

Article

3D-Printed Tesla Valve with IoT-Based Flow and Pressure Sensing

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Abstract

Tesla valves are passive flow-control devices that enables asymmetry without moving parts. In recent years, they have attracted renewed interest due to their wide range of applications, spanning from biomedical and agricultural systems to thermal and marine engineering. The performance of a 3D-printed double Tesla valve is experimentally investigated using an integrated low-cost Internet of Things (IoT) measurement system. The valve performance is evaluated for inlet volumetric flow rates ranging from 5 to 20 L/min. The results demonstrate a clear asymmetry between forward and reverse flow, with a maximum diodicity of 1.96 observed at the lowest (5–6 L/min) flow rate. The proposed low-cost experimental framework combines additive manufacturing and real-time IoT-based monitoring, offering a reproducible and accessible approach for investigating passive flow-control devices at flow-rate regimes beyond typical microfluidic applications.

Keywords: 3D printed; Tesla valve; Arduino; sensor; IoT

1. Introduction

The Tesla valve (valvular conduit), which was invented and patented by Nicola Tesla in 1920, is in fact a passive valve without any moving parts. A Tesla valve can be considered any valve that exhibits a higher pressure drop for flow in one direction (reverse) than the other (forward). The performance of the valve is expressed in terms of the diodicity (D), which is defined as the ratio of directional resistances.

Nowadays, the Tesla valve has found applications across a wide range of research fields. It has been used as a bio-sensor for determination of food-borne pathogens [1], as wearable device for monitoring glucose, oxygen, and heart rate [2] and for sweat colorimetric analysis [3]. Many applications fall within the framework of green energy, such as photovoltaic systems [4] and wind turbines [5]. Another field that has attracted significant research interest is thermal transport [6–9], with applications ranging from heat sinks [10] to battery heating management [11,12]. Tesla valve can also be applied in large-scale projects, such as passive stabilization in combustion chambers [13] and as 3D-printed antifouling devices in marine environment [14]. Finally, a Tesla valve could act successfully as a micromixer [15,16].

Previous research has extensively investigated geometry optimization [10,17] strategies to maximize the diodicity demonstrating various design modifications including altered channel angles, modified loop geometries and obstacles [18–21], and multi-stage



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configurations. Other factors affecting the diodicity include the inlet velocity, which can be expressed in terms of Reynolds (Re) number or volumetric rate (Q), as well as the multi-stage configurations (N number of Tesla valves which are connected in series) [22,23]. Relevant studies show an increase in diodicity when Re is increased [24], while a decrease in D has been observed after further increase in Re [25]. An increase in number of valves (N) generally leads to a higher diodicity; however, this increase is not proportional [24].

While extensive research numerically and experimentally has been devoted to microscale Tesla valves [9,20,26–29], typically operating at very low volumetric flow rates, large-scale or macroscale implementations are primarily associated with industrial piping systems. Such macroscale solutions often involve significantly larger dimensions, higher manufacturing costs, and complex integration requirements, which limit their applicability in compact or modular fluidic systems. Consequently, experimental investigations focusing on centimeter-scale geometries and volumetric flow rates on the order of several liters per minute remain comparatively scarce.

Moreover, centimeter-scale geometries and flow rates on the order of several liters per minute [30] cannot be treated as a simple downscaled version of macroscale systems nor as an upscaled microfluidic device. At this intermediate geometric scale, the flow behavior is strongly influenced by geometry-induced effects, such as flow separation, recirculation, surface roughness, and minor hydraulic losses, which become increasingly important at elevated flow rates. Hence, experimental data obtained at either the micro- or macroscale cannot be directly extrapolated to intermediate-scale applications.

Over the last decade, 3D printing technology has been widely used for both research and domestic purposes. 3D printing is involved in many research fields, including biomedical engineering [31,32], construction [33], microfluidic devices [29,34] and sensors [35,36]. The cost of desktop 3D printing systems and commonly used polymeric materials has decreased in recent years, improving the accessibility of rapid prototyping, while new materials produced with enhanced properties continue to be developed [37,38].

