INFLUENCE OF THE PELLETIZING PROCESS PARAMETERS ON THE MECHANICAL PROPERTIES OF RECEIVED ALUMINA OXIDE PELLETS

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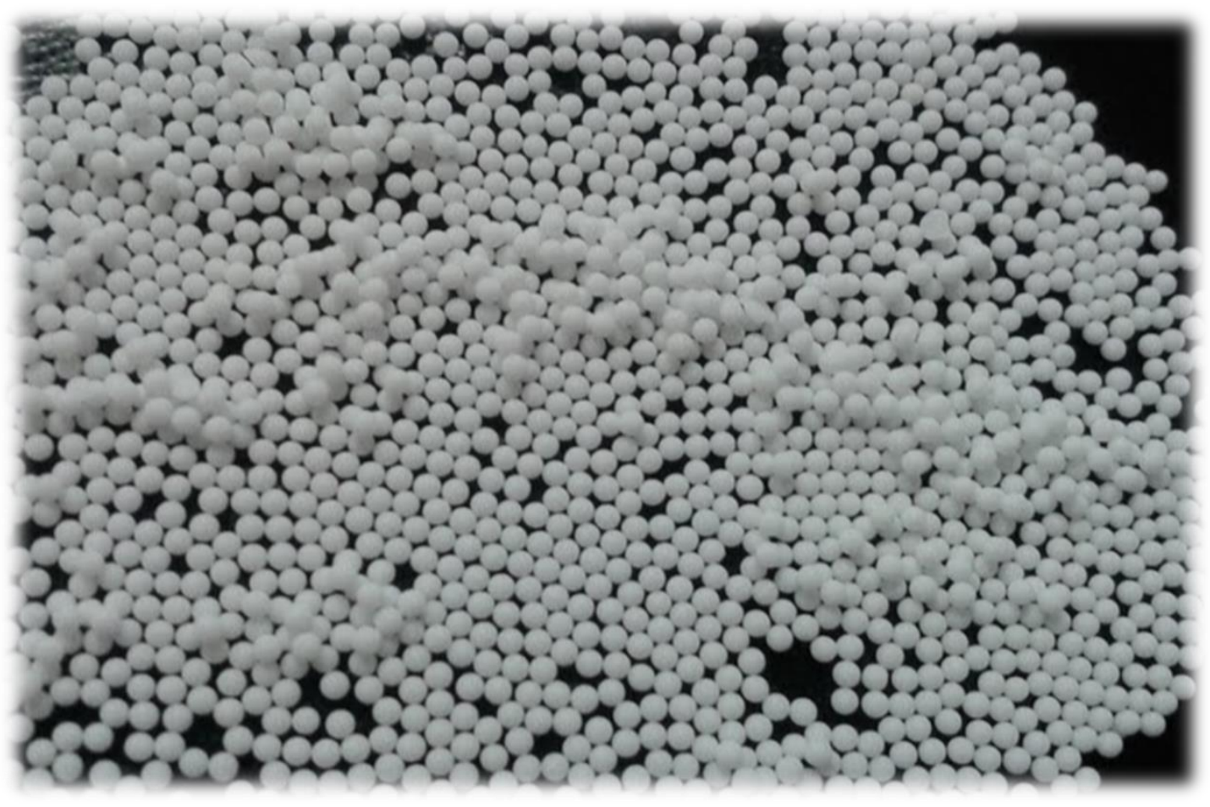
I. Introduction

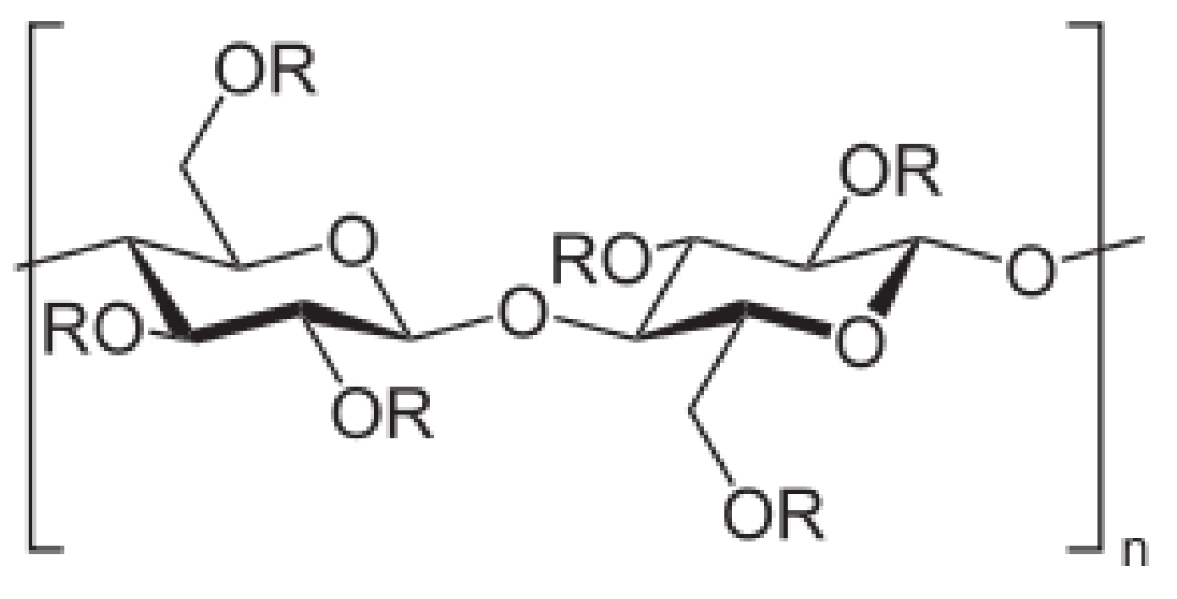
Pelletizing is a common process to optimize the mechanical properties of various powder materials. Industrially produced alumina oxide (γ-Al_2O_3) granules are used here as primary model particles for the pelletizing process, carried out in a laboratory rotating pan-pelletizer (spheronizer) at constant processing time of 20 minutes. Solution of viscoelastic polymer - hydroxypropyl methylcellulose (HPMC) is used as binder. Its concentration was increased until finding of the most suitable binder content for the model pellets. The rotational velocity of the pan-pelletizer was varied in order to find the optimal speed, which provides pellets with improved properties. The influence of the process parameter on the received pellet product properties like density and porosity, size distribution, breakage characteristics and breakage probability was analysed.

