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asbestos-cement manufacturing technology

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PLAINTIFF'S EXHIBIT

CT-1458

friction — the relation felt speed, concentration — agitation

based on work by Dr. I. I. Berney — part XI

Friction, minimum concentration of the suspension depending on the speed of the felt and the importance of the agitation of the suspension in the vats.

When considering friction which takes place in the vat of the sieve cylinder of a forming machine, between the asbestos-cement layer under formation and the syspension, the following points must be remembered:

1) During the process of filtration, the asbestos-cement layer builds-up uniformly; the most compact microlayers are located near the wire. Compactness of the layer is steadily reduced as the distance between the outer edge of the layer and the wire increases. The strength of the layer is also reduced an will depend on « yield stress ». Graph fig. 42 (see AC/M No. 9/10-1969) shows this and indicates a decrease of the « yield stress » as the compactness of the layer decreases. Therefore, destruction of the layer does not start over all its thickness but where the weaker microlayers are, i.e. on the outer edge of the layer which is in contact with the suspension in the vat.

2) The microlayers at the outer edge of the asbestos-cement layer under formation, do not differ from the suspension in regard to compactness and moisture content.

3) Mixing and agitation of the suspension in the vats is so intense, that the adhesion between the single bundles composed of asbestos-cement particles, is impossible. This means that the microstructure of the suspension is not affected.

4) In the turbulent flow occuring around the surface of the rotating sieve cylinder, a thin laminar layer, contiguous to the surface, can be distinguished.

5) The microstructure of the suspension.

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Remembering the a/q points based on the general principles of the structural-mechanical properties of the dispersion systems, the friction taking place

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between the layer and the suspension can be conceived in the following way (see fig. 44).
The asbestos-cement layer (1) has on the surface which is contiguous to the suspension, a microlayer (2) which is in the state of formation and which has the same density and water content as that of the suspension in the vat. This microlayer differs from the suspension with which it is in contact (3) only because the asbestos-cement particles contained in it have stopped moving thus permitting the formation of a structure; the asbestos-cem particles in area (3) are free and move in a lamir flow. The interaction of particles and the formati of a structure in area (3), is hindered by the f: that these particles are continuously passing fr the suspension to the microlayer (2).
When the formation of the structure begins, micr layer (2) will possess the properties of a viscoelast body and will be characterised by two rheologic constants: « yield stress *To* » and « viscosity ηpl

