TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
MECHANICS | MECHANIKA
2-M/2016

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MIXING WASTE GYPSUM SUSPENSIONS

MIESZANIE ODPADOWYCH ZAWIESIN GIPSOWYCH

A b s t r a c t

The paper deals with experimental research of the waste suspensions mixing from the energy industry. Mixing experiments were carried out in a transparent baffled vessel with a diameter of 290 mm. Standard pitched six-blade turbine and folded four-blade turbine with diameters of 100 mm in two relative distances from bottom H_2/d = 1 and 0.5 were used in experiments. Measurements were carried out with three volumetric concentrations of suspensions: 16, 31.5 and 47%.

Keywords: mixing, suspension, gypsum

S t r e s z c z e n i e

W pracy przedstawiono badania eksperymentalne mieszania odpadowych zawiesin gipsowych powstających w energetyce. Badania prowadzono w przezroczystym zbiorniku o średnicy 290 mm, z przegrodami. W badaniach stosowano mieszadła osiowe o średnicy 100 mm: standardowe mieszadło sześciołopatkowe oraz mieszadło czterołopatkowe, zakrzywione dla dwóch odległości od dna zbiornika H_2/d = 1 i 0.5. Badania przeprowadzono dla trzech stężeń objętościowych zawiesiny 16, 31.5 i 47%.

Słowa kluczowe: mieszanie, zawiesina, gips

DOI:

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1. Introduction

This paper reports on an experimental study of the waste suspensions mixing from the energy industry. The sedimentation and the rheological behaviour of these suspensions were described in our recent paper [1]. Figs. 1 and 2, reproduced from that paper, show that the settling velocity decreases and the viscosity of these suspensions increases rapidly with increasing particle concentration.

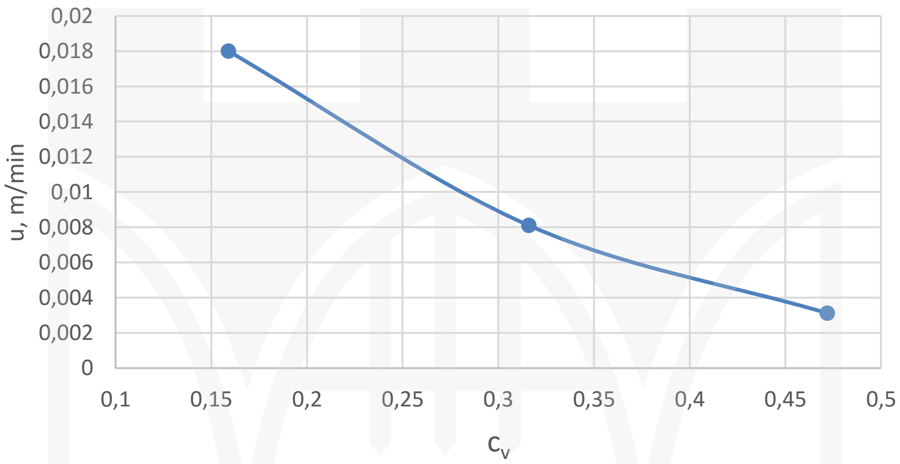

Fig. 1. Dependence of sedimentation velocity on concentration

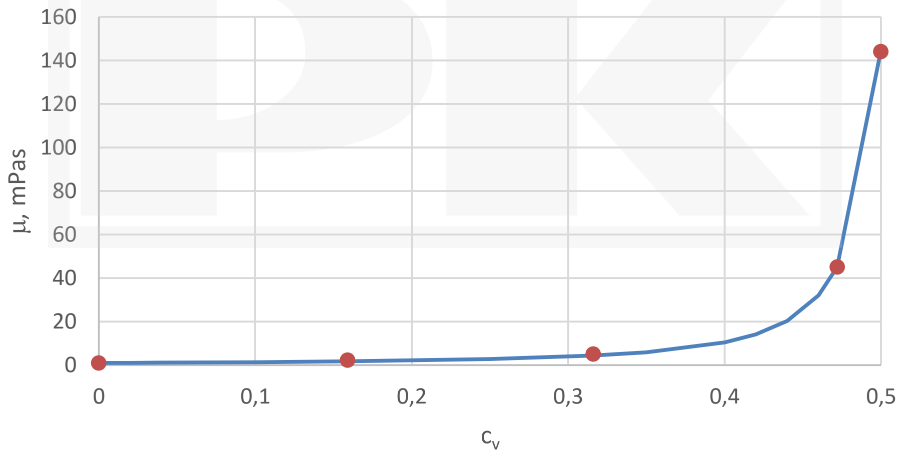

Fig. 2. Dependence of viscosity on volumetric concentration

2. Experimental

Mixing experiments were carried out in a transparent baffled vessel (see Fig. 3) 290 mm in diameter.