II. Materials : Primary particles and binder



γ-Al_2O_3 properties

diameter (mm)	1.0
crush strength (MPa)	45
bulk density (g/m³)	740-820
porosity (%)	75



R = –H, –CH_3, –CH_2–CHOH–CH_3

Hypromellose (HPMC) Solution

- non Newtonian fluid -pseudoplastic behavior
- prepared by directly dissolving HPMC powder into distilled water

AMW (g/mol)	pH	chemical reactivity
748.807	5.0-7.5	combustible and react vigorously with oxidizing agents

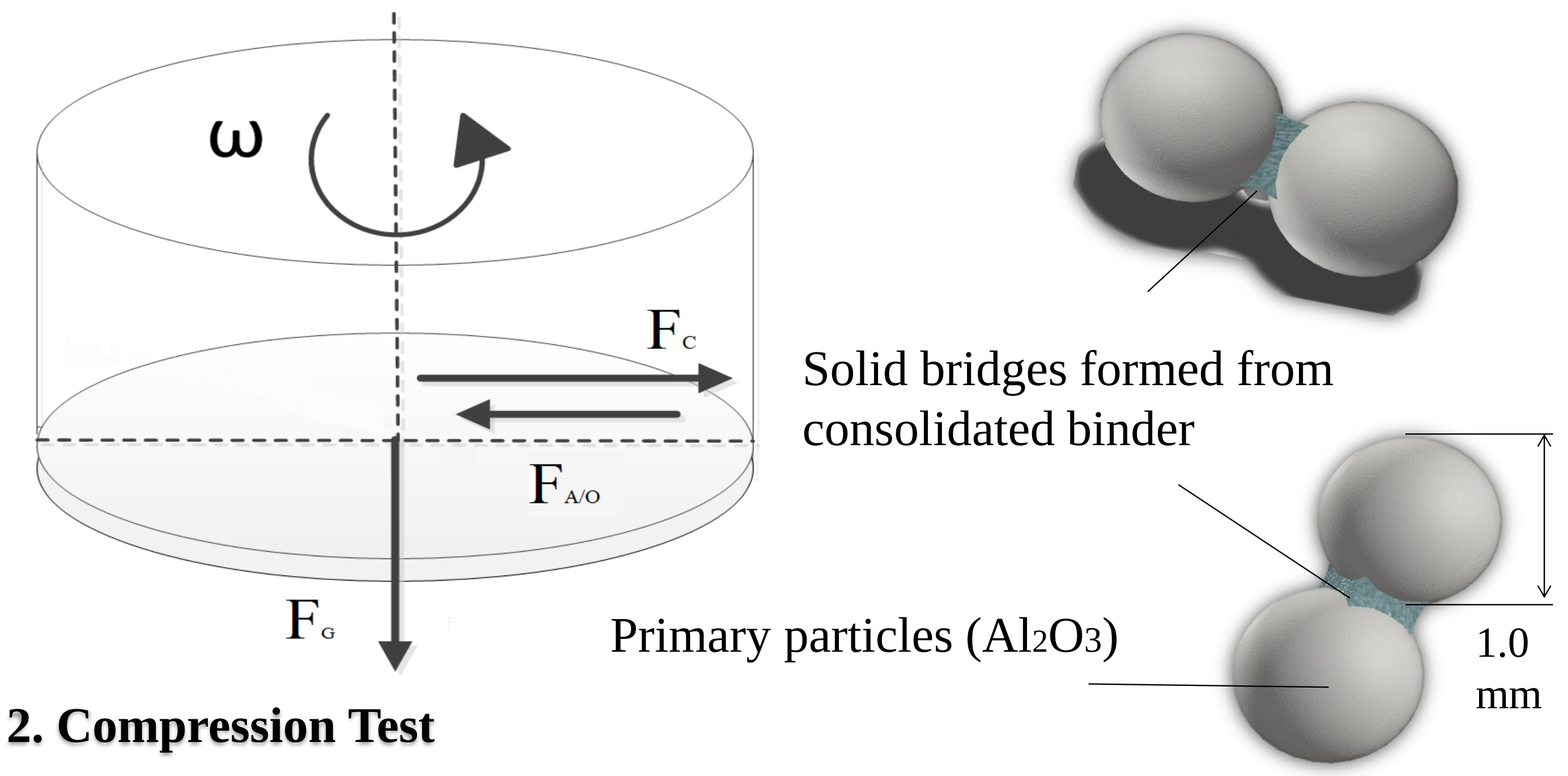
III. Experimental setup

1. Pelletizing

Critical velocity : $\omega_{crit}=\sqrt{\frac{\mu_R * g}{r}}$, rad/s ; $V_{crit}=r_a*\omega_{crit}$, m/s

Force balance

$$\sum F_n=0=F_c-F_R\ ;\ F_c-\mu_R*\left(F_G+F_{\underset{O}{A}}\right)=0;\ F_c=m_P*r*\omega^2;F_R=\mu_R*(F_G+F_{\underset{O}{A}})$$

