

particles of maximum diameter of 2 mm). The bed's apparent viscosity has been determined by a free falling porcelain ball ($d = 37.6$ mm) in a column of 100 mm ID. Preliminary tests with a glycerol have been conducted for a calibration of the device. Transverse field in two modifications (pulsed sinusoidal field (50 Hz) and a rotating field) has been applied as in the case of the hydrodynamic experiments of Nekrassov and Chekin (1961). The initial bed height has been varied in the range from 150 to 450 mm with a step of 50 mm. The bed expansion ratio during fluidization did not exceed 1.3.

The results of the rheological measurements described above are shown in Fig. 35. The curves in Fig. 35a exhibit sharp changes of the effective bed viscosity η in a narrow range of the Reynolds number despite the case of fluidization. Nekrassov and Chekin pointed out that the minima in the curves $\eta = f(\text{Re})$ occurred just before the onset of bubbling. The further increase of η was attributed to the intensive gas bubbling hindering the free fall of the

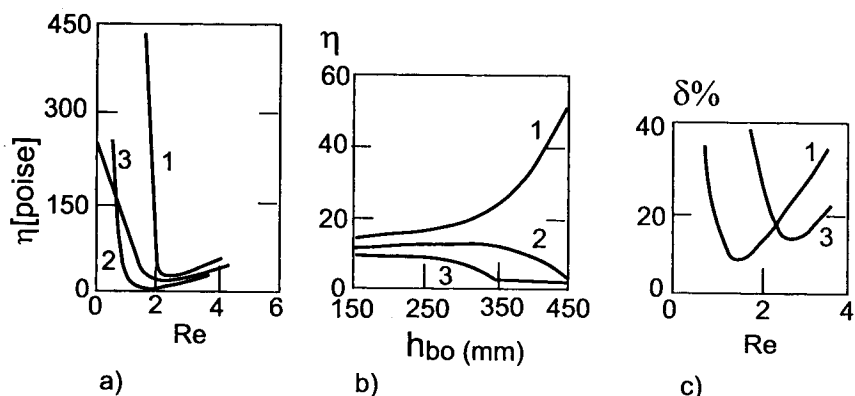


Fig. 35: Rheological results of Nekrassov and Chekin (1962). Line numeration for all the figures: 1 - a non-magnetized bed; 2 - a bed magnetized by a pulsed sinusoidal time-varying field; 3 - a bed in a transverse rotating field. The apparent bed viscosity η is presented in Poise (Ps), where $10\text{Ps} = 1 \text{ Pa.s}$.

- a) Variations of the effective bed viscosity with the particle Reynolds number. $h_{bo} = 350$ mm.
- b) Effect of the initial bed height on the minimum value of the bed viscosity.
- c) Deviations of the bed viscosity δ from the mean values as a function of the particle Reynolds number. $h_{bo} = 350$ mm.

measuring ball. Moreover, the curves obtained under the action of a magnetic field are located below that of the conventional bed. The lowest values of η correspond to a bed in a rotating transverse field.

The initial bed height in the experiments of Nekrassov and Chekin (1962) has different effects on the bed viscosity as a result of the external action on the solid phase. In contrast to the conventional fluidized bed (Line 1 in Fig. 35b) the magnetic field decreases the effective viscosity of deep initial beds. Like in the situation shown in Fig. 35a, the beds in a transverse rotating field demonstrate the lowest effect of h_{b0} on η .

The non-homogeneous particle distribution (due to the inhomogeneous mixing) leads to deviations of the measured values (Fig. 35b). The values of Reynolds number corresponding to the minima of the curves in Fig. 35a coincide with those shown in Fig. 35b.

The experiments of Nekrassov and Chekin (1962) are unique in the area of MFAF. The use of a free falling ball and the application of Stokes' law (comments in the original paper) correspond to the approaches employed for non-magnetic beds (Leva, 1959). Techniques applicable for rheological measurements of liquids have not been applied further in the case of MFAF.

The measurements did not detect the effect of the bed regimes on the measured effective viscosity. However, taking into account the experiments of Siegell (1988) with sinking weights mentioned above the decreasing branch of the curves in Fig. 35 may be attributed to developing stabilized regimes. The minima correspond to the onset of bubbling. The hypothesis relies on the phenomenological bed behaviour discussed here at length. The results presented in the next point support the hypothesis.

III. 2. Rheology of MSB

III. 2.1. Yield stress measurements by a drawing-plate experiments

The rheology of MSB has been investigated extensively (Lee, 1983, 1984, 1991) by a drawing-plate technique well known from the powder mechanics (Brown and Richards, 1970). The drawing-plate measurements are suitable in the case of low shear stresses and low normal stresses in the granular medium (Brown and Richards, 1970).

The yield stress corresponds to the minimum force needed to pull out a thin plate from a powder bed (see inset in Fig. 38). This plate, coated with a thin layer of the particles studied, is vertically inserted to a specific depth in

the bed of a test. When an increasing force is exerted to pull this plate, it serves to transmit shear stresses inside the medium.

Lee (1983, 1984, 1991) has performed a series of tests with a plate pulled at various depths and under axial fields of different intensities. Fluidization vessels of rectangular cross-section (0.076 by 0.051 m) and circular cross-section (0.069 I.D.) have been employed. Initial bed height of 0.4 m has been retained in all the experiments. Plexiglas and non-magnetic stainless steel plates (12.7 to 38.1 mm in width and about 1 mm in thickness) have been used as drawing plates.

The plate has been inserted into a gently fluidized bed in absence of a magnetic field before the formation of the initial settled bed (Lee, 1983). After that the field has been slowly increased to stabilize the bed at a desired intensity for the test (Lee, 1983). The procedure corresponds to the Magnetization LAST mode. However, the yield stress map (Fig. 38) is superposed on a phase diagram corresponding to the opposite Magnetization FIRST mode. The analysis of the data (see below) indicates that the rheological measurements correspond to Magnetization FIRST mode. The misunderstanding comes from the description of the preliminary procedure (Lee, 1983). Hereafter, the results will be described as consistent with the fluidization behavior of the Magnetization FIRST mode.

