EFFECT START-UP RESISTANCE ON FLOWING POWER IN THE HIGH CONSISTENCE FIBRE SUSPENSION PUMPED

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ABSTRACT

It has been shown that there is start-up flowing resistance that is instant friction resistance, and the value is greater than viscosity resistance of fiber suspension in stable flowing when the high consistency fiber suspension is pumped from static state. The start-up resistance phenomena shows visco-elasticity and specific flowing property. This paper has determined the value of start-up flowing resistance and the characteristic curve in the high consistency fiber suspensions of wood and grass. At last the relationship between the start flowing resistance and its consistency is known from computation.

KEYWORDS: high consistency fiber suspension start-up resistance flowing power.

INTRODUCTION

The high consistency fiber suspension is an important raw material in papermaking mill textile mill and chemical fiber mill. The high consistency fiber suspension loses fluidity when its consistency exceeded 6% and it is difficult for traditional pumping system to transport so that making fiber suspensions by above mentioned mills were performed at low consistency (<6%). This results in larger energy consumption higher investment costs and more serious pollution, therefore , making the fiber suspension must be led to move toward high consistency (6%), that is realizing the high consistency technique. It is important for us to research the characteristic of flowing for the high consistency fiber suspension.

We have researched for many years and published some papers in this field. There are three phases for the research work, the first is the theoretical research, the second is the experimental research of leading the high consistency fiber suspensions to reach fluidization, the third is application.

THEORY

In the static state or low speed the fibers intertwine meshy frame in the high consistency suspension and make it having strong intensity. The higher consistency is, the stronger intensity is [1]. The process of pumping high consistency suspension consist of three parts 1 start-up part (2) accelerating or transition part and (3) turbulence or fluidization part. These critical shear stresses can be expressed as Tsw Taw and Tfw respectively[2]. The three parts are shown in Fig.1.

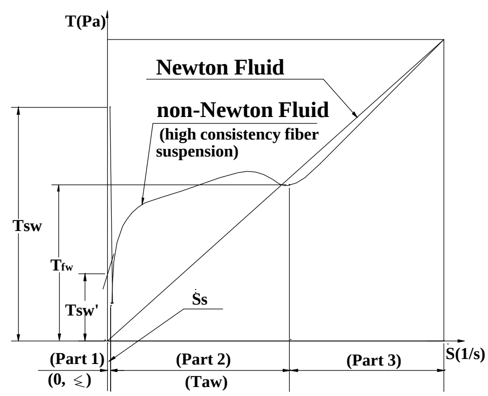

Fig.1. Shear stress T versus shear rate S of high fiber suspension

In theory, the equations of Bingham pseudo-plastic fluids and Bingham plastic fluid can be used to solve the engineering important practical problems of fiber suspensions. But, that is limited in low consistency and stable-flowing and it is difficult to solve for the high consistency suspensions and non-stable flowing cases. It is because of the elastic effect. The higher consistency is, the more salient elastic effect is.

In the part 1, for high consistency fiber suspension the set-up flowing consists of two phases, first is the set-up phase from static to dynamic and considered as static friction phase, the second is instant accelerate flowing from dynamic to a certainty speed and considered as dynamic friction phase. The fiber network of the high consistency fiber suspensions is similar to elastic solid from static to dynamic in the action of thrust when set-up. The static friction resistance is greater than dynamic friction resistance. On the other hand, fiber network result in instant shape change and must be stand to great value of shear stresses. These two aspects combination action should result in high consistency fiber suspension having great shear stresses, it is considered as start-up resistance in fact application engineering.

Therefore, it has been shown that the start-up resistance is dependent on the kind coefficient K and consistency C of high consistency fiber suspensions.

Above-mentioned theories can be confirmed by experiments. The experiments have shown that the values of static friction shear stress are greater than those of the dynamic friction and that start-up resistance is not accord with the start point of part 2 extend to the T axis when $\dot{S}s$ 0, and existing the extremum value of shear stress Tsw shown in the Fig.1. The start-up resistance phenomena opens out visco-elasticity and specific flowing property of high consistency fiber suspension, as well as pseudo-plastic non-Newton fluids.

