SIMULATION OF LOAD RELIEVING TABLET PRESSES

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BACKGROUND INFORMATION - PRESS DESIGN

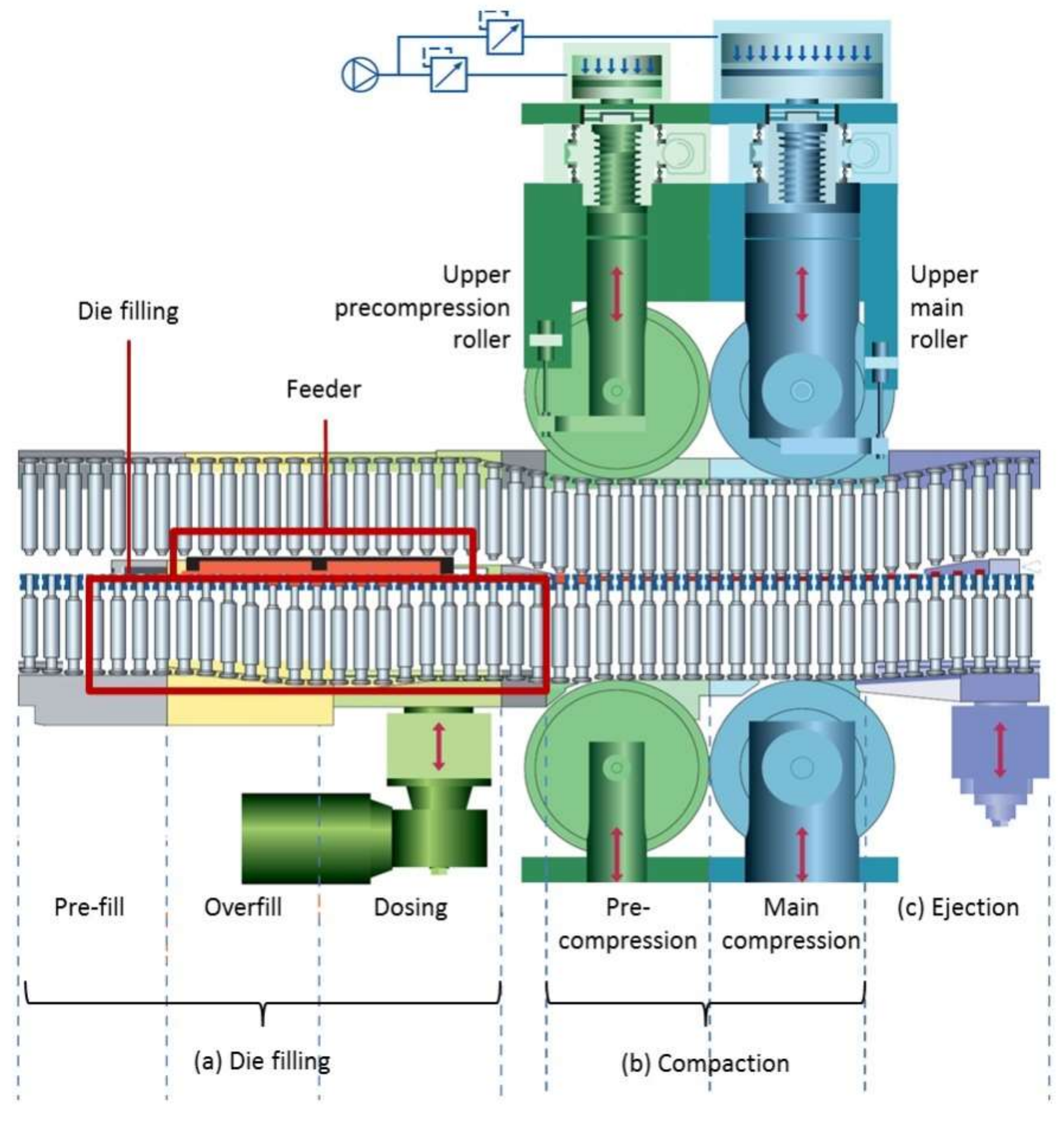
Traditional rotary tablet presses are sturdily built to withstand hundreds of millions of loading cycles as tablets are pressed. However the support for the compression rollers must either span the rotating turret or cantilever in from the side. Add the adjusting mechanism for the roller heights and the assembly can become quite large, and inevitably it has some elasticity.

Whilst the elasticity is low, the assembly is very large compared to a tablet, so a small elasticity can still create large percentage change in the height of the tablet at peak load.

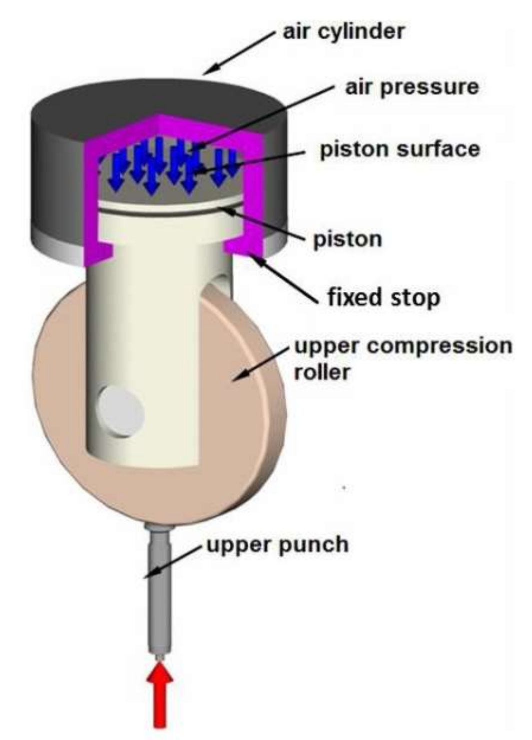
To a machine builder, elasticity is generally a bad thing. It can indicate high stresses, which might be a sign of potential fatigue failure, and when combined with high frequency loading cycles, it risks problems with vibration, resonance and noise. The usual aim is to reduce it as far as is economically possible.

In a simple tablet press, a lack of elasticity increases the variation in peak loading that may be caused by fill weight variation, lubrication changes, level of fines, or mechanical variation. Variations in peak load have a primary effect on tablet mechanical properties and need to be avoided as far as possible.

Some tablet presses have load limiters on the "pre" and/or main compression rollers. The compression rollers are typically backed by cylinders with a controlled pressure, that can retract small distances to relieve the maximum load on the tablet. Variation in peak force can then be reduced. Dwell time increases significantly when the peak is removed from the loading curve, and the compression process is significantly changed. This can now be effectively simulated in development.



Load relieving on pre and main compression (Courtesy of GEA, CourtoyTM)



Load relieving mechanism (Courtesy of GEA, CourtoyTM)

VARIABLES AND VARIATION

A compaction simulator is designed for the study of compaction properties of formulations and also to simulate production. A high power simulator can simulate high speed production and study strain rate effects to high speeds.

For confidence in scale-up, all the process variables should be studied for effect. This might include:

- Press geometry
- Press speed
- Press stiffness and its effect on strain rate and peak temperature
- Die wall temperature and punch tip temperature
- Tooling tolerance and air escape at higher speeds
- Pre-compression force or first layer tamping
- Main compression force
- Shear effects and feeder residency times
- Die wall peak and residual pressures
- Ejection speeds, and loads
- Take-off loads, tablet orientation, and flashing
- Dwell time on load relieving presses

PIDL FF— INTRODUCTION

Hydraulic compaction simulators have been developed since the 1980's or earlier to simulate tablet production presses, and the control systems have evolved for this specialist challenge.

Hydraulic actuators are typically controlled by a constant oil pressure supply and a servo-valve to control their speed and direction. Servo valves have a very high frequency response and high oil pressure allows very high power to be applied in a very precise and controlled manor. At the high performance end, the mechanical technology has not changed very much, but the control systems have undergone several generational changes in that time.

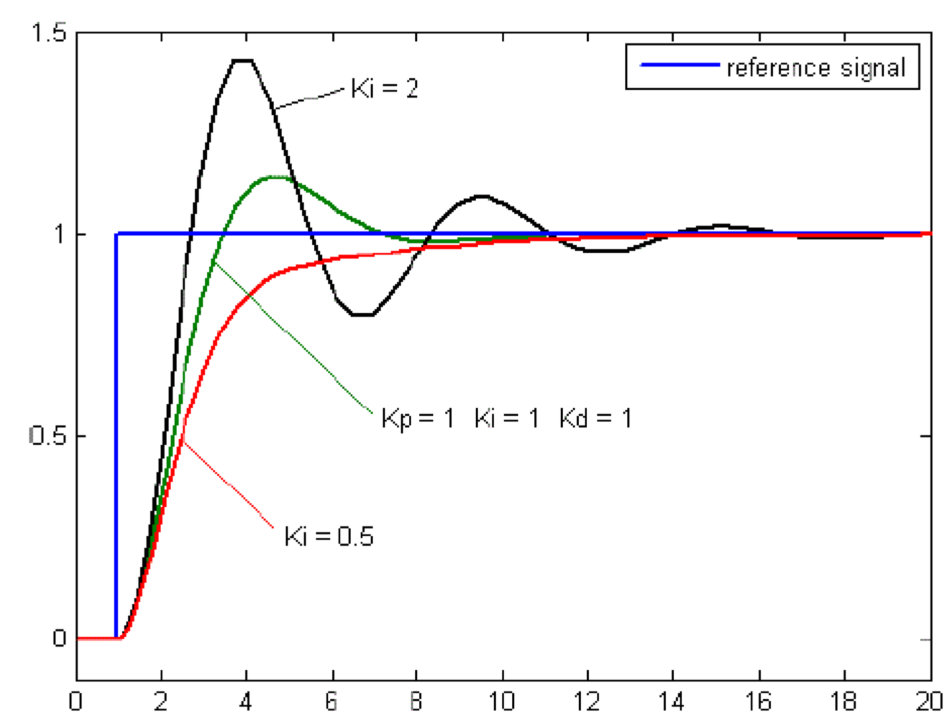
Hydraulic servo control loops can be anything from simple proportional error feedback loops to sophisticated loops involving modelling to predict the response of the system and provide artificial stability. Modern "programmable gate array" processors allow very fast control loops to be employed even with considerable number crunching for sophisticated control within the loop. It is ineffective however to use a control loop speed too many times faster than the mechanical system under control.

The servo drive signal to the actuator is created by the difference between the current demand and the current reading. This is the sum of: "PIDL and FF" as follows

- P—Proportional error – the size of the difference between demand and actual reading
- I—Integrated error – the sum of the size of the error multiplied by the time it has existed
- D—Differential error – the rate of change of the error
- L—Lag – a stabilising input
- FF—Feed Forward – a predictive correction

The graph on the right, shows the dynamic effect of increasing the Integral factor on a simple PID control system as an example. The Ki=2 overshoot is created by the area between the demand and the actual reading curves, i.e. the sum of the error over time. It could be reduced by increasing the differential factor to react to the speed of the change in error. A high integral factor is good for correcting small errors that produce only a small proportional drive, but the penalty is a trend to oscillation.

The control of compacting machines is notoriously difficult due to the large changes in the behaviour of the test sample. This changes the control loop behaviour, and control parameters that are ideal for soft powder would prove unstable with a hard tablet. To counteract this effect, the control parameters must change as the test progresses, which adds extra complexity to the control software.



A typical servo control response showing increasing "Integral" factor.

IMPLEMENTATION:

