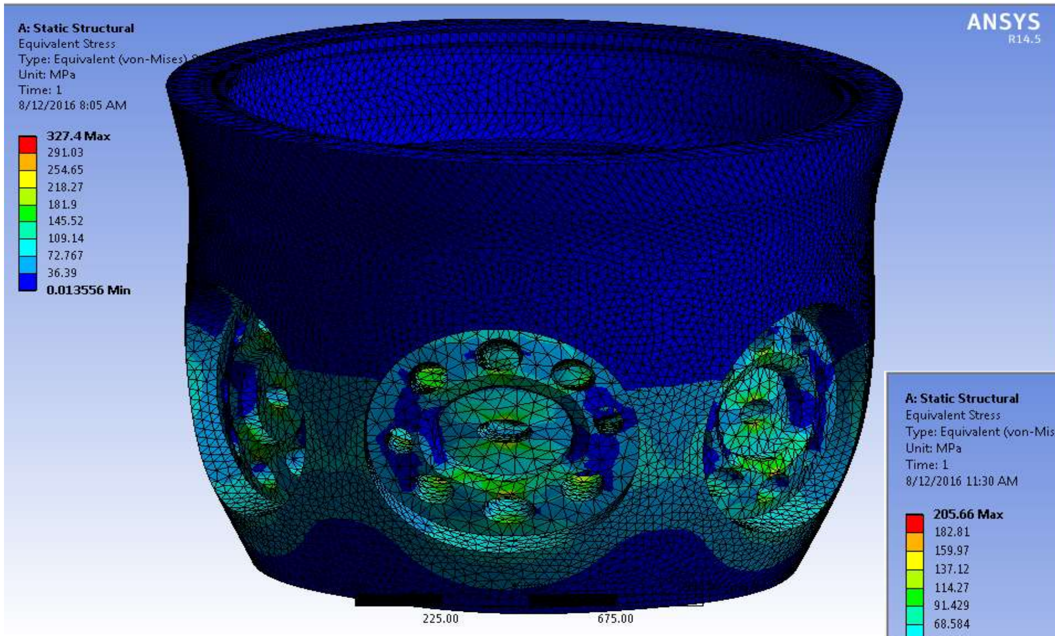
RUNNER BLADE DESIGN

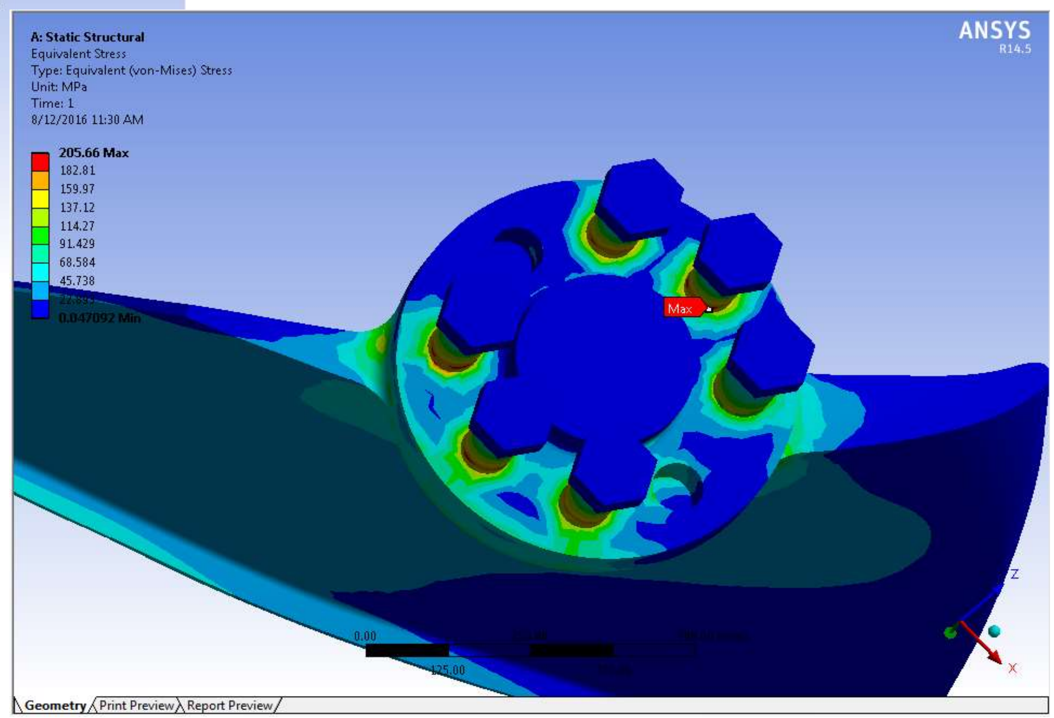


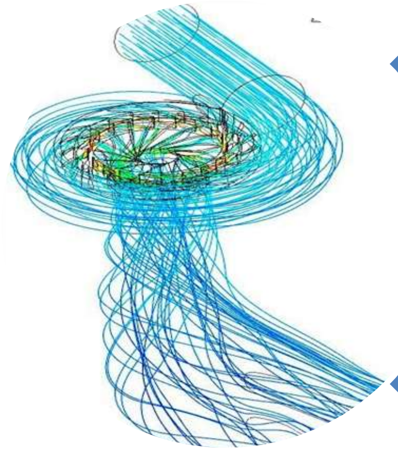
Stress Plot (Max 108 MPa)



FEA OF RUNNER BLADE & HUB FOR KAPLAN TURBINE







Special Feature Studies

SPECIAL FEATURE STUDIES

Special studies like erosion of water wetted areas can be conducted using CFD.

