STUDIES ON FLOW PROPERTIES OF GUM ARABIC POWDER

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Abstract

In the manufacture of tablets, tableting processes, design of reliable solids handling equipment such as hoppers, silos, and storage bins the flowability of powders and other flow property data are most important characteristics. In the case of powder discharge from silos or hoppers, arches and ratholes may be formed, especially in the presence of humid air, resulting in poor flow of the powder. Keeping in this view flow properties of gum arabic powder was evaluated by powder flow tester in which gum arabic powder with particle size 700 micron to 300 micron was tested. It was found that gum arabic powder follow two type of flow behaviour first easy flowing between 0.6 to 3 kPa major principal consolidating stress, σ_1 and 0.07 to 0.30 kPa unconfined faliure strength, σ_c then free flowing between 3 to 9 kPa major principal consolidating stress, σ_1 and 0.30 to 0.80 kPa unconfined faliure strength, σ_c. The critical arching values for gum arabic were density 717.3 kg/m^3, effective angle of internal friction 38^{o}C, effective lengh 0.011m at stress level 0.038 kPa and critical rathole values were density 797 kg/m^3, effective angle of internal friction 36.5^{o}C, diameter 0.29 m at stress level 0.80 kPa. All these properties can be used in handling and processing equipments.

Keywords: *Gum arabic, Flow behaviour, Arching values, Rathole values*

Introduction:

Knowledge of the flow properties of a powder or a bulk solid is necessary to design silos andother bulk solid handling equipment so that no flow problems (flow obstructions, segregation,irregular flow, flooding, etc.) occur. Furthermore, quantitative information regarding flowability of bulk products is required, e.g. as part of comparative tests (e.g. effect of flow agents or other additions on flow behaviour) and quality control (Schwedes, 2003). The flow properties depend on several parameters, e.g particle size distribution, particle shape,chemical composition of the particles, moisture,temperature, (Saw *et al*., 2014). It is not possible to determine theoretically the flow behaviour of bulk solids in dependence of all of these parameters. The present paper deals with flow properties of gum arabic powder.Gum arabic is a dried exudate obtained from the stems and branches of Acacia senegal (L.)

It consists mainly of high-molecular weight polysaccharides and their calcium, magnesium and potassium salts, which on hydrolysis yield arabinose, galactose, rhamnose and glucuronic acid(Whistler, 1993).It is stable in acid conditions and is widely used as an emulsifier in the production of concentrated citrus and cola flavour oils for application in soft drinks. It is also used to form a glaze on coated nuts and similar products (Williams, 1990). In marshmallows the gum is used as a foam stabiliser while in toffees it is used to emulsify the fats present. From a scientific point of view the role of gum arabic as a dietary fibre is well established as was confirmed in the confirmation of its regulatory status as an ingredient when evidence of its use for this purpose was presented to the UK Food Safety Agency and the EU (Williams *et al*., 2001).Numerical characterization of flowability:Flowability of a powder & bulk solid is characterized mainly by its unconfined yield stress, σ_c, in dependence on consolidation stress, σ_1, and storage period, t. Usually the ratio $ff_c$of consolidation stress, σ_1, to unconfined yield strength, σc, is used to characterize flowability numerically:

$ff_c = \sigma_1 / \sigma_c$

The larger ff_c is, i.e., the smaller the ratio of the unconfined yield strength, σ_c, to the consolidation stress, σ_1, the better a bulk solid flows. Similar to the classification used by Jenike (1964), one can define flow behaviour as follows:

ffc< 1 not flowing

1 <ff_c< 2 very cohesive

2 <ff_c< 4 cohesive

4 <ff_c< 10 easy-flowing

10 <ff_cfree-flowing

Several problems can develop as material flows through the equipment. If the powder has cohesive strength an arch or ratehole may form. An arch is a stable obstruction that forms within the hopper section generally converging portion of the bin near the bin outlet. Such an arch supports the rest of the bin contents, preventing discharge of the remaining powder. The occurrence of arching is a function of bin or hopper geometry, and the outlet size in particular. Theoretical analyses of arching in hoppers originate from various studies by Jenike (1961). It assumed that the bulk material in a hopper can be regarded as a stack of isolated structural members, arches or domes, and arching may occur if the strength of members is greater than the weight-induced stresses; this approach can thus be termed the structural mechanics (SM) approach. Theories in which the bulk material occupying a hopper is regarded as one mass, and arching is identified with the state of global equilibrium with no support from below has been suggested (Drescher, 1991., Mroz*et al*., 1969) and can be termed the continuum mechanics (CM) approach.