The continuous reduction in sensor, microcontroller, and communication costs has made the Internet of Things (IoT) a widely adopted solution in research, industry, and smart infrastructure. The IoT enables interconnected physical devices to collect, transmit, and process data in real time, offering significant benefits such as remote monitoring, automation, and data-driven decision making [39,40]. However, IoT systems also present challenges, including data security and privacy risks and dependence on network connectivity.

Pressure sensors and flow rate sensors can be attached to a 3D-printed double Tesla valve for real-time monitoring via the Arduino cloud platform. This experimental setup could serve systems whose flow rate requirements cannot be established at the microscale. Moreover, it is a low-cost component with short manufacturing time and could find applicability from agriculture to marine and thermal system fields.

Consequently, dedicated experimental investigations at the centimeter-scale are required to bridge the gap between microfluidic studies and industrial-scale implementations. The present work addresses this gap by experimentally investigating a centimeter-scale 3D-printed double Tesla valve operating at volumetric flow rates up to 20 L/min. Manufactured using low-cost fused deposition modeling, it is combined with an integrated IoT-based sensing and data acquisition system. Rather than introducing a new valve geometry, this work emphasizes practical implementation, reproducibility, and real-time monitoring, targeting application scenarios where microfluidic devices are unsuitable, but fully industrial solutions are unnecessary.

2. Materials and Methods

The Tesla valve geometry was selected based on an existing Tesla structure [41]. That geometry consisted of two valve units ($N = 2$) connected in series, with both the inlet and outlet of the micromixer having a squared cross section of height and width $W = H = 10^{-4}$ m [42], corresponding to the length of each side (a), and a length ratio of $\frac{L_1}{L_2} = 2$ as illustrated in Figure 1.

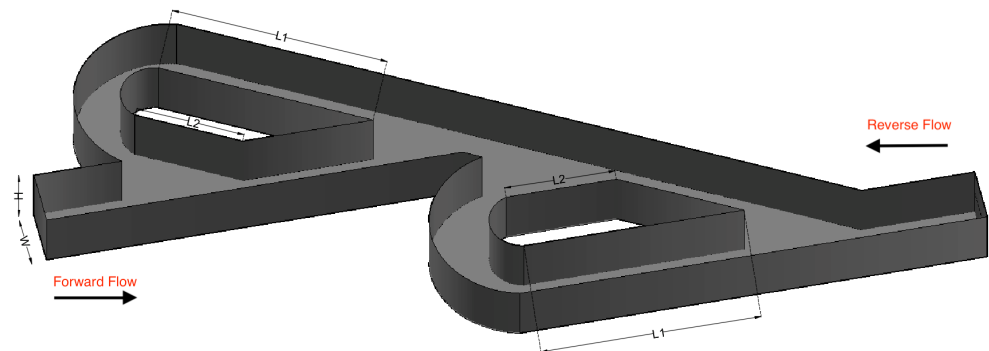


Figure 1. Valve geometry and flow directions.

An experimental setup was implemented for the double Tesla valve geometry under various volumetric rates (Q). The scaling factor was defined based on the design principles of previously studied Tesla valve [43] configurations and adapted to a centimeter-scale implementation suitable for experimental investigation at liter-per-minute flow rates and the capabilities of the 3D printer (Ultimaker B.V. S3, Zaltbommel, The Netherlands). Since the geometry consisted of a 3D-printed part with a finite thickness, the interior dimensions were $W_{int} = H_{int} = 1.0^{-2}$ m, while the exterior dimensions were $W_{ext} = H_{ext} = 1.4^{-2}$ m, and the total length of the valve was $L = 15^{-2}$ m. Additionally, two pipes with the same interior and exterior diameter were attached to the inlet and to the outlet of the valve in order to connect it to the water supply; a sectional view of the experimental geometry is presented in Figure 2.