III. 2.1.1. Experiments and calibration procedures

The yield force F^Y plotted versus bed depth from the surface z allows the determination of the yield stress from the relation:

$$\tau^y|_{z=1} = \frac{1}{p} \left(\frac{dF^y}{dz} \right) \Big|_{z=1} \quad (19)$$

The yield is considered as the force required overcoming the frictional resistance caused by the horizontal pressure of the solids in the vessel. In a vertical granular medium the yield stress is described well by Janssen's theory (of solid pressure distribution in vertical cylindrical silos) (see Brown and Richards, 1970) in the form:

$$\tau^y = \mu p_H = \mu_K p_V = \frac{\rho_b D}{4} \left(1 - e^{-\frac{4\mu_K z}{D}} \right) \quad (20)$$

The experimental results in absence of a field have been well fitted by a simple relationship (Lee, 1983):

$$\tau^y = 762.7 \left(1 - e^{-15.51z} \right) \quad (21)$$

with $\mu_K = 0.267$. Equation (21) having been used as a calibration curve.

III. 2.1.2. Results - yield stress variations with the bed depth and the gas velocity

Typical yield stress curves obtained with increased solid magnetization are shown in Fig. 36. The Janssen's law of yield stress distribution as a function of the depth is completely satisfied in a wide range of solid magnetization. The value of τ^y increases from zero at the bed top surface ($z=0$) to asymptotic value inside the bed. This fact undoubtedly confirms fixed structure of MSB, in contrast to the fluidized beds where the Janssen's yield distribution is not valid (the vertical pressure varies from zero at the surface to the bed weight per unit cross-section area at the bottom).

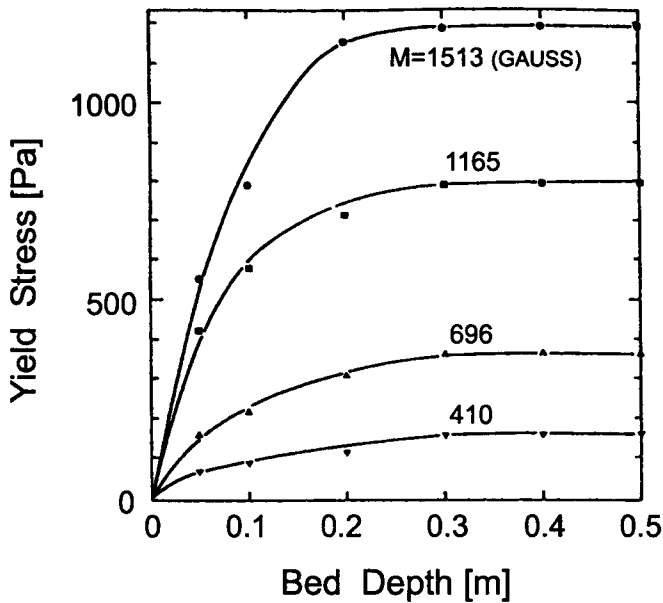


Fig. 36: Yield stress increases with the solid magnetizations. Iron particles (250-297 μm) at $U = 0.587$ m/s. $U_{\text{mfo}} = 0.228$ m/s. From Lee (1983).

The plot in Fig. 37 confirms the above statement. The experiments performed under conditions close to the transition from MSB into the fluidized (bubbling) regime clearly indicate that the bed exhibits yield stresses only in MSB regime. A plot of the yield stress distribution at various bed depths is presented on a bed phase diagram (Fig. 38).

The map clearly confirms all the discussions carried out previously on the loss of bed mechanical stability near the breakdown of the stabilized bed. The yield stresses are stronger in the region close to the bed initial expansion and vanish in the region close to the transition point (fluidization onset). The map in Fig. 38 also shows the yield stress distribution in the packed bed domain (at velocities $U < U_c$).

III. 2.1.3. Results in AC fields

The above results have been obtained in axial DC fields. The application of AC fields (Lee, 1983) leads to the same trends of the yield distributions in the phase diagram. However, the values of the yield stresses in a bed stabilized by AC field are lower. The fact confirms the bed stabilization experiments in time varying fields (Stevens *et al.* 1988) discussed in Part 1 (Hristov, 2002). Figure 39 compares the yield stresses measured in MSB

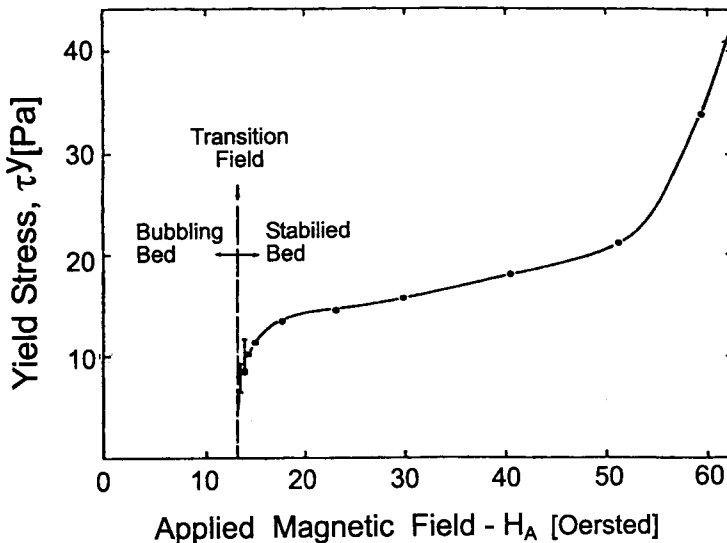


Fig. 37: Yield stress appears as the bed is stabilized. From Lee (1983). A bed of iron particles (74-105 μm) at $U = 0.052$ m/s. $U_{mfo} = 0.0445$.

