고점도 용액에서 적혈구의 변형

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RBC deformation in high viscous solutions

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Introduction

Blood is quiet an interesting material in rheological point of view. Blood is composed of three important particles. They are RBC, WBC, platelet. All those particles are very vital to our body in physiological aspect, but if we know the RBC constitutes 95% of the whole particles, we recognize that RBC is the main factor to control the blood behavior. RBCs have their unique shape and material property. They are shown as biconcave disc in microscope and has incompressible bilipid layer its outside. The incompressible membrane has high elasticity and this makes it easy to deform and to retain its original shape. RBC has hemoglobin solution inside of the membrane. We can say that RBC is a kind of capsule which has elastic membrane[1]. This capsule has its unique rheological property unlike normal polymer drops. There are two widely used methods to observe RBC deformation. One is to use rheoscope method[2] and the other is ektacytometry[3]. The former method is proper to qualitative purpose and the latter one is fit to quantitative one. We did our experiment with rheoscope in a high viscous solutions because we are interested in large deformation and following break up in shear flow and want to observe the break up scene. Morris and his coworker did research to relate deformation and lysis in shear flow[4]. We did the experiment in more high viscous solutions and found universal behavior of RBC deformation.

Experimental

We made suspending system with polymer solution and RBC particle. Two kinds of polymer solutions were used, which were PVP solution and HA solution. PVP solution was made by mixing PVP(Polyvinyl-pyrrolidone, Mw =360,000, Sigma) powder and PBS(Phosphate buffered saline) solution. The same method is valid to HA(Hyruan acid, Mw=1,000,000, donated by LG LS) solution. Wemade four different weight percentage solutions by both the HA and PVP solutions. The concentration of PVP solutions were 6.8wt%, 10wt%, 12.5wt% and 15wt%. HA ones were 0.4wt%, 0.6wt%, 1.0wt% and 1.2wt%. The shear viscosity of the each solution was measured by Bohlin rheometer Fig.2. Blood was taken from healthy donor through venipuncture. 40uL of whole

blood was added to 5mL of each solution. The mixture was dispersed by shaking machine. The rheoscope is composed of CCD camera(TKC1380, JVC), optical microscope(BX-51, Olympus) and shearing system(CSS450, Likam). The shearing system has parallel plate fixture inside. The diameter of the bottom plate is 55mm and the one of the top plate is 32mm. Each plate was made of quartz[5]. Experiment was performed in isothermal condition, which temperature is 37℃. The shear rate range is 9.68~969.03(1/s). The duration time of each shear rate is 1 minute. The total test time of each solution is 18 minutes.

Result and Discussion

The image of RBC deformation through CCD camera on the computer screen is used for data analysis. We use Taylor deformation parameter EI(Elongation Index).

$$EI = \frac{A-B}{A+B}$$ (A=major axes of RBC, B=minor axes of RBC)

20 cells were selected at each shear rate and obtained their EI value. 20 EI values at each shear rate were averaged and their standard deviation value were calculated. EI values in each PVP solution were plotted against shear rate Fig.3. EI value becomes larger as the shear rate and viscosity increase. EI value can be plotted against shear stress Fig.4. Here shear stress is defined like following.

$\sigma = \eta(\dot{\gamma}) \times \dot{\gamma}$ (σ=shear stress, η=viscosity, $\dot{\gamma}$=shear rate)

Shear stress is measured by Bohlin rheometer without RBC particle because hematocrit(volume percentage of RBC particle) is only 0.8%, which make it negligible cell to cell interaction and influence to the whole shear stress. EI value falls on one curve regardless of the viscosity of the medium and shear rate. EI value in HA solution shows same result in Fig.5. This result presents EI value does not change with kinds of polymer solution. Ektacytometry data from academic medical center, University of Amsterdam has a good consistency with rheoscope data Fig.1. Ektacytometry data was done with another racial human blood. EI value does not differ from among normal persons and has its own value.

