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# FUZZY SIMULATION OF DRUG DELIVERY SYSTEM THROUGH VALVE-LESS MICROPUMP

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**Original Research Article**

**ABSTRACT**

This research article presents Fuzzy estimation of fluidic parameters for valve-less micropump. The drug delivery system is incomplete without a micropump. The proposed Fuzzy controller micropump (MDDFC) consists of three inputs and two outputs. The investigation through Fuzzy simulation is carried out in order to evaluate the drug flow rate and drug speed. The simulation based on the real time conditions for fluidic parameters. Results are in good agreement with previous researches. The difference between simulated and calculated results is just 1 µl/min for drug flow rate and 0.01 milliliter/sec for drug speed.

**Keywords:** Micropump, Micro Drug Delivery System, Fuzzy MATLAB



## Introduction:

In order to cure a disease, drug is delivered to the infected patient. Diabetic patients examined their blood glucose level continuously. After examining, insulin must be given for the prevention of extra glucose in the body. There are some traditional methods of drugs for this purpose. Drugs may be in form of solid tablets or liquids. Liquid drug is delivered to the body with the help of subcutaneous injections. Sometimes, injections produce some side effects infection and damaging of human tissues. For the safety of patients, there is a system for injected the drug into the body which is called Micro Drug Delivery System (MDDS). This system needs microneedles and piezoelectric micropumps. Micropump is used to pump the drug and microneedle is used to inject the drug into the body. The purpose of this paper is to find the flow rate and speed of drug delivered by micropump. The key components of MDDS are electric unit, sensors, micropump and drug delivery device. The schematic diagram of complete system is shown below in Fig. 1 below.

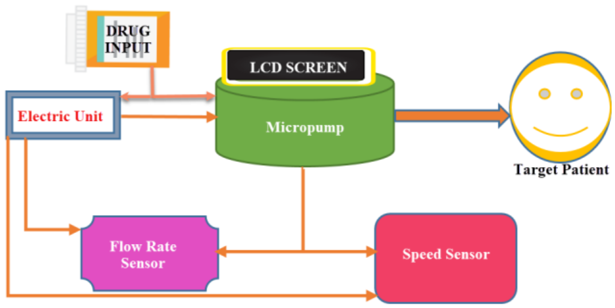


Fig. 1: Block Diagram of MDDS

MDDS has the capability of injecting tiny measures of drugs in micro/min and also milliliter/min. This system can be focused in a diversity of biomedical applications like drug delivery and lab-on-a-chip platforms. Numerous positive methods have been established for microfluidic delivery and actuation. The micropumps have established a great repute as a healthy drug delivery technique in biomedical field. There eight mechanical and eight non mechanical micropumps [1]. Stemme and Stemme established a valve-less micropump which had 15.6 ml/min consistent flow rate [2]. Normally, flow rate can be controlled by input frequency and voltage. Abbas Z. Kouzani et al. investigated 21 milliliter per minute value of flow rate at the lowermost speed while 157 milliliter per minute at the maximum speed [3]. Tayyaba et al. calculated 501 microliter per minute flow rate at 200 hertz frequency with 105 volts applied voltage for valve-less micropump [4]. Fen and Kim investigated 3.2 microliter per minute flow rate with applied voltage 80 volts [5]. Koch et al. investigated 120 microliter per minute flow rate with 600 volts applied voltage at 200 hertz frequency [6]. Che-Yi Shen and Hsien-Kuang Liu reported with the help of experiment that flow rate must increase with the increase of frequency when constant voltage is applied. They also investigated that if voltage is increased (more than 100 volts) with frequency (more than 50 KHz) then flow rate decreased. This pump worked best under given conditions with frequency ranges from 5 to 20 hertz and voltage ranges were from 60 to 120 volts [7]. Flow rate of micropump depends upon frequency, voltage and applied pressure. The micropump controls the requirement of flow rate and speed of the drug. The schematic diagram of micropump is shown in Fig. 2 below.