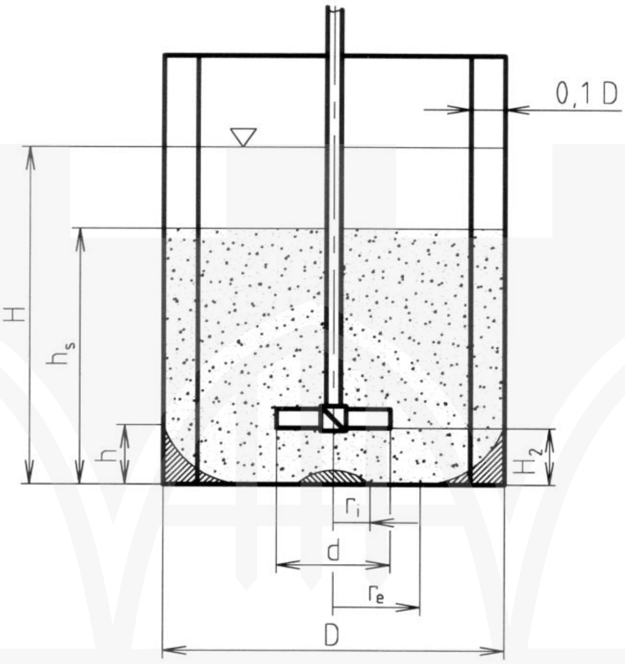

Fig. 3. Experimental vessel, $H/D = 1$

A standard pitched six-blade turbine (6SL45) and a diagonally folded four-blade turbine (4RLL) 100 mm in diameter, as shown in Fig. 4, at two relative distances from the bottom, $H_2/d = 1$, 0.75, and 0.5, were used in the experiments. Measurements were carried out with three volumetric concentrations of the suspensions: 16%, 31.5% and 47%.

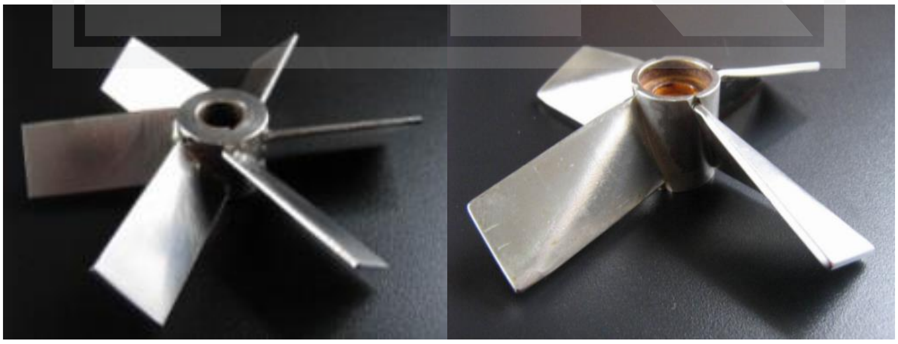

Fig. 4. Agitators used in the experiments

The just suspension speed of the agitator was stated as the speed at which the height of the particle layer *h* in the bottom corner was zero. The height of the suspension layer h_s and the concentration distribution at the suspension speed were also measured. The concentration distribution was stated on the basis of an analysis of samples taken from the wall of the vessel at various distances from the bottom of the vessel, see Fig. 5. Samples were taken at just-suspension speed and at the speed at which the height of the interface between the suspension and clear water $h_s = H$. An analysette A22 laser analyser was used for sample analysis. The distances *z* of the places at which samples were taken are specified in Table 1.