A rathole is a stable pipe or vertical cavity that empites above the bin outlet. Material is left stranded in stagnant zones that usually remain in place until an external force is applied to dislodge it. Erratic flow is the result of an obstruction alternating between an arch and a rathole (Carson *et al*.,1998). Other flow problems related to the state of aeration or density of powder can occur during powder discharge. The discharge of sufficiently fine powder can create flooding when ratholecollapses, the falling particles air and become fluidized.

Martial And Methods:

The Brookfield powder flow tester (PFT 3230, Brookfield Engineering Laboratories, Inc., Middleboro, MA, US) (Berry *et al*., 2015) is a ring shear tester whose measuring principle is similar to that of the Schulze tester. The tester operates by applying a vertical compression through the lid onto the powder sample contained in the annular trough (internal volume 230 cm3, external annulus diameter 152.4 mm). An internal automated procedure controlled by the ‘powder flow software’ is used to operate the cell to reproduce the sequences of normal stresses and the shear movement necessary to define the yield loci. Raw gum arabicwere purchased from BhaubaliUdyog, Chhattisgarh. 500 gram of gum arabic (grade 1) tears were cleaned and powdered by using hammer mill. The size of powdered was in the range of (700 micron to 300 micron).

Initially recorded the weight of empty trough of powder flow tester (PFT) then attached the outer catch tray outside the trough.Inner catch tray locks into place with slight rotation and pin in the trough engaged with one of the multiple pinholes in the bottom of inner catch tray. Gum arabic powder filled and leveled with the shaping blade with curved profile for test using a vane lid and flat profile used for wall friction test then removed both catch trays. The weight of powder and trough were recorded and subtracted the weight of trough to determine the weight of sample. Trough was installed on the PFT and rotated by hand until the pinhole on the bottom of the trough engages the pin on PFT tunable. Vane lid was used for the flow function test and time consolidated flow function test and wall friction lid used for the wall friction and bulk density test. Sample information and weight of gum arabic powder was entered by using powder pro software application. Standard flow function was selected and display test stresses button was pushed for detail list of the steps. When the test were run. The lid moved downward to the position above, but not touched the sample. The instrument performs an automatic check on position and lead/torque sensor condition. during this self-check procedure , the lid will bounce up and down for several seconds. When completed, the lid will move downward to make contact with the powder sample. The real time display showedthrough axial load applied to the powder used to calculate the consolidation stress, and the torsional torque measured used to calculate the failure strength of the powder. The test runs automatically to completion.After completion of the test, the lid will automatically lift off the sample then clean the trough and lid.

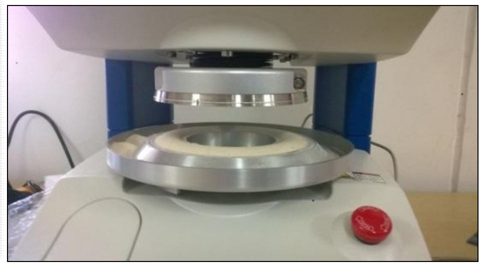

Fig 1: Powder flow Tester Fig 2: Trough with lid for powder flow properties

Results And Discussions:

The flow behavior of gum arabic powder in powder flow tester (PFT) indicate two type of trends in range of 0.6 to 9 kPamajor principal consolidating stress, $\sigma_1$and 0.07 to 80 kPa unconfined faliure strength, σ_c.first trend is easy flowing having flow function $8.5 < ff_c < 10$ between 0.6 to 3 kPa, σ_1 and 0.07 to 0.30 kPa, σ_c then free flowing having flow function $10 < ff_c < 11.25$ between 3 to 9 kPa, σ_1 and 0.30 to 0.80 kPa, σ_c.This follows Jenike (1964) classification for flow behavior of powder materials. The locus point for flow behavior of gum arabic is shown in table 1. It shows variation of density and effective angle of internal friction with applied stress .