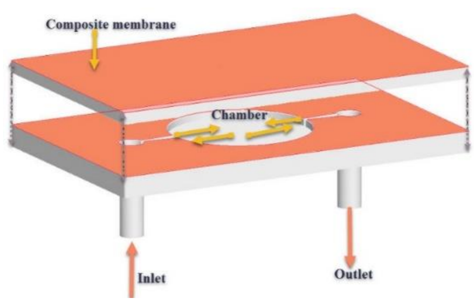


Fig. 2: Schematic diagram of Valve-less Micropump

Olsson et al. developed a model for flow rate [8], which is given below as equation 1. Here, V, f and n can be taken in terms of voltage, frequency and pressure respectively.

$$Q = 2Vf\frac{n^{1/2} - 1}{{n_o}^{1/2} + 1} - - - - - - - - - - - (1)$$

For the estimation of flow rate and speed for valve-less micropump, MATLAB Fuzzy simulation is applied in this research article. Numerous researches have been carried out by using Fuzzy and other simulation techniques [9-15].

## Fuzzy Estimation for flow rate and speed

For simulation purpose, three inputs (each with three membership functions) and two outputs (each with three membership functions) are taken for the Fuzzy controller. The ranges for inputs are taken 150 to 250 hertz for frequency, 50 to 150 volts for voltages and 10 to 200 for Reynolds Number. The ranges for outputs are taken as 450 to 550 µl/min for flow rate and 0.1 to 0.4 milliliter/sec (100-400 µL/sec) for speed of drug injected to patient. These ranges are taken as real time values [7, 16]. Fuzzy simulation diagrams have shown below.

