

## FLOW OF THIXOTROPIC FLUID THROUGH AXISYMMETRIC EXPANSIONS-CONTRACTIONS

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**Abstract.** *The behavior of thixotropic fluids through axisymmetric expansions-contractions is studied in this research. The aim is to visualize the “shear banding” in the flow of a thixotropic fluid, which is the interface between a flowing fluid and a non-flowing fluid. This research uses an experimental approach to visualize the “shear banding” within the fluid. The variables used in the experimental procedure were: steady flow rate time, flow rate and geometric characteristics. A dispersion of laponite RD was utilized as the experimental fluid due to its thixotropic and transparent properties. The fluid flow curve, strain sweep and frequency sweep were used to obtain the rheology characterization. The rheology characterization showed lack of repeatability due to several factors, such as: aging, type of rheometers, geometry used in the rheometers and lack of sample pre shearing. Finally, the results showed that laponite RD is a thixotropic fluid, more elastic than viscous in the viscoelastic region and that the flow through the axisymmetric expansion-contraction device showed three types of behaviors constant flow area, variable flow area with an expansion in the middle zone and variable flow area with layers of different velocities.*

**Keywords:** Thixotropy, Expansion-contraction, Yield stress, Visualization of flow with laser.

### 1. INTRODUCTION

A thixotropic fluid is a structured fluid that under constant stress conditions for a long period of time, acquires a stable configuration, as result of the equilibrium between the microstructure buildup and breakdown rate. These microstructure changes do not occur instantaneously when a stress change is applied to the fluid, that is why the fluid is said to be time-dependent. Note that yield-stress as well as other structured fluids can in principle be either time-dependent or time-independent, but in most cases this classification itself is a function of the combination and range of parameters under study (Souza Mendes, P.R., 2009).

A time-dependent fluid is said to be thixotropic if its steady-state viscosity decreases with the shear rate, and if in addition the viscosity changes are reversible (Souza Mendes, P.R., 2009).

The flow of these fluids is necessarily complex and still requires a significant amount of investigation. There is a wide range of literature regarding the rheology of thixotropic fluids which in the most of cases does not take into account the hydrodynamics flow inside the pipes (Pereira, A.S., Pinho F.T., 2001) (Escudier, M.P., Presti, F., 1996)

Thixotropic fluids are found in a wide range of industries and human daily activities. For instance, food, paints, inks, personal care products, cosmetics, drilling muds, crude oils, coal metal slurries are some of their applications.

A better understanding of flow through axisymmetric expansions-contractions involving thixotropic fluids will help in a better development of engineering projects. It is important to mention that in pipeline system projects there are pipe sections with axisymmetric expansions-contractions geometries (e.g. pipeline fittings). Due to the lack of compression of thixotropic fluids in these type of projects, there is an oversizing of the equipment utilized to start or restart the flow in the pipeline which affects directly in the efficiency and economy of the project. This could be avoided with a deeper understanding of these fluids which permit a better design of the equipment.

A typical problem that thixotropic fluids show in pipelines is when the fluid rests inside the pipeline after the flow passes through it. The velocity and pressure fields to restart the flow inside the pipeline and pipe fittings are very complex. Also the high pressure involved in the recovery of the flow causes pumps cavitation.

The aim of this study is to visualize the “shear banding” which is the interface between a flowing fluid and a non-flowing fluid. The research about “shear banding” in the flow of thixotropic fluids permit to observe fluid characteristics that have not been taking into account previously in other studies.

The variables used in the experimental procedure of the present paper are: steady flow rate time, flow rate and geometric characteristics of expansion-contraction section. The rheological characterization of aqueous Laponite RD dispersion *utilized as the experimental fluid* is another focus of this work.

## 2. EXPERIMENTAL RIG AND INSTRUMENTATION

The flow loop used for the experiments is shown schematically in Figure 1. The fluid was pumped from the tank to the test section through a hoses and piping system. The test section is an axisymmetric expansion-contraction device which is changeable to allow analysing the influence of its geometry. After the fluid goes through the test section, it is carried to a T connection before the pump for liquid supply in case of fluid losses. The flow control pump and the valve were used to analyse the influence of flow rate and to modify the mass flow rate, respectively. A balance and timer were used to measure the mass flow rate. Glass particles were immersed in the flow and an infrared laser was used to visualize the flow. The laser plane was located at the middle plane of the test section. To capture the images of flow, a camera was positioned perpendicular to the laser plane.