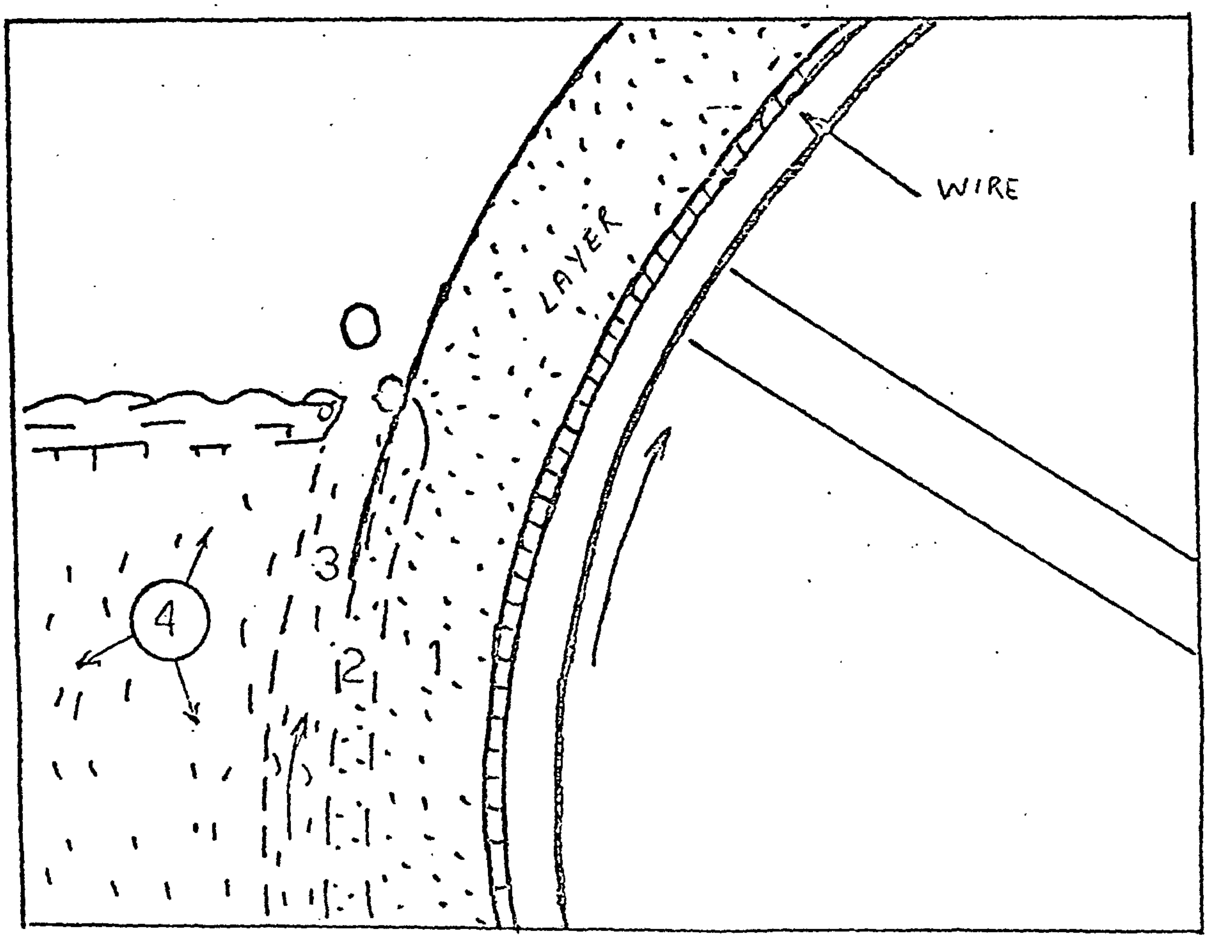

Fig. 44. - Schematic drawing of the formation of the asbestos-cement layer on the cover wire of the sieve cylinder.

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At point «0», where hydrostatic pressure is zero, both these values will correspond to the values obtained with the equipment shown in fig. 40 (see AC/M No. 9/10-1969) because the flow at point «0» is similar to the flow near the surface of the internal cylinder of the equipment shown in fig. 40. The suspension in area (3) appears to be a non-structural system and consequently a liquid with an increased viscosity equal to η_{pl}.
Fig. 39 (see AC/M No. 9/10-1969) shows the conditions of flow of microlayer (2) corresponding to line $OToA$ and of the suspension (3) corresponding to the straight line OB. Suspension in area (3) is gradually passing into area (4) with a turbulent flow of the particles. The friction which is under examination refers to the friction between microlayer (2) and the suspension in area (3). Studies on the conditions of flow of two dispersion masses in contact which possess the properties of viscoelastic bodies, reveal the following two cases as possible:

a) The tangential stress on a given layer from another layer with which it is in contact, can be less that the yield stress *To*. In this case a sliding of the layers will be observed but the rate will be equal to zero.

b) *To* is exceeded and in this case the structure desintegrates.

Further to the above, it is pointed out that a quantitative relation also exists.
The asbestos-cement layer moves in the laminar flow of the asbestos-cement suspension which is non-structural. The suspension can be considered as a liquid the viscosity of which is equal to η_{pl}. Friction under these conditions can be calculated according to equation (5-5).
In conformity with equation (5-5), the following expression can be written:

$$A = \eta \cdot \frac{du}{dx} = \eta_{pl} \cdot \beta u'$$

where: A is the friction on the surface of the layer
β is the coefficient of proportionality
η_{pl} is the viscosity of the A/C suspension
u' is the rate of flow of the layer in contact with the suspension.