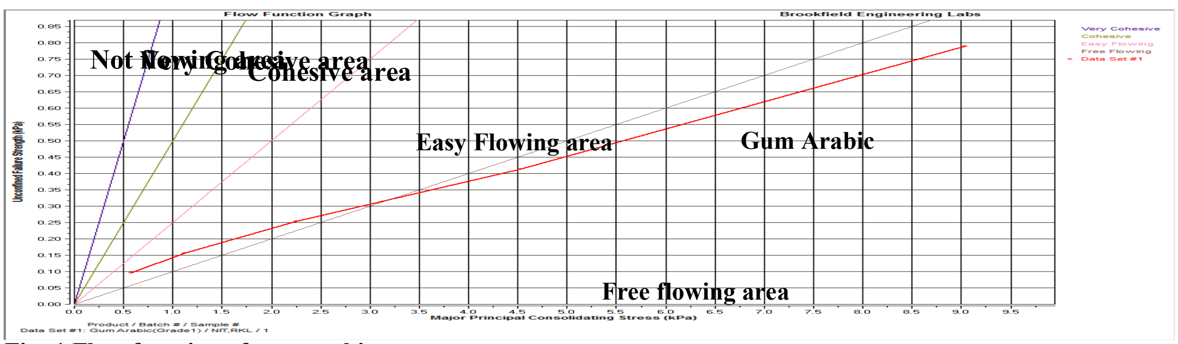

Fig: 1 Flow function of gum arabic

Table: 1 Locus point for flow behaviour of gum arabic

Locus	Consolidation Endpoint σ_E (kPa)	Major Principal Consolidating Stress σ_1 (kPa)	Unconfined failure strength σ_c (kPa)	Density (kg/m³)	Effective Angle of Internal Friction(°)
0	0.000	0.091	0.000	719.1	0.0
1	0.313	0.574	0.096	741.2	37.3
2	0.607	1.125	0.157	749.7	36.5
3	1.204	2.255	0.254	761.2	36.1
4	2.408	4.517	0.413	774.7	36.3
5	4.842	9.043	0.790	789.7	36.5

Critical arch is the largest arch span that a given powder can support before collapsing under its self weight and its value is 0.011 m with stress 0.038kPaacting on the powder in the hopperduring mass flow. The bulk density and angle of internal friction of the powder forming the critical arch is 717.3 kg/m³ and 38 ° respectively.The critical arching values are shown in table 2.

Table:2 Critical arching values for gum arabic

Stress (kPa)	Density (kg/m³)	Effective Angle of Internal Friction (°)	Diameter (m)
0.038	717.3	38	0.011

Critical rathole (stable pipe or vertical cavity that empites above the bin outlet) is the largest diameter a powder can support before collapsing in a core flow regime and its value is 0.29 m with stress, density and effective angle of internal friction are 0.79 kPa, 797 kg/m³ and 36.5 ° respectively. When these values exceed the limit rathole collapses create flooding and falling particles air become fluidized during mass flow. The critical arching values are shown in table 3.

Table:3 Critical rathole values for gum arabic

Stress (kPa)	Density (kg/m³)	Effective Angle of Internal Friction (°)	Diameter (m)
0.79	797	36.5	0.29

Results of gum arabic powder tests by PFT have provided flow parameters for use in predicting the critical outlet size preventing arching. This is described in the companion paper by Drescher*et al*., 1995. Knowledge of the above flow properties of gum arabic powder can be utilized to design silos and other bulk solid handling equipment to avoid flow problems like flow obstructions, segregation, irregular flow, flooding, etc.

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