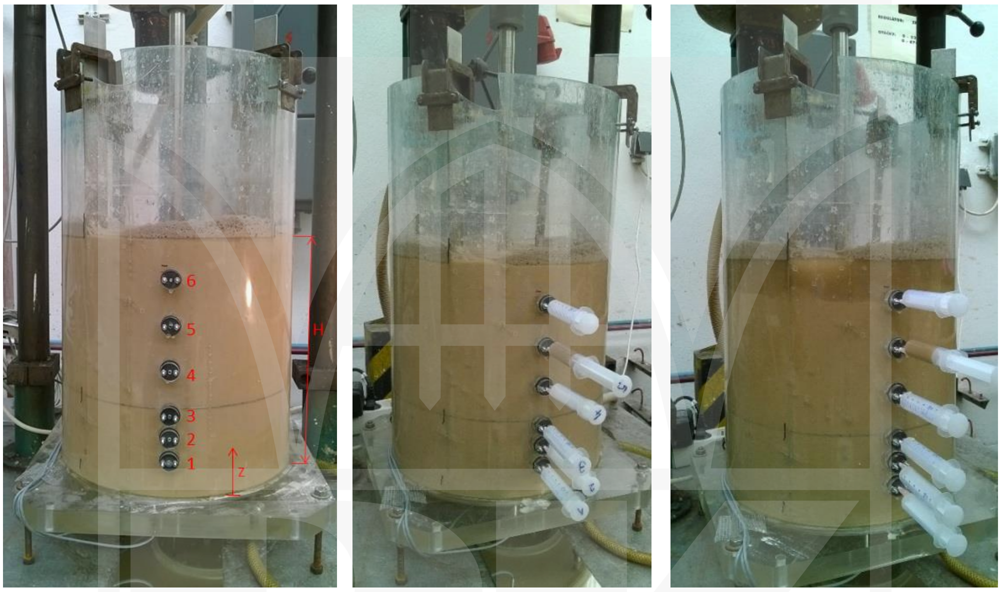

Fig. 5. Experimental vessel

Table 1

Sampling point	**1**	**2**	**3**	**4**	**5**	**6**
z [mm]	48	73	97	145	193	242
z/H	0.17	0.25	0.33	0.50	0.67	0.83

3. Experimental results

Analyses of the samples were carried out for a standard pitched six-bade turbine at the lowest concentration of 16%, at which the settling velocity is highest (see Fig. 1). The results for the agitator speed at which $h_s = H$ (see Fig. 5, second photo) are shown in Fig. 6. The results for just-suspension speed (see Fig. 5, third photo) are shown in Figs. 7 and 8. It follows from the results shown in Fig. 6 that at $h_s = H$ there is homogeneity and the particle size distribution is uniform. From Figs. 7 and 8, when $h_s < H$ at z = 48 mm the concentration is higher, and near the interface at z = 242 mm the concentration is smaller and the particle size distribution is not uniform (the suspension contains only the smallest particles). At the other sampling points (2-5), the suspension is uniform.

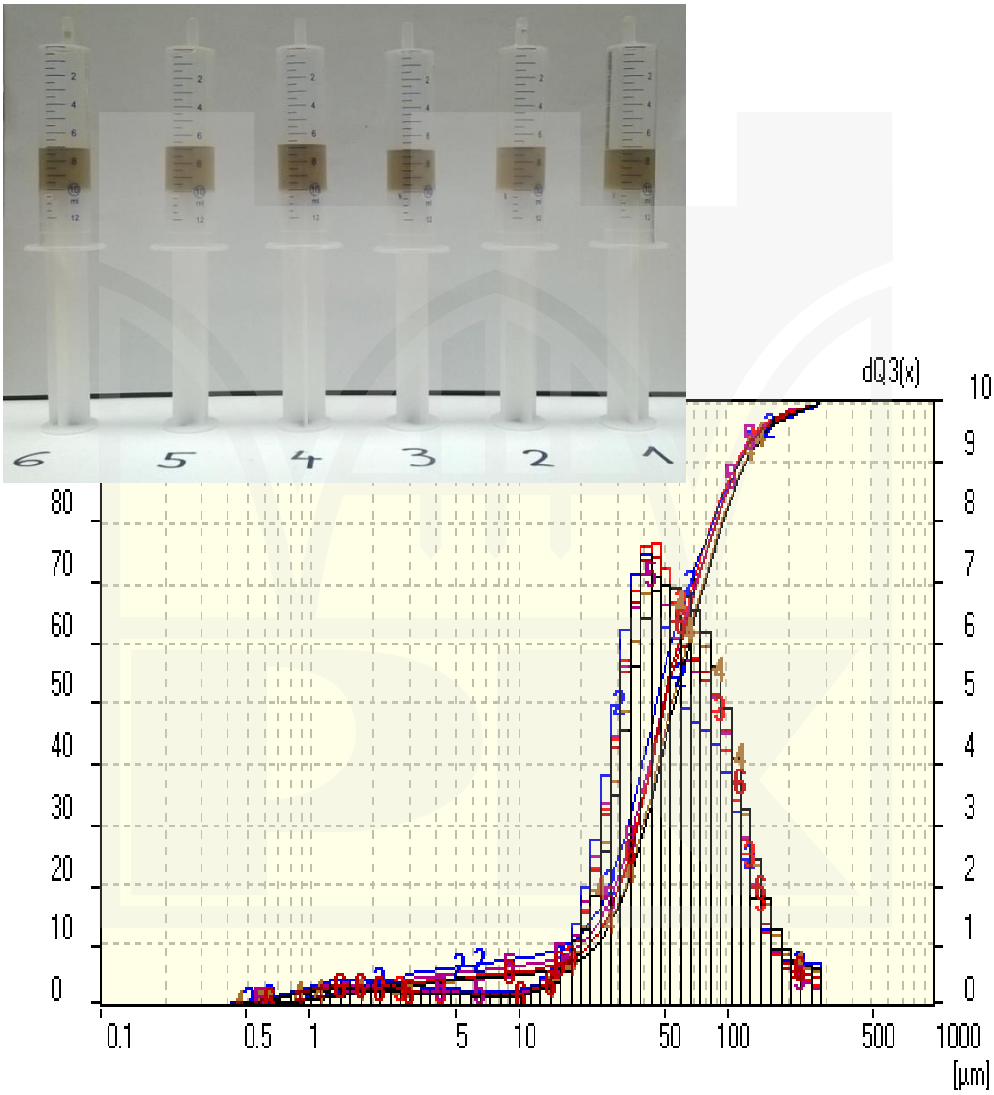

Fig. 6. Analysis of the concentration profile and the particle size distribution at $h_s = H$ (c_v = 16%, pitched blade turbine: H_2/d = 1, n_h = 502 min^{-1})

