Viscosity of the ferrosilicon suspension as a function of the solid phase parameters

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Viskozita ferosiliciovej suspenzie ako funkcia parametrov tuhej fázy

V príspevku sú uvedené výsledky meraní viskozity suspenzií mletého a granulovaného ferosilícia. Hodnota viskozity suspenzie je jedným z určujúcich parametrov rozhodujúcich o možnosti využitia tohto rozdružovacieho média v praxi. Namerané údaje viskozity suspenzií sú rádovo vyššie, ako hodnoty uvedené v citovanej literatúre.

Key words: Suspension, granulated, grinded, ferrosilicon, viscosity, rotary viscosimeter.

Introduction

At the present time the ferrosilicon suspensions are still utilized in dressing and coal preparation plants as separation media despite of relatively high FeSi production costs. Therefore the research of their principal physical, physico-chemical and chemical properties is of great significance.

The properties of the suspension and suspensoid, for example their density, viscosity, grain size distribution, physical and chemical stability, reactivity, abrasion and so on, determine the possibilities of the suspension industrial utilization. The project was originated on the base of impulse from the industry and its purpose was to compare the selected technological properties of the suspensions made of the granulated and grinded ferrosilicon. The term "granulated" is related to the production of this type of the suspensoid - it is granulated melt. As the "grinded" ferrosilicon is called the powderlike suspensoid, which is produced by the FeSi alloy fragments grinding. The present paper is devoted above all to the viscosity problem of the suspension.

Viscosity of the suspension

Before the suspension viscosity measurement, it was necessary to estimate the grain size distribution and density of the suspensoide.

The grain size distribution of the ferrosilicon

The ferrosilicon grain size distribution estimation was carried out by applying the dry method on the sieves of 0,12 - 0,090 - 0,071 - 0,053 - 0,040 mm with the constant classification time. The grain size distribution of the fraction 0 - 40 μm was estimated by the photosedimentograph of the Japanese firm Sheishin in the environment of bromoform. The grain size distribution of both ferrosilicon types and of the entire grain size spectrum is given in the Tab.I.

According to obtained results given in the Tab.I. it follows that the investigated two types of FeSi differ in the grain size distribution in such a manner that while in the granulated FeSi there are 46,75 % of the particles with the size smaller than 40 μm, the grinded FeSi contains by 8 % wgt. more of this fraction, which equals to 54,8 % and this fact possibly influence the suspensions stability. The differences in other classes are smaller. In the class 0,071 - 0,090 mm the difference represents 5,2 % in favour to the grinded FeSi.

The ferrosilicon density estimation

The density was estimated by the pycnometry from the homogenized samples as well as from the individual fractions after the dry classification of granulated and grinded FeSi original samples. The

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densities of the granulated FeSi = 7070 kg.m^{-3} and grinded FeSi = 7060 kg.m^{-3} were calculated from the obtained values. The densities estimated from the mean samples were 7040 and 7080 kg.m^{-3}. The difference represents less than 0,7 % and ranges in the limits of the experimental error.

Tab.I. The grain size distribution of the ferrosilicon - cumulated values.

