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Blood-mimicking Fluid for a Flow Doppler Test Object
ドップラー血流測定装置の性能試験に用いる擬似血液

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1. Introduction

The performance of Doppler ultrasound equipment can evaluated with various test objects[1)]. The flow Doppler test objects comprise tissue and blood mimic. To make test meaningful, the acoustic properties of the main component should closely match the properties of the corresponding human tissues and blood and not change with time.

A variety of blood-mimicking fluids (BMF) have been reported[2)]. We have developed a new fluid for BMF. Density and acoustic velocity of the new liquid for BMF can be settled in any desired values, i.e. the density of the liquid can be adjusted, in order to maintain the density of the liquid at the same value as that of polystyrene particles, thus ensuring neutral buoyancy of the particles.

2. Method and material

In this study, our aim is to develop the new liquid with same density as blood. For developing the liquid, we have adopted a new method of designing experiments with a mixture that has been devised by Scheffe[4)]. This method was much practical use in our experiment[5)]. In a three-component system, the general polynomial model[5),6)] that expresses the response τ as a function of component is expressed as

$$\tau = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3$$

$$x_1 + x_2 + x_3 = 1. \quad (1)$$

In the nomenclature proposed by Scheffe, seven equations with seven coefficients are used, where the seven coefficients are unknown. We now have seven equations containing seven unknowns.

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The seven experimental data points τ for the seven components of x_1, x_2, and x_3 can be used to solve the equations. We use 1-propanol and 2, 2, 3, 3 - Tetrafluoro-1-propanol (TFP) aqueous solutions as the fluid of BMF.

The acoustic velocity and density of 1-propanol and TFP aqueous solutions has been measured, and the results are shown in Fig. 1 and 2.

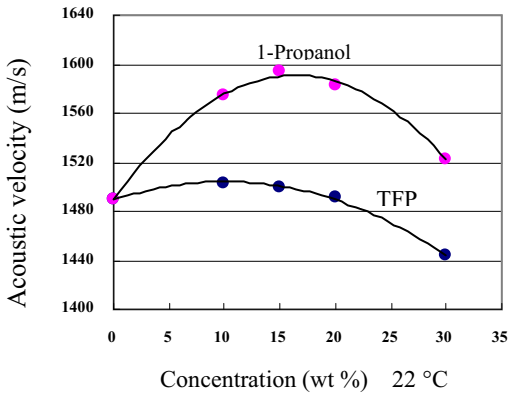

Fig.1 Acoustic velocity of the aqueous solutions.

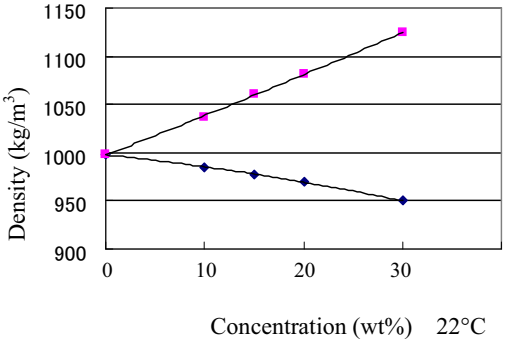

Fig. 2 Density of the aqueous solution.

It is indicated that the acoustic velocity and density of 1-propanol and TFP aqueous solution with appropriate mixing ratio satisfy the IEC standard[4)]. The responses of τ_d and τ_v values to components are given by the data shown in Table I, where the τ_d and τ_v values are the densities and

velocities of the samples, respectively. Tables I gives the values of τ_d, τ_v, x_1, x_2, x_3 in eq.(1), and we also give the following:.

Table I Acoustic velocity and density for pure liquid, binary and ternary mixture at 22.0 °C.

	Purifying water (wt %)	1-Propanol (wt %)	TFP (wt %)	Acoustic velocity (m/s)	Density (10^3 kg/m^3)
1	100.0	0.0	0.0	1489.7	0.998
2	85.0	15.0	0.0	1594.5	0.978
3	70.0	30.0	0.0	1522.7	0.950
4	85.0	0.0	15.0	1500.0	1.082
5	70.0	0.0	30.0	1443.6	1.124
6	70.0	15.0	15.0	1460.9	1.028
7	84.0	8.0	8.0	1551.0	1.018

$$\begin{pmatrix} 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.85 & 0.15 & 0.0 & 0.1275 & 0.0 & 0.0 & 0.0 \\ 0.70 & 0.30 & 0.0 & 0.21 & 0.0 & 0.0 & 0.0 \\ 0.85 & 0.0 & 0.15 & 0.0 & 0.1275 & 0.0 & 0.0 \\ 0.70 & 0.0 & 0.30 & 0.0 & 0.21 & 0.0 & 0.0 \\ 0.70 & 0.15 & 0.15 & 0.105 & 0.105 & 0.0225 & 0.01575 \\ 0.84 & 0.08 & 0.08 & 0.0672 & 0.0672 & 0.0064 & 0.005376 \end{pmatrix} \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \\ \beta_7 \end{pmatrix} = \begin{pmatrix} 0.998 \\ 0.978 \\ 0.950 \\ 1.082 \\ 1.124 \\ 1.028 \\ 1.018 \end{pmatrix} \quad (2)$$

Solving the seven equations simultaneously, which is possible, we can determine β_1, β_2, β_1, β_{12}, β_{13}, β_{23}, and β_{123} in eq.(1). The numerical value of the density τ_d can be determined in eq.(1).

Similarly, the acoustic velocity τ_v can be determined.

The results are shown as contour plots of the density and acoustic velocity calculated using the experimental values in Fig.3.

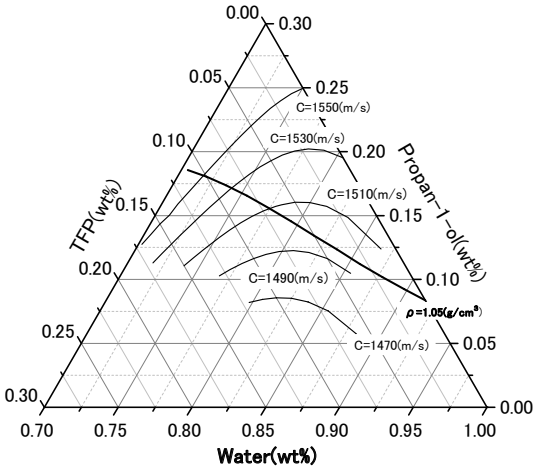

Fig. 3 Contour plots of the density and acoustic velocity in 1-propanol and TFP aqueous solution.

The density of BMF specified in the IEC standard is specified 1050 (kg/m^3). For preparation of the BMF the components x_1, x_2, and x_3 can be determined with Fig, 3.

3. Conclusion

We have developed the 1-propanol and TFP aqueous solution as the liquid of BMF that has the density 1050 (kg/m^3) and the acoustic velocity from 1500 to 1550 (m/s).

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