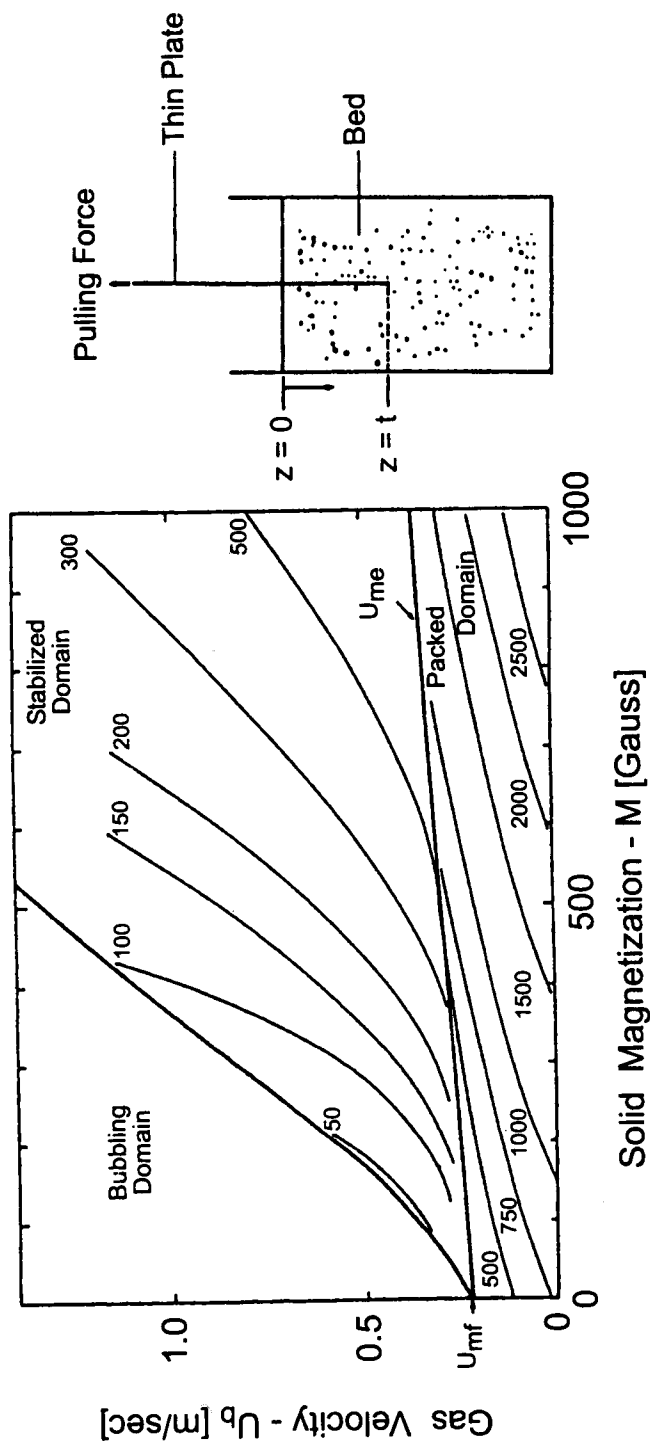


Fig. 38: Yield stress distribution in an MSB-map. From Lee (1983). $Z = 0.30 \text{ m } \tau_y$ in [Pa]. A bed of iron particles (250-297 μm). Inset: A drawing-plate yield stress experiment. From Lee (1983).

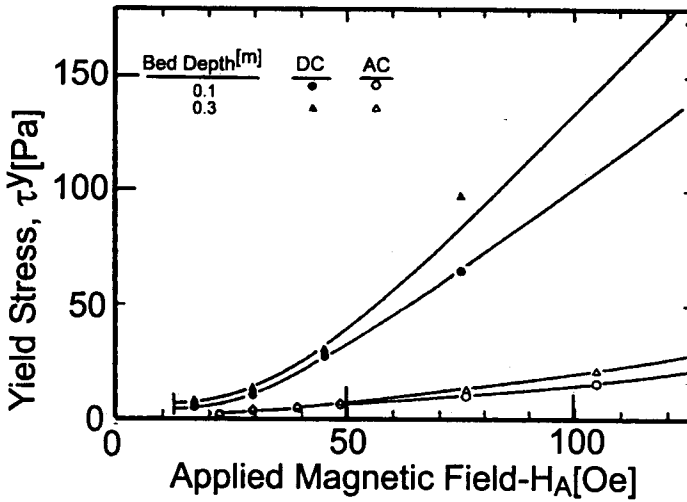


Fig. 39: Yield stresses in AC and DC magnetically stabilized beds. From Lee (1983). Iron particles (250-297 μm) at $U = 0.46$ m/s. $U_{\text{mfo}} = 0.228$ m/s.

stabilized by both types of fields. As commented upon in Hristov (2002) the attractive forces disappear twice per cycle and the possibility to stabilize the medium requires higher field intensities (Stevens *et al.*, 1988).

III. 2.2. Bed rheology measurements by various techniques

III. 2.2.1. Angles of repose

The angle of repose is a very convenient measure of the powder flowability (Hiestand, 1966; Brown and Richards, 1970). Figure 40 presents schematically different versions of that technique and the experiments carried out in a magnetic field. There are two principle devices for powder purring on the base: a funnel and a rising cylinder. On the other hand the base for pile formation may be also without borders or with a fixed diameter. The former is applied with fixed height of the funnel, while the second is suitable for powder purring from rising funnels. Coualoglou and Siegel (1981) have applied a version of the fixed base cone and the rising funnel (see Fig. 40) for evaluation of the flowability of stabilized solids.

The rising cylinder forms a pile by a slow rise of a preliminary filled cylinder. This technique has been applied by Hristov (1991b).