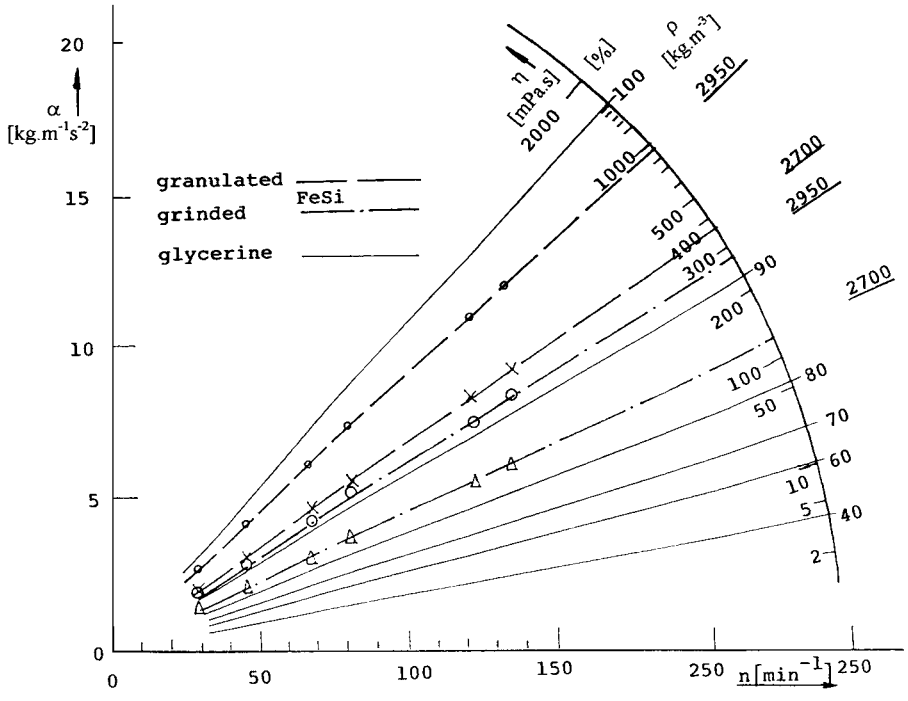
Class of the grain size	Granulated FeSi		Grinded FeSi	
	Sample		Sample	
	A	B	A	B
[mm]	$\sum\gamma$ [%]	$\sum\gamma$ [%]	$\sum\gamma$ [%]	$\sum\gamma$ [%]
-0,006	12,13	14,31	12,85	12,43
0,006 - 0,010	15,24	17,99	13,60	12,96
0,010 - 0,015	18,27	21,62	15,76	15,41
0,015 - 0,020	20,88	24,54	18,00	17,10
0,020 - 0,030	30,98	34,63	36,62	34,94
0,030 - 0,040	46,76	46,75	54,43	55,18
0,040 - 0,056	60,64	60,80	63,08	62,44
0,056 - 0,071	70,78	71,13	75,42	74,47
0,071 - 0,090	81,11	81,48	86,62	86,48
0,090 - 0,120	99,70	99,70	99,87	99,91
+ 0,120	100,00	100,00	100,00	100,00

Measurment of the suspension viscosity

The viscosity of the suspension is that property of the suspension, which in the essential degree influences the results of the separation, mainly of the smaller grain size classes. It is obvious from the physical definition of the viscosity that it represents the resistance of the layers against the mutual movement which is called internal friction (Ulický & Vavra, 1974).

To measure the viscosity, the rotary viscosimeter Rheotest 3 was applied, which was adjusted for the measurment of the unstable suspensions of the relatively high densities. To measure the shear stress α the hollow cylinder labelled by N was used, which was located in an extra adjusted measuring vessel. The suspension homogeneity was ensured by the pneumatic mixing.

As the measuring method the proportional method was used based on the principle of the shear stress α estimation for the liquid with the known density and viscosity (glycerine) and the suspension of known density. The measurments were carried out under the conditions.



The viscosity measurements were carried out as follows: The suspension of the known density was prepared in the measuring vessel and the shear stress values were read under the alternated rotations of the measuring cylinder. Similar measurements were carried out for the solutions of glyce-rine (100, 90, 80, 70, 60 and 40 % wgt.) in advance. The results of realized measurements, processed applying the least squares method are graphically shown in Fig.1.

Fig.1. The dependence of viscosity on the measuring conditions.

The change of glycerine solution viscosity as the concentration dependence is expressed by the logarithmic law, which is represented on the graph by the arc scale of viscosity. For various viscosity series is effective a different scale module.

The presented figure enables the simple viscosity determination for variety of the suspensions. The value of the suspension viscosity is determined in such a manner that measured values of α for alternating rotations are drawn in the diagram. The connection line of these points and of the zero point shows on the arc scale the value of the measured viscosity.

From the obtained knowledge related to the measured viscosity the most significant results are as follows:

- viscosity of the suspension made of the granulated ferosilicon is higher than the viscosity of the solution made of the grinded ferrosilicon,
- the average values of the suspensions for both types of the ferrosilicon are by order higher than the values presented in the literature until the present time(19-22 mPa.s) (Špaldon, 1985; Tarjan, 1986).

