Estimation of nip angle by roll compaction simulation

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INTRODUCTION

On a roll compactor (RC), the space between the rolls is divided into a slip, a compaction and a release zone. The angle between the beginning and the end of the compaction zone is called nip angle. This angle is an important parameter for the process understanding. There are several approaches to determine the nip angle but they are laborious and difficult. The aim of this study was to use a uniaxial compaction simulator (Styl'One Evolution, Medelpharm) for the nip angle estimation and to evaluate the influence of the specific compaction force, gap width and roll speed on the nip angle of different excipients.

MATERIALS & METHODS

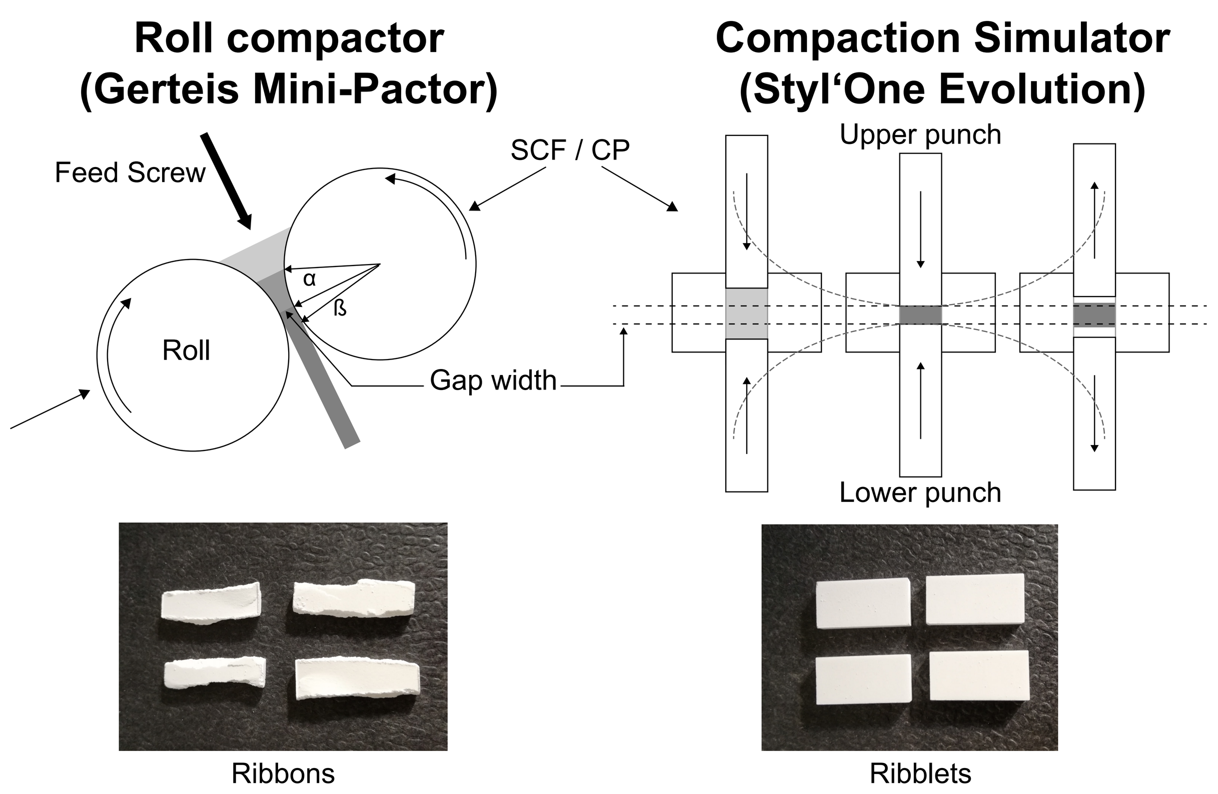

Figure 1: Principle of hybrid modeling; SCF = specific compaction force, CP = compression pressure [1]

Roll compaction simulation

RC of Microcristalline Cellulose (MCC, Vivapur 102, JRS), Lactose (Tablettose, Meggle) and DCPA (DiCaFos A150, Budenheim) was simulated on the Styl'One Evolution (Medelpharm) using the hybrid modeling approach [1] shown in figure 1. The materials were compacted at different simulated specific compaction forces (SCF) between 3 and 16 kN/cm, gap widths (GW) from 2 to 4 mm at a constant roll speed (2 rpm). MCC was additionally compacted at mimicked roll speeds between 1 and 11 rpm (3 mm GW, 6 kN/cm).