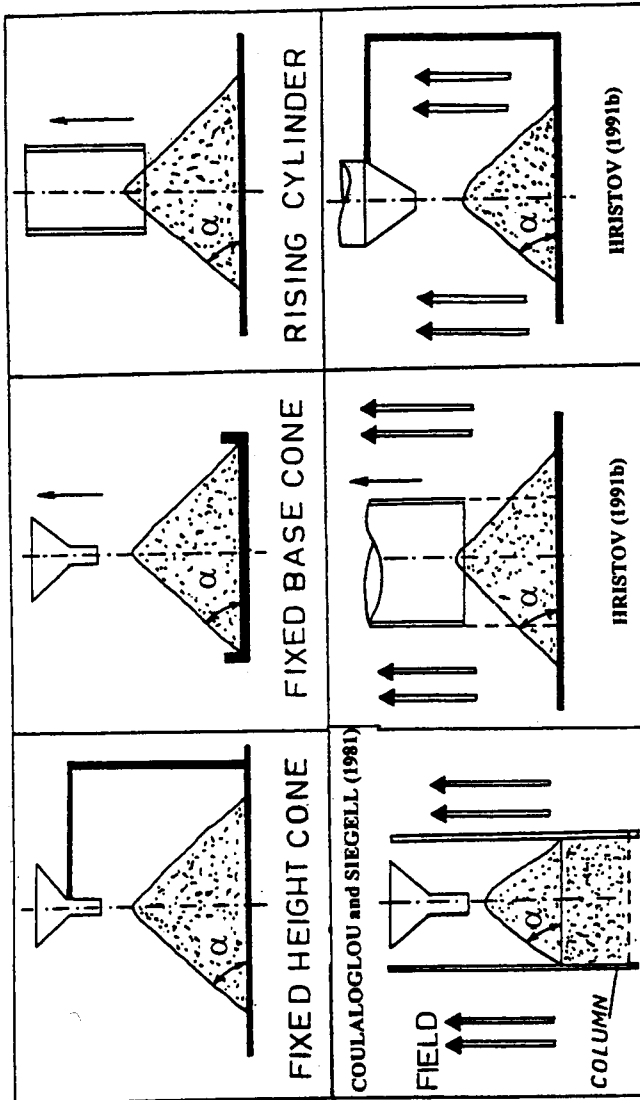


Fig. 40: Angles of repose. Different techniques and a definition of α . From Hristov (1991b).

III.2.2.1.1. *Purred angles of repose - funnel experiments* – The experiments of Coualoglou and Siegel (1981) concerned the flowability of the bed under various field intensities (axial field) and at different gas velocities in the range $U_c < U < U_{mf}$.

In the case of cohesionless materials the angle of repose gradually decreases as the gas superficial velocity is increased from $U = 0$ to the minimum fluidization point (U_{mf}) Coualoglou and Siegel (1981). Thus,

$$\tan \alpha = \left(1 - \frac{U}{U_{mf}}\right) \cdot \tan \alpha_0 \quad (22)$$

The initial angle of repose α_0 is approximately equal to the angle of internal friction ϕ of loosely packed beds (Hiestand, 1966; Brown and Richards, 1970). For sand-like materials (Brown and Richards, 1970) such as Geldart's (1973) B materials, the value of α_0 is approximately 23-25°. Thus (22) may be expressed as

$$\tan \alpha = \left(1 - \frac{U}{U_{mf}}\right) \cdot \tan \phi \quad (23)$$

where $\tan \phi$ is the coefficient of the internal friction.

Following the above theory Coualoglou and Siegel (1981) performed a series of experiments in a 7.62 mm ID column. A part of the experimental results obtained in these experiments is shown in Fig. 41a,b.

Coualoglou and Siegel (1989) decided that the flowability of the magnetized bed manifests itself in the angle of repose. Thus the angle of repose may be used as a measure of the relative bed flowability (they used the term "fluidity") in the stabilized bed by a definition of the solids flow resistance index R_α defined as

$$R_\alpha = \frac{\tan \alpha}{\tan \phi} = \frac{\tan \alpha}{\tan \alpha_0} \quad (24)$$

According to Coualoglou and Siegel (1989) when $R_\alpha = 0$ the bed is fully fluidized and its fluidity is similar to that at $U = U_{mfo}$ and $H = 0$. When $R_\alpha = 1$ the bed fluidity is the same as that of a packed bed of solids. Thus, the range $0 < R_\alpha < 1$ defines the regime of the stabilized bed. Coualoglou and Siegel

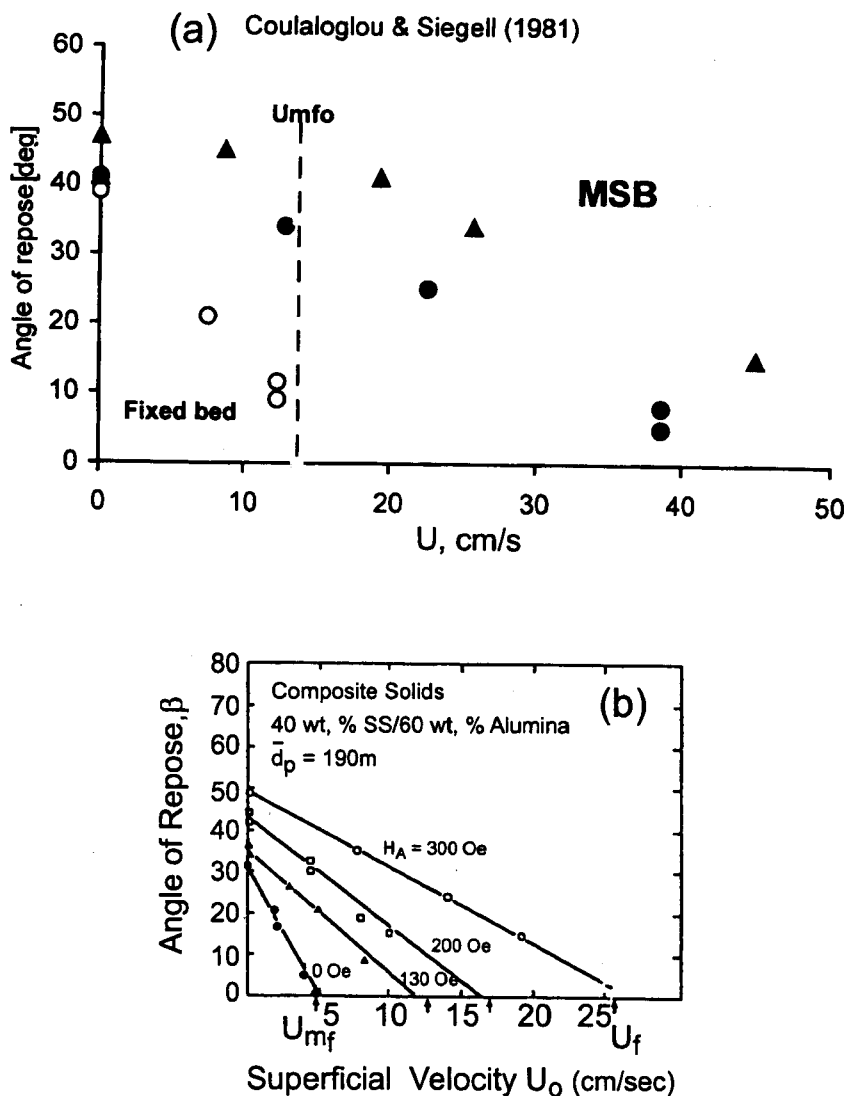


Fig. 41: Purred angle of repose (from a funnel) and a flow resistance index:

a) Purred angle of repose as a function of the gas velocity. Data from Table IV of Coulaloglou and Siegel (1981). Present author's graphical presentation. Magnetite bed (266 μm), density = 5000 kg/m^3 ; $h_b = 2.5 - 5\text{ cm}$. $D_c = 76.2\text{ mm}$ ○ - $H = 0$; ● - $H = 65\text{ Oe}$ and $U_T = 43.3\text{ cm/s}$; ▲ - $H = 130\text{ Oe}$ and $U_T = 65.8\text{ cm/s}$.

b) Effect of applied field intensity and superficial fluid velocity on angle of repose. From Siegel and Coulaloglou (1984a).