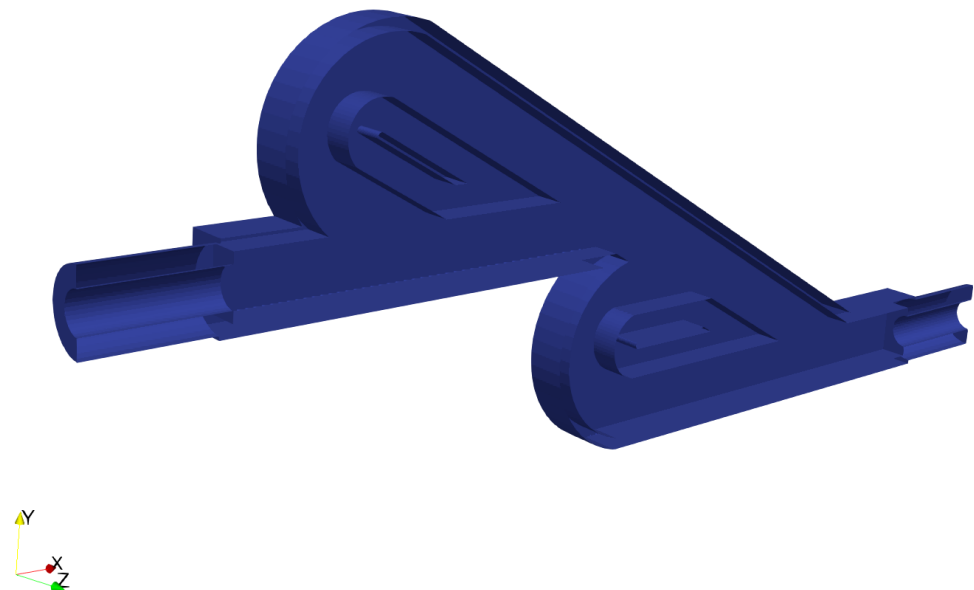


Figure 2. Experimental valve geometry.

The Ultimaker S3 printer is equipped with dual excursion heads, one head used for printing the main part (valve) and the other one for printing the support structures (inside the valve). Thus, during the 3D printing, the final part was produced using two different filaments. Tough PLA (Ultimaker) filament was used for the main part, while Polyvinyl Alcohol (PVA), which is a biodegradable, non-toxic, and water-soluble filament, was used for support structures.

Diodicity (D) is the performance indicator of the Tesla valve and is defined as the ratio:

$$D = \frac{\Delta P_{rev}}{\Delta P_{for}} \quad (1)$$

where ΔP_{rev} is the pressure difference $P_{inlet} - P_{outlet}$ for the reverse flow, and ΔP_{for} is the pressure difference $P_{inlet} - P_{outlet}$ for the forward flow as shown in Figure 1.

The pressures P_{inlet} and P_{outlet} were measured using two analog pressure sensors located near the inlet and outlet, respectively. These sensors, along with a water flow sensor were connected to an Arduino Uno R4 WiFi board, and the code used to measure the inlet volumetric rate and pressure from the sensors was uploaded to the Arduino cloud platform. This experimental setup can be considered an IoT (Internet of Things) device, as it could provide real-time measurements, enabling data storage for future use, creating plots from the data, and remote access from any device connected to the platform.

The experimental device was placed parallel to the ground in order to avoid pressure losses due to height difference between inlet and outlet. Moreover, the valve remained fixed in position, and the selection of water supply direction was achieved using conventional valves in the system. Figure 3 illustrates the connection between the pipe and the 3D-printed valve.



Figure 3. 3D-printed Tesla valve.

The experimental procedure was carried out as described below: Initially, the Arduino R4 was powered on and connected to the WiFi network; afterwards, the water supply was activated to feed the valve system until the hoses were completely filled up with water (without turning off the water supply). Measurements then began at a low volumetric flow rate and were gradually increased up to the maximum of 20 L/min, using a constant time step. The maximum investigated flow rate of 20 L/min was selected based on laboratory water supply stability rather than structural failure of the valve. Flow-rate control was achieved using the laboratory water supply and conventional mechanical valves, allowing gradual adjustment of the inlet volumetric flow rate. Pressure and flow signals were acquired continuously via the Arduino Uno R4 WiFi board and transmitted to the Arduino Cloud platform. The data were logged at a constant acquisition rate determined by the microcontroller loop and stored in CSV format for post-processing, while real-time data were displayed on a mobile device.

3. Results

The post-processing analysis was performed with Python (version 3.9.6), which is a free software program. The direct results of the experiment are presented in Figure 4; the y-axis represent the pressure while the x-axis the volumetric flow rate. As the flow rate increased the pressure difference between the reverse and the forward flow also increased. As expected, the diodicity (D) was always ≥ 1 , as can be observed from the raw data. It should be noted that while the sensors could measure during the forward flow under flow rates of 3–5 L/min, they returned a zero value under reverse flow at the same flow rates, since the voltage was out of the sensor range. Therefore, these values were removed from the post-processing analysis. Additionally, all the other measured data points were retained and are presented in the corresponding figures.

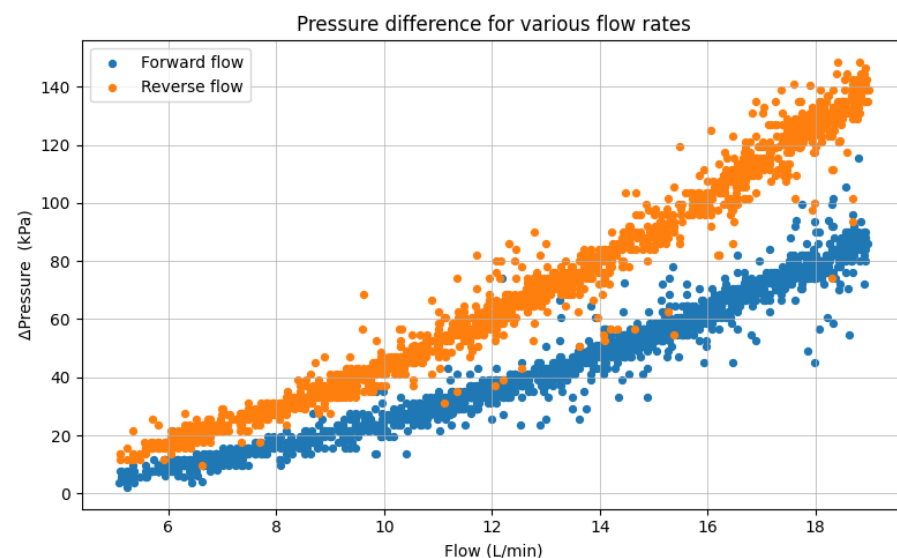


Figure 4. Pressure difference.

Moreover, the water supply at the lab had fluctuations as shown in the above Figure 4, and therefore, the data were grouped into 1 L/min flow rate bins for further analysis. Figure 5 demonstrates more clearly the pressure difference between the forward and reverse flow over the investigated flow-rate range.

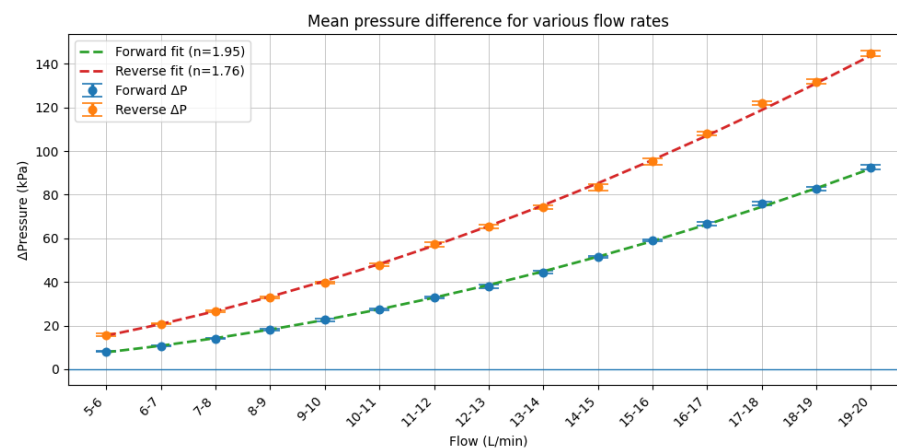


Figure 5. Mean Pressure difference and standard error of the mean (SEM).

In both flow directions, the pressure drop followed a nonlinear dependence on the volumetric flow rate that could be described by a power-law relation of the form

$$\Delta P \propto Q^n. \quad (2)$$

The fitted exponents were $n \approx 1.95$ for the forward flow and $n \approx 1.76$ for the reverse flow, indicating predominantly inertia-dominated behavior, with consistently higher pressure losses observed in the reverse direction.

