Design and Development of Slurry Jet Erosion Wear Test Rig For Hydro Machinery

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***Abstract*—**Slurry erosion which is the process of material removal by impact of fine and minute particles known as erodent"s poses significant challenges to hydro machinery, leading to substantial economic losses and performance degradation. Various researchers have developed slurry erosion wear jet type test rigs to assess erosion wear under different conditions, primarily focusing on impingement angles of 30° and 90°. Coatings were also explored to mitigate erosion effects. In this research review, we present a novel slurry jet erosion test rig designed to accommodate a wider range of impingement angles (0° to 90 at 15° intervals) and test four specimen materials simultaneously. Our innovative design aims to enhance testing efficiency and accuracy, offering a promising avenue for assessing erosion wear in hydro machinery components. Validation against standard test rigs is anticipated to corroborate the efficacy of this novel design.

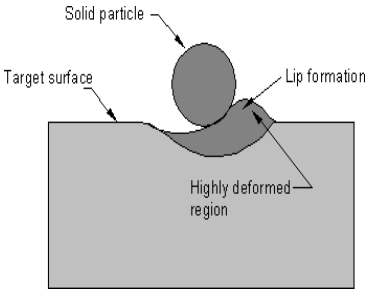
I. INTRODUCTION

The mixture of solid and liquid is known as slurry, the most common liquid is water. Slurry erosion of hydro machinery refers to the gradual degradation caused by the abrasive action of suspended solid particles in a fluid medium, leading to material loss and reduced efficiency of hydraulic equipment over time. There are mainly two types of slurries namely homogeneous flows or non settling slurries and heterogeneous flows or settling type of slurries.[1][2] Now a days hydropower is considered as one of the reliable and clean sources of energy, it provides sufficient amount of power as per the load requirements. Presently there is increasing worldwide demand for hydro - electric power, which resulted intensive utilization of available hydropower resources. Hydro power and its system equipment's faces one of the major problem of slurry erosion. The water flowing to the hydro machines has presence of slit particles which are extremely small and bypass the filter mechanisms, such particles are fine and abrasive in nature. these particles along with flow possess high kinetic energy due to which when these particles collide with hydro machines equipment's such as pump casings, turbine blade surfaces, pipe lines etc. they remove the material from the surfaces and causes degradation of these parts results in considerable reduction in the performance of the hydro machinery and equipment's also after some time these equipment's needs to be changed which is cost consuming.[3] To solve this problem of slurry erosion various researches has been carried out and to estimate the slurry erosion various bench scale test rig set ups are designed and developed which are mainly based on main four types of bench test apparatus namely Miller Test Apparatus, Slurry pot tester, Jet impingement tester, Coriolis erosion tester. Among these most research has been carried out on design and development of slurry pot test set ups and slurry jet erosion test set ups due to their compact size and accuracy in estimating erosion rates.[4][5][6] Main parameters considered for slurry jet erosion test rig are impingement angle at which the slurry jet will strike the specimen surface the most study has been carried out for 30°, 60° and 90 impingement angle.[7][8] The second important parameter is velocity of slurry jet which ranges from 10 m/s to 50 m/s. type and concentration of slurry is third important parameter like water and sand slurry with concentration ranging from 10% wt. to 20% wt. [9][10] , another important parameter is Particle size which is ranging from 100 µm to 500 µm [9] . the specimens for testing are cut into appropriate sizes and cleaned as per test requirements. [1][6] Various coatings of materials like TiO2, Al_2O_3, Elastomers, Stellite 6, Tin, Graphite etc. are used on specimens with techniques like HVOF Spray coatings, Thermal Spray Coatings etc. [11][13]

From the review it is found that the designs are primarily made for testing at 30° , 90°, 60° angles, there is least study about the erosion of specimen materials at angles like 0°, 15°,45°,75° and the designs have complexity of changing the specimen after each test and again doing proper set up arrangement for next specimen material testing, that is at a time at most two specimens are tested which is quite time consuming. Our novel design of slurry jet erosion test set up which consists of specimen holder and indexing mechanism gives provision for the carrying test at angles ranging from 0° to 90° at 15° segment interval to estimate proper erosion rate and appropriately simulates the condition of applications like hydro turbine blades, impellers, pipe walls etc. the novel design ensures its accuracy by properly validating it with the available standard results and can be utilized for further study of erosion wear.