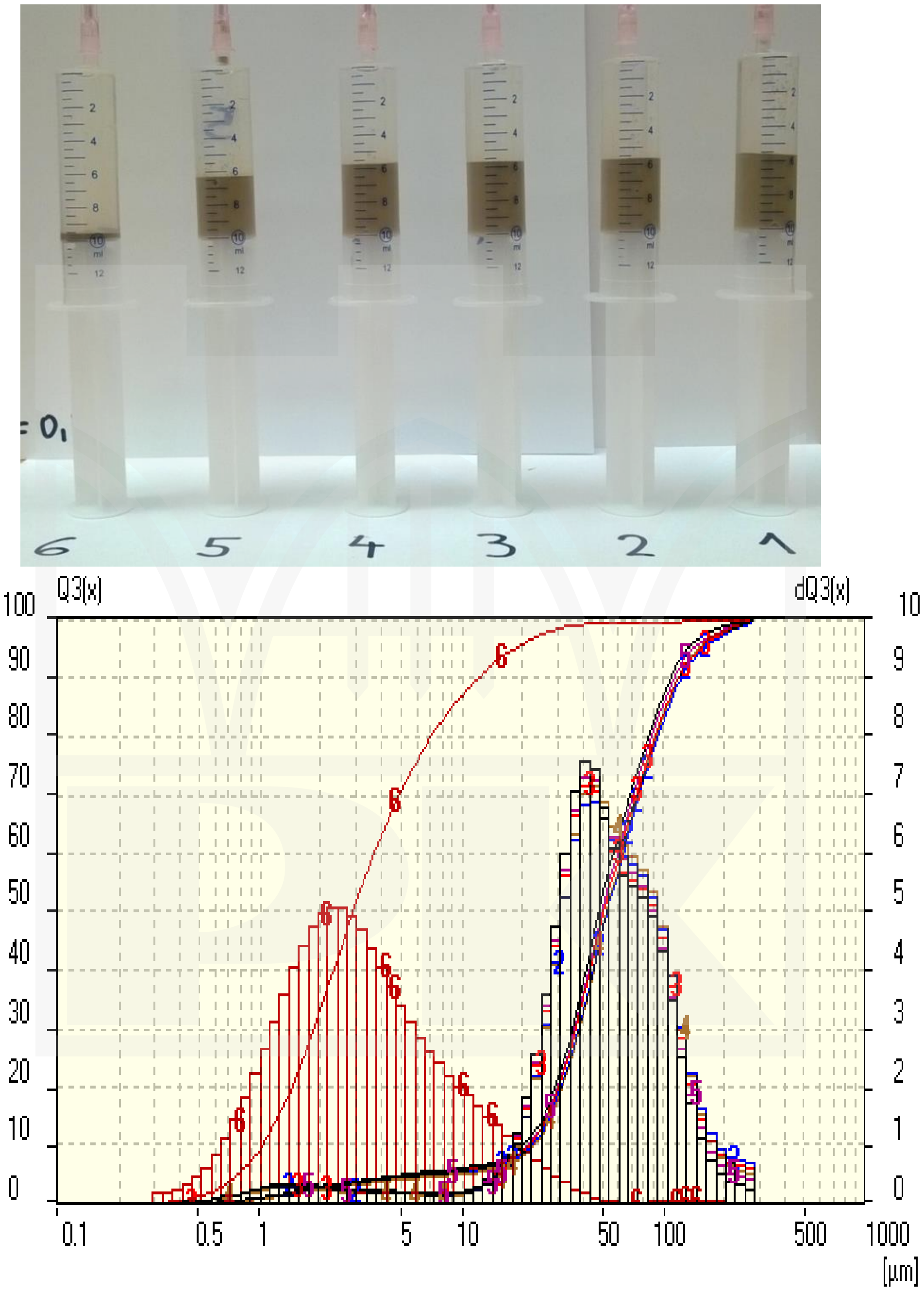

Fig. 7. Analysis of the concentration profile and the particle size distribution at just-suspension speed (c_v = 16%, pitched blade turbine: H_2/d = 0.5, n_{cr} = 226 min^{-1}, h_s/H = 0.724)