As a scaling reference, it is noted that for turbulent flow in smooth pipes, combining the Darcy–Weisbach equation with the Blasius correlation ($f \propto Re^{-0.25}$) yields an effective relation $\Delta P \propto Q^{1.75}$ over $Re \sim 3 \times 10^3$ – 10^5 . Although the present geometry is three-dimensional and fabricated via additive manufacturing, and therefore does not correspond to an ideal smooth conduit, the close agreement between the reverse-flow exponent ($n \approx 1.76$) and the $Q^{1.75}$ scaling suggests that reverse-flow separation and recirculation introduce Reynolds-number-dependent dissipation. This results in an effective loss scaling slightly below the ideal quadratic inertial limit ($n = 2$). The data of the reverse and forward flow are presented in Tables A7 and A8, respectively.

Finally, the next step was the evaluation of the double Tesla valve performance. Note that the difference between the forward and reverse flows, shown in Figures 4 and 5, may lead to misunderstanding, since the diodicity is defined as the ratio of the corresponding pressure differences. Therefore, since our analysis employs the mean pressure difference for each flow value, Equation (2) should be expressed as:

$$D = \frac{\overline{\Delta P}_{rev}}{\overline{\Delta P}_{for}} \quad (3)$$

while the error calculated from:

$$\sigma_D = D \sqrt{\left(\frac{\text{SEM}_{rev}}{\overline{\Delta P}_{rev}}\right)^2 + \left(\frac{\text{SEM}_{fwd}}{\overline{\Delta P}_{fwd}}\right)^2} \quad (4)$$

It should be noted that Equation (3) quantifies the statistical uncertainty of the measured pressure differences through the standard error of the mean (SEM), reflecting temporal fluctuations due to water supply instability and transient flow behavior. Instrumental uncertainty associated with sensor accuracy was not explicitly propagated in the diodicity calculation. However, since the diodicity is defined as a ratio of pressure differences measured using identical sensors and acquisition electronics, systematic sensor bias is expected to partially cancel. While instrumental uncertainty affects absolute pressure and flow-rate values, it is not expected to alter the observed qualitative trends in diodicity or the asymmetry between forward and reverse flow.

Figure 6 demonstrates the performance of the double Tesla valve for various inlet flow rates. As the flow rate increased, a decrease in diodicity was observed, the maximum diodicity (1.96) being obtained under a flow rate equal to 5–6 L/min. The diodicity remained almost stable ≈ 1.72 – 1.75 and ≈ 1.59 – 1.62 under flow rates of 9–13 L/min and 14–19 L/min, respectively. The minimum diodicity (1.56) was obtained under the higher flow rate (19–20 L/min). The dashed trend line highlights a monotonic decrease in diodicity with increasing inlet flow rate, indicating a gradual reduction in flow asymmetry at higher flow regimes. This behavior suggests that inertial effects become increasingly dominant, diminishing the relative difference between forward and reverse pressure losses.

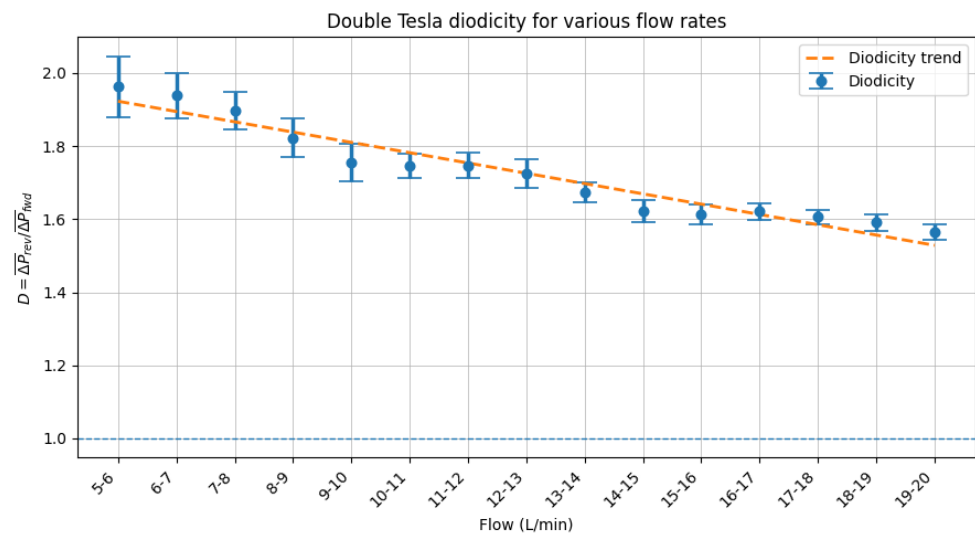


Figure 6. Tesla valve diodicity under various flow rates.