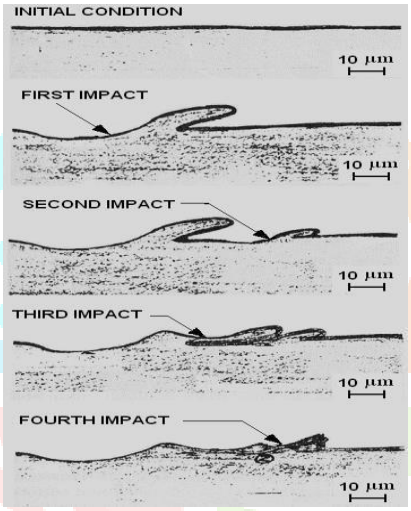
A. Slurry Erosion wear mechanism-

- Ploughing mechanism- Micro cutting and micro ploughing are the main reason for removing materials in ductile materials like metals and alloys.[13][14]



Ploughing Mechanism

- Extrusion and Forging Mechanism- This mechanism is also known as platelet mechanism. The impact of a solid particle spreads the target material over the adjacent crater in the direction of impact. This spread material get further flattened and extended to develop a platelet.[2][13]



Sequence of platelet erosion mechanism of a copper-plated steel

II. PROBLEM DEFINITION

To solve the problem of slurry erosion for hydro machinery equipment's tests are to be conducted to study the behavior and material removal from surface of sample specimen, such test cannot be performed at actual sites and special test set up is needed which simulates the exact erosion conditions on specimen and predicts the erosion behavior in terms of material removal from sample specimen and with the help of these results we are able to suggest material at different sections of hydro machinery and also to runner blades of turbines and pump impeller blades. But such test set ups are needed to make compact and must be validated to predict exact results as that of standard validated results of already validated test set ups. Another drawback of these set ups is that at a time only one specimen can be tested for particular impact angle, our study and development aims to test 4 different samples at different impact angles and give one by one results by creating new designs of specimen holder, runner and their positions.

III. METHODOLOGY

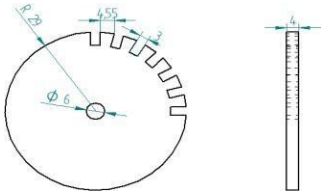
- Select appropriate materials and dimensions for the test rig- Appropriate materials like stainless steel (SS04) pipes and structural frame, valves, nozzle material are selected and the dimension are chosen as per the design parameters, compact design of specimen holder and runner
- Develop a design plan for the erosion wear test rig- Initially a basic layout is made which is in 2D format, then after identifying correct dimensions and components to be used made a computerized CAD model of the design of the erosion wear test rig set up, further improvements are made like dimensional accuracy, components proper assembly etc.
- Construct the test rig according to the design- As per the CAD layout and material selection, the prototype model is builds and initial testing that weather it is working or not found out, changes are made to make the prototype work properly like placing of specimen holder, runner position, valves position and waste valve, position of acrylic box chamber, slurry tank, nozzle-specimen distance, etc.
- Conduct the trial on test rig for performance- Further test is made by altering parameters like changing impact velocity, adjusting proper pressure of jet spray, and making proper overall arrangement of specimens, changing the impact angles for various angles ranging from 0 to 90 with 15 angle segments, calculate erosion wear in terms of material removal from surface of the specimen for particular time interval and plot the results.
- Troubleshoot any issue arise during the trials.
- Refine the design as necessary.

A. Working of Jet Erosion Tester

In jet erosion testing a high velocity jet strikes a flat specimen at some adjustable angle. The amount of material removed is determined by the weight loss. The material which accumulates on the specimen surface interferes with the incoming particle. The weight loss of the specimen corresponds to the average erosion over the surface. Jet erosion tester investigate the effect of different parameters particularly the impact angle. A jet of solid–liquid mixture strikes the specimen fixed in a fixture, which can be changed at any angle with respect to the former. The pump supplies water at high pressure and the solid particles are being sucked through an injector. The slurry is mixed in the mixing chamber before the jet comes out through a nozzle.[4][5][14][6]

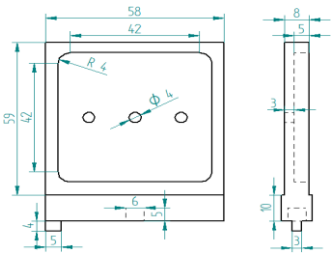
IV. EXPERIMENTAL TEST SETUP

- Indexing Plate- To set the specimen holder at different angles ranging from 0° to 90°



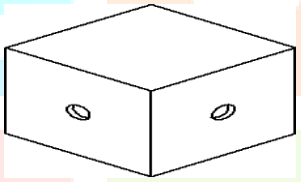
Index Plate

- Specimen Holder- To hold the specimen properly at stand of distance from the nozzle at required impact angle.