If the high consistency fiber suspension in set-up phase considered as simple shear flowing, the relationship between the shear stress T and the shear rate $\dot{S}$ can be expressed as Eq.(1):

$$T_{XY} = h(\dot{S}) \cdot \dot{S}_{XY} \qquad (1)$$

Where, $h(\dot{S})$ -----apparent viscosity of non-Newton fluid or high consistency fiber suspension, $\dot{S}_{XY}$ ---shear rate. If shear stress is in the wall, that is the set-up resistance Tsw, then Eq.(1) is expressed as:

$$Tsw = h(\dot{S}) \cdot \dot{S}_S \qquad (2)$$

The apparent viscosity $h(\dot{S})$ is mainly dependent on the consistency C, and secondly shear rate $\dot{S}s$ for high consistency fiber suspension [3], then, the Eq.(2). can be rewritten as Eq.(3):

$$Tsw = K \cdot f(c, \dot{S}s) \qquad (3)$$

Where, the K is the kind coefficient of high consistency fiber suspensions. When the $\dot{S}s \to 0$, the Eq. (3) can be approximatively expressed as:

$$Tsw = K \cdot f(c) \qquad (4)$$

THE DETERMINING OF THE START-UP RESISTANCE

Experiments have been carried out with two kinds of wood and three kinds of grass high consistency fiber suspensions by the fluidization tester of literatures [2] and [3]. We have obtained flowing character curve shown in Fig.1 and determined the start-up resistance Tsw for various kinds high consistency fiber suspensions shown in table 1 and table 2 respectively.

Table 1. The start-up resistance Tsw of wood high consistency fiber suspensions in various consistency

Bleached pine kraft			Unbleached chemistry pine kraft		
Con.(%)	Tsw(Pa)	$\dot{S}s$ (1/s)	Con.(%)	Tsw(Pa)	$\dot{S}s$ (1/s)
5.5	300	7	5.1	300	5
6.3	350	7	6	450	4
7.3	500	8	7.2	460	4
8.4	1010	8	8.3	600	5
9.4	1600	8	9.5	700	5
10.1	1660	8	10	850	7
11.1	1850	8	11	890	7
12.1	2430	8	12.4	1200	8

Table 2. The start-up resistance Tsw of grass high consistency fiber suspensions in various consistency

Unbleached reed stock			Bleached reed stock			Unbleached rice stock		
Con.(%)	Tsw(Pa)	$\dot{S}s$ (1/s)	Con.(%)	Tsw(Pa)	$\dot{S}s$ (1/s)	Con.(%)	Tsw(Pa)	$\dot{S}s$ (1/s)
5.2	300	8	5.2	300	8	5.4	280	8
6.5	400	9	6.6	350	8	6.6	350	8
7	700	8	7	700	8	7.5	730	8
8.2	800	8	8.3	900	8	8.3	900	8
9	1180	8	9	1100	8	9.1	980	8
10	1190	8	10.4	1500	8	10.4	1130	8
11.3	2010	8	11.3	2000	8	11.5	1580	8
12.2	2020	8	12.3	2050	8	12.3	1810	8

THE EXPERIENTIAL EXPRESSIONS OF START-UP FLOWING RESISTANCE

We can obtained the relationship between start-up resistance Tsw and its consistency C of different kinds high consistency fiber suspensions by regress analysis computation from table 1 and table 2, and be shown in Eq.(5) to Eq.(9).

(1) Bleached pine kraf:

$$Tsw = 1.84C^{2.92} \quad (5)$$

(2) Unbleached chemistry pine kraft:

$$Tsw = 3.98C^{2.32} \quad (6)$$

(3) Unbleached reed stock:

$$Tsw = 6.40C^{2.32} \quad (7)$$

Bleached reed stock:

$$Tsw = 5.67C^{2.36} \quad (8)$$

Unbleached rice stock:

$$Tsw = 6.19C^{2.27} \quad (9)$$

CONCLUSION

1. The relationship curve between start-up resistance Tsw and shear rate $\dot{S}s$ is not obey to the extensional law and existing the extremum value of shear stress within the $\dot{S}s \in [0, e]$ from Fig.1.

2. The values of static friction shear stress are greater than those of the dynamic friction. The start-up resistance phenomena opens out visco-elasticity and specific flowing property of high consistency fiber suspension, as well as pseudo-plastic non-Newton fluids

3. The start-up resistance is mainly dependent on the kinds coefficient (k) and consistency (c) for the high consistency fiber suspension.

4. Flowing pressure loss is one of the key factors in power calculation, therefore, it must attach importance to the effect the start-up resistance Tsw on the import power P. We can forecast the start-up resistance Tsw value base on the types and consistency of the high consistency fiber suspension from Eq.(5) to Eq.(9).

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