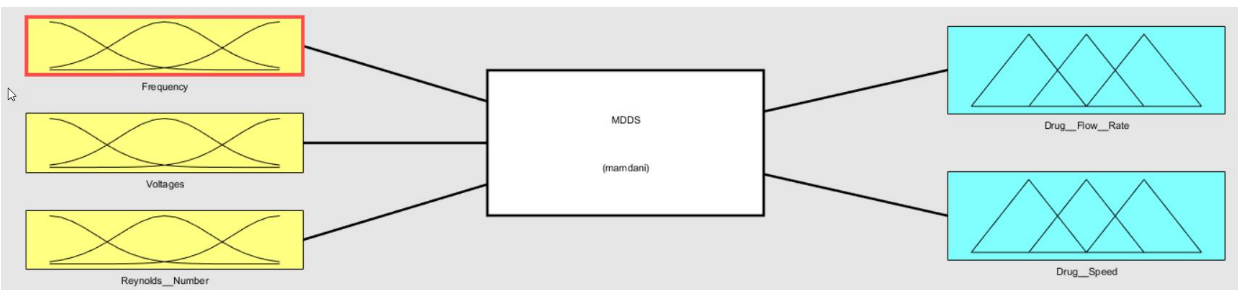


Fig. 3: MDDFC

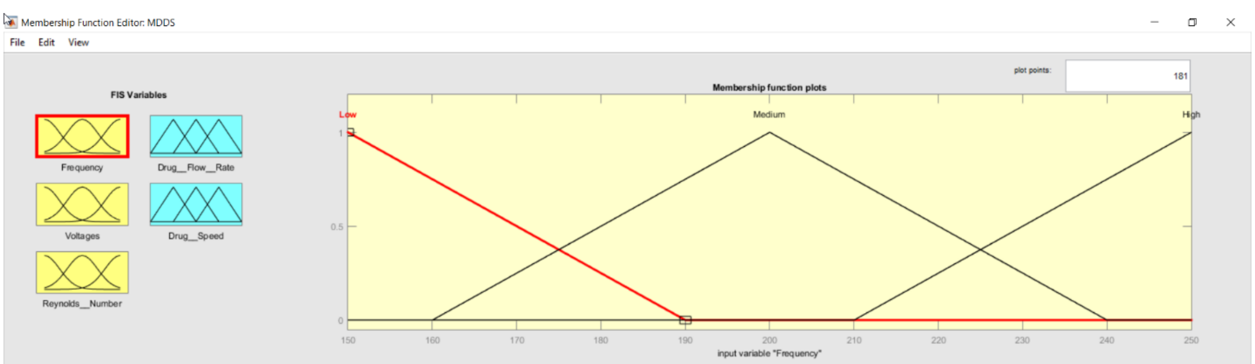


Fig. 4: FIS Variables with membership function plots

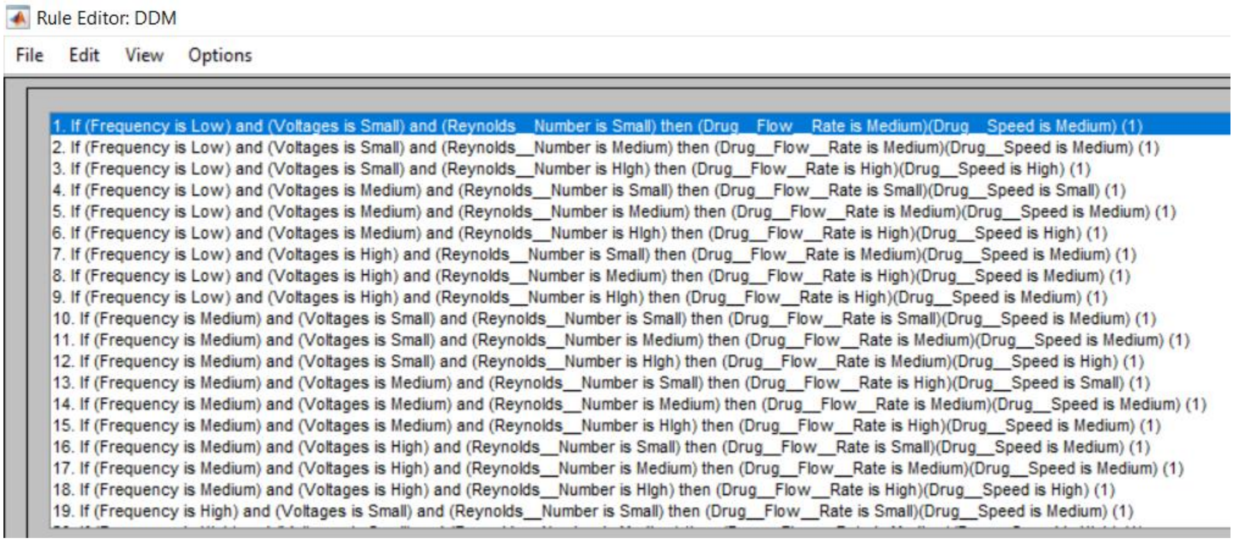


Fig. 5: Rule Editor DDM

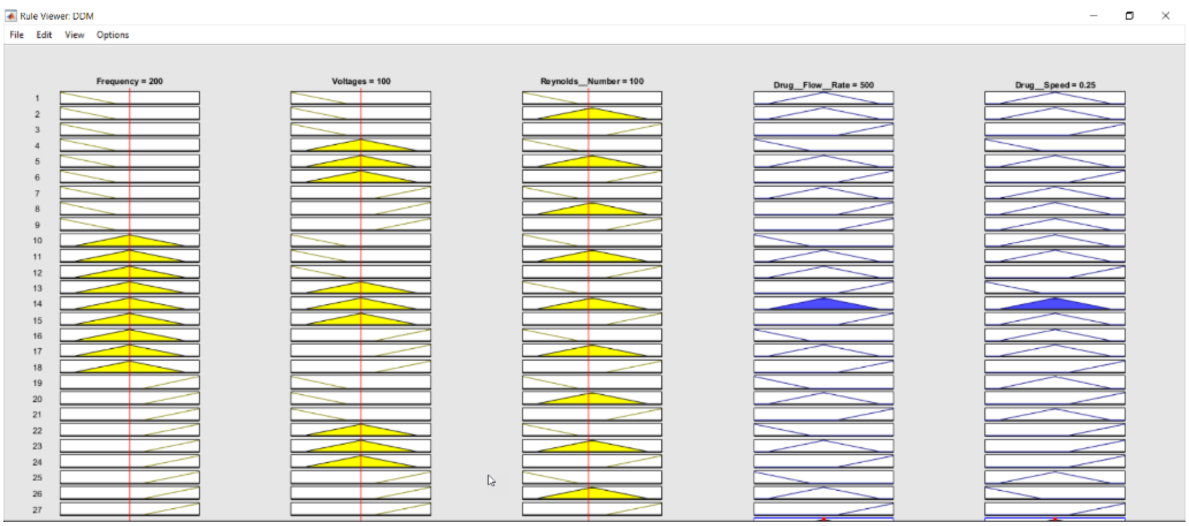


Fig. 6: Rule Viewer DDM

Fig. 3 presents drug delivery micropump (DDMFC) system with three inputs (voltages, frequency and Reynolds numbers) and two outputs (drug flow rate and speed). Fig. 4 presents FIS variables with membership function plots. Fig. 5 presents twenty-seven ($3^3$=27) rules in DDM rule editor diagram with the help of "If and Then statement". Fig. 6 presents DDM rule viewer diagram which shows inputs 200 hertz frequency, 100 V voltages with 100 Reynolds Number. The simulation estimations for outputs are 500 µl/min for drug flow rate and 0.25 milliliter/sec for speed.