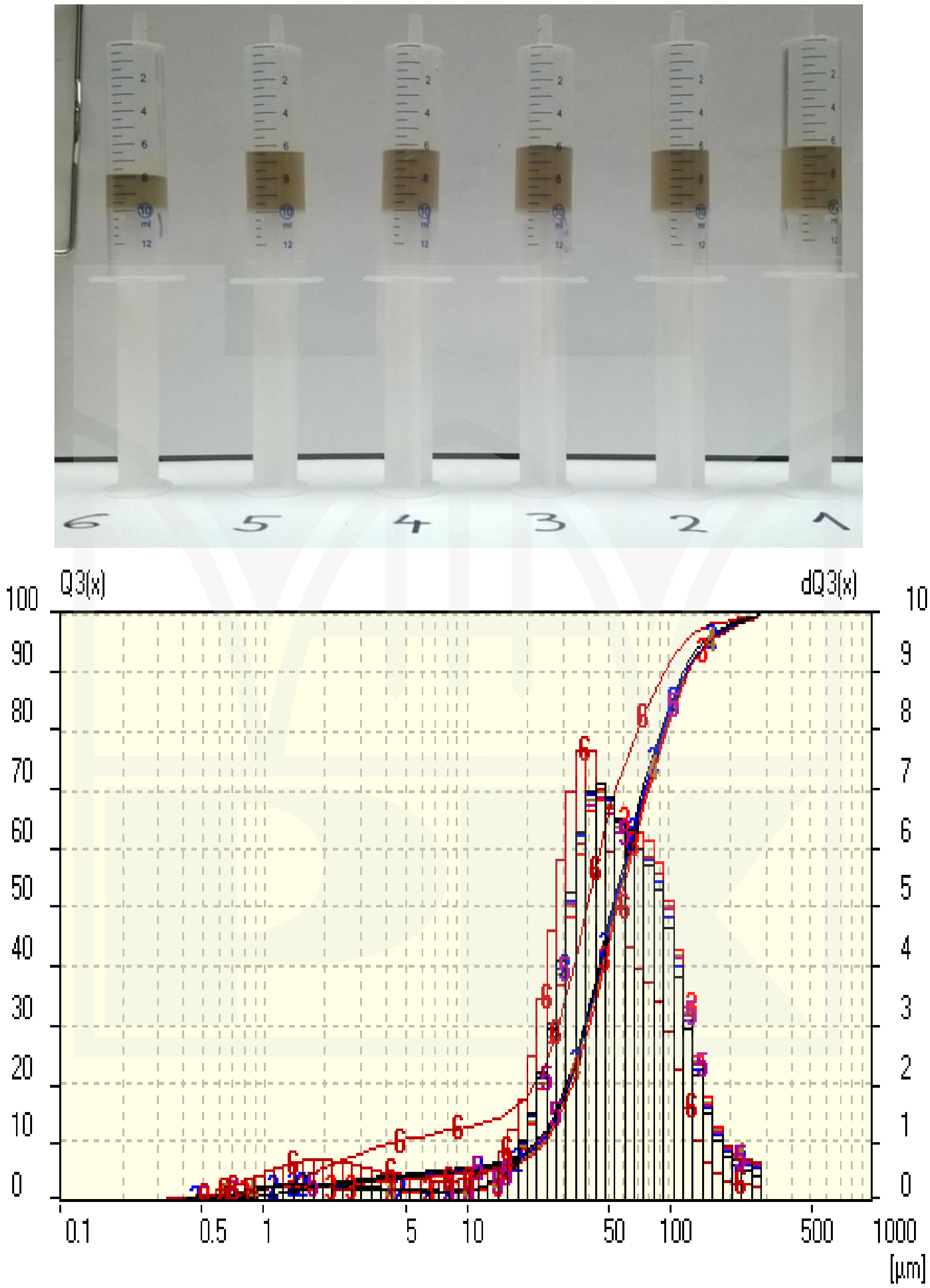

Fig. 8. Analysis of the concentration profile and the particle size distribution at just-suspension speed (c_v =16%, pitched blade turbine: H_2/d = 1, n_{cr} = 330 min^{-1}, h_s/H = 0.879)

The experimental values of just-suspension speed and agitator speed at $h_s = H$ are presented in tables 2 and 3. These tables also contain values for the power consumption and for specific power, calculated from the power number values presented in [2].

Table 2

Values obtained at just-suspension speed

Volumetric particle concentration	*Agitator*	H_2/d	n_{cr} [min^{-1}]	h_s [mm]	h_s/H	*Po*	*P* [W]	ε [W·m^{-3}]
16 %	**6SL45**	1	330	255	0.879	1.66	3.31	173
		0.5	226	210	0.724	1.81	1.16	61
	4RLL	1	302	215	0.741	0.78	1.19	62
		0.5	260	195	0.672	0.99	0.97	50
31.5 %	**6SL45**	1	349	270	0.931	1.66	4.57	239
		0.5	245	245	0.845	1.81	1.73	90
	4RLL	1	345	240	0.828	0.78	2.08	108
		0.75	290	240	0.828	0.80	1.26	66
		0.5	280	230	0.793	0.99	1.41	74
47 %	**6SL45**	1	430	290	1.000	1.66	8.55	447
		0.5	390	290	1.000	1.81	6.96	363
	4RLL	1	508	290	1.000	0.78	6.63	346
		0.75	500	285	0.983	0.80	6.48	338
		0.5	480	290	1.000	0.99	7.10	370

Table 3

Values obtained at $h_s = H$

Volumetric particle concentration	*Agitator*	H_2/d	n_h [min^{-1}]	h_s [mm]	h_s/H	*Po*	*P* [W]	ε [W·m^{-3}]
16 %	**6SL45**	1	502	290	1	1.66	11.67	609
		0.5	483	290	1	1.81	11.33	592
	4RLL	1	580	290	1	0.78	8.45	441
		0.5	505	290	1	0.99	7.08	370
31.5 %	**6SL45**	1	510	290	1	1.66	14.27	745
		0.5	470	290	1	1.81	12.18	636
	4RLL	1	539	290	1	0.78	7.92	413
		0.75	490	290	1	0.80	6.10	318
		0.5	485	290	1	0.99	7.32	382

It follows from the results presented here that at just-suspension speed for concentrations of 16% and 31.5% $h_s < H$, and for a concentration of 47% $h_s = H$. The just-suspension speeds at the maximum concentration of 47% are significantly higher than at lower concentrations. A comparison of the power consumption shows that a folded blade turbine needs less power than a standard pitched blade turbine.