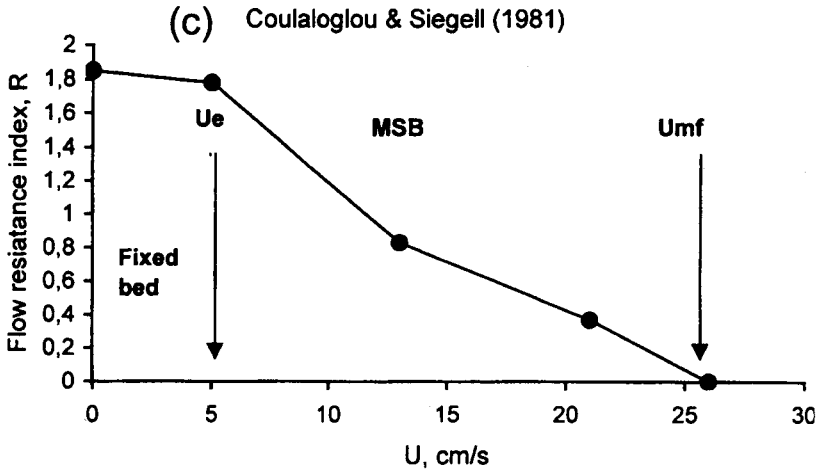


Fig. 41 continued

- c) Flow resistance index as function of the gas velocity. Bed of 38 wt% stainless steel beads (192 μm) at $H_A = 300$ Oe and $M_p = 125$ Gauss). Present author's graphical presentation.

(1989) termed this state: “semifluidized” as bed exhibiting properties neither of a fixed nor of a fluidized bed.

The discussion of the present review shows that the solids flow resistances index R_α defined in such a manner represents the ability for deformations of the granular bed by the fluid drag forces and represents the static equilibrium of solids. It cannot be related directly (Coualoglou and Siegel, 1989) to the solids flowability (unrestricted flow) or to the dynamic viscosity once solids are in motion. Figure 41c shows the decrease of R_α as the bed expansion in the regime of MSB is developed.

III.2.2.1.2. Purred angles of repose - rising cylinder experiments – The purred angle of repose formed by a slowly rising cylinder is a technique more suitable for the case of a magnetically stabilized bed. First of all, the cylinder wall forms the bed in a manner similar to the column wall. Second, the stability of the granular bed against to destruction if the bed becomes unbounded (as the cylinder rises) depends on the stability of the interparticle contacts.

The experiments of Hristov (1991b) have been performed by a slowly rising (less than 0.5 mm/s glass cylinder (45 mm ID)) and a Helmholtz pair (i.e., an axial field). The materials tested are summarized in Table 14. Parallel experiments with a calibrated fixed bed funnel (10mm orifice diameter) have been performed. The fluidization experiments have been carried out in a 65 mm ID column with the same magnetic system.

Table 14

Materials used in test with a rising cylinder in an axial field. Hristov (1991b)

Material	Key	Fraction, μm	Density, kg/m^3	M_s , kA/m	α_{C0} (average)
Catalyst H. Topsoe KM-1	A1	600 - 800	5000	237	22.7
	A2	800 - 1000			24.0
Magnetite	B1	100 - 200	5100	478	24.6
	B2	200 - 315			23.5
	B3	315 - 400			25.2
	B4	400 - 500			26.0

Figure 42 shows qualitatively the particle behaviours under fields of different intensities. The variations of the angle of repose with the field intensity are shown in Fig. 43. The plot in Fig. 43 shows that there is an upper limit of the correct pile formation. The reproducibility of measurements (not presented here) shows the applicability of the method up to the formation of vertical slender aggregates. The values of the angles of repose obtained were of about 60° with a cylinder and of about 30° with the funnel (at higher fields the flow through the orifices stops). The plot in Fig. 43 shows that the particle packing inside the pile depends on the field. The values of α_{C0} are measured after the pile formation and a consequent turn off of the field.

The correlation between the fluidization behaviour and the variations of the angle of repose with the field intensity is illustrated in Fig. 44. The plot shows that both the fluidizability index FIM and the ratio α_{CM}/α_{C0} decrease as the field intensity is increased. For both ratios the limiting field intensity corresponds to values of them in the range 0.2 - 0.3. As mentioned earlier, at $\text{FIM} \approx 0.2$ the fluidization is impossible. The plots of the angle of repose (Fig. 44a) show that at $\alpha_{CM}/\alpha_{C0} \approx 0.2$ the pile formation is impossible and the

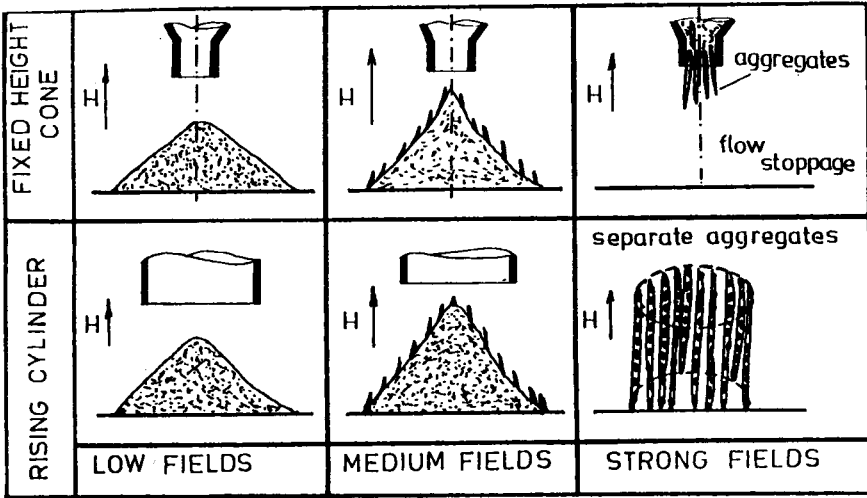


Fig. 42: Pile formation (qualitatively) by a fixed height cone (funnel) and a rising cylinder. From Hristov, 1991b)