**Results and Discussion**

All 3d graphs for this simulation have been shown here below. The 3d graphs are between Voltage and frequency and Reynolds Number as inputs and drug flow rate and drug speed as outputs.

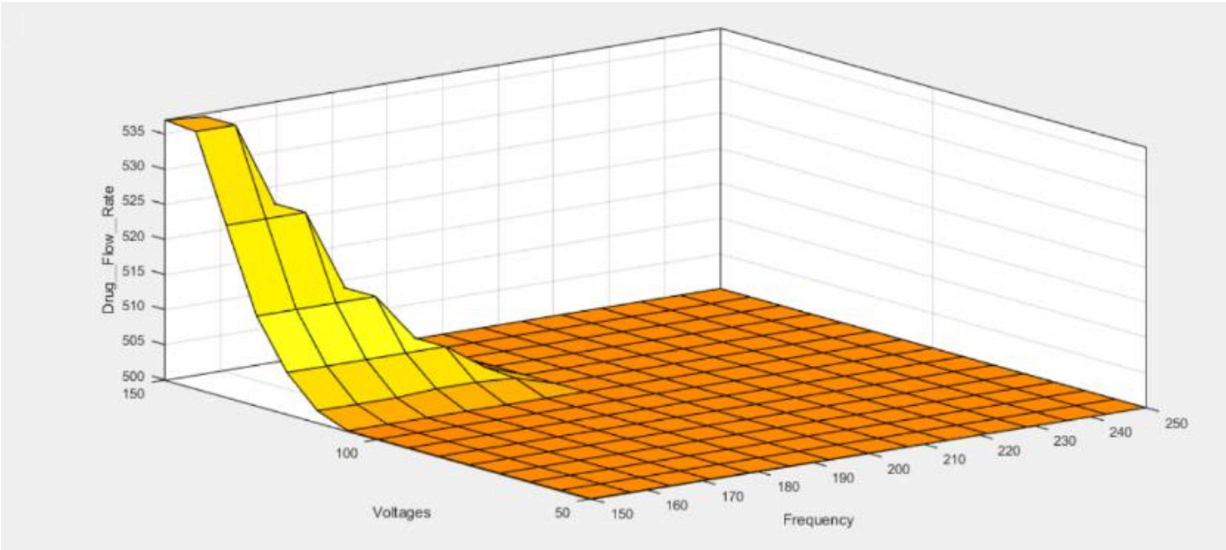


Fig. 7: 3D graph between Voltages and Frequency with drug Flow rate as output

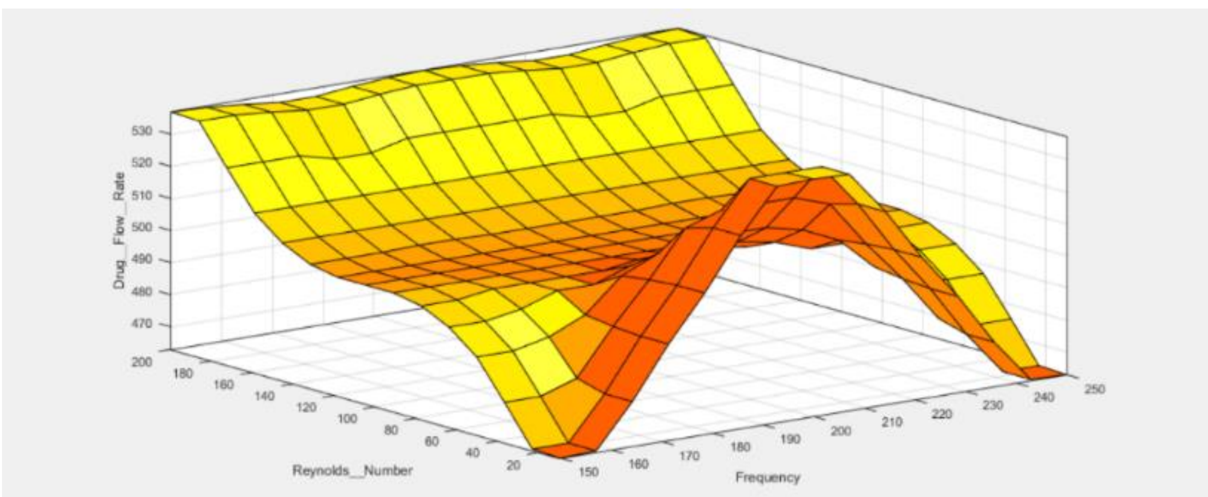


Fig. 8: 3D graph between Reynolds Number and Frequency with drug Flow Rate as output

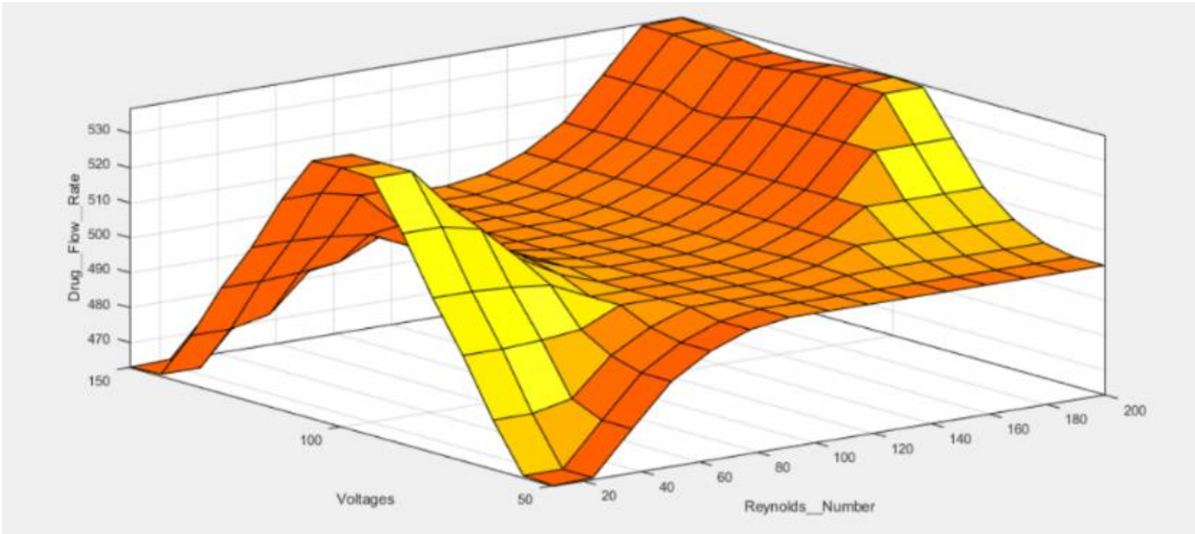


Fig. 9: 3D graph between Reynolds Number and Voltages with drug Flow Rate as output