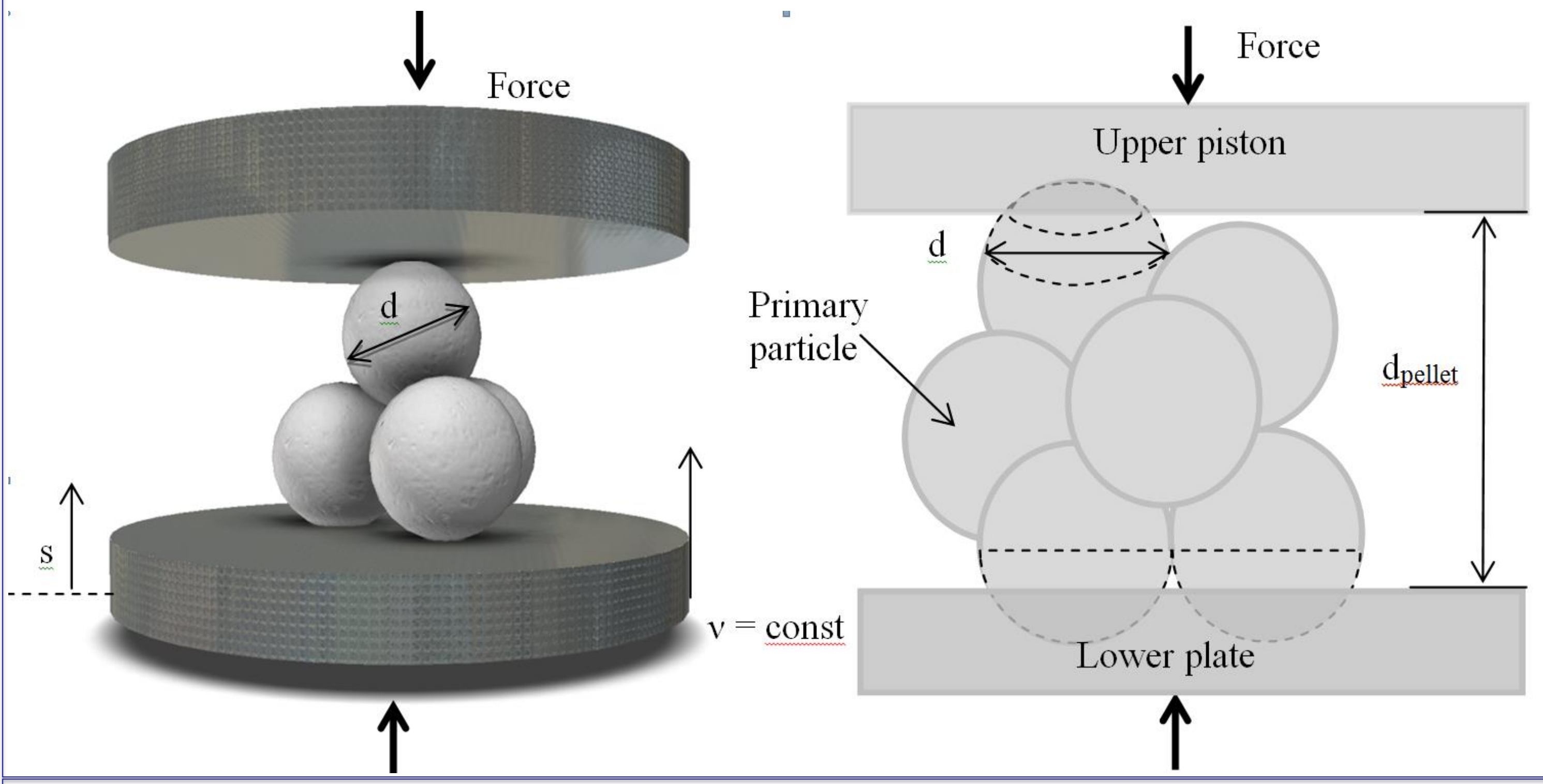


Solid bridges formed from consolidated binder

Primary particles (Al_2O_3)

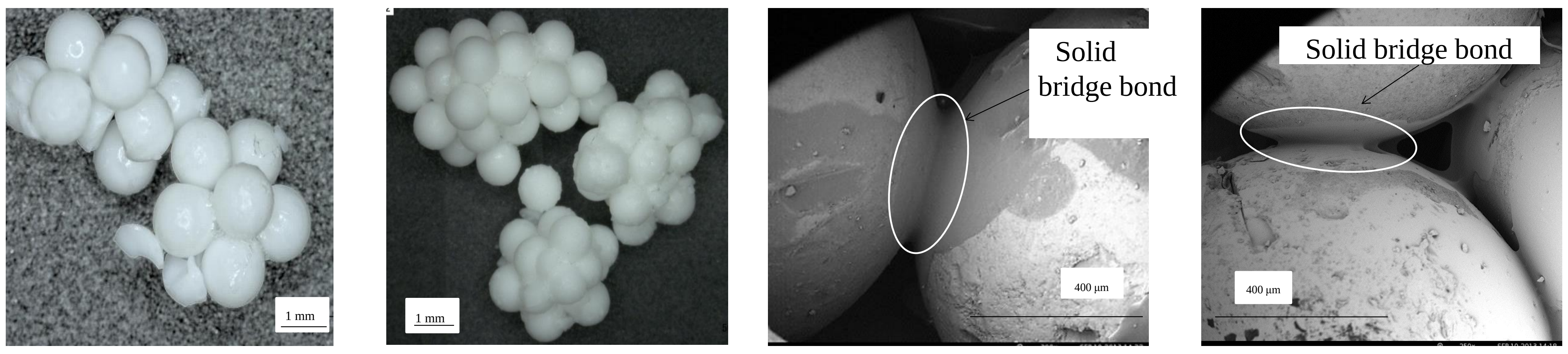
2. Compression Test

- The breakage test was carried out using special equipment provided by Ewete, Germany. The loading velocity v was fixed to 0.05 mm/s.
- In order to perform a reliable compression test the pellet has to take an initial stable position. During the stressing a deformed contact area will be developed between the pellet and the piston.
- The roughness of the irregularly shaped pellet is considered as a distribution of hemispherical asperities with the curve radius (diameter) of the primary particles d < dpellet that forms the surface of the pellet[3]. Thus for the approach, one may assume characteristic, microscopically smooth, hemispherical asperities, whose curves are equivalent to the primary particles so that the force-displacement models of Hertz and Tomas can be applied[2].