A comparison of the experimental just-suspension speed values with the values calculated from the relations presented in [3] is shown in Fig. 9. It follows from this figure that there is no significant difference between the experimental values and the calculated values at concentrations of 16% and 31.5%. The experimental values obtained at the maximum concentration of 47% are significantly higher than the calculated values. This is due to the high viscosity of the suspension and the transitional flow in the vessel (the relations presented in [3] hold only for turbulent flow).

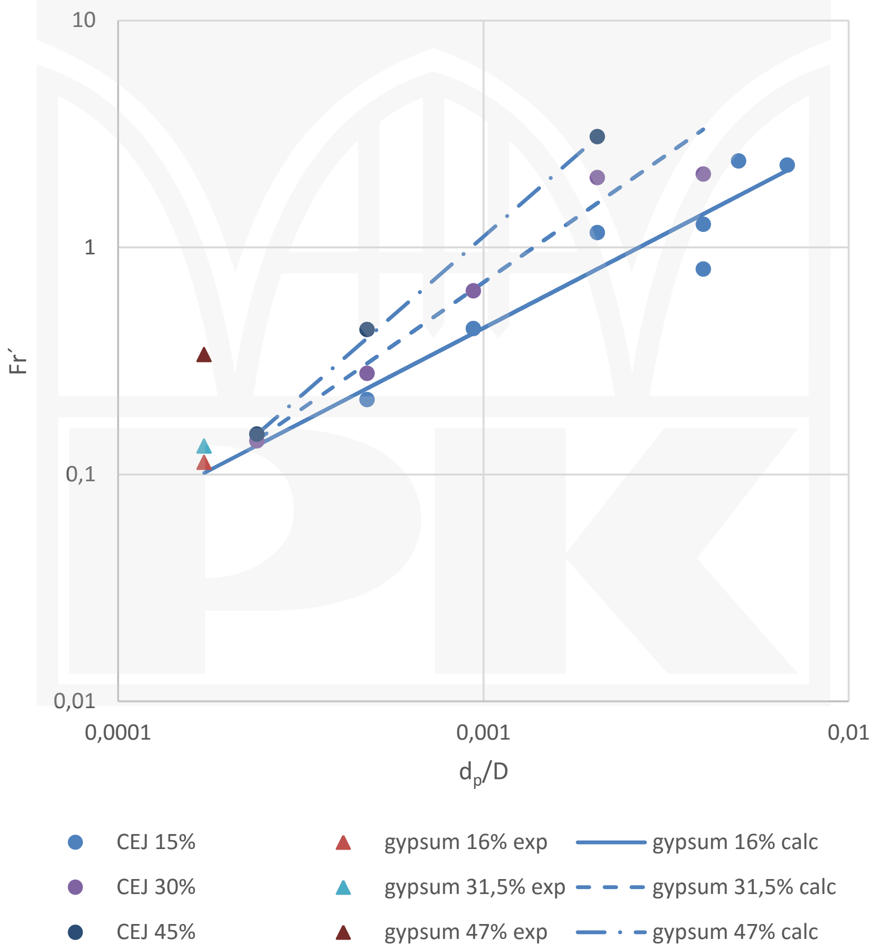

Fig. 9. Comparison of experimental values with results from [3]

List of symbols

c_v – mean volumetric particle concentration
d – agitator diameter
D – vessel diameter
d_p – particle diameter
Fr' – modified Froude number $Fr'=n^2 d\rho/g\Delta\rho$
g – gravity acceleration
h – sediment height
h_s – height of interface between suspension and clear liquid
H – batch height
H_2 – distance between agitator and bottom
n – agitator speed
n_{cr} – just-suspension agitator speed
n_h – agitator speed at which $h_s = H$
$r_{i,e}$ – radii of sediment layer
u – settling velocity
z – distance of sampling point
μ – dynamic viscosity
ρ – suspension density

References

[1] Moravec J., Rieger F., Jirout T., *Viscosity measurements of gypsuzm suspensions*, Proceedings of 22nd Polish Conference of Chemical and Process Engineering, Spala, 5-9 September 2016.
[2] Medek J., *Power characteristics of agitators with flat inclined blades*, Int. Chem. Eng., vol. 20, 1980, 665-672.
[3] Rieger F., *Effect of particle content on agitator speed for off-bottom suspension*, Chem. Eng. J., vol. 79, 2000, 171-175.