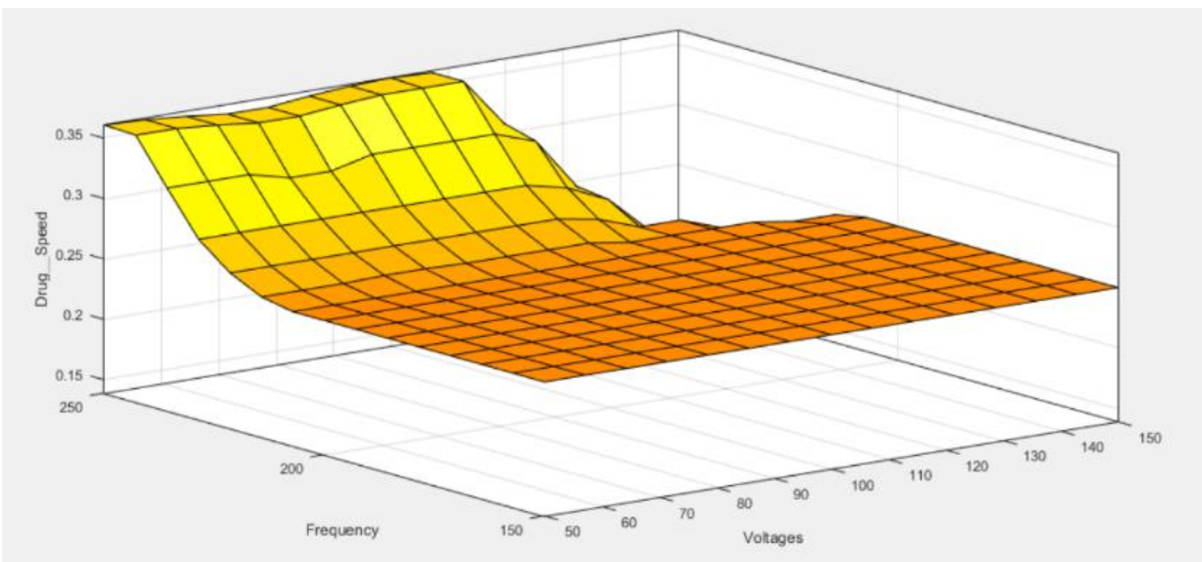


Fig. 10: 3D graph between Frequency Number and Voltages with drug Speed as output

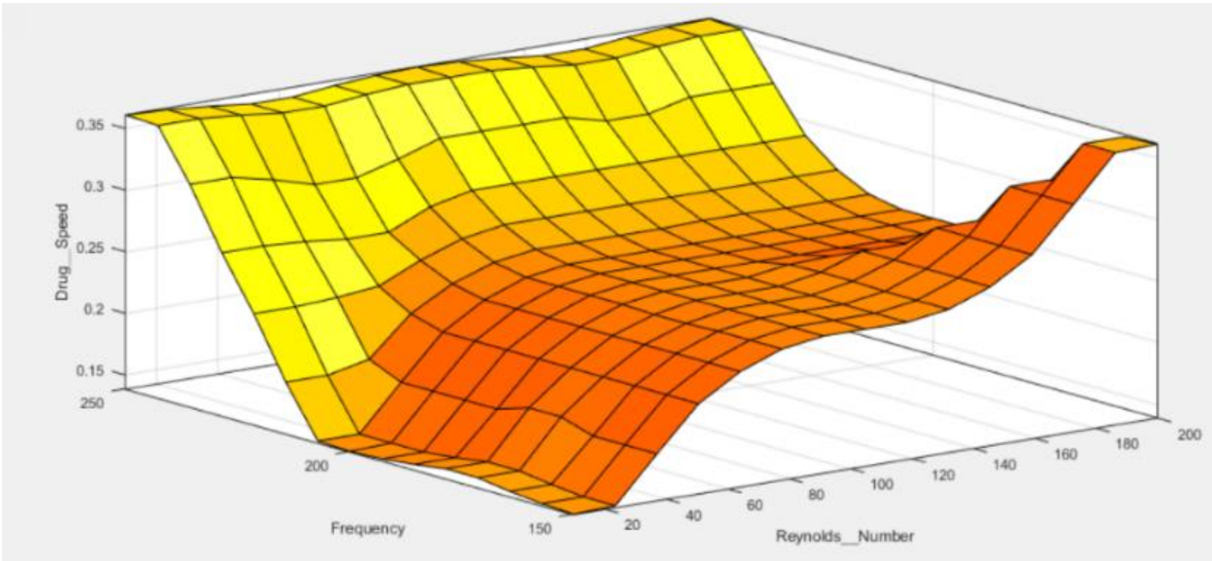


Fig. 11: 3D graph between Reynolds Number and Frequency with drug Speed as output