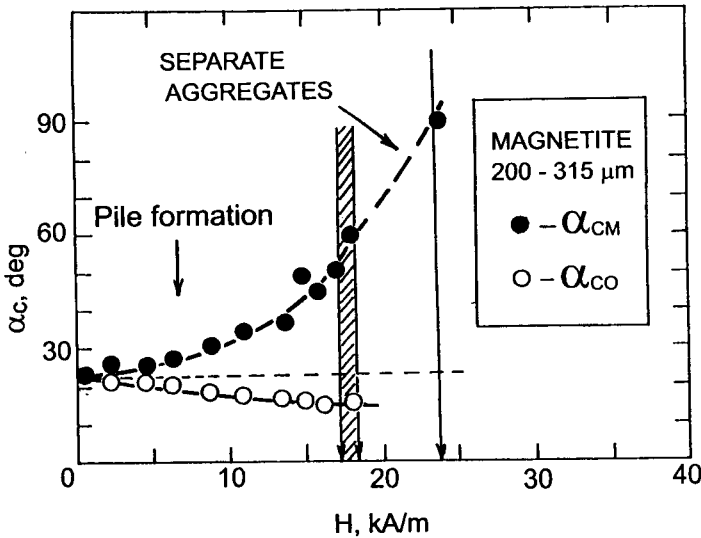


Fig. 43: Angles of repose obtained by a rising cylinder. From Hristov (1991b). Pile formation and variations of the angle of repose with the field intensity. Effect of the field intensity on the particle packing in the pile.

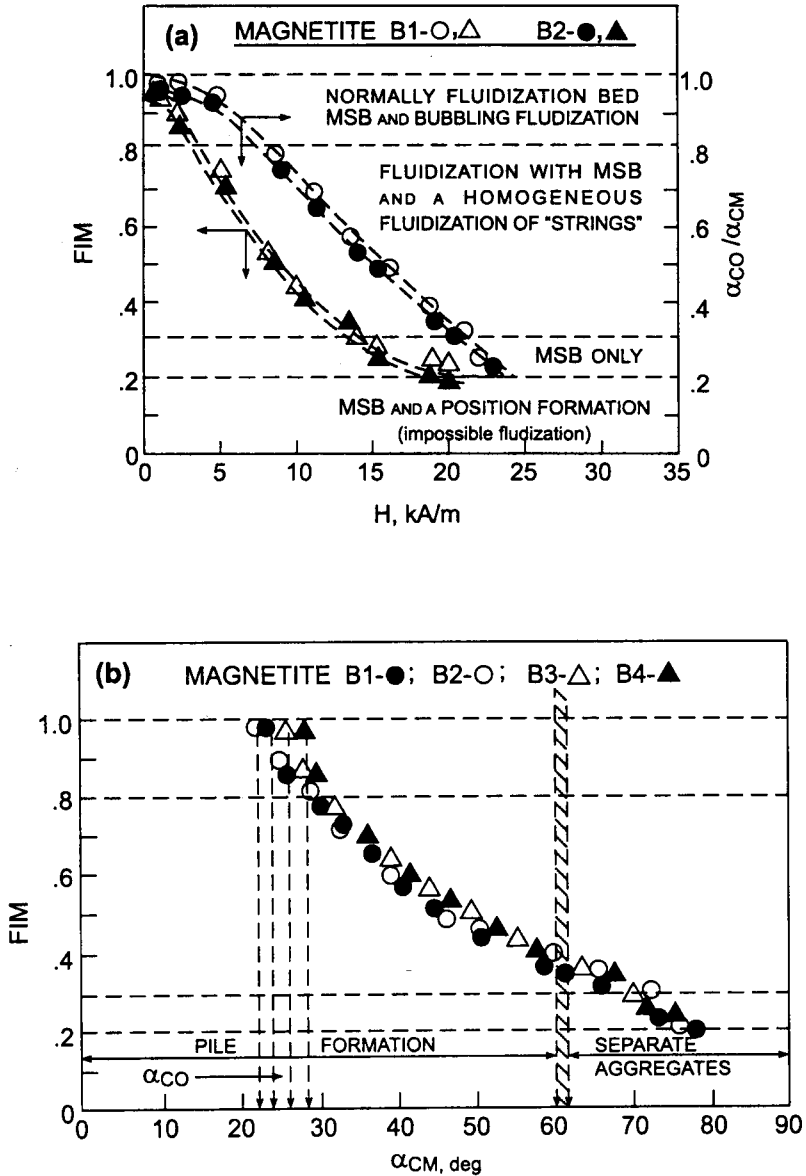


Fig. 44: Correlations between the angles of repose and the bed fluidizability represented by the FIM index. (Hristov, 1991b)

- a) Simultaneous variations of the fluidizability index FIM and the relative angle of repose with the field intensity. Fluidization; $h_{bo} = 50$ mm.
- b) Variations of FIM with α_{CM} .

bed passes into the “frozen bed” regime (Sieggell, 1988). The bed body consists in individual aggregates oriented along the field lines (see Fig. 42). The cross-correlation of both quantities leads to the diagram shown in Fig. 44b. It resembles those demonstrated for FIM (Penchev and Hristov, 1990c) and commented upon in Part 1 (Hristov, 2002).

Both figures clearly indicate that the upper limit of MSB or in other words the onset of Sieggell’s “frozen regime” (SFR) corresponds to values of α_{CM} in the range of 60- 70°. In fact, the value range of 70-73 degrees is the upper limit of angles of repose of non-magnetic materials exhibiting higher degrees of cohesiveness. The schematic presentation in Fig.42 shows that at such higher values of α_{CM} the magnetic powder is compacted by the field (as a slug if a surrounding wall exist) or separated in strong slender aggregates. There is no possibility to fluidize such bodies.

The measured angles of repose by a rising cylinder allows detection of the upper limit of the field causing stabilization or *vice versa* the minimum field intensity for transition in frozen regime (FR) as defined by Sieggell (1988). The device has advantages in the field of MSB with respect the funnels.