4. Discussion

The performance indicator of the Tesla valve is the diodicity, which was investigated in the present work under various inlet flow rates. The maximum diodicity, D_{max} , was obtained at the minimum flow rate, while the minimum diodicity, D_{min} , occurred at the maximum flow rate, resulting in a difference $\Delta D = D_{max} - D_{min} = 0.4$. This indicates a clear relationship between the diodicity and the volumetric flow rate. The diodicity decreased with the increasing inlet flow rate, indicating that the experimental setup operated at inlet flows rates higher than the optimum values of the inlet flows [25]. Hence, higher values of D_{max} were expected for lower inlet flow rates, but these conditions could not be carried out due to sensor limitations.

The observed decrease in diodicity with the increasing volumetric flow rate can be attributed to the convergence toward similar inertia-dominated scaling in both directions and hydraulic losses within the valve geometry. At lower flow rates, flow separation and recirculation in the reverse direction enhance asymmetry, resulting in higher diodicity. As the flow rate increases, entrance losses and pressure dissipation in both directions become more pronounced, reducing the relative difference between forward and reverse pressure drops.

Although a precise identification of flow regime transitions would require detailed flow-field measurements or numerical simulations, the observed trends are consistent with previous studies reporting a decline in diodicity at higher Reynolds numbers [25].

From a scaling perspective, a fully developed laminar flow in simple channels is characterized by a linear relationship $\Delta P \propto Q$, whereas flow regimes dominated by minor losses and inertial effects tend to follow a quadratic relationship $\Delta P \propto Q^2$, as commonly reported in internal flow theory and loss-coefficient formulations. The fitted exponents obtained in the present work ($n \approx 1.95$ for the forward flow and $n \approx 1.76$ for the reverse flow) therefore indicate that the valve operates in a regime where inertial and geometry-induced losses are dominant rather than purely viscous effects.

The slightly lower exponent observed in the reverse flow suggests additional energy dissipation mechanisms associated with flow separation, recirculation zones, and enhanced pressure-drop asymmetry. Such mechanisms have been extensively discussed in numerical and experimental investigations of Tesla-type valves, where diodicity enhancement is linked to separation bubbles, distorted inflow conditions, and Reynolds-dependent flow structures [1,17,24,25,44]. As the flow rate increased, both flow directions remained within an inertia-dominated scaling regime over the investigated flow range thereby reducing

the relative asymmetry between forward and reverse pressure drops and leading to the observed gradual decrease in diodicity, consistent with previously reported Reynolds-dependent behavior [1,7,45].

Direct comparison of Tesla valve performance across studies remains challenging due to differences in geometry, number of stages, and operating Reynolds numbers. Nevertheless, the maximum diodicity achieved in the present work $D_{max} = 1.96$ is higher than that in our previous study $D = 1.43$ for a double Tesla valve under $Re = 450$ [43]. Another relevant research study [45] with a total valve length $L = 30$ cm, which is double that of the present work, with $N = 11$ achieving $D = 2$ at $Re = 500$, also reported a diodicity values close to two up to $Re = 1000$. A heat transfer Tesla valve approach performed simulations with a wide range of Reynolds values from 4000 up to 14,000, where three different Tesla valve configurations were used for specific Reynolds values, and obtained a diodicity value close to 1.4 [46], which is comparable in terms of Re with the present study, where the maximum diodicity (1.96) occurred under a flow rate range of 5–6 L/min and a corresponding value of Re in the range of 8000–10,000. Moreover, similar trends were reported in diodicity enhancement for multistage Tesla valves, demonstrating that the diodicity behavior is Reynolds-dependent across different geometric configurations [28]. Additionally, relevant studies [44] have shown that variable angle designs can optimize performance across specific flow regimes. The systematic optimization approach by Li et al. [47] using response surface methodology further corroborates the complex relationship between geometry, flow rate, and diodicity that we observed in our experimental results.