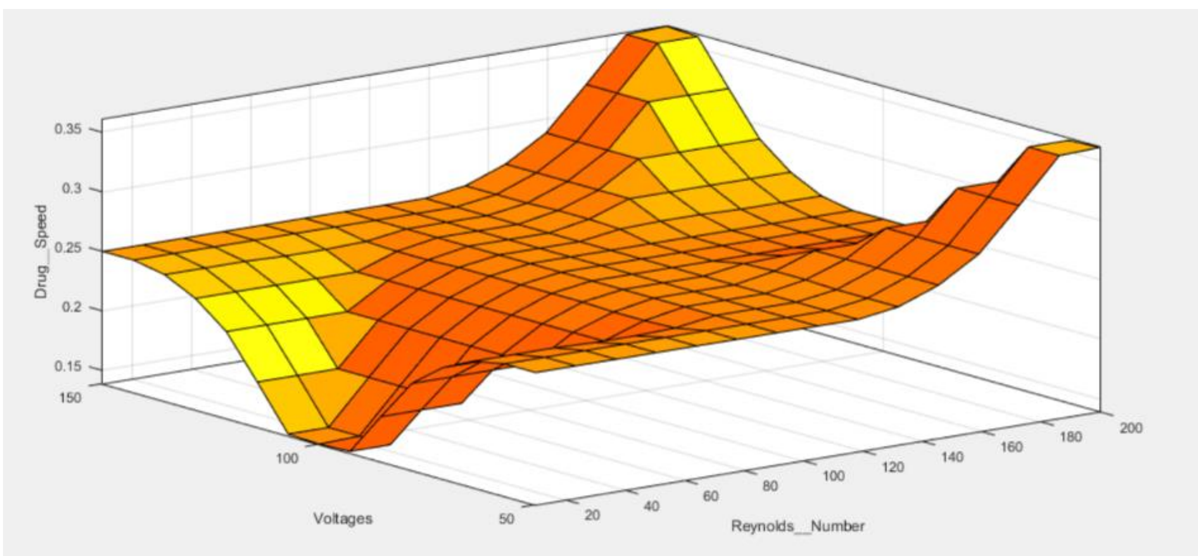


Fig. 12: 3D Graph between Reynolds Number and Voltages with Drug Speed as Output

The Fig. 7 presents 3D graph between voltages and frequency with drug Flow rate as output. Fig. 8 presents 3d graph between Reynolds number and frequency with drug flow rate as output. Fig. 9 presents 3d graph between Reynolds number and voltages with drug flow rate as output. Fig. 10 presents 3d graph between frequency number and voltages with drug speed as output. Fig. 11 presents 3d graph between Reynolds number and frequency with drug speed as output. Fig. 12 presents 3d graph between Reynolds number and voltages with drug speed as output. In order to authenticate simulated results, the Mamdani's method applied and the results were found as 501 µl/min drug for flow rate and 0.26 milliliter/sec for speed. Fuzzy estimated results of micropump are in good agreement with the previous research [4]. Moreover, Fen and Kim investigated 3.2 microliter per minute flow rate with applied voltage 80 volts [5], Koch et al. investigated 120 microliter per minute flow rate with 600 volts applied voltage at 200 hertz frequency [6]. These are summarized in the following table I.

Table I: Previous Research Comparison

| References | Voltage (V) | Frequency (Hz) | Drug Flow Rate (µl/m) |
|---|---|---|---|
| Fen and Kim [5] | 80 | 100K | 3.2 |
| Koch et al. [6] | 600 | 200 | 120 |
| Tayyaba et al. [4] | 105 | 200 | 501 |
| This research (Fuzzy Estimation) | 100 | 200 | 500 |
| This research (Mamdani's method) | 100 | 200 | 501 |

Table I clearly shows that more the frequency lesser is the flow rate of micropump. Our Fuzzy estimation is in well agreement with previous results.

## Conclusion

Micropump is an essential part of any drug delivery system. These are devices embedded on single chip which is responsible for continuous laminar drug flow. According to Fuzzy simulation drug flow rate is 500 µl/min and drug speed is 0.25 milliliter/sec. As calculated by Mamdani's method, drug flow rate and drug speed are 501 µl/min, 0.26 milliliter/sec respectively. The results are concluded here in the following Table II.

Table II: Results

| Category | Results |
|---|---|
| Fuzzy simulation | Drug Flow Rate = 500 µl/min<br>Speed = 0.25 milliliter/sec |
| Mamdani's method | Drug Flow Rate = 501 µl/min<br>Speed = 0.26 milliliter/sec |

**Author's Contribution:** F.J., Conceived the idea; F.J., Designed the simulated work and S.M., did the acquisition of data; F.J., Executed simulated work, data analysis or analysis and interpretation of data and wrote the basic draft; S.M., Did the language and grammatical edits or Critical revision.

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