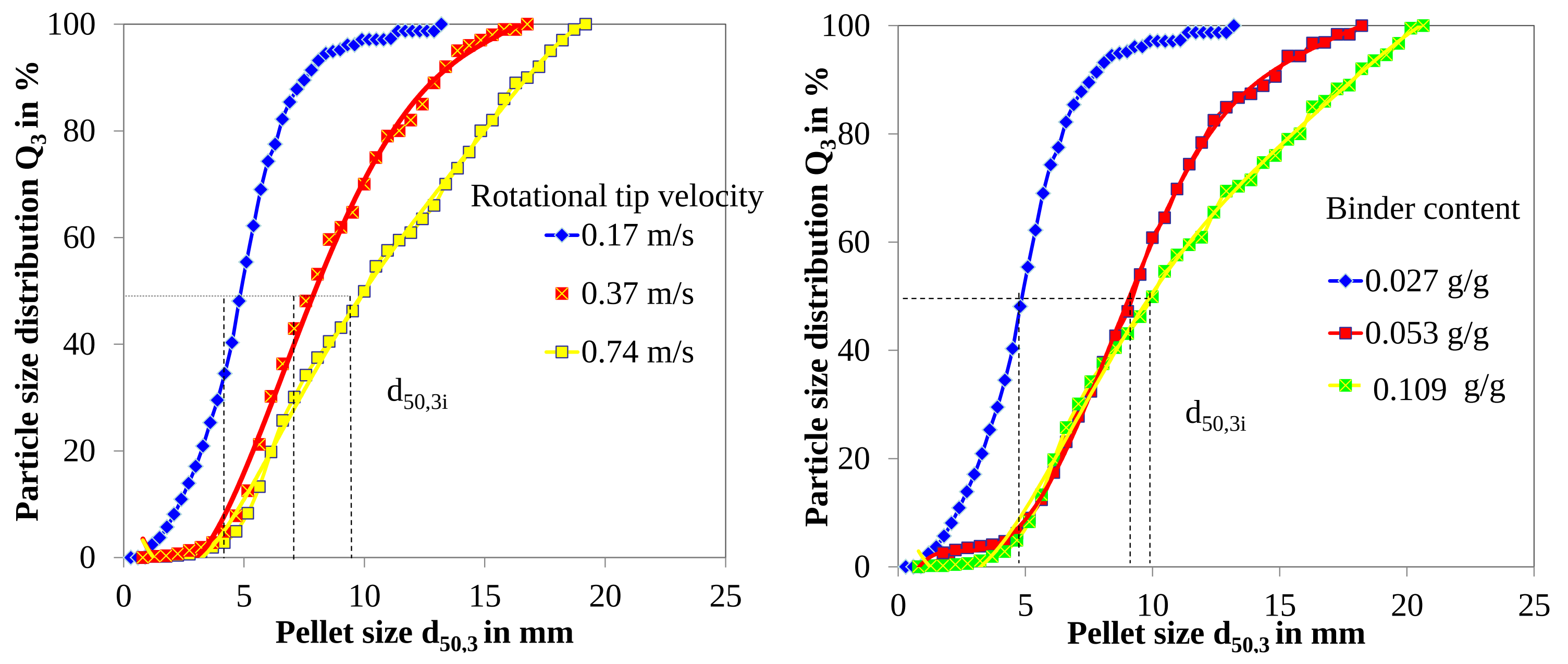


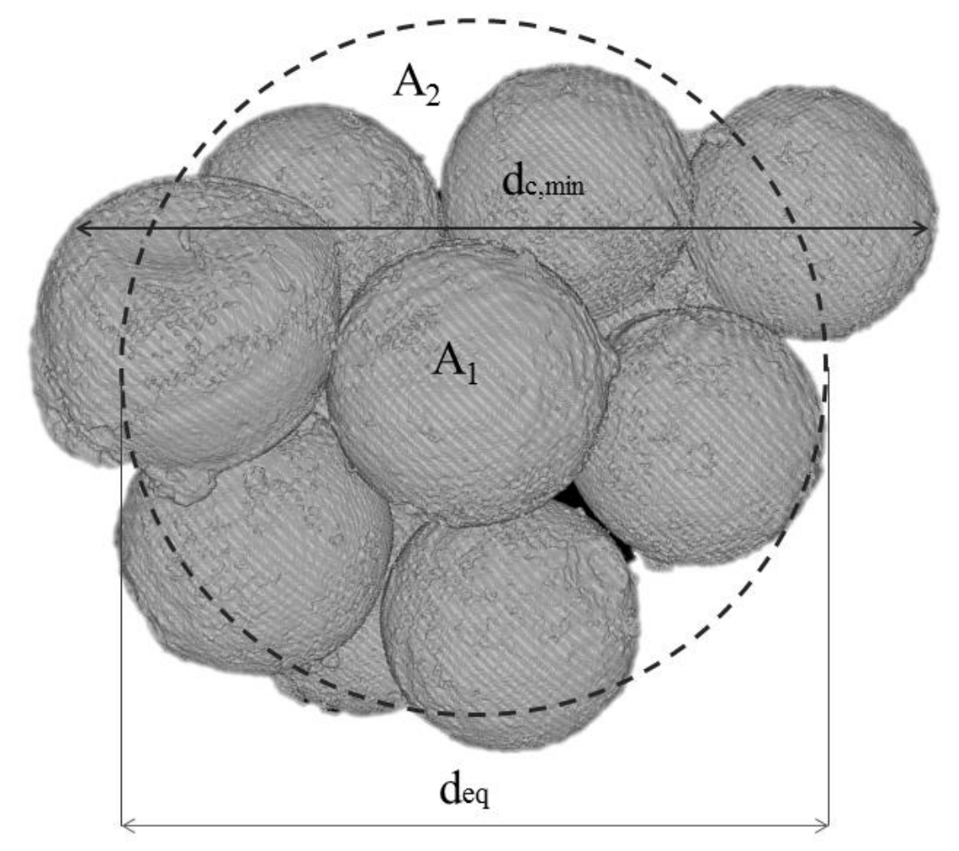
IV. Results and discussion

1. Light and scanning electron microscopy of the produced pellets



2. Influence of process parameters on the pellet cumulative size distribution





A_1 – Area of the pellet, A_2 – Circular area corresponding to the size of the projected area of the pellet, A_1=A_2 *