In any case the suspension viscosity made of the grinded FeSi cannot be the reason for the restriction of its utilization as the granulated FeSi replacement.

Stability of the ferrosilicon suspension

The deficiency of the suspensions is more or less fast sedimentation which results in the fact that their density close to the surface diminishes and close to the bottom increases. This natural phenomenon, which is called suspension instability, reduces the sharpness of the demixing of mineral raw materials. The solid phase sedimentation speed is considered as the characteristics suspension stability (Špaldon, 1986).

Many authors recommend to determine the suspension stability on the basis of the rate of its upper layer clarification, using the subsidence of the interface clarified water - suspension $\Theta = v^{-1}$.

The suspension stability increases with its increasing viscosity. The suspension stability was determined from the values obtained when observing the speed of the upper layer clarification. The measurements were carried out in the calibrated cylinders, where the suspensions made of the granulated and grinded FeSi with the density of 2950 kg.m^{-3} were placed. The measurements were carried out after the 24 hours wetting of the suspensoid. The average values from 5 measurements are given in the graph in Fig.2.

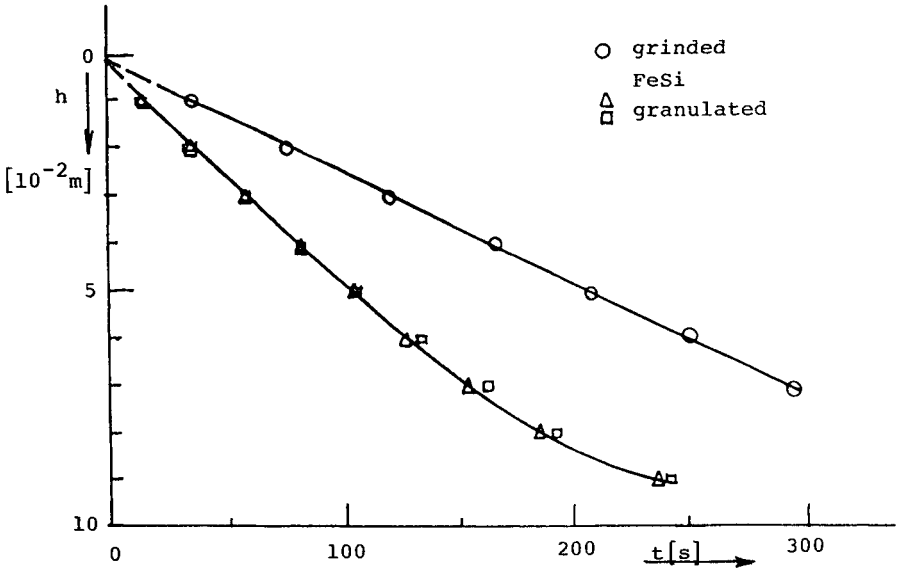


Fig.2. The clarification - time dependence.

On the curve for the granulated FeSi, the mean values from the measurements after the 120 hours wetting of the suspensoide (small squares) are al-so provided, showing no significant differen-ces in the measured values.

The thickening rates values of the grinded FeSi v = $0.231.10^{-3}$ m.s^{-1} and granulated FeSi v = $0.446.10^{-3}$ m.s^{-1} were stated from the linear portions of the above relations. The calculated value of the stability of the grinded FeSi is 4329 s.m^{-1} and of the granulated FeSi is 2242 s.m^{-1}. When comparing the both above values, it is obvious that the stability of the grinded FeSi is about two time greater than the stability of the granulated FeSi.

The problem of the suspension stability observation as dependence on the operational time is importance in the technical practice. The "contamination" of the suspension by the clay or other fine

mineral particles occurs in the plant. The presence of the fine and colloidal particles positively influences the stability value.

Conclusion

On the basis of the executed measurements, the following was found out:

- the viscosity of the ferrosilicon suspension is by order higher than the values presented values in the literature,
- the viscosity of the suspension made of the granulated ferrosilicon is higher than the viscosity of the suspension made of the grinded ferrosilicon.

The measurements reproducibility confirms that the presented method of the viscosity measurements is suitable for the laboratory research and for its application in the practice as well.

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