With the concentration of the suspension maintained constant in the vat, position «0» is the critical point where a possible destruction of the layer under the forces of friction, can take place, see fig. 44. At this point, the rate of flow of the layer will have a maximum value and will be equal to the speed of the felt. When the layer will be moving towards point «0», its rate of flow can be less than the speed of the felt because of the obstruction caused by the laminar flow which has a motion parallel to the layer in area (3). Consequently the possibility exists that the layer which flows in the suspension towards point «0» will be subject to friction the value of which is less than the «yield stress». At point «0» however, where the rate of flow will have a maximum value, the forces of friction can exceed the yield stress and this will lead to the destruction of the layer.
An undamaged layer can therefore be obtained under conditions where:

$$To \geqslant \beta \eta_{pl}$$

and therefore:

$$uc \leqslant \frac{To}{\eta_{pl}} \qquad (5\text{-}8)$$

This last expression can be used to calculate the maximum tolerable felt speed which will permit the delivery of an undamaged layer on the sieve cylinder, provided the value of coefficient β is known. For the purpose of determining the value of coefficient β, a series of experiments were conducted, under actual factory conditions. With a constant concentration, the speed of the felt of a machine was increased as follows: from 17.7 to 23.6 first and then to 28.9, 33 and 37.8 metres/minute. At each of the above speeds, the coefficient of collection Ky, was determined with the use of formula:

$$Ky = \frac{G}{aV}$$

As a consequence of damage occuring to the layer, its weight «G» will decrease and the volume of filtrated material «V» will increase. Ky is highly sensitive to any disturbance and if the layer is damaged, Ky will decrease sharply.
The relation Ky/felt speed has permitted to establish the speed of the felt corresponding to the best Ky. When the speed of the felt uc, the viscosity η_{pl} and the yield stress To are known, coefficient β can be determined using equation (5-8). Experimental work has established β to be equal to 1.17.
Calculations of the tolerable felt speeds, under

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different conditions, are contained in table 19 (see AC/M No. 7/8 - 1969).

Measurements of the concentration of the suspension at different points in the vat has revealed that the concentration at point « 0 » is higher than the average values by about 20%. Table 19 shows the values at point « 0 » and also the average values.

The felt speeds indicated in table 19 are for suspensions with a temperature of 20° C. The relation *To* and *τ,pl*/temperature can be used to establish the tolerable felt speeds with higher temperatures of the suspension. The calculations indicate that the speeds shown in table 19 must be multiplied by 0.99 when the temperature of the suspension is 30° C and by 0.88 when the temperature is 35° C.

The analysis of the effects of the rotation of the sieve cylinder allows to draw the following practical and important conclusions:

1) Between the wire and the layer, the forces of adherence are of a considerable value and this excludes the threat of the destruction of the layer by centrifugal forces, especially at the currently practiced felt speeds.

2) Friction between the layer and the suspension can destroy the layer formed on the surface of the sieve cylinder. When destruction occurs, the output of the machines is lowered and the quality of the end product deteriorates.

3) The layer obtained from a suspension of low concentration, is particularly subjected to destruction as it has a high moisture content and consequently a low resistance to the flow.

4) The danger to see the layer damaged increases with the increase of the speed of the felt. In such cases it is necessary therefore to increase the strength of the layer by decreasing its moisture content; this is obtained by increasing the concentration of the suspension. At given felt speeds, the concentration of the suspension in the vats must not be less than the values indicated in table 19.

5) The values for concentrations and tolerable felt speeds, referred in table 19, are only safe when the formation of structures in the suspension is prevented (consisting in the reciprocal adhesion of asbestos-cement particles). When structures are formed in the suspension, the viscosity increases considerably and the forces of friction which act on the layer will increase and destroy the layer.

6) To prevent the formation of structures in the suspension, it is necessary to agitate the suspension intensively in the vats. The necessity to have agitators in the vats derives principally from this reason. Preventing the sedimentation of the solid phase, though advisable, is however of secondary importance.

7) Any increase of the concentration made necessary as a result of the increase of the speed of the felt, requires at the same time an increase of the intensity of agitation as with the increase of the concentration it becomes more difficult to prevent the formation of structures in the suspension. *At this stage it is importat to know that the probabilities to see structures formed in the suspension, increases with the use of long fibres of asbestos.*

   Agitation can be intensified by either increasing the number of revolutions of the agitators or by increasing their diameter.

8) The destruction of the layer begins at the point where the surface of the sieve cylinder carryi-- the layer, emerges from the suspension, in ot[illegible] words at point « 0 » (see fig. 44).