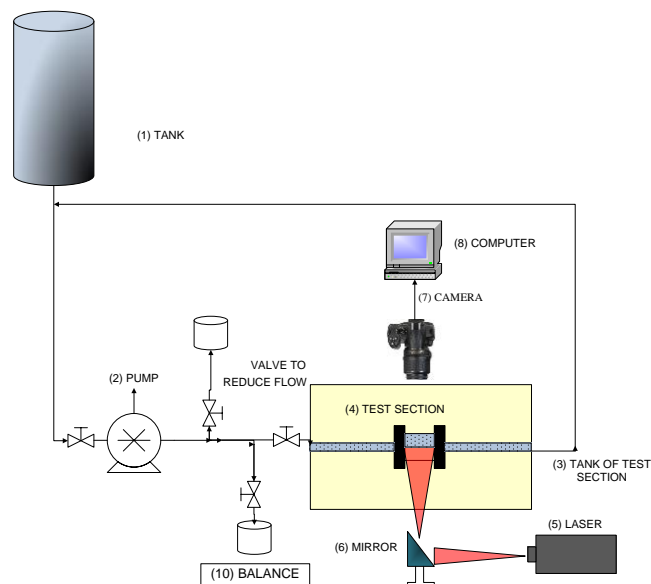


Figure 1: Schematic diagram of experiment facility.

## 3. FLUID CHARACTERIZATION

2 % w/w aqueous dispersions of laponite RD were prepared for the experiments. Laponite is a trade name for synthetic hectorite clay (Pereira, A.S., Pinho, F.T., 1999). It is insoluble in water but hydrates and swells to give clear and colourless colloidal dispersions. Highly thixotropic gels can be produced at 2 % concentration or greater in water (Labanda, J., Llorens, J., 2006).

The rheological characteristics of the test fluid were determined using the rheometers Paar Physica MCR 501 and ARES –G2. Paar Physica MCR 501 is a controlled-stress rheometer and the ARES-G2 is a controlled-shear rate rheometer. The rheological characterization is based on the flow curve and oscillatory tests. The flow curve represents the behaviour of the fluid in flow conditions, and the strain sweep and frequency sweep characterize the behaviour in

the viscoelastic region. For the rheological characterization of the low shear rate the ARES -G2 equipment was used whereas for the high shear rate the Paar MCR 501 equipment was used.

## 4. RESULTS

### 4.1 Rheology characterization of laponite RD dispersion.

The rheology characterization of fluid is based on the tests: strain sweep frequency sweep and flow curve. The strain sweep and frequency sweep allow analysing the behaviour in the viscoelastic region and the flow curve permits to analyse the behaviour of the fluid in flow conditions.

#### 4.1.1 Rheology of laponite RD dispersion in the viscoelastic region.

In the viscoelastic region, the dispersion showed a more elastic than viscous behaviour due to domain of storage modulus above the loss modulus; therefore, the material can be considered elastic, see figure 2 (a).

#### 4.1.2 Rheology of laponite RD dispersion under flow in steady state.

A test flow curve was done for the rheology characterization of 2% laponite RD dispersion under steady-state flow. The test was done in the shear rate range between 4150 1/s and 1 1/s. The flow data in steady state was fit to Herschel-Bulkley viscosity function. The flow curve and fitting are shown in figure 3.

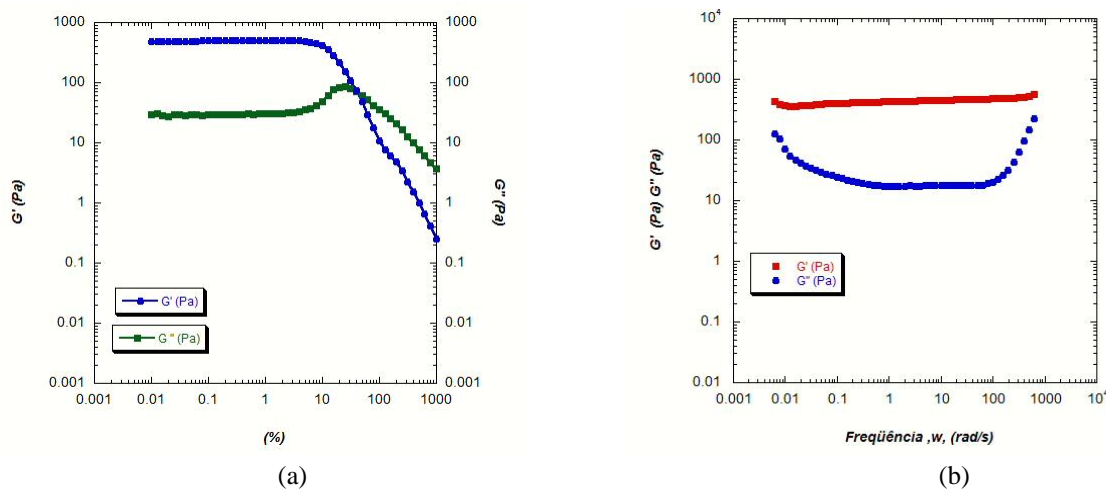


Figure 2: Oscillatory shear test of 2% laponite RD dispersion, (a) strain sweep, (b) frequency sweep.

### 4.2 Flow visualization through axisymmetric expansion-contractions

The image obtained from the 2% laponite RD dispersion flow through axisymmetric expansion-contractions showed three different behaviours: constant flow area (figure 4a), variable flow area with an expansion in the middle zone (figure 4b), and variable flow area with layers of different velocities (figure 4c).