Factors of RBC deformation in shear flow are divided by internal one and external one. Oxygen content, ATP content and membrane rigidity are kinds of former one. All the things are related to the membrane rigidity so that the membrane rigidity is the most important thing among internal factors. Osmolarity, pH, temperature, hematocrit, viscosity and shear rate are kinds of the latter one. If RBC can deform and have its physiological meaning, most these factors should not change much. The value of viscosity and shear rate, however, can vary much when comparing to the other factors. The viscosity of whole blood is very closely related with hematocrit, which is known as 45%, but this is not always constant because it depends on where the blood is in our body. For example in large artery and vein the hematocrit is about

50%, while in small artery, vein and capillary the value ranges from 10% to 70%. In the case of shear rate it varies from 0 to 1000 (1/s). Because of these wide ranges, shear rate and viscosity are much more important external factor than those of among others. In the case of using artificial organs it is also important to consider those things, because there always exist wide range of shear rates. This result gives useful information in that RBC deformation should be understood in terms of shear stress because RBC deformation shows the graph which has typical sigmoid shape with shear stress independent of other parameters. Further research requires to do about leakage of hemoglobin and effect of hematocrit in RBC deformation with high viscous solution.

Reference

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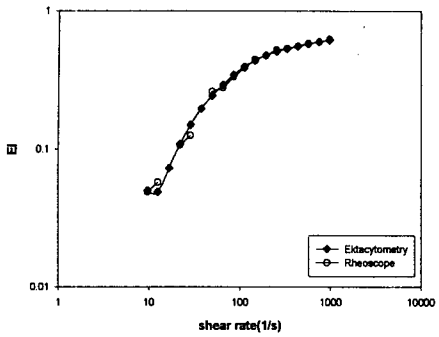


Fig. 1 Data comparison between ektacytometry and rheoscope method

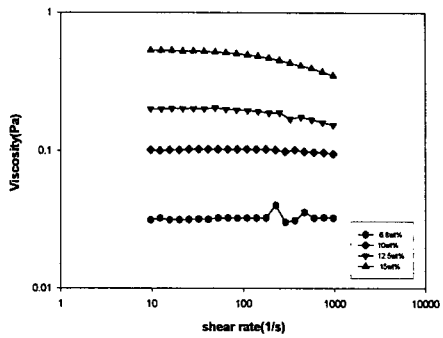


Fig. 2.(a) Shear viscosity data of PVP solution

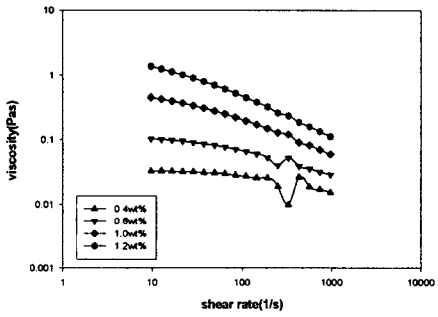
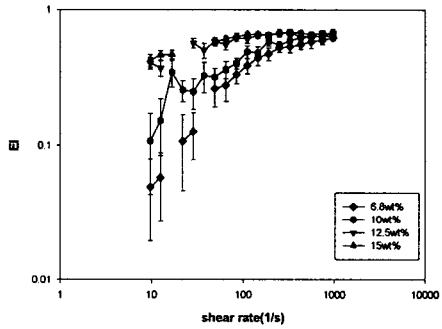


Fig. 2.(b) Shear viscosity data of HA solution



ig. 3 EI value in PVP solution

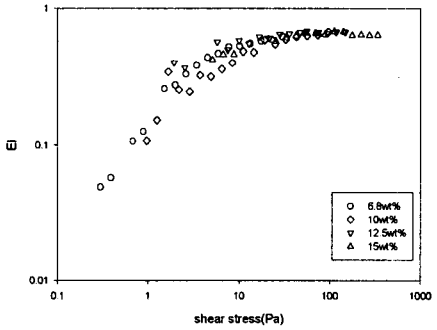


Fig. 4 EI value in PVP solution

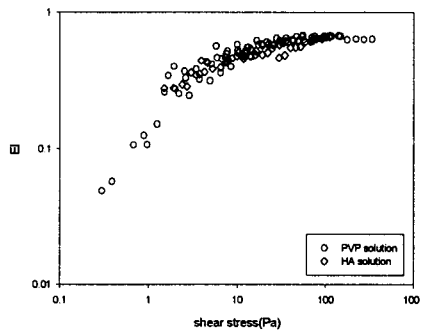


Fig. 5 EI value in PVP and H solution