Nip angle calculation

Figure 2 illustrates how the nip angle is determined by roll compaction simulation on a uniaxial compaction simulator. The nip angle on the roll compactor is calculated by the following equation:

$$\alpha = \arccos\left(1 - \frac{(T_0 - T_1)}{D}\right)$$

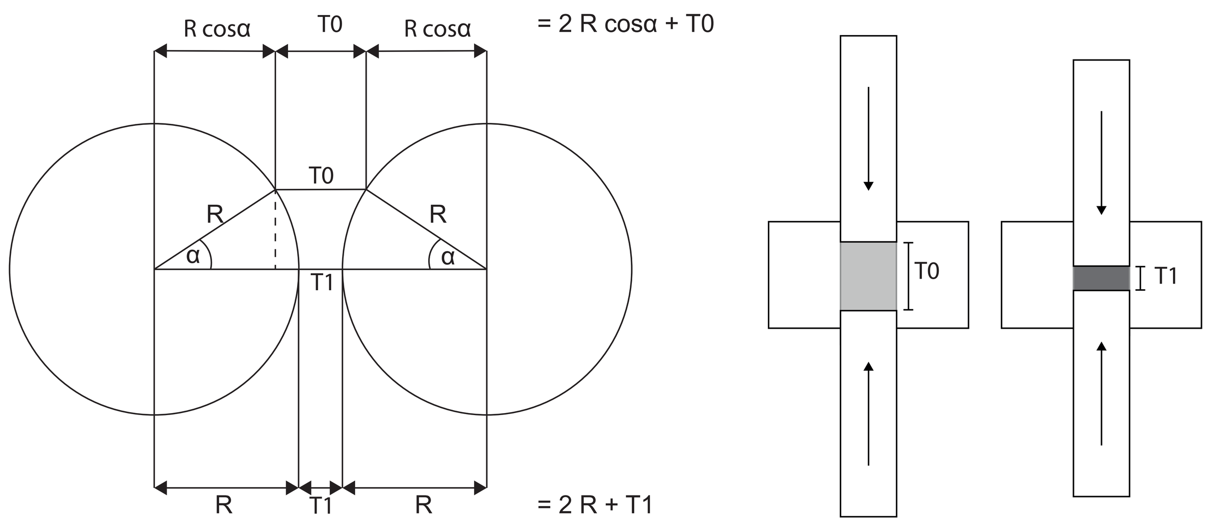

Figure 2: Principle of the nip angle determination with a uniaxial compaction simulator

T_0 is the powder bed thickness at zero pressure which corresponds to the angular position at the beginning of the compaction zone on the mimicked roll compactor. T_1 is the minimal distance between upper and lower punch during the compression which represents the GW. D is the roll diameter of the mimicked roll compactor.

RESULTS & DISCUSSION

The nip angles differ between the three investigated excipients (Fig. 3). MCC shows the highest nip angles between 9 and 15 ° whereas lactose and DCPA both have smaller nip angles of appr. 6-10 °.