Further studies have already combined 3D printing and Tesla valves at the microscale as antifouling functional tablets in the marine industry [14], which connect microscale valves to bigger clusters, such as turbine motor [48] or microfluidic chip [49].

Additionally, no leakage was observed in the 3D-printed part during the experimental procedure. It should be noted that the experiments were repeated more than ten times with consistent results. This behavior indicated good short-term mechanical integrity of the 3D-printed part under the tested operating conditions. No long-term fatigue or constant-load durability tests were conducted, and therefore, conclusions regarding service life remain preliminary. The standard errors reported in Figures 5 and 6 and Tables A7 and A8 reflect the natural variability across these repeated measurements, primarily due to water supply fluctuations rather than measurement inconsistency or structural degradation of the valve.

From an application perspective, the investigated double Tesla valve operates at volumetric flow rates that are not easily accessible by typical microfluidic devices, while remaining significantly simpler and more cost-effective than industrial-scale solutions. The stable diodicity observed over the flow-rate ranges of 9–13 L/min and 14–19 L/min suggests that the proposed geometry can provide reliable passive flow asymmetry under moderately high-flow conditions. Combined with the integrated low-cost IoT monitoring system, the valve can be considered suitable for applications requiring real-time flow supervision and passive flow control, such as agricultural irrigation subsystems, experimental thermal loops, and laboratory-scale fluid transport setups, where robustness, simplicity, and monitoring capability are prioritized over maximizing diodicity. Such monitoring enables early detection of performance degradation, partial blockage, or unintended variations in inlet flow rate, thereby enhancing operational reliability in practical flow-control systems.

5. Conclusions

The purpose of this work was to experimentally investigate the performance of a double 3D-printed Tesla valve over a range of volumetric flow rates and to develop a low-cost sensing system capable of real-time monitoring of the inlet flow rate and the pressure at both the inlet and outlet of the valve.

Several findings arose from the experimental setup. The results indicated that the diodicity D did not vary proportionally with the volumetric flow rate Q , which could be explained by the fluid phenomena inside the selected valve. Moreover, a stabilization of the diodicity with only minor fluctuations was observed over specific flow-rate ranges. In particular, the volumetric flow rate ranges of 9–13 and 14–19 L/min exhibited only a minor effect on the diodicity. A maximum diodicity of 1.96 was observed at low flow rates (5–6 L/min), while a gradual decrease was recorded at higher flow rates.

Future work will focus on two main directions: experimental and numerical. For the experimental part, further investigation of lower volumetric rates will be conducted to identify conditions yielding the maximum diodicity for the double valve. Additional staging configurations with different N values, experiments with air instead of water, and geometry optimization will be pursued, and the limitations of the 3D-printed part will be explored, such as maximum Q (before leakages) and lifespan of the material. For the numerical part, future efforts will focus on validating the experimental results through numerical simulations and using the validated models to further optimize the valve geometry and flow performance.

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Abbreviations

The following abbreviations are used in this manuscript:

IoT	Internet of Things
D	Diodicity
D_{max}	Maximum diodicity
D_{min}	Minimum diodicity
N	Number of Tesla valves
Re	Reynolds number
W	Width of micromixer
H	Height of micromixer
W_{int}	Interior width of valve
H_{int}	Interior height of valve
W_{ext}	Exterior width of valve
H_{ext}	Exterior height of valve
L_1/L_2	Length ratio of valve
a	Side of square inlet and outlet of micromixer

Q	Volumetric flow rate
ΔP_{rev}	Pressure difference for reverse flow
ΔP_{for}	Pressure difference for forward flow
ΔD	Diodicity difference
n	Exponent of the volumetric flow rate in the fitted power-law pressure–flow relationship
σ_D	Diodicity error

Appendix A

Table A1. Pressure sensor specifications.