The studied flow behaviour was function of: flow rate, steady flow rate time, and geometric characteristics of expansion-contraction section. The observed flow is function of Reynolds number. The dimensions of the expansion-contraction section was changed in length, pipe diameter and expansion diameter ( $L$ ,  $d$  and  $D$  respectively), see figure 5. The used  $L/D$  ratios were 1/1, 0.5/1 and 1.5/1. The  $d/D$  expansion-contraction ratios used were 1/3 and 1/5.

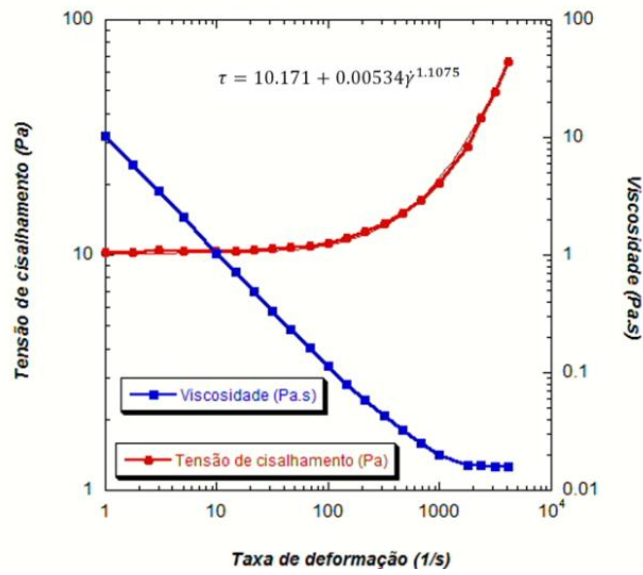


Figura 3: Flow curve of 2% Laponite RD dispersion.

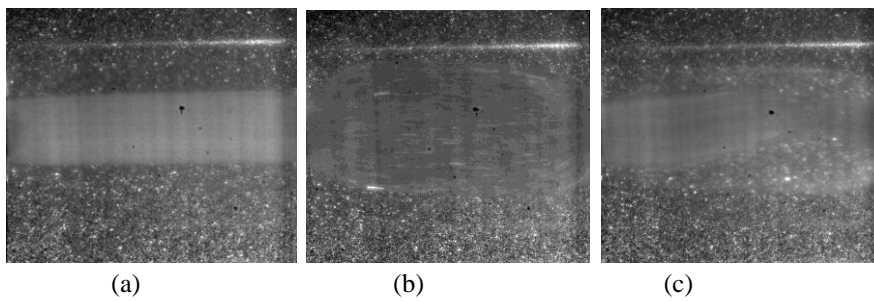


Figura 4: The three different flow behaviours of the thixotropic fluid through axisymmetric expansion-contractions: (a) constant flow area, (b) variable flow area with an expansion in the middle zone and (c) variable flow area with layers of different speeds.

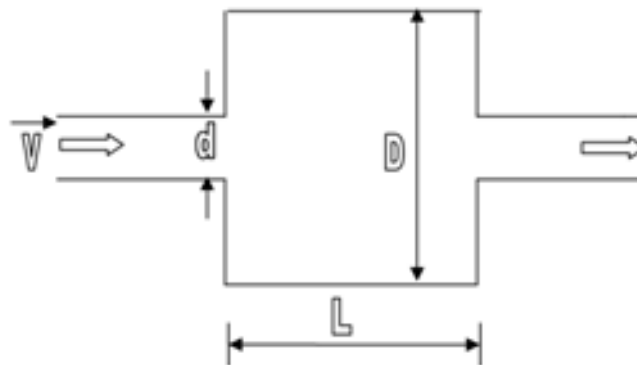


Figura 5: Schematic diagram of expansion-contraction (Souza Mendes *et al*, 2009)

## 5. CONCLUSION

This work experimentally approached the flow of a thixotropic fluid through axisymmetric expansion-contractions. The thixotropic fluid used was a 2% laponite RD dispersion. The material exhibited a viscoplastic behavior that fit the Herschel-Bulkey model. Furthermore, it showed an elastic behavior in the viscoelastic region. The yield stress was 10.17 Pa which was obtained through the Herschel-Bulkey model extrapolation.

The flow images showed a slight opacity that affected their quality. The fluid flow presented three types of behavior: constant flow area, variable flow area with an expansion in the middle zone and variable flow area with layers of different velocities. The first and second behaviors were time-independent whereas the third was time-dependent and showed diverse flow zones with different velocities. The different types of behavior depended on the geometric characteristics ( $L/D$ ,  $D/d$ ) of the expansion-contractions and the Reynold's number.

As the Reynold's number increases, the yielding of the variable flow area with an expansion in the middle zone decreases, whereas the yielding increases as the  $L/D$  ratio increases. The structural change from one level to another as a result of the variation of the shear rate applied requires of given time which produces zones of different viscosity. These zones are visible until the material acquires a structural equilibrium.

## 6. REFERENCES

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