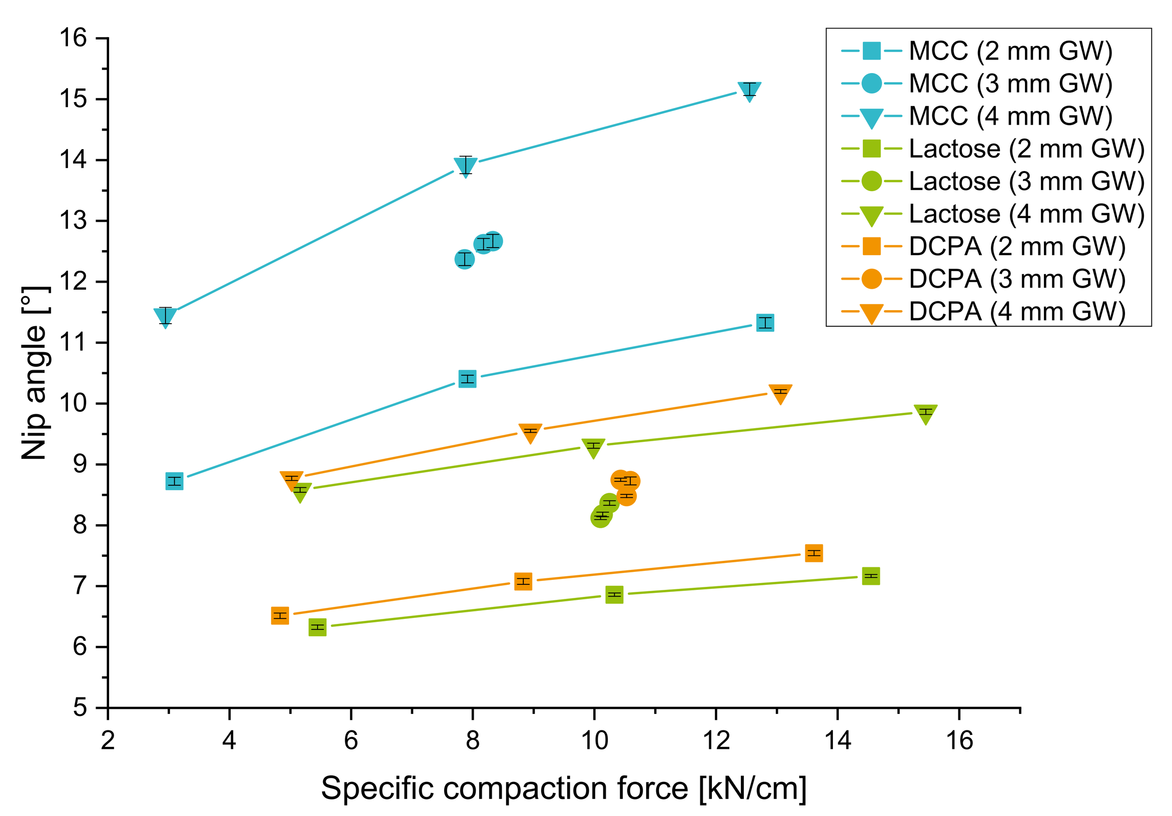

Figure 3: Nip angles of MCC, lactose and DCPA as a function of SCF at a roll speed of 2 rpm (n ≥ 20; mean ± SD)

Statistical analysis shows that this can be connected to the Hausner ratio of these materials (Fig. 4). A high ratio results in a high nip angle because the volume of the material that has to be compacted to a certain thickness is bigger than for materials with a low Hausner ratio [2]. The gap width (GW) and the specific compaction force (SCF) have as well a significant positive influence on the nip angle.

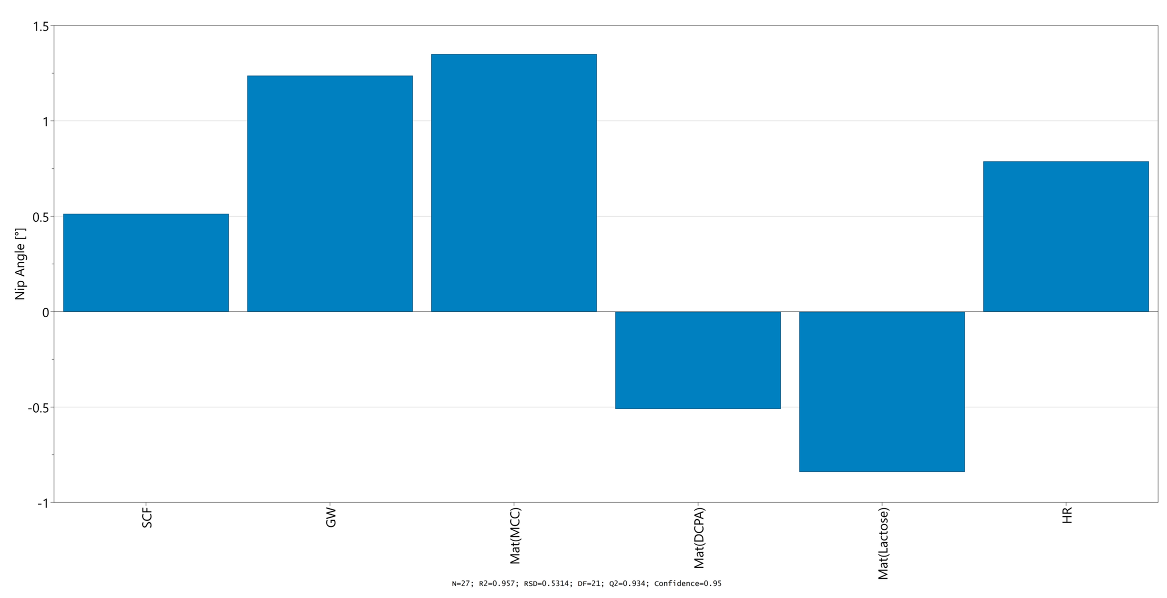

Figure 4: Coefficient plot - effects of specific compaction force (SCF), gap width (GW) Hausner ratio (HR) and material on the nip angle

With an increasing SCF an increase in nip angle is observed: to maintain the GW at a higher SCF, it is necessary to transport more material between the rolls which is then compressed to the same thickness [3, 4]. An increase from 2 to 4 mm GW results as well in an increasing nip angle [2]. The extent of the effect on the nip angle is bigger compared to the one of the SCF. The nip angle of MCC reacts most sensible to changes in the SCF and GW, followed by lactose and DCPA. This is linked to the compressibility of the materials. The better compressible the material is the more powder has to be drawn between the rolls to achieve the same SCF and GW compared to a less compressible excipient.

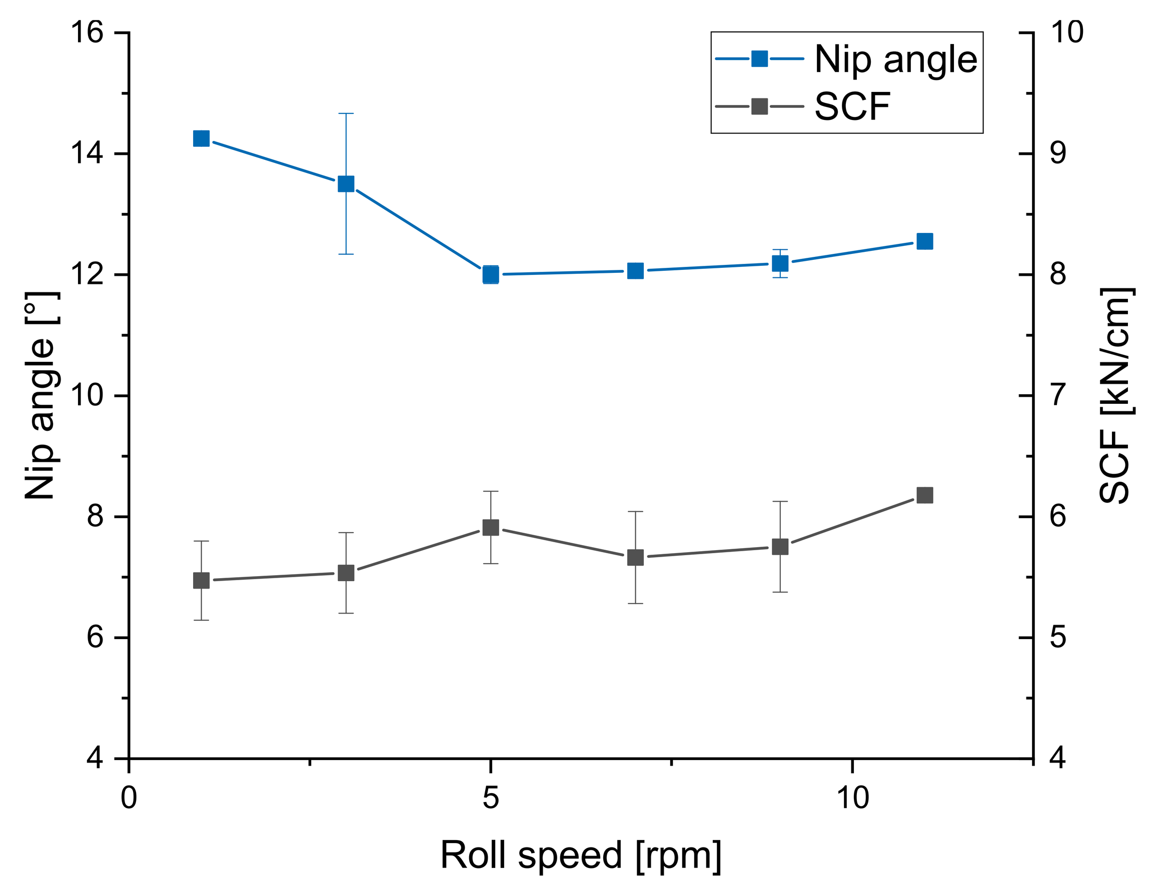

Figure 5: Nip angle of MCC depending on the roll speed at 3 mm gap width and a specific compaction force of 6 kN/cm

Fig. 5 illustrates that the nip angle of MCC slightly decreases with an increasing roll speed what is in accordance with [2]. A slightly increase is observed at roll speeds higher than 5 rpm. The difference between the minimum and the maximum angle is 2.3 °.
Our findings confirm what is known from literature [2, 3, 4] but so far, the nip angle estimation was not confirmed experimentally on a roll compactor.

[1] Reimer, H.L., Kleinebudde, P., 2019. Hybrid modeling of roll compaction processes with the Styl'One Evolution. Powder Technology 341, 66-74.
[2] Mansa, R.F., Bridson, R.H., Greenwood, R.W., Barker, H., Seville, J.P.K., 2008. Using intelligent software to predict the effects of formulation and processing parameters on roller compaction. Powder Technology 181, 217-225.
[3] Mazor, A., Orefice, L., Michrafy, A., de Ryck, A., Khinast, J.G., 2018. A combined DEM & FEM approach for modelling roll compaction process. Powder Technology 337, 3-16.
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CONCLUSION

This method is a promising simple approach to estimate the nip angle of a material or formulation. So far, the influence of the roll surface and a precompression induced by the feeding system cannot be mimicked by this method. Nevertheless, it gives an estimation of the general product properties and the behaviour during roll compaction.

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