Parameter	Specification
Medium	Liquid/gas (non-corrosive)
Wiring	Gravity-3Pin (Signal-VCC-GND)
Pressure Measurement Range	0~1.6 MPa
Input Voltage	+5 VDC
Output Voltage	0.5~4.5 V
Measurement Accuracy	0.5%~1% FS (0.5%, 0~55 °C)
Thread	G1/4
Adapter	G1/2 to G1/4
Waterproof Level	IP68
Operating Temperature	−20~85 °C
Response Time	<2.0 ms
Quiescent Current	2.8 mA
Normal Operating Pressure	≤2.0 MPa
Damaged Pressure	≥3.0 MPa
Service Life	10,000,000 cycles

Table A2. Flow sensor specifications.

Parameter	Specification
Operating Voltage	4.5–18 V DC
Output Type	5 V TTL
Maximum Current Draw	15 mA at 5 V
Sensor Type	Hall effect
Working Flow Rate	1–30 L/min
Accuracy	±10%
Pulses per Liter	450
Output Duty Cycle	50% ± 10%
Maximum Water Pressure	2.0 MPa
Flow Rate–Pulse Relationship	Frequency (Hz) = 7.5 × flow rate (L/min)

Table A3. Ultimaker S3 technical specifications.

Parameter	Specification
Print Technology	Fused Deposition Modeling (FDM)
Compatible Filament Diameter	2.85 mm
	0.25 mm nozzle: 150–60 µm
	0.4 mm nozzle: 200–20 µm
	0.6 mm nozzle: 300–20 µm
	0.8 mm nozzle: 600–20 µm
Layer Resolution	6.9, 6.9, 2.5 µm
XYZ Resolution	6.9, 6.9, 2.5 µm
Feeder Type	Dual-gearfed feeder, reinforced for composite materials
Print Head	Dual extrusion print head with auto-nozzle lifting system and swappable print cores
Nozzle Diameters	0.25 mm, 0.4 mm, 0.6 mm, 0.8 mm

Table A4. Mechanical properties of tough PLA.

Property	Orientation	Value
Tensile (Young's) Modulus	XY	2797 ± 151 MPa
	YZ	2797 ± 99 MPa
	Z	2696 ± 180 MPa
Tensile Stress at Yield	XY	45.3 ± 2.0 MPa
	YZ	47.5 ± 0.5 MPa
	Z	33.4 ± 0.5 MPa
Tensile Stress at Break	XY	27.5 ± 7.8 MPa
	YZ	31.3 ± 4.4 MPa
	Z	32.5 ± 0.8 MPa

Table A5. Thermal properties of tough PLA.

Property	Value
Heat Deflection Temperature (HDT) at 0.455 MPa	58.3 ± 0.7 °C
Melting Temperature	152 °C

Table A6. Thermal properties of PVA.

Property	Value
Melt Mass-Flow Rate (MFR)	17–21 g/10 min
Glass Transition Temperature (T_g)	58.4 °C
Melting Temperature (T_m)	175.4 °C

Appendix B

Table A7. Reverse flow: mean pressure difference and SEM per flow bin.

Flow Bin (L/min)	N	Mean ΔP (kPa)	SEM (kPa)
5–6	45	15.80	0.45
6–7	148	20.73	0.25
7–8	91	26.67	0.39
8–9	114	32.87	0.46
9–10	144	39.64	0.52
10–11	102	47.72	0.65
11–12	118	57.19	0.88
12–13	142	65.49	0.94
13–14	132	74.27	0.69
14–15	90	83.48	1.46
15–16	79	95.20	1.47
16–17	143	108.09	0.93
17–18	140	121.93	0.94
18–19	151	131.71	1.07
19–20	77	144.95	1.26

Table A8. Forward flow: mean pressure difference and SEM per flow bin.

Flow Bin (L/min)	N	Mean ΔP (kPa)	SEM (kPa)
5–6	90	8.05	0.25
6–7	123	10.69	0.31
7–8	75	14.06	0.33
8–9	76	18.04	0.46
9–10	92	22.59	0.61
10–11	118	27.32	0.37
11–12	171	32.73	0.41
12–13	114	37.99	0.68
13–14	168	44.40	0.61
14–15	222	51.47	0.42
15–16	221	59.03	0.48
16–17	147	66.70	0.68
17–18	152	75.92	0.76
18–19	157	82.80	0.93
19–20	95	92.62	0.96

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