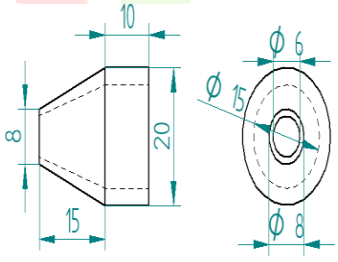
Workpiece Holder

- Runner- Used to carry specimen holders of 4 different specimens and confront the required material specimen holder to the nozzle.



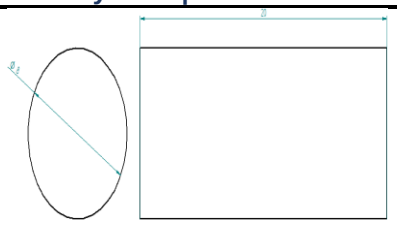
Runner

- Nozzle- To create jet spray of slurry which is to be impacted on the specimen surface at required impact velocity.



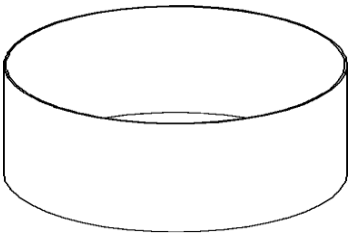
Nozzle

- Specimen Holder Shaft- This shaft is used to mount the specimen holder on Runner.



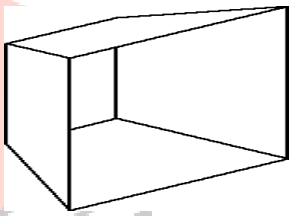
Specimen Holder Shaft

- Slurry Tank- The tank used for prepare a sand and water concentration for the test rig operation.



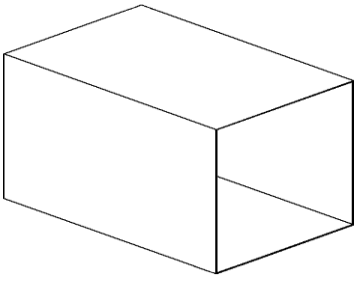
Slurry Tank

- Water Collector Hopper- The Hopper is used for the transfer the water that impact on the workpiece toward the slurry tank.

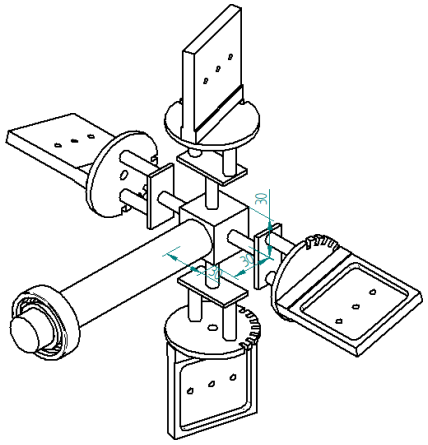


Water Collector Hopper

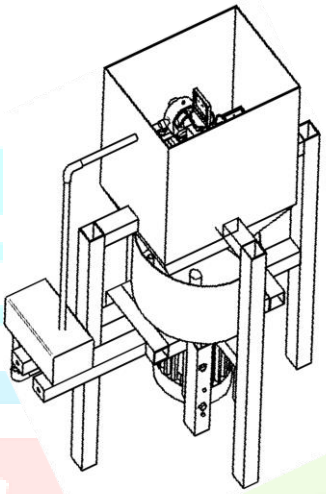
- Acrylic Box- The Acrylic box is used to cover the workpiece holding assembly.



Acrylic Box



Runner Assembly



Assembly of test rig

CONCLUSION

In this study, a novel design for a slurry jet erosion wear test rig has been developed to address the limitations of existing testing methodologies. The new design features a specimen holder with an indexing plate, allowing for testing at various angles ranging from 0° to 90° with 15° increments. This innovative approach enables the simultaneous testing of four different specimen materials without the need for individual removal.

The primary objective of this project was to design a rig that not only facilitates efficient testing but also ensures that the obtained results align with standard benchmarks. Through rigorous experimentation and analysis, it has been demonstrated that the performance of the new slurry jet erosion wear test rig meets or exceeds industry standards.

The development of this new slurry jet erosion wear test rig represents a significant advancement in the field of material wear testing. Its innovative design and reliable performance make it a valuable tool for researchers and engineers seeking to evaluate the erosion resistance of different materials accurately. Further studies and refinements may be warranted to explore additional applications and optimize the rig's performance further.

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