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Short Communications

Interpretation of creep behaviour of microcrystalline cellulose powders and granules during compaction

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The phenomenon of creep may be defined as the slow progressive deformation of a material with time, under constant stress. Creep compliance measurements therefore differ from stress relaxation studies where the strain is maintained constant and the force decay is plotted vs time. Creep compliance analysis has been achieved by graphical methods for semi-solid systems as described elsewhere (Warburton and Barry, 1968; Sherman, 1968, 1970).

Recently, creep compliance was studied during tablet compaction by treating powder deformation or flow as analogous to the rheological behaviour of semi-solids (Patel and Staniforth, 1987). The creep analysis test involved application of a constant stress to a powder sample held in a punch and die assembly between the platens of a tensile tester so that strain response could be monitored with time. Creep compliance curves for the samples could be differentiated into 3 distinct types of behaviour; elastic, viscoelastic and plastic deformation. These authors described the rheological characteristics of direct compression excipients in interpreting the different mechanical behaviours of powders.

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Microcrystalline cellulose (MCC) has been used widely in the production of solid dosage forms both by direct compression and following wet granulation. Results from an earlier study had revealed a loss in compactibility of MCC when it was granulated with different amounts of water (Staniforth et al., 1987). Tablet tensile strength, work of failure and apparent failure viscosity data for compressed tablets of MCC had revealed that the non-granulated cellulose samples formed the strongest and toughest tablets. A progressive decrease in MCC tablet strength and toughness was found with increasing amounts of water utilized as granulating fluid. The authors attributed this phenomenon to a loss in plasticity of MCC on granulation.

The object of the present study, therefore, was to assess the effect of wet granulation on the physicomechanical properties of MCC by utilizing a creep analysis test. Test material consisting of either MCC powder (Emcocel, lot 5114, manufactured by Finnish Sugar Co., Helsinki, Finland for Edward Mendell Co. Inc., Carmel, NY, U.S.A.) or granules of MCC with different amounts of water as granulating fluid (Staniforth et. al., 1987) required to produce a tablet of 2.5 mm thickness at zero theoretical porosity was manually transferred into a prelubricated die and creep analysis conducted as described earlier (Patel and Staniforth,

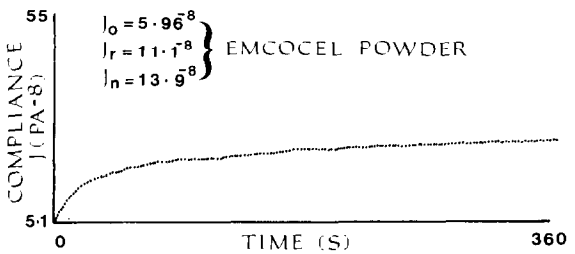

Fig. 1. Creep compliance curve for microcrystalline cellulose powder. J_o = elastic compliance, J_r = retarded or viscoelastic compliance, J_n = Newtonian or plastic compliance.

1987) at a constant stress value of around 20 kN at a crosshead speed of 10 mm/min. A typical compliance curve is shown in Fig. 1 where the magnitude of the elastic, viscoelastic and plastic components as described by sections J_o, J_r and J_n (Fig. 1) were measured off the y-axis and are presented in Table 1.

According to the canonical model presented in Fig. 2A J_o and J_r sections correspond to reversible deformation which can be recovered on removing stress, but J_n corresponds to irreversible or permanent deformation thus contributing to bond formation and strength of compacts. Thus by dividing J_n by $J_o + J_r$ it should be possible to rank materials on the basis of the ratio of their reversible to irreversible deformation and hence the strength of compacts formed. Such data for MCC powder and granules with different amounts of water as granulating fluid demonstrated mini-

TABLE 1

Relationship between formulation and compliance determinations

J_n, Newtonian or plastic compliance; J_r, retarded or viscoelastic compliance; J_o, elastic compliance and $J_n/J_o + J_r$, ratio of permanent to recoverable compliance or deformation of test material. S.E.M. in parentheses.

Formulation	J_n	J_r	J_o	$J_n/J_o + J_r$
MCC powder	1.36 E-7 (0.03)	9.80 E-8 (1.61)	6.79 E-8 (0.99)	0.8193
MCC + 800 ml water	9.07 E-8 (1.92)	9.14 E-8 (1.72)	4.41 E-8 (0.75)	0.6669
MCC + 1000 ml water	1.64 E-7 (0.15)	1.44 E-7 (0.21)	7.23 E-8 (1.66)	0.7593

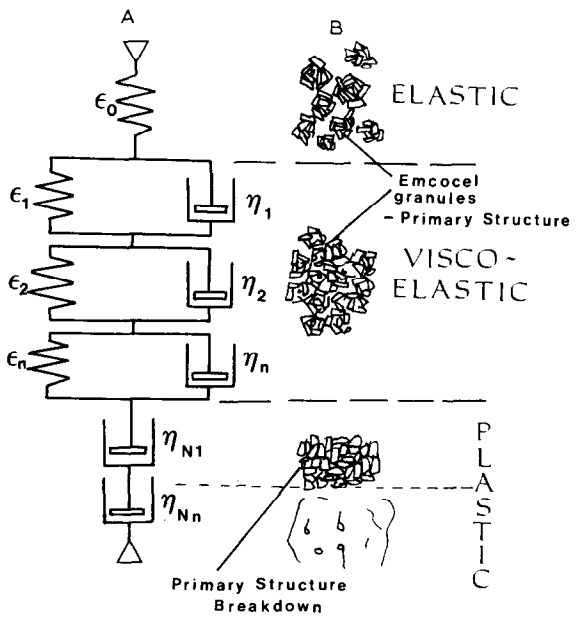

Fig. 2. A: canonical model of creep behaviour for MCC particles. B: corresponding schematic interpretation of material behaviour.

mum differences in these values (Table 1) as compared to their tablet tensile strength, work of failure and apparent failure viscosity data (Staniforth et al., 1987). It is proposed that part of the permanent deformation of MCC granules, as evidenced in the creep analysis test, occurs as a result of a breakdown in the primary structure of particle agglomerates and hence contributes less to bond formation as indicated by tablet failure strength, energy and apparent viscosity data. Fig. 3A shows a possible canonical model of this behaviour, with corresponding material changes shown in Fig. 3b. This interpretation of the creep analyses suggests that elastic and viscoelastic compliance result from changes in strain caused by initial and secondary granule rearrangement. When the granule bed is packed at minimum voidage, the viscoelastic limit is reached and further changes in strain (and therefore compliance) can only occur through plastic deformation. It is proposed that this occurs in two distinct phases: firstly, the primary granule structure is irreversibly destroyed by shearing; this stage is then followed by deformation of individual MCC particles. These 2

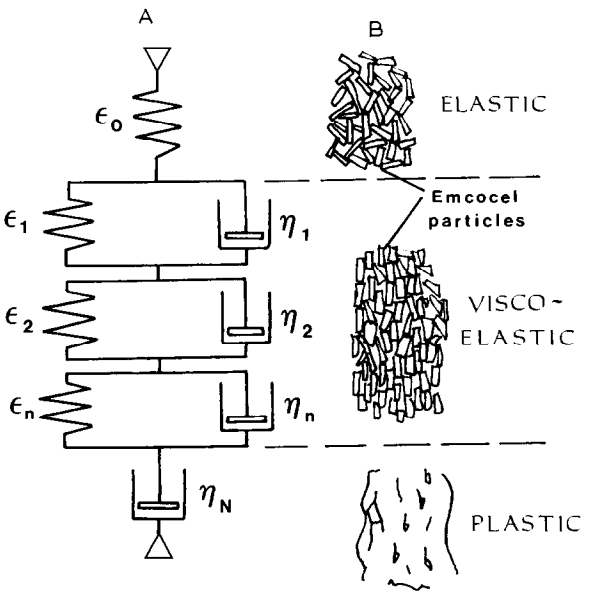

Fig. 3. A: canonical model of creep behaviour for MCC granules. B: corresponding schematic interpretation of material behaviour.

phases have been modelled using two dashpots connected in series (Fig. 3) but it is possible that the two phases have inseparably close compliances. Whatever the case it is clear that plastic compliance due to granule breakdown will not contribute significantly to increasing the area of contact over which bonding can occur.

In the case of the powder sample the entire permanent deformation is utilized in bringing particles in close proximity to one another thus facilitating plastic deformation and hence propensity for bond formation which contributes to tablet strength.

Although MCC powder and granules respond differently when subjected to constant stress conditions, the creep test appears to be unable to separate this behaviour.

In conclusion, while data from creep analysis testing can be utilized in differentiating materials on the basis of their degree of reversible to irreversible deformation, it might sometimes prove erroneous as a method of predicting the strength of compacts formed using individual particles in comparison with particle agglomerates.

References

Patel, C.I. and Staniforth, J.N., Creep compliance behaviour of direct compression excipients, *Powder Technol.*, in press.

Sherman, P., *Emulsion Science*, Academic, London, 1968, pp. 255–268.

Sherman, P., *Industrial Rheology*, Academic, London, 1970.

Staniforth, J.N., Baichwal, A.R. and Hart, J.P., Effect of addition of water on the rheological and mechanical properties of microcrystalline cellulose. *Proceedings of the 6th Pharmaceutical Technology Conference*, Canterbury, U.K., 1987.

Warburton, B. and Barry, B.W., Concentric cylinder creep investigation of pharmaceutical semi-solids. *J. Pharm. Pharmacol.*, 20 (1968) 255–268.