Using numerical tool more insights can be thrown into the mechanism of erosion of under water components by silt.

This erosion causes losses in terms of power generation, equipment damage and machine down time.

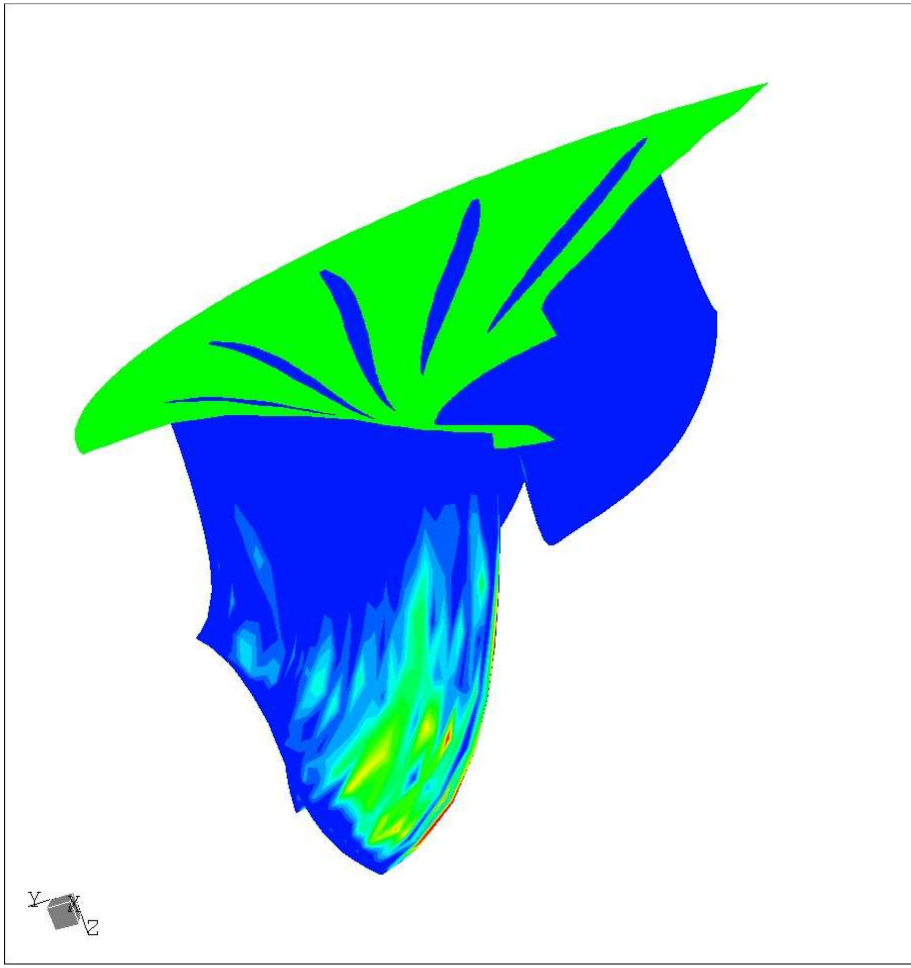
Using Lagrangian particle tracking module, the flow of silt particles in the turbine passage can be simulated.

Exact location where a silt particle of a typical size will hit the surface and the damage done by it can be assessed by this numerical tool.

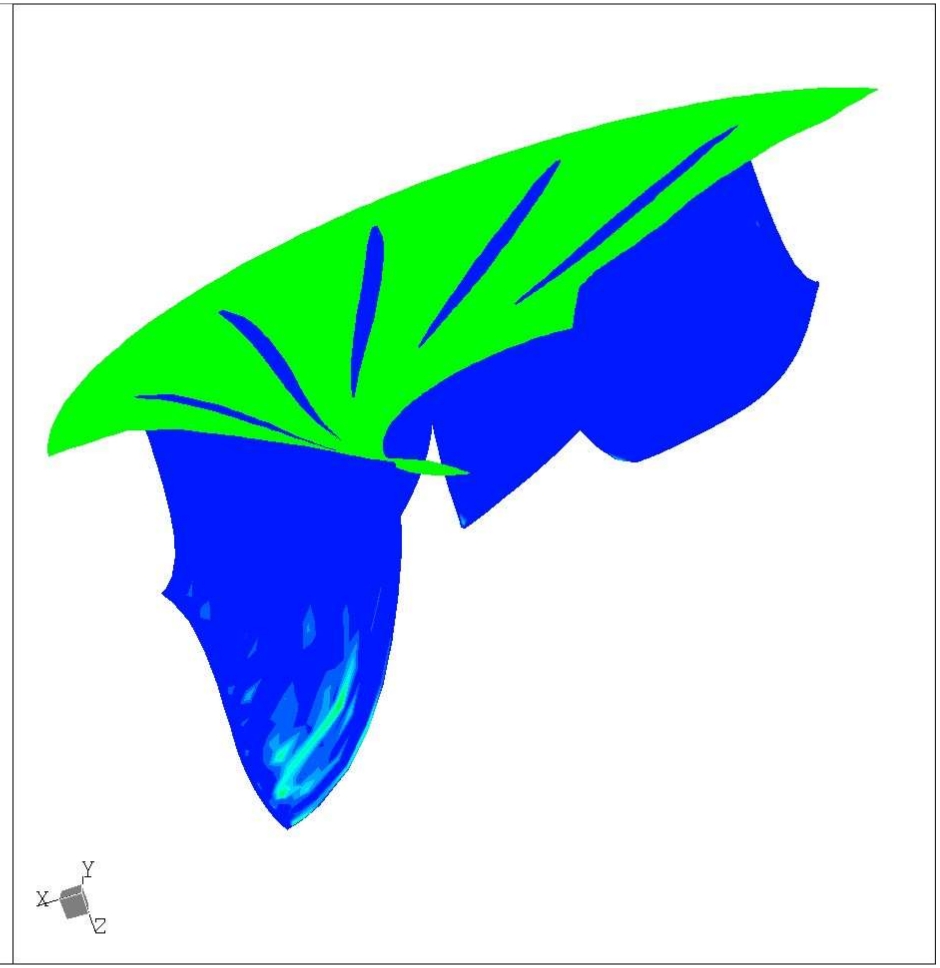
Hydraulic design for R&M projects

EROSION PATTERNS

EROSION PATTERNS



Basic Runner Blade



Improved Runner Blade

CAVITATION STUDY

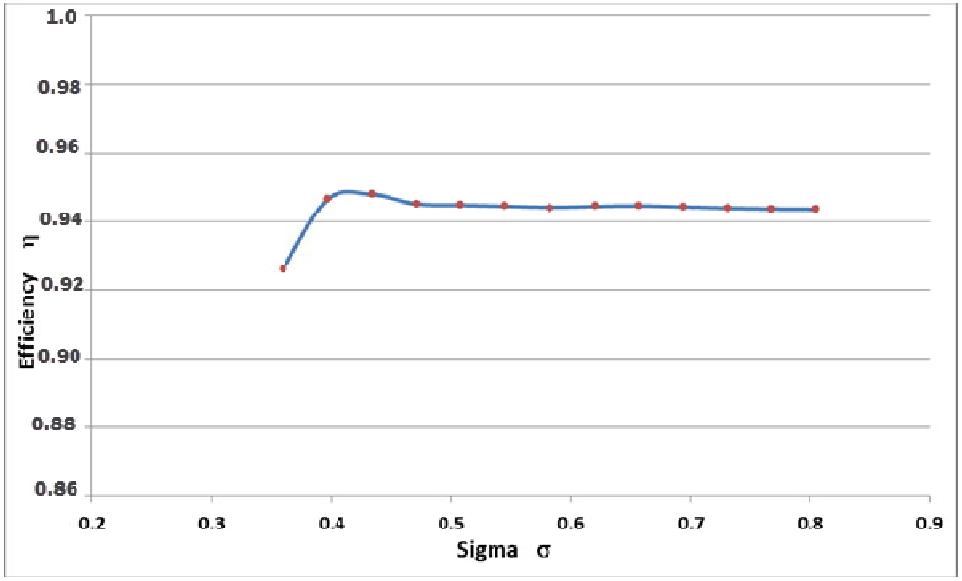
Cavitation prediction through CFD tools ,i.e. Extreme low-pressure areas

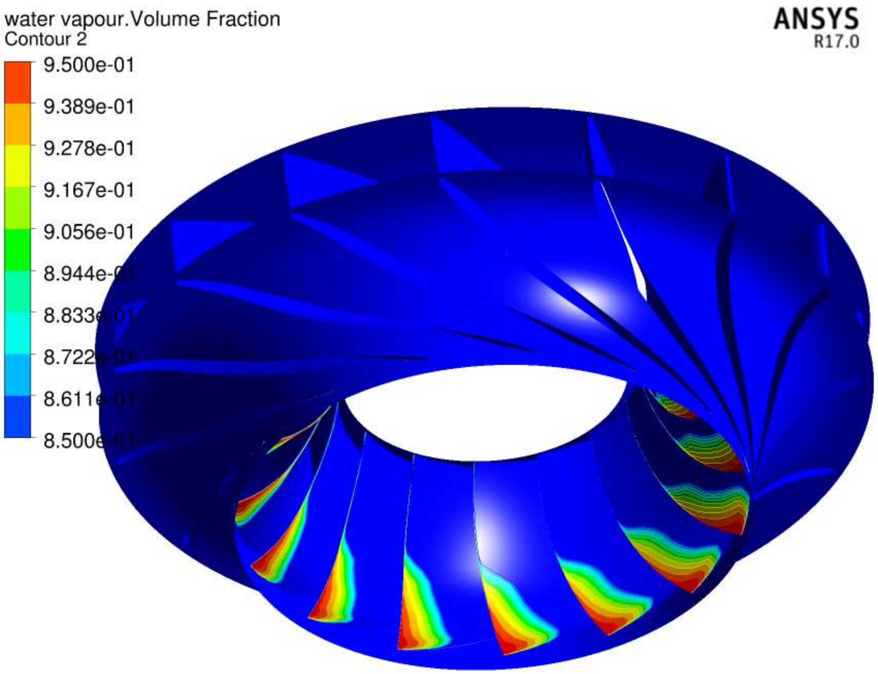
Runner improvements reduce cavitation problems, reducing long-term turbine maintenance costs

Distribution of static pressure and dynamic pressure inside draft tube are related to operation stability

Influence of cavitation on pressure pulsation

CAVITATION STUDY





Cavitation Curve from CFD analysis

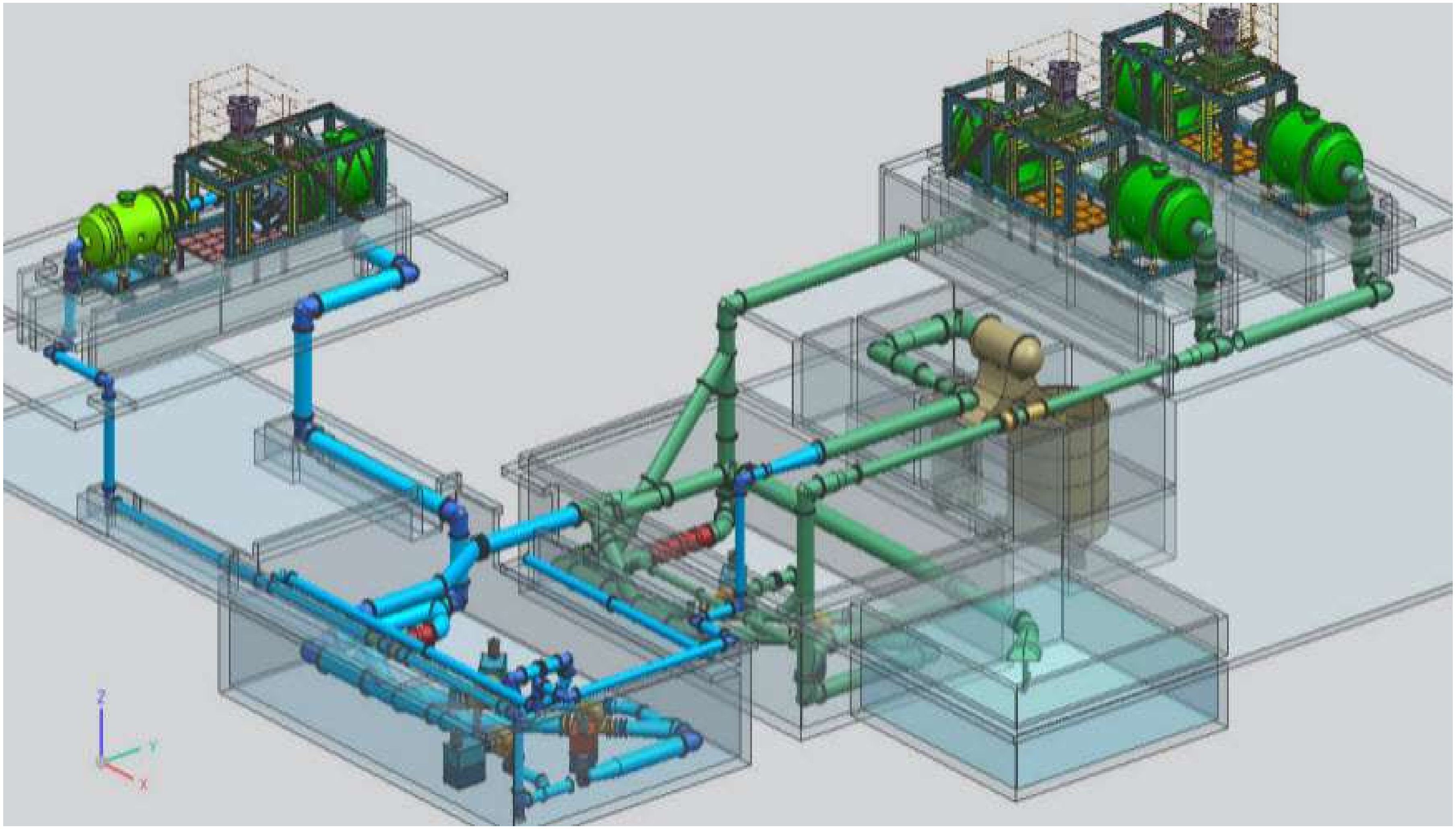
Cavitation results from CFD Analysis

CFD ANALYSIS INFRASTRUCTURE AT BHEL BHOPAL

- Established in 1989, and accredited by NABL
- Recognized by the Department of Scientific & Industrial Research (DSIR), Government of India as in-house R & D group for Hydraulic Design & Development of Hydro Turbines
- State-of-the-art Hydro turbine development and model testing facility
- Sophisticated model testing laboratory
- Hydraulic design & development of all types of hydro turbines

CENTRE OF EXCELLENCE – HYDRO MACHINES

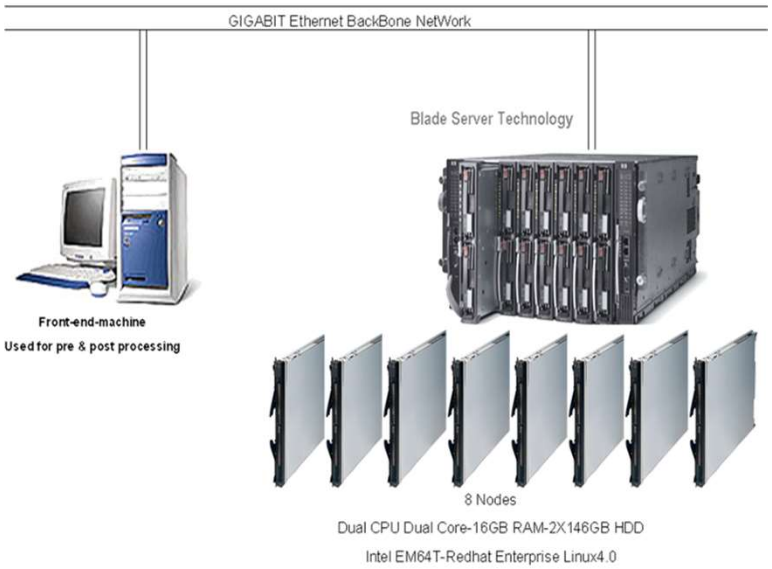
MODEL TESTING FACILITY



STATE-OF-THE- ART TESTING FACILITIES

- More than 150 Development Tests & 50 Contractual Witness Tests conducted till date.
- All types of Hydro turbines
- Pumps & Valves
- In-situ calibration of all measuring devices

CFD ANALYSIS OF HYDRO TURBINES



Latest parallel processing technology is being used

High performance Cluster (HPC) dedicated for CFD analysis

State of the art Hardware & software facility for CFD Analysis

ADVANTAGE - BHEL

- HBG single window facility to meet all the requirements
- Concept to Commissioning solutions for Uprating/R&M of Hydro plants
- First hand knowledge of O&M practices with Excellent Lab Facilities
- Availability of original design data and performance test results
- Make in India – In house Manufacturing facilities

HYDRO R&M POTENTIAL

Sets identified for R&M

	No. of Sets	MW
BHEL Make	90	4748.35
Non-BHEL Make	81	2463.70
Total	171	7212.05

RMU PROJECTS CURRENTLY BEING EXECUTED BY BHEL

Ganguwal Kotla HEP (BBMB), 2 x 24.2 MW

- Renovation, modernization & Life Extension of Propeller turbines.

Balimela HEP (OHPC), 6 x 60 MW

- Renovation, modernization & Life Extension of Francis turbines

Bairasiul HEP (OHPC), 3 x 60 MW

- Renovation, modernization & Uprating of Francis turbines

Keban HEP (Turkey), 8 x 183 MW

- Renovation, modernization & Uprating of Francis turbines

Rihand HEP (UPJVNL), 3 x 50 MW

- Renovation, modernization & uprating of Francis turbines

RMU PROJECTS EXECUTED BY BHEL

SN	Customer	Project	Rating (No. of Units x MW)
1	NEEPCO	Khandong	1x25
2	NEEPCO	Kopili	2x50
3	GSECL	Ukai	2x75
4	OHPC	Rengali	2x50
5	UPJVNL	Rihand	3x50
6	KESB	Idamalayar	2x37.5
7	KPCL	Nagjhari	1x150
8	DGPC, Bhutan	Chukha	2x84
9	NEA, Nepal	Devighat	3x5
10	Barki Tojik, Tajikistan	Varzob	2x4.75

RMU PROJECTS : BHEL OBSERVATIONS

- No. of years of operation should be clearly defined in the guidelines for Hydro projects, after which R&M to be made mandatory.
- To bring down the frequency of Unplanned outage, replacement should be made mandatory for the machines that are above 35 years.
- Sharing of firm Hydrological & Petrographic data for better design.
- History card of the Units should be shared with R&M bidders.
- Civil structure drawings/ data should also be shared.
- Complete scope to be defined clearly during tender stage.

CONCLUSION

R&M, uprating & life enhancement of Hydro Power Plants is very important in order to ensure the full utilization of nation's precious natural resource

Advanced Numerical Simulation techniques like CFD Analysis offer very potent solutions to the challenges associated with Hydro power plant R&M

CFD has an added advantage in terms of cost as well as flexibility to simulate complex phenomenon

BHEL is fully equipped with the latest technologies to offer the best R&M solutions

THANK YOU