III.2.2.1.3. Angles of repose - tilting bed experiments – The tilting bed measurements are widely applicable in gas solid fluidized beds of cohesive powders (Verloop and Heartless, 1973). The method allows establishment of the stability of a particle bed percolated by a flowing fluid (Heertjés *et al*, 1976). The vessel is initially placed with the bottom plane in a horizontal position. The flat free surface of the bed is then parallel to the porous bottom. When the vessel is tilted angularly around an axis normal to the gravitational and flow forces, the bed surface will form a slope with the horizontal of α_t degrees in any plane normal to this axis. Gradually increasing the displacement will cause an increase of α_t until a limiting value is reached. At this stage, a differential increase from α_t will cause sloughing of the surface. The value of α_t will be influenced by the fluid percolation. Percolation toward the bottom plate will increase the slope stability resulting in an increase of α_t . On the other hand when the fluid flow is from the bottom plate up, the value of α_t will decrease

In the case of an axial magnetic field acting on the bed the increased stability of the interparticle contacts will increase the value of α_t . Coulaloglou and Sieggell (1981) employed an open ended container 7.62 mm (ID) with a porous plate at the bottom as a supporting grid for air-fluidization.. The results are shown in Fig. 45.

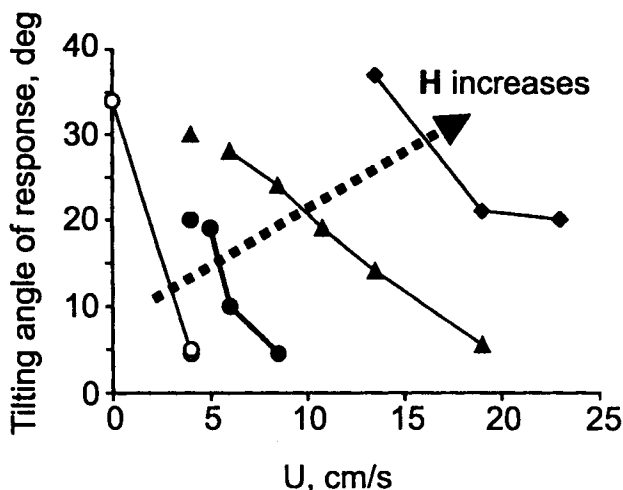


Fig. 45: Tilting angle of repose α_t as a function of the gas velocity under different field intensities. Present author's graphical presentation of data extracted from Table V of Coualoglou and Siegel (1981). 33% WL %80 RO stainless steel beads. Particle sized 177 - 205 μm . Particle density 1700 kg/m^3 . $h_b = 38$ mm. $D_c = 76.2$ mm. Labels: $\circ$ - $H = 0$; $\bullet$ - $H = 150$ Oe; $\blacktriangle$ - $H = 300$ Oe; $\blacksquare$ - $H = 480$ Oe.

III.2.2.1.4. Angles of repose - effect of the type of the stabilizing field – Stevens *et al.* (1988) have employed the technique of an angle of repose purred on the top surface of particle bed (Coualoglou and Siegel (1981) -see the picture in Fig. 40) in an alternating axial magnetic field. Figures. 46 demonstrates the less stable structure of the AC stabilized bed. .

III.2.2.2. Solids discharge tests

An alternative technique for a measurement of solid bed fluidity is the rate of solids discharge from a calibrated orifice in the side of the vessel. Rosensweig (1979, 1980) gave the basis of solids discharge test for magnetically stabilized bed flowability. The experiments described by Rosensweig (1980) were carried out in a tall vessel ($D_c = 73.7$ mm) with a circular orifice ($d_o = 8.3$ mm) located at 75 mm above the bed supporting grid. The initial bed height was varied from 80 to 142 mm (-40/60-mesh catalyst G87RS) and the experiments were performed at a constant gas velocity of 15.6 cm (U_{mfo} is about 2.6 cm/s- example 1 of Rosensweig (1980)). An axial

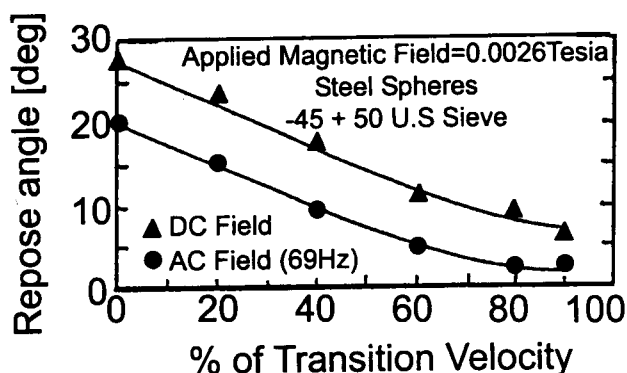


Fig. 46: Effect of the field type employed for stabilization on the purred angle of repose. From Stevens *et al.* (1988).

steady state field was applied along the bed of both sides of the orifice. The time for solids discharge to a level of $L_o = 40$ mm above the distributor was used determined by a stopwatch and a discharge coefficient C was defined as:

$$C = \frac{\sqrt{L} - \sqrt{L_o}}{\sqrt{2.9}} \cdot \frac{1}{T} \left(\frac{D_c}{d_o} \right)^2 \quad (25)$$

Rosensweig pointed out that the orifice coefficient was constant at 0.14-0.15 and independent of the initial bed height and the field applied (80 and 400 Oe). The discharge time obtained in both AC and DC fields as a function of the field intensity is shown in Fig.47. The plot shows the better fluidity of AC stabilized bed at higher field intensities. The fact is attributed to the lower magnitudes of the interparticle forces created by AC fields.

III 2.3.3. Solid settling tests

III.2.3.3.1. Basic idea – The solid settling experiments of Lee (1983) concerned the effect of the magnetizable solids on an immersed tracer sphere. A solid sphere of known density and diameter is neutrally released at the top of the bed at desired gas velocity and field intensity. Time mark of each experiment starts at this moment. At the end of a specified time interval the gas is abruptly switched off and the test sphere is entrapped in the defluidized MSB. The penetration depth of the sphere is a measure of the bed rheology.

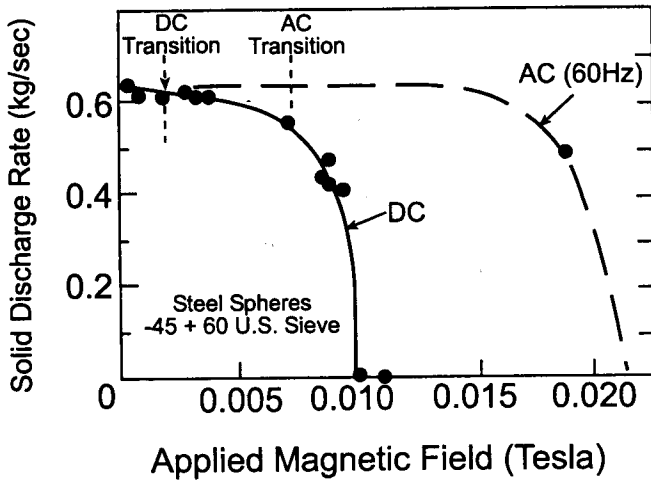


Fig. 47: Comparison of bed fluidities by solids discharge rate for AC and DC axial magnetic fields. From Stevens *et al.* (1988).

The size of the tracer spheres ranged from 3.175 mm to 9.52 mm and their densities varied from 1000 to 8450 kg/m³ (densities both higher and lower than the bulk density of the examined bed).

Several “multisphere” tests with a simultaneous releasing of several test spheres on the bed top surface have been carried out too. Figure 48 presents some typical solid settling results.

III.2.3.3.2. Solid settling tests - major results – The results of these tests may be generalized as follows (according to Lee (1991):

- There is a transient solid settling kinetics :
 - The tracer sphere moves at high speed in the early phase and then quickly decreases. The first phase involves unsteady-state solid phase interactions due to the gravitational settling and the frictional forces between the sphere and the bed solids.
 - After the transition state two solid patterns exist:
 - The small and light particles stall inside the bed.
 - The heavy and large particles are able to settle deeper in the bed.
- Lee (1991) suggested that a constant settling velocity is established similar to the Stokes terminal velocity. The terminal velocities observed are as low as 0.03 cm/s in AC MSB, while the settling process in DC beds is much slower.

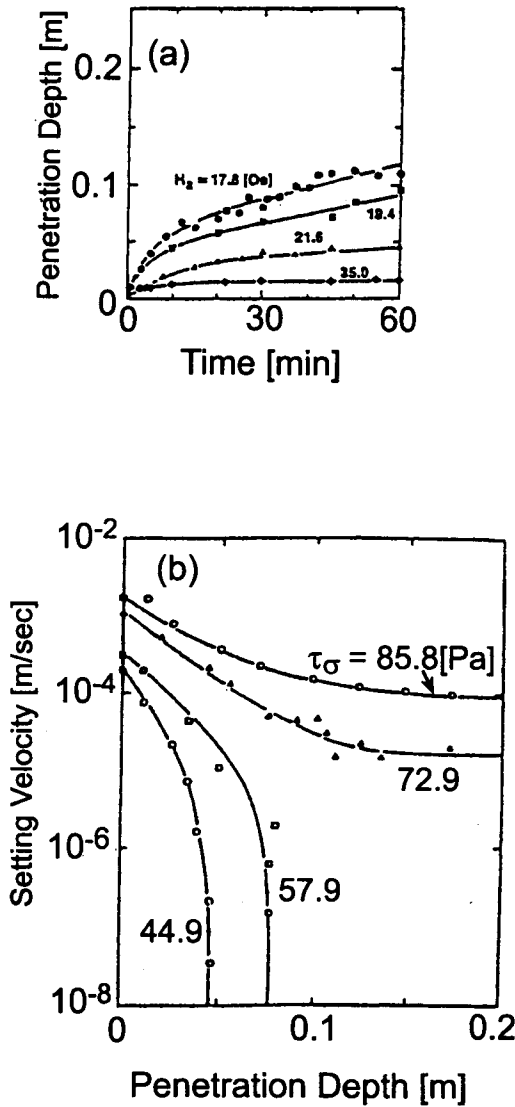


Fig. 48: Solid-settling results.

- a) Effect of gas velocity on solid settling. Solids: 841-100 μm iron particles. Test sphere diameter = 9.525 mm of density = 5340 kg/m^3 . Field intensity of 21.6 Oe (60 Hz -AC field). From Lee (1983).
- b) Solids settle to their driving forces. Particle bed like in Figs 48a,b. $U = 1.49$ m/s. $H_A = 35$ Oe (60 Hz -AC field). Test sphere diameters: from 6.3 to 9.525 mm. From Lee (1984,1993).

- The sphere settling velocity increases as the gas velocity increases.
 - Only spheres with densities higher than 3000 kg/m³ can penetrate the bed, while only those of 9000 kg/m³ density can reach the gas distributor.
- Lee (1991) suggested a Stokes' law of the settling based on a simple force balance (Lee, 1984). A parameter termed a "driving stress" combining both the density and the size effect on the sphere settling was defined :

$$\tau_d = \frac{2}{3\pi} d_p g |\rho_s - \rho_b| \quad (26)$$

Figure 48b shows a map of the solid settling velocity and the penetration depth according to the driving stress defined by Eq. (26).

- According to some critical levels of the driving stress two types of settling kinetics were defined :
- For solids exhibiting a higher driving stress in a band somewhere between 58 and 72 Pa the solid sphere continues to settle into the bed.
 - For lower levels of the driving stress the test sphere "freezes" in the bed.
- The simple explanation of Lee (1991) relies on the equilibrium between the driving stress and the yield stress given by Janssen's law (Eq. 20 or, more convenient, Eq (21)). Obviously the motion of the solid sphere will stop at the position (depth) where the driving stress is equal to local yield stress.

III.2.3.3.3. The "apparent" viscosity concept - magnetic field effects – The magnetic field effect of the sphere terminal velocities observed was the basis for Lee's proposal (1984): "apparent" viscosity of MSB. The viscosity was calculated using the Stokes' law after discounting the yield stress effects. An example of 7 600 Pa.s was mentioned by Lee (1991) based on the solid settling results shown in Fig. 48b. The value of 7 600 Pa.s is as high as those demonstrated by commonly used molten polymers.

The value noted above is consistent with the physics of MSB since the state is a transitional between a fixed bed and a free flowing fluidized suspension. The strong particle-particle interaction and the magnetic pressure (see Part 1 (Hristov, 2002)) lead to a behaviour that is neither of a deformable solid body nor of a free flowing liquid.