Numerical Simulation of Die Compaction: Case Studies and Guidelines

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Abstract

Numerical Simulation of powder die pressing is conducted on Case Study geometry. Influence of fill density distribution and punch kinematics upon green density distribution and punch loading are studied and discussed. Deviations in punch kinematics due to punch deflection influence the most the results in term of density and force.

Keywords: powder compaction, numerical simulation

1. Framework for the Numerical Simulation

In addition to the material data of the powder, a detailed framework for the numerical simulation of powder compaction must be established prior to any calculation. This framework should contain specific initial and process data explained as following:

Initial Data 1: Geometry of the pressing tools – Punches, die, core – [mm]

Initial Data 2: Initial position of the pressing tools [mm] prior to compaction; Initial height(s) of the powder [mm] prior to compaction.

Initial Data 3: Fill density [g/cm³] *or* mass of the powder [g] (*Optional: Fill density distribution [g/cm³])*

Process Data 1: Friction coefficient between powder and pressing tools.

Process Data 2: Kinematic of the pressing tools **at the powder surface** (taking into account tool deflection) [mm] *and/or* Loading history [N/mm²].

In this example, the compaction of a two level geometry as shown in Fig. 1 is studied. The powder used for this study is an iron based powder – Distaloy AE – provided by Höganäs AB.

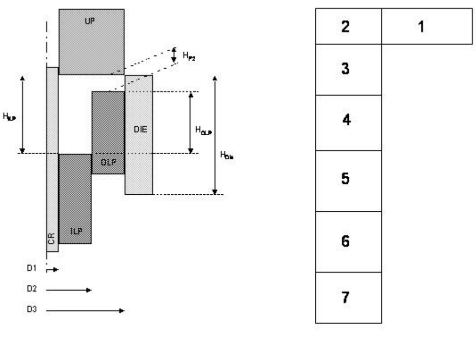

Fig. 1. Case Study Geometry. Right: The fixed diameters are: D1=10 mm, D2=30 mm, D3=50 mm. The heights set for the Distaloy AE powder are H_{F2}=6 mm and H_{ILP}= 56 mm after filling. Left: Sections used for the assessement of the density distribution after compaction according to the numerical simulation and the experimental measurements. The heights of sections 3-7 are more or less equal.

The main goal of the current simulations is to predict gradient of density within the compacted part and forces applied on the punches.

2. Influence of the Initial and Process Data

The measurements of Initial Data 1 and 2 were easily obtained. Initial Data 3 was given in term of mass of the part. The Process Data 1 was obtained from measurements, whereas the Process Data 2 was obtained from the kinematics of the pressing tools but with elastic deflection that could not be measured directly on the press machine. Using these data, the punch deflections could be roughly estimated. Numerical simulations of die compaction of this Case Study were performed, taking into consideration these uncertainties (Initial Data 3 and Process Data 2).

A first simulation denoted HOM was first performed according to the defined material, initial and process data to reproduce the experimental compaction of a part. A second simulation, denoted DIST, was conducted with an initial fill density distribution in the seven sections. A third and fourth simulation, denoted HOM-defl and DIST-defl respectively, were carried out with a correction of the upper punch deflection of 0.2 mm.

The Tables 1 and 2 recapitulate the results obtained with the different variants in term of precision in the prediction of density and load distribution, respectively.

A closer look on the forces measured experimentally showed that the equilibrium was achieved with a contribution of -143 kN, which is usually provided by the friction between the powder and the die and the core. In

Table 1. Difference in % between measured and simulated density for the different variants. Positive values means an overestimation of simulation compared to experiment.

Variant	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
HOM	-8.25	-1.79	0.27	0.95	1.59	1.24	1.15
DIST	-7.17	-1.94	0.06	0.79	1.43	1.11	1.02
HOM-defl	-1.91	-1.28	0.49	1.14	1.74	1.38	1.28
DIST-defl	-1.01	-1.55	0.14	0.84	1.48	1.15	1.06

Table 2. Difference in % between measured and simulated forces for the different variants. Positive values means an overestimation of simulation compared to experiment.

Variant	Upper punch	Lower Inner Punch	Lower Outer Punch
HOM	-27.06	2.77	134.21
DIST	-25.3	4.35	120.56
HOM-defl	-7.88	2.52	57.33
DIST-defl	-4.37	4.07	46.78

this case, the value was at first excessively high and pointing in the other direction. According to numerical simulation, the contribution to the axial forces due to friction was 20 kN. It means that the die and core must have reacted with -163 kN against one of both lower punches. In all probability, the Lower Outer Punch can be said to interact with the die and develop an additional force needed for the powder compaction. The later one is then in the order of 587-163 = 424 kN. Consequently, this gives a discrepancy of 13 % with the numerical prediction, hence improving the first result by a factor 10.

3. Discussion

Based on the results of this work, the following conclusions could be drawn. At high level of pressures and densities, it is recommended to model punches and contingently die and cores because punch deflection and tools interaction may influence the result in term of densities, loads and eventually stress states. All these data are for example essential for cracking study during die compaction, which is one of the main concerns for the PM industry.

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