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Recent Developments in Pelton Turbines: A Review

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ABSTRACT: Pelton turbines are widely used in high-head hydropower plants because of their high efficiency and reliable operation. Recent developments have focused on computational fluid dynamics (CFD), artificial intelligence (AI), digital twins, advanced materials, additive manufacturing, multi-jet configurations and predictive maintenance. These innovations improve hydraulic efficiency, reduce cavitation, enhance durability and lower maintenance costs. This review summarizes recent research trends and future opportunities.

KEYWORDS: Pelton turbine, Hydropower, CFD, Artificial Intelligence, Digital Twin, Cavitation, Renewable Energy

I. INTRODUCTION

Hydropower is one of the most sustainable renewable energy resources. Pelton turbines are impulse turbines suitable for high-head and low-discharge conditions. They convert the kinetic energy of high-speed water jets into mechanical energy. Over the last decade, researchers have emphasized improving turbine efficiency using numerical simulation, optimization algorithms and smart monitoring technologies. These developments support reliable power generation and reduced lifecycle cost.

Traditional Pelton turbines were designed mainly through experimental methods. Modern computational tools enable engineers to optimize bucket geometry, nozzle alignment and runner design before manufacturing.

II. CONSTRUCTION AND WORKING PRINCIPLE

The turbine consists of a runner, double-cup buckets, nozzle, spear valve, casing, brake nozzle and shaft. Water from a penstock passes through the nozzle at very high velocity and strikes the buckets. The momentum change rotates the runner and drives an electric generator. Spear valves regulate flow while deflectors protect the turbine during sudden load changes.

III. RECENT DEVELOPMENTS

CFD is extensively used to optimize bucket profiles and nozzle geometry, reducing hydraulic losses. AI and machine learning are applied for fault diagnosis and predictive maintenance. Digital twin technology creates virtual models for real-time monitoring. Stainless steel alloys, HVOF coatings and composite materials improve erosion resistance. Additive manufacturing enables complex bucket shapes. IoT sensors continuously monitor vibration, temperature and pressure. Multi-jet turbines provide smoother torque and higher output under varying operating conditions.

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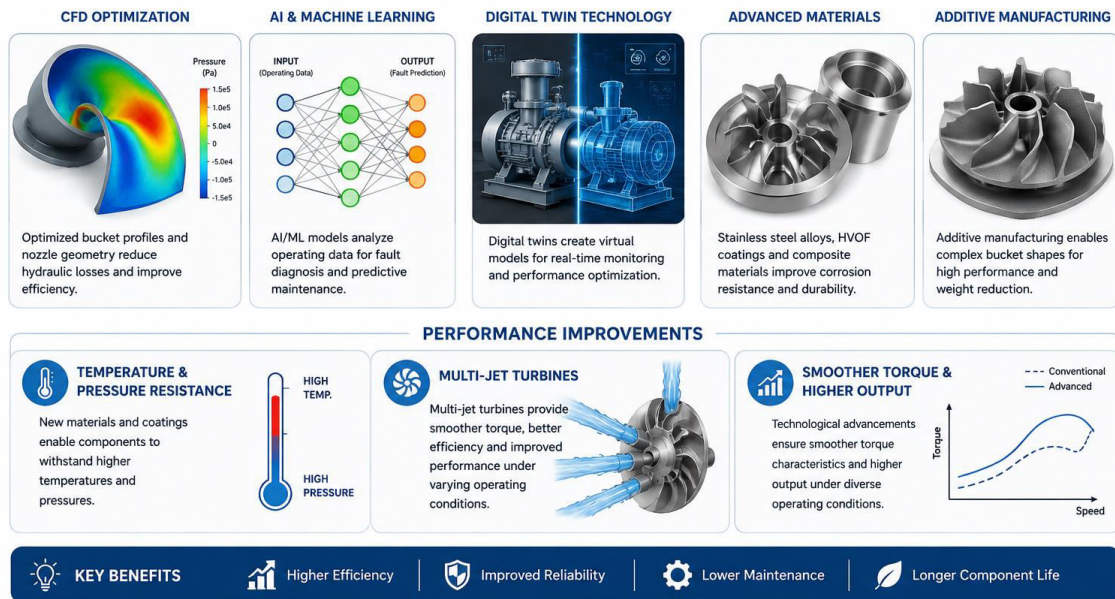


Fig 1

IV. ADVANTAGES, CHALLENGES AND FUTURE SCOPE

Advantages include high efficiency, excellent performance under high head, simple maintenance and long service life. Challenges include erosion from sediment-laden water, cavitation and high installation cost. Future work will focus on AI-based autonomous control, hybrid renewable integration, smart grids, sustainable materials and digital twin assisted optimization.

V. CONCLUSION

Recent advances demonstrate that Pelton turbines continue to evolve through CFD optimization, intelligent monitoring and advanced manufacturing. These technologies increase efficiency, improve reliability and support sustainable hydropower generation. Continued research will further enhance turbine performance in conventional and micro-hydropower applications.

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