$$d_{eq}=\sqrt{\frac{4A}{\pi}}$$

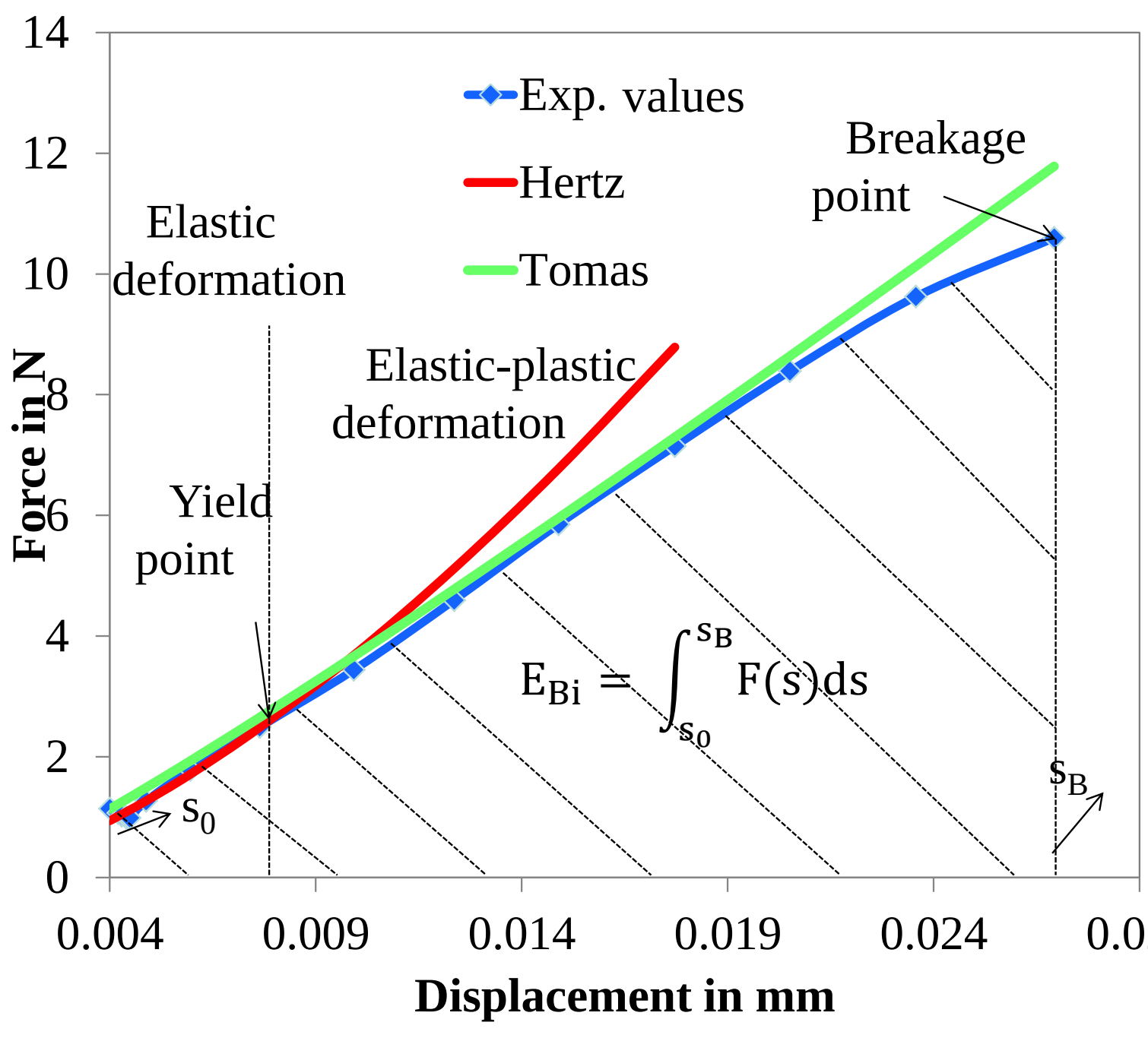
3. Force-displacement behaviour and breakage probability

Elastic: Hertz law[1] $F_{el}=\frac{2}{3}E^*\sqrt{R^*\left(\frac{s}{2}\right)^3}=\frac{4}{3}\frac{E_1}{(1-\nu_1^2)}\sqrt{R_1\left(\frac{s}{2}\right)^3}=\frac{1}{3}\frac{E_1}{(1-\nu_1^2)}\sqrt{d_1 s^3}$

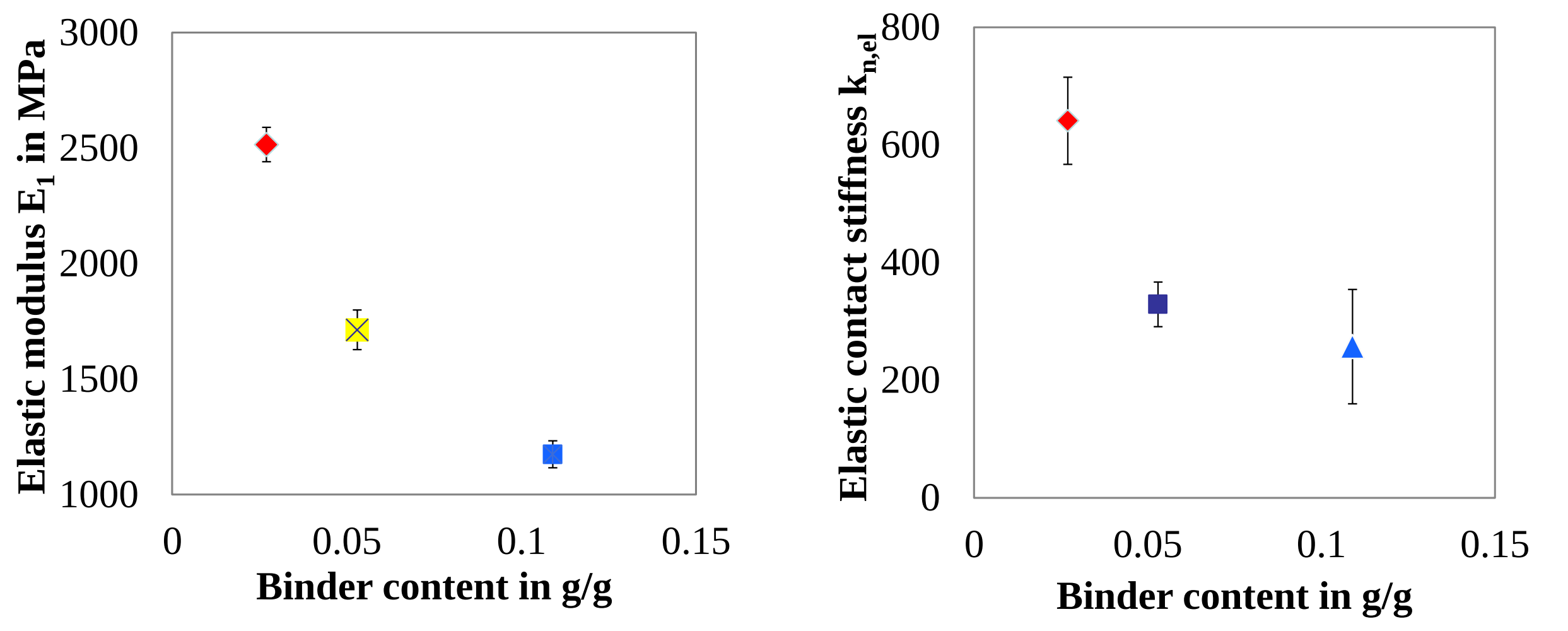
Elastic-plastic: Tomas[2] $F_{el-pl,w-p-w}=\lambda_{el\_pl}\,\pi R_1 p_F\left(1-\frac{1}{3}\sqrt{\frac{s_F}{s}}\right)\frac{s}{2}$