   It is properly in this area of the vat that any decrease in intensity of the agitation becomes dangerous. Currently used vats do not permit the proper agitation of the material in this area due to the distance separating it from the agitators, and also because of the narrowness of the space between the surface of the sieve cylinder and the wall of the vat; the distribution in an upward direction of the turbulence caused by the agitators is prevented (this is particularly dangerous in machines with sieve cylinders of 1250 mms ⌀),

   The formation of structures in the suspension can be prevented by expanding the vat in this area, by introducing supplementary agitators or by feeding in this zone of the vat water of dilution. By so doing, the layer already formed in other zones of the vat where concentration is higher, will be stronger and will resist friction.

9) The way the suspension is mixed in vats of current construction, creates a very uneven flow. The rate of flow of the upper layer is considerably slower than that of the layers nearer to t[illegible] agitators.

   If the revolutions of the agitators are excessively increased in order to prevent the formation of

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structures in the upper layers of the suspension, the asbestos-cement layer already formed on the wire while this is in the vicinity of the agitators may be destroyed unless the layer is sufficiently strong; therefore it is necessary, before increasing the number of revs of the agitators, that the density of the concentration is such that the delivered layer has the required strength to resist the action of the forces of destruction.
A relation thus results: intensity of agitation/concentration of the suspension. A too low concentration is hardly ever recommended as it is often not tolerated by the system and periodically is the cause of the damage of the asbestos-cement layer during its formation on the sieve cylinder. The relation intensity of agitation/concentration of suspension makes it necessary to have at the disposal of the technologists, agitators with varying speeds adjustable in relation to the concentration of the suspension.

10) Over agitation can deteriorate the technological properties of the suspension by washing off the cement particles which have adhered already to the surface of asbestos fibres.
11) Any occuring destruction of the asbestos-cement layer can be detected by the value of the coefficient of collection Ky which is the ratio between the weight of asbestos-cement deposited on the wire of the sieve cylinder and the total weight of asbestos-cement introduced in the vat in a unit of time.

The quantity of asbestos-cement delivered on the wire of the sieve cylinder, will be equal to:

$$Gc = a_z V_z - a_y V_n$$

where: a_z, V_z are the concentration and volume respectively of the suspension which is introduced in the vat per unit of time.
a_y is the concentration of the solid phase in the filtrated material.
V_n is the volume of filtrated material from the sieve cylinder, per unit of time.

The quantity of asbestos-cement delivered on the wire of the sieve cylinder, can be determined by another way using the formula:

$$Gc = Ky \cdot a_v \cdot V_n$$

where: Ky is the coefficient of collection
a_v is the average concentration in the vat.

By equating the last two expressions and considering that:

$$V_z = 1.07\, V_n \text{ and } a_y = 0.10\, a_z$$

the following equation can be written:

$$Ky = \frac{V_n(1.07\, a_z - 0.10\, a_z)}{V_n \cdot a_v} = 0.97\, a_z/a_v\,.$$

In practice however, the value of the coefficient which is very near to 1, can be ignored and the following formula can be used with enough accuracy.

$$Ky = \frac{a_z}{a_v} \tag{5-9}$$

Concentration should only be measured, after that the vat has been working with a constant concentration for at least 5-7 minutes.
If Ky is found to be between 0.80-0.86, the conditions of operation of the machine can be considered satisfactory. If on the other hand, Ky is found to be less than 0.80, this would mean that the layer under formation on the sieve cylinder is subject to damage caused by friction or is being washed off by the action of the agitators.
The correctness of the points listed above, is being proved in many modern factories using advanced technological methods. Considerable increases of the output of many factories have and are registered as a result of increases of the speeds of the felts with simultaneous increases of the concentration and of the number of revolutions of the agitators. The expansion of the vats at the point where the sieve cylinder emerges from the suspension, has also proved to be a correct step to take. This measure prevents in many cases the formation of structures in the suspension at this point. Expansion of the available area can be obtained by either modifying the vats or by using smaller sieve cylinders. In many plants, it was made necessary to create such conditions as measurements of Ky were found to be as low as 0.60.