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Design and Fabrication of Multi Junction Pipe Connector

Prof G. R. Jodh
Ass. Professor,
Department of Mechanical Engineering
Priyadarshini College of Engineering,
Nagpur, Maharashtra, India

Kadu Vipul Namdev
Student,
Department of Mechanical Engineering
Priyadarshini College of Engineering,
Nagpur, Maharashtra, India

Ninawe Ritik Nitin
Student,
Department of Mechanical Engineering
Priyadarshini College of Engineering,
Nagpur, Maharashtra, India

Kokate Satyam Rajendra
Student,
Department of Mechanical Engineering
Priyadarshini College of Engineering,
Nagpur, Maharashtra, India

Rahate Umesh Sunil
Student,
Department of Mechanical Engineering
Priyadarshini College of Engineering,
Nagpur, Maharashtra, India

Ganjare Vaibhav Gajanan
Student,
Department of Mechanical Engineering
Priyadarshini College of Engineering,
Nagpur, Maharashtra, India

Abstract— The Design and Fabrication of a Multi-Junction Pipe Connector focuses on creating a smart and efficient joint that enables the connection of several pipes from a single point. In conventional pipe connection setups, multiple fittings are often required to link pipes, leading to numerous joints. This not only extends installation time but also takes up more space, increases the risk of leaks, and raises the overall cost of the system. The proposed connector is thoroughly examined and tested for its dimensional accuracy, structural strength, leak resistance, and the alignment of the connected pipes. We can evaluate the performance of this new connector against traditional pipe joints based on factors like strength, compactness, manufacturing costs, and assembly time. The suggested multi-junction pipe connector has potential applications in various fields, including industrial piping systems, water supply networks, agriculture, chemical industries, HVAC systems, and other fluid transport systems. The goal of this project is to design a straightforward, cost-effective, durable, and compact solution for connecting multiple pipes with fewer fittings.

Keywords— Multi-Junction Pipe Connector, Pipe Fitting, CAD Design, Fabrication, Pipe Joint, Branch Connection, Fluid Flow, Welding, Mechanical Design, Leakage Testing, Structural Strength, Industrial Piping System.

I. INTRODUCTION

Piping systems are an essential part of many engineering and industrial applications because they are used for the transportation and distribution of liquids, gases, and other fluids from one location to another. They are widely used in water supply systems, agricultural irrigation, chemical processing plants, petroleum industries, power plants, HVAC systems, manufacturing industries, and various other applications. A piping system consists of pipes, valves, elbows, tees, reducers, couplings, and other fittings that are used to control and change the direction of fluid flow. Among these components, pipe connectors and junctions play an important role in providing secure and efficient connections between multiple pipes.

In conventional piping arrangements, when several pipes have to be connected at a common location, separate fittings are generally used. For example, a combination of tees, elbows, couplings, reducers, and additional short pipe sections may be required to create a multi-branch connection. Although this method is widely used, it increases the total number of joints and components in the system. A greater number of joints can increase the possibility of leakage, pressure losses, alignment problems, maintenance requirements, installation time, and overall cost. It may also require more installation space and make the piping arrangement more complicated.

To overcome these limitations, the Multi-Junction Pipe Connector is proposed as an integrated pipe-fitting solution. The main objective of this connector is to provide a common junction through which multiple pipes can be connected using a single fabricated component. In the proposed project, a connector with multiple branches is designed according to the required piping arrangement. The number, diameter, and orientation of the branches can be modified depending on the application. This approach can reduce the dependency on multiple individual fittings and provide a more compact and organized piping system.

The design of the multi-junction pipe connector is an important stage of the project. Computer-Aided Design (CAD) software can be used to develop the three-dimensional model of the connector. During the design process, important parameters such as pipe diameter, branch angle, connector dimensions, wall thickness, material properties, operating pressure, and manufacturing requirements are considered. The CAD model helps in visualizing the component, checking the arrangement of different branches, obtaining accurate dimensions, and identifying possible design problems before fabrication.

Material selection is another important aspect of the development of the connector. The material should have sufficient mechanical strength, durability, corrosion resistance, manufacturability, and reasonable cost. Depending on the intended application, materials such as mild steel, stainless steel, aluminium alloy, or other suitable engineering materials may be considered. The selected material should be compatible with the type of fluid, pressure, temperature, and environmental conditions under which the connector will operate.

After completing the design, the connector is fabricated using appropriate manufacturing processes. The fabrication process may include material cutting, drilling, fitting,

welding, machining, grinding, and surface finishing. Proper alignment of the branches is maintained during fabrication to ensure that the connected pipes can be installed correctly. Welding or another suitable joining process can be used to provide a strong connection between the main body and branch sections. Dimensional inspection and visual inspection are carried out after fabrication to identify defects and ensure that the manufactured component corresponds to the CAD design.

The fabricated multi-junction connector can then be evaluated through suitable performance tests. These may include dimensional accuracy, leakage testing, pressure testing, structural strength evaluation, and inspection of weld joints. The testing process helps determine whether the connector can withstand the expected operating conditions. The performance of the developed connector can also be compared with conventional multi-fitting arrangements based on parameters such as number of components, manufacturing cost, installation time, compactness, reliability, and leakage possibility.

The proposed multi-junction pipe connector has potential applications in industrial piping systems, water distribution, agricultural irrigation, chemical industries, HVAC systems, process plants, and other fluid transportation systems. By integrating multiple pipe connections into one component, the design can help simplify piping arrangements and reduce the number of individual fittings required. It can also provide a compact and practical solution where space and installation efficiency are important considerations.

Therefore, the Design and Fabrication of a Multi-Junction Pipe Connector is an important mechanical engineering project that combines principles of mechanical design, CAD modelling, material selection, manufacturing, welding, and testing. The project aims to develop a reliable and economical connector that can provide effective multi-pipe connections while maintaining adequate strength, dimensional accuracy, and operational reliability

I. Problem Identification

- Multiple fittings required: Several individual fittings are needed to connect multiple pipes, increasing component count and assembly complexity.
- Higher leakage possibility: A larger number of joints increases the chances of leakage, particularly under pressure or during long-term operation.
- Increased installation time: Assembly and alignment of multiple fittings require additional time and effort.
- Higher manufacturing and maintenance cost: More components increase material, fabrication, installation, and maintenance costs.
- Space requirement: Conventional arrangements may occupy more space because of the use of multiple fittings and connecting pipe sections.
- Alignment difficulties: Maintaining proper alignment and branch angles becomes difficult when several separate fittings are assembled together.
- Flow losses: Sudden changes in direction and irregular junction arrangements can contribute to pressure losses and disturbance in fluid flow.
- Maintenance complexity: Inspection, repair, and replacement become more difficult when the system contains a large number of interconnected fittings

A. Existing System

In the existing system, multiple pipe branches are generally connected using conventional fittings such as T-joints, Y-joints, cross-joints, elbows, couplings, and reducers. When a piping arrangement requires four or more branches, several individual fittings are connected together by welding, threading, or flanged joints. This arrangement increases the number of joints, resulting in greater chances of leakage and pressure loss. Sudden changes in flow direction and cross-sectional area can also create turbulence and non-uniform flow distribution. Moreover, the use of multiple fittings makes the system bulky, requires more installation space, and increases manufacturing, installation, and maintenance costs. Therefore, the conventional system has limitations in terms of compactness, flow efficiency, reliability, and ease of maintenance. The proposed Multi-Junction Pipe Connector is developed to overcome these limitations by integrating multiple branches into a single compact and efficient connector

B. Drawbacks

The existing conventional pipe-junction system requires multiple fittings such as T-joints, elbows, couplings, and reducers to connect several branches. This increases the number of joints and consequently increases the possibility of leakage. Multiple fittings also cause additional pressure loss and turbulence due to sudden changes in flow direction. The system occupies more space and has a bulky structure. Installation and maintenance are comparatively difficult and time-consuming. Moreover, the use of more components increases the overall material, fabrication, and installation cost. The conventional arrangement may also provide non-uniform flow distribution between different branches.

II. LITERATURE REVIEWS

A) Literature Survey:

- Idelchik (2007) – Hydraulic Resistance of Pipe Junctions

Idelchik presented extensive experimental and analytical information about hydraulic resistance in different types of pipe fittings and junctions. The work explains how pressure losses occur when fluid passes through bends, branches, expansions, contractions, and other fittings. In a pipe junction, the change in flow direction produces additional turbulence and energy loss. Parameters such as branch angle, diameter ratio, flow velocity, and flow direction have a significant effect on the pressure-loss coefficient. The study is particularly useful for the present project because it provides fundamental information for selecting the geometry of a multi-junction connector. A connector with abrupt changes in flow direction can produce greater pressure losses, whereas a smoother junction can reduce turbulence and improve flow distribution. Therefore, the design of the proposed connector should consider smooth transitions between the main pipe and branches.

- Miller (1990) – Internal Flow Systems

Miller investigated pressure losses in pipe fittings and internal flow systems. The study included different types of fittings, junctions, bends, valves, and other components used in fluid transportation systems. It was observed that local losses are generated due to changes in velocity and flow direction. The research showed that the geometry of a fitting has a direct relationship with its hydraulic performance. A poorly designed junction can create flow separation and recirculation, resulting in increased pressure drop. The findings are relevant to the proposed multi-junction pipe connector because several branches are connected to a common body, making proper geometric design essential for controlling flow losses.

- Blevins (1992) – Applied Fluid Dynamics

Blevins studied fluid flow through various engineering components and provided information on pressure losses and flow behavior. The study discussed the effect of bends, branches, contractions, expansions, and other geometric discontinuities on fluid flow. According to the study, sudden changes in cross-sectional area or flow direction can cause turbulence and flow separation. Such effects can reduce the efficiency of a fluid transportation system. For a multi-junction connector, this means that the junction region should be designed with appropriate transition geometry rather than using sharp and sudden changes wherever possible. This work provides a theoretical basis for improving the internal geometry of the proposed connector and reducing unnecessary pressure losses.

- Research on Branch-Pipe Junction Geometry

Several researchers have studied the effect of branch geometry on the performance of pipe junctions. Particular attention has been given to branch angle, branch-to-main-pipe diameter ratio, and the shape of the intersection between the pipes. Research indicates that the branch angle can significantly influence the velocity distribution and pressure pattern inside the junction. At certain angles, the fluid undergoes a significant change in direction, increasing turbulence and energy loss. Smoothly connected branches can provide better flow characteristics than branches with sharp intersections. These findings are important for the present project because the proposed connector contains multiple branches. The branch arrangement and angle must be selected according to the intended application so that the connector provides proper flow distribution while maintaining adequate structural strength.

- CFD Studies of Pipe Junctions

Computational Fluid Dynamics (CFD) has become an important method for studying the behavior of fluid inside pipe junctions. Researchers have used CFD simulations to investigate velocity distribution, pressure distribution, turbulence, recirculation, and pressure drop. CFD analysis allows different junction geometries to be tested without manufacturing every physical prototype. A CAD model can be imported into a CFD software package, and the flow conditions can be applied to determine the performance of the design. The results can then be used to modify the geometry before fabrication. For the proposed multi-junction pipe connector, CFD can be useful for comparing different branch arrangements and identifying regions where high turbulence or pressure loss may occur. This can help in developing a more efficient connector.

- Research on Stress Concentration in Pipe Junctions

Pipe junctions are also critical from a structural point of view. When internal pressure acts on a pipe connector, stresses are generated in the pipe wall. The junction region between the main pipe and branch pipe may experience higher stress because of the change in geometry. Researchers studying branch connections have found that stress concentration can occur near the intersection of the main pipe and branch. The magnitude of the stress depends on factors such as wall thickness, branch diameter, branch angle, material properties, and internal pressure. This research is important for the proposed project because a multi-junction connector has several branch intersections. The design must therefore provide sufficient wall thickness and appropriate junction geometry to prevent excessive deformation or failure.

- Finite Element Analysis of Pipe Connections

Finite Element Analysis (FEA) is widely used for evaluating the structural performance of pipe components. Researchers have applied FEA to determine von Mises stress, deformation, strain, and factor of safety in pipe junctions subjected to internal pressure and external loads. The advantage of FEA is that critical regions can be identified before manufacturing the physical component. If excessive stress is found in a particular region, the CAD model can be modified by increasing wall thickness, changing the branch geometry, or providing a smoother transition. For the proposed multi-junction pipe connector, FEA can therefore be used as a design-validation technique. It can help determine whether the selected material and dimensions are capable of withstanding the expected operating conditions.

- CAD-Based Design of Pipe Connectors

Computer-Aided Design (CAD) has significantly improved the design process for pipe fittings and connectors. CAD software allows engineers to create accurate three-dimensional models and control important

parameters such as diameter, length, branch position, branch angle, wall thickness, and connection dimensions. In traditional design, modifications to a physical model can be time-consuming and expensive. In contrast, CAD allows the designer to modify the model before fabrication. Different design alternatives can also be compared easily. For the proposed project, CAD modelling is an important stage because the multi-junction connector consists of several interconnected branches. A 3D CAD model can ensure accurate positioning of all branches and provide the dimensions required for manufacturing.

- Research on Manufacturing and Fabrication of Pipe Fittings

Research on the manufacturing of pipe fittings indicates that the selected fabrication method affects dimensional accuracy, surface quality, strength, and cost. Depending on the material and application, pipe connectors can be produced by machining, welding, casting, forging, additive manufacturing, or combinations of these methods. For a student-level prototype, fabrication methods such as cutting, drilling, turning, welding, and machining can be selected according to the available equipment. Proper alignment during fabrication is particularly important because inaccurate branch positioning can affect both the appearance and functional performance of the connector. Therefore, the proposed project considers not only the theoretical design but also the practical manufacturability of the connector.

- Experimental Testing of Pipe Connectors

Experimental testing is an important part of validating a newly designed pipe connector. Researchers commonly evaluate pipe components using pressure tests, leakage tests, dimensional inspection, and flow-performance tests. A pressure test can be used to determine whether the connector can withstand the specified internal pressure without leakage or permanent deformation. Dimensional inspection can verify whether the fabricated component matches the CAD model. If required, flow testing can be conducted to compare pressure drop and flow distribution with theoretical or CFD results. For the proposed project, experimental testing will help determine whether the fabricated multi-junction connector performs satisfactorily under practical conditions.

B) Literature Summary

- Idelchik (2007): Studied hydraulic resistance in pipe fittings and junctions. Found that branch angle, diameter ratio, and flow direction significantly affect pressure loss.
- Miller (1990): Investigated pressure losses in pipe fittings and internal flow systems. Reported that sudden changes in flow direction and area increase energy losses.
- Blevins (1992): Studied fluid flow through bends, branches, expansions, and contractions. Emphasized the importance of smooth geometry to reduce turbulence and flow separation.
- Branch Junction Geometry: Previous studies show that branch angle and diameter ratio strongly influence flow distribution and pressure loss in pipe junctions.
- CFD Studies: CFD is useful for predicting velocity, pressure, turbulence, and recirculation inside pipe junctions before physical fabrication.
- Stress Concentration: Research shows that high stress can occur at the intersection of the main pipe and branch pipe. Proper junction geometry is required to reduce stress concentration.
- FEA Studies: Finite Element Analysis can determine stress, deformation, and factor of safety and helps identify critical regions before manufacturing.
- CAD-Based Design: CAD software helps create accurate 3D models and easily modify pipe diameter, branch angle, wall thickness, and branch positions.
- Fabrication Studies: Manufacturing methods such as machining, welding, casting, and cutting affect the dimensional accuracy, strength, and surface quality of pipe connectors.
- Experimental Testing: Pressure, leakage, dimensional, and flow tests are useful for validating the performance of a fabricated pipe connector.

C) Research Gap

- Limited study on multi-junction configuration: Most existing studies focus on individual T, Y, or cross pipe junctions rather than a connector having multiple branches in one compact structure.
- Optimization of branch arrangement: There is a need to study the suitable branch angle, branch position, and diameter to obtain better flow distribution and reduce pressure losses.
- Stress concentration: Multiple branches can create critical stress-concentration regions. Further work is required to develop a geometry that provides adequate strength while maintaining a compact design.
- Integration of CAD and fabrication: Many studies concentrate on numerical analysis, while comparatively less attention is given to converting an optimized CAD model into a low-cost, practically manufacturable prototype.
- Experimental validation: There is a need for practical testing of the fabricated connector to verify dimensional accuracy, leakage resistance, pressure capability, and functional performance.
- Cost-effective design: There is scope for developing a connector that is simple, economical, lightweight, easy to manufacture, and suitable for small-scale applications.
- Design–fabrication–testing approach: A complete methodology combining CAD modelling → design analysis → fabrication → inspection → testing can provide better validation of the proposed connector

I. RESEARCH METHODOLOGY

A) Proposed System

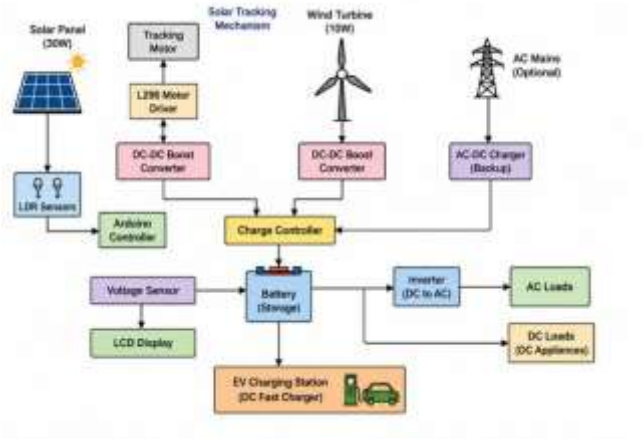


Figure 2. Proposed System

- The 30 W solar panel captures solar energy, while LDR sensors detect the direction of maximum sunlight to improve energy generation throughout the day.
- The Arduino controller processes the LDR sensor signals and controls the L298 motor driver, which rotates the DC geared motor to automatically align the solar panel with the sun.
- Simultaneously, the 10 W wind turbine converts wind energy into electrical energy whenever sufficient wind is available, providing an additional renewable power source.
- The electrical output from both the solar panel and wind generator is regulated using DC-DC boost converters to obtain a stable DC voltage.
- The regulated power is supplied to a battery charging circuit, which safely charges the rechargeable battery and stores energy for continuous operation.
- When renewable energy is insufficient, the optional AC mains supply automatically acts as a backup source to maintain uninterrupted battery charging and EV charging.
- A voltage sensor continuously monitors battery voltage and system status, while the 16×2 LCD display shows real-time voltage, charging status, and active power source.
- The stored battery energy powers the EV charging station, supplies DC loads directly, and, through an inverter, provides AC power for household or industrial AC loads, ensuring reliable and efficient hybrid energy utilization.

B) Hardware Used

- Arduino UNO: Acts as the main controller, processing LDR signals and managing the solar tracking operation.
- 30 W Solar Panel: Converts sunlight into electrical energy for battery charging and EV charging.
- 10 W Wind Turbine: Generates additional electrical energy from available wind.
- LDR Sensors: Detect sunlight intensity from different directions for automatic panel positioning.
- L298 Motor Driver: Controls the direction and speed of the tracking motor according to Arduino signals.
- DC Geared Motor: Mechanically rotates the solar panel toward the direction of maximum sunlight.
- DC-DC Boost Converter: Regulates and increases the generated DC voltage to the required level.
- Rechargeable Battery: Stores renewable energy and supplies power when generation is insufficient.
- Voltage Sensor: Measures battery/system voltage for monitoring and control.
- 16×2 LCD: Displays voltage, charging status, and operating conditions.
- Inverter: Converts battery DC into AC for AC loads.
- EV Charging Unit: Provides regulated electrical power for charging the electric vehicle.

II. CALCULATION

1. Solar Power Generation

Given:

- Solar panel rating = 30 W
- Operating voltage ≈ 12 V

Solar current:

$$I_s = \frac{P_s}{V_s}$$

$$I_s = \frac{30}{12} = 2.5A$$

Therefore, the solar panel can provide approximately 2.5 A at rated conditions.

2. Wind Power Generation

Given:

- Wind generator rating = 10 W
- Output voltage ≈ 12 V

Wind generator current:

$$I_w = \frac{P_w}{V_w}$$

$$I_w = \frac{10}{12} = 0.83A$$

Therefore, the wind generator can provide approximately 0.83 A at rated conditions.

3. Total Renewable Power

$$P_{total} = P_{solar} + P_{wind}$$

$$P_{total} = 30 + 10 = 40W$$

Thus, the theoretical maximum renewable generation is approximately 40 W.

4. Battery Energy Storage

Assuming a 12 V, 7 Ah battery:

$$E = V \times Ah$$

$$E = 12 \times 7 = 84Wh$$

Therefore, the battery has approximately 84 Wh of nominal stored energy.

5. Approximate Battery Charging Time

Assuming the full 40 W renewable power is available and ignoring losses:

$$t = \frac{E}{P}$$

$$t = \frac{84}{40} = 2.1\ hours$$

Considering converter, wiring, charging, and environmental losses, the practical charging time will be higher than 2.1 hours.

6. Boost Converter Output

If the renewable source provides 12 V, 3 A and the boost converter produces 24 V, assuming 90% efficiency:

$$P_{out} = 12 \times 3 \times 0.9$$

$$P_{out} = 32.4W$$

Output current:

$$I_{out} = \frac{32.4}{24} = 1.35A$$

7. Inverter Output

If the battery supplies 84 Wh and the inverter efficiency is assumed to be 85%:

$$E_{AC} = 84 \times 0.85$$

$$E_{AC} = 71.4Wh$$

Therefore, approximately 71.4 Wh of usable AC energy can be obtained from the battery through the inverter.

8. EV Charging Energy

If the prototype EV charging load is assumed to be 40 W:

$$t = \frac{84}{40}$$

$$t = 2.1\ hours$$

Considering system losses, the actual charging duration will depend on battery condition, converter efficiency, renewable generation, and EV charging requirements.

III. Advantages And Applications

A) *Advantages*

- Renewable Energy: Utilizes clean solar and wind energy, reducing dependence on conventional electricity.
- Solar Tracking: LDR-based tracking improves solar energy collection by maintaining better panel orientation.
- Hybrid Operation: Combines solar, wind, battery, and optional AC mains for improved reliability.
- Energy Storage: Battery stores excess renewable energy for later use.
- Real-Time Monitoring: Voltage sensor and LCD provide simple system-status monitoring.
- Eco-Friendly: Supports sustainable EV charging and reduces environmental impact.

B) *Applications*

- EV Charging: Suitable for small-scale electric vehicle charging stations and demonstration prototypes.
- Residential Charging: Can support EV charging and auxiliary household loads.
- Educational Institutions: Useful for demonstrating solar tracking, wind generation, and hybrid energy systems.
- Parking Areas: Can provide renewable charging facilities in parking locations.
- Remote Areas: Suitable for locations with limited grid availability.
- Renewable Laboratories: Useful for research, testing, and practical demonstrations of hybrid renewable-energy technologies.

IV. Conclusion

The proposed **Hybrid Solar Tracking, Wind Energy, and AC Mains Based EV Charging Station** provides a sustainable and reliable approach for renewable-energy-powered electric vehicle charging. The system combines a 30 W solar panel with an LDR-based automatic tracking mechanism, enabling the panel to follow the direction of maximum sunlight and improve energy harvesting. A 10 W wind turbine provides additional renewable power during suitable wind conditions. The generated energy is regulated using a DC-DC boost converter and stored in a rechargeable battery for later use. An optional AC mains supply provides backup power whenever renewable generation is insufficient. The Arduino controller, L298 motor driver, voltage sensor, and LCD display enable automatic tracking, monitoring, and basic system control. The stored battery energy can supply the EV charging unit and DC loads, while an inverter supports AC loads. Overall, the proposed system demonstrates the feasibility of integrating multiple renewable sources with energy storage and backup supply, reducing dependence on conventional electricity and

supporting cleaner transportation. The prototype can serve as a foundation for developing larger and more efficient renewable-powered EV charging stations.

V. FUTURE SCOPE

- Higher Capacity: Use higher-rated solar panels, wind turbines, and batteries for practical EV charging.
- Advanced Tracking: Implement dual-axis tracking and MPPT for improved solar energy harvesting.
- IoT Monitoring: Add Wi-Fi/IoT for remote monitoring, data logging, and smart energy management.
- Smart Charging: Develop automatic renewable/grid source selection based on battery SOC and charging demand.

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