Specific mass-related Breakage energy

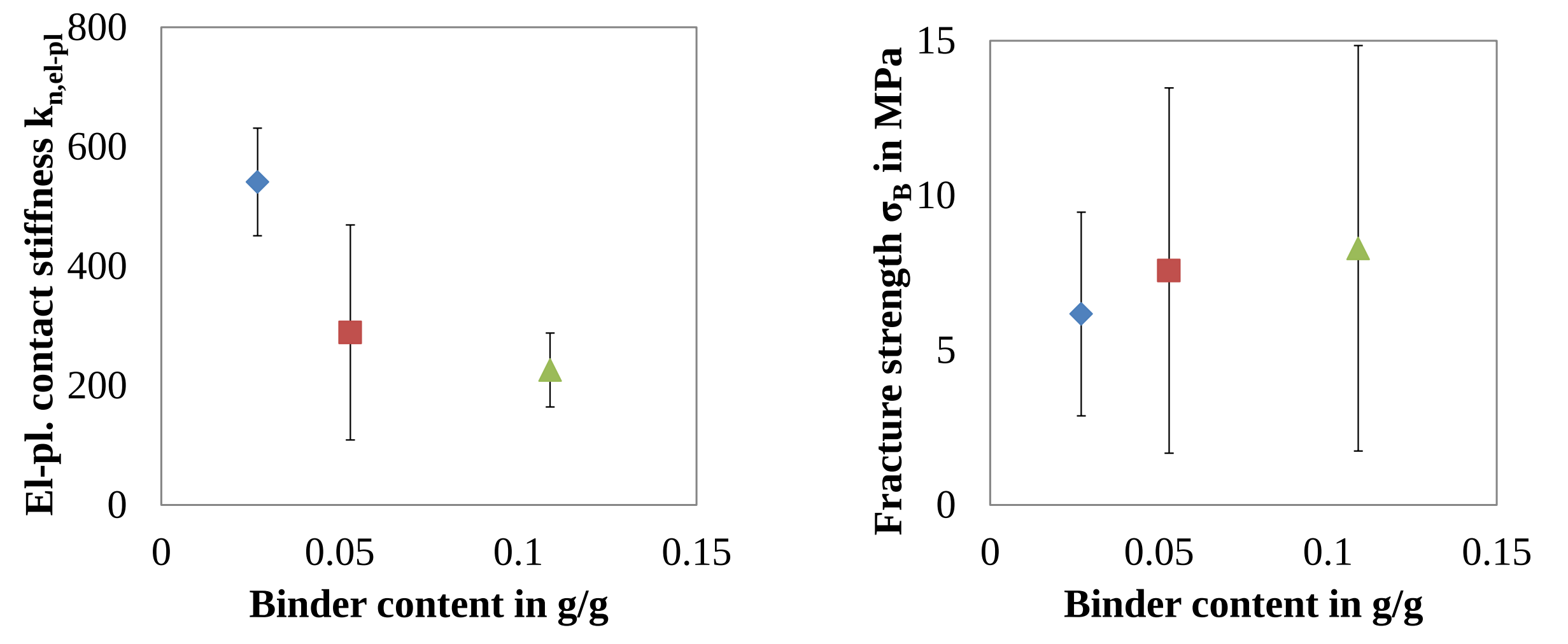
$$E_m=\frac{E_B}{M_P}=(\rho_P V_P)^{-1}\int_{s_0}^{s_B}F(s)ds$$



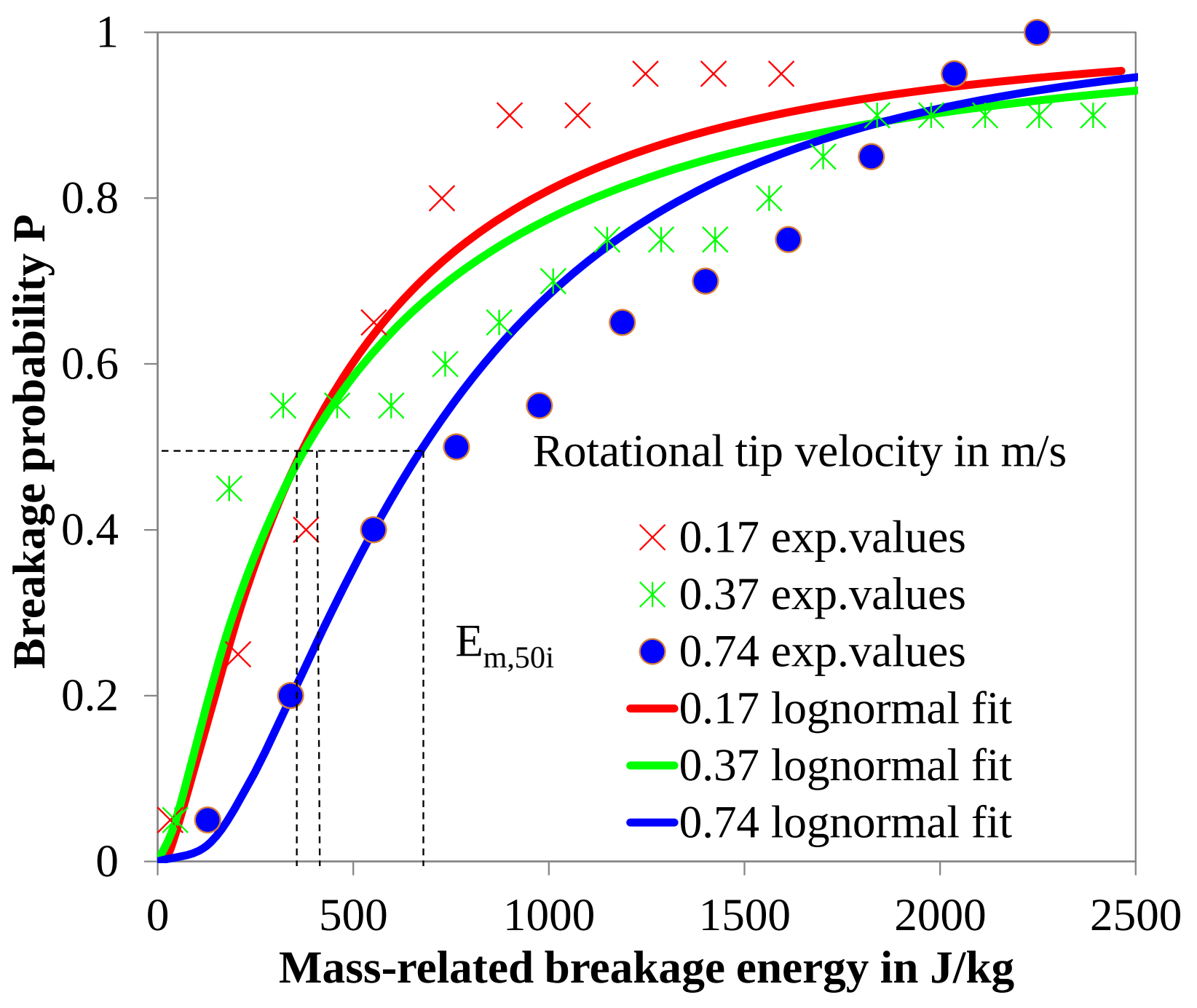
Force-displacement diagram for γ-Al_2O_3 pellets with $d_{50,3}$=2.5 mm, produced at rotational velocity 0.37 m/s, 20 min processing time and binder content 0.053 g/g

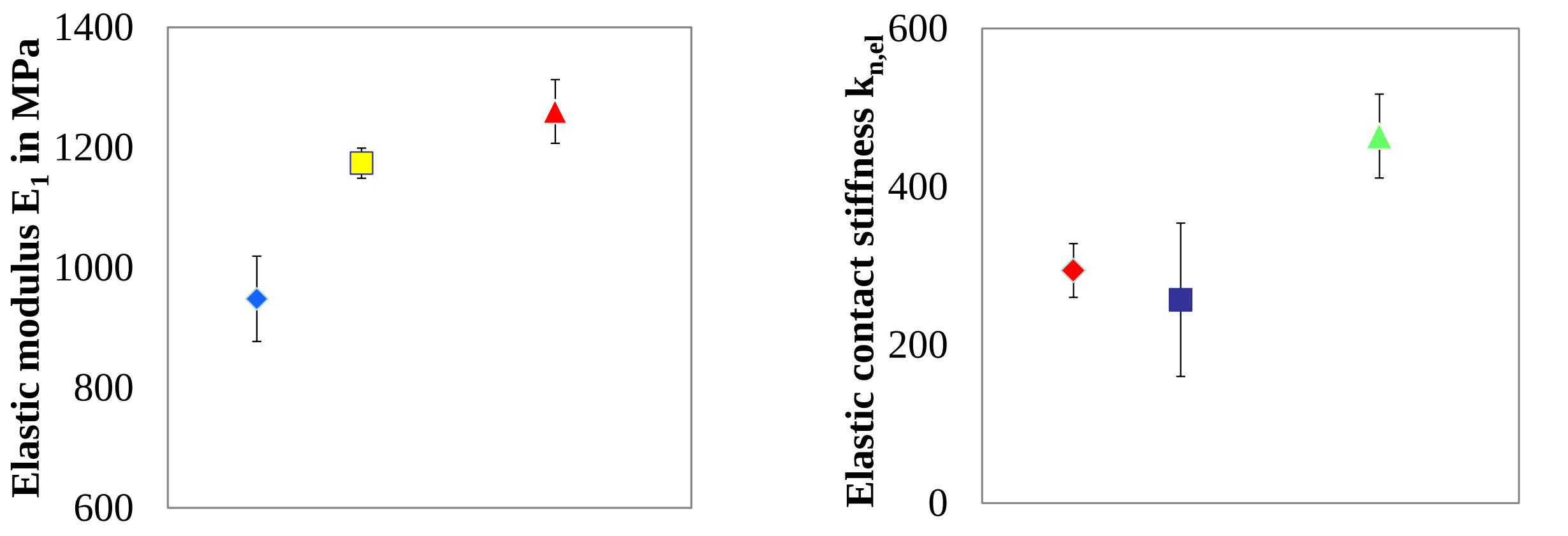


Elastic modulus E_1 and elastic contact stiffness $k_{n,el}$ as function of the binder content

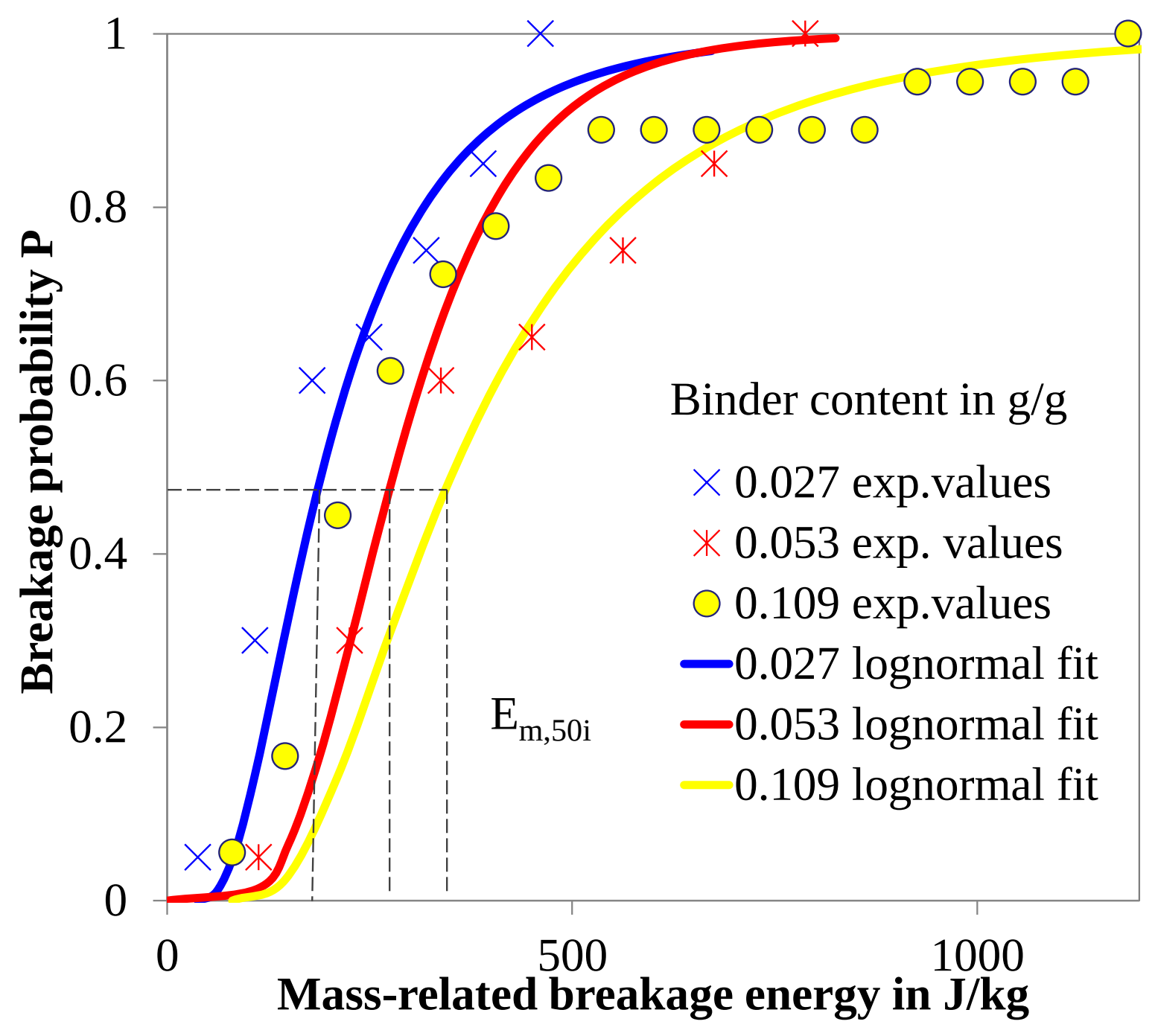


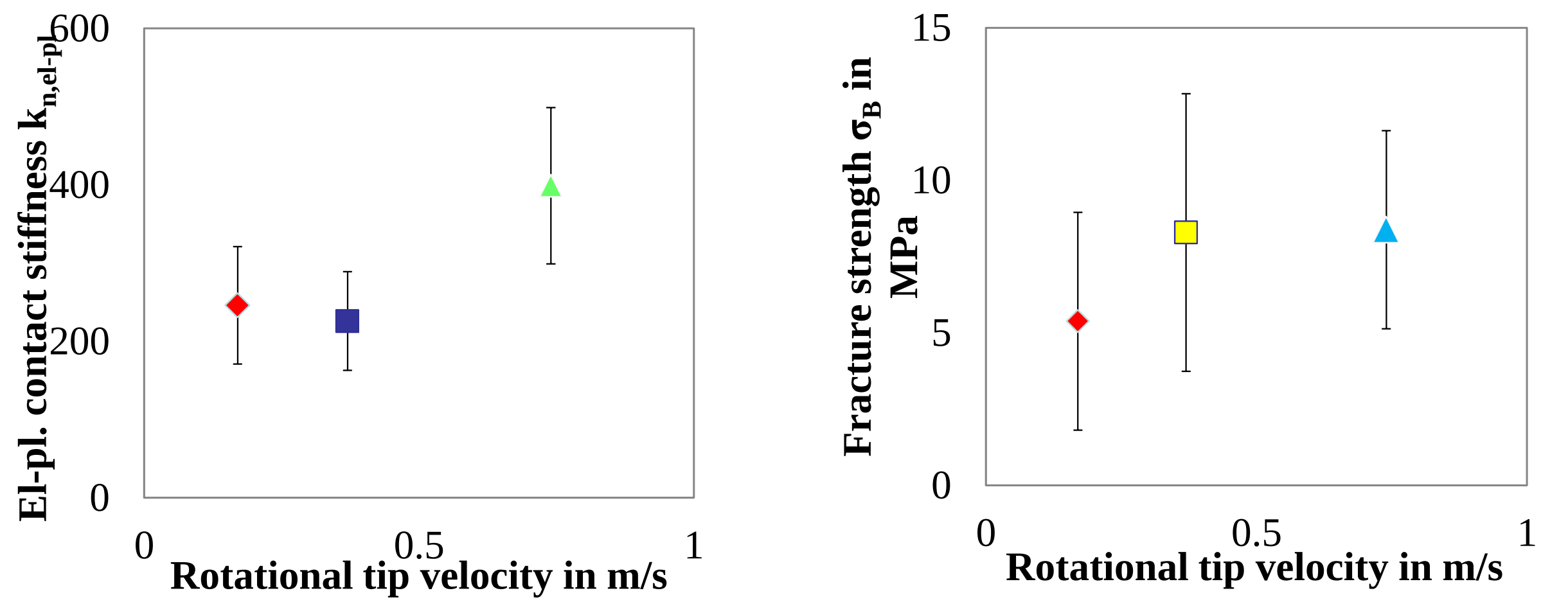
El-pl. contact stiffness $k_{n,el-pl}$ and fracture strength σ_B as a function of the binder content





Elastic modulus E_1 and elastic contact stiffness $k_{n,el}$ as function of the tip velocity v





El-pl. contact stiffness $k_{n,el-pl}$ and fracture strength σ_B as a function of the tip velocity v

V. Conclusions

- **It was clearly shown that the change in the rotational velocity of the bottom rotating disk and the amount of added binder exert an enormous influence on the mechanical properties of the received agglomerated product.**
- **It was proven that larger pellets can be obtained by increasing the binder amount.**
- **Strong and compact pellets can be produced at large rotational velocities.**
- **The binder content in the pellet increases its breakage resistance, but changes the breakage behaviour because of the binder's plasticity and proves to be more problematic in case of binder addition to the batch of primary particles.**

Future outlook:

- **As future outlook, an investigation of the influence of the primary particle diameter on the mechanical properties of the pellets is suggested.**
- **The influence of different binders will be proved in future research.**
- **In order to understand better the process of breakage of the pellet by compression, DEM simulations should be accomplished in future.**

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[1] H. Hertz „Ueber die Berühung fester elastischer Körper, J. reine u.angew. Math. 1881, 92, 156-171; [2] J.Tomas: Zur Mechanik trockener kohäsiver Schüttgüter, Schüttgut 2002, 8(6), 522-537;
[3] S.Aman, J.Tomas and H. Kalman „Breakage probability of irregularly shaped particles“ Chem.Eng. Science, 2010. 65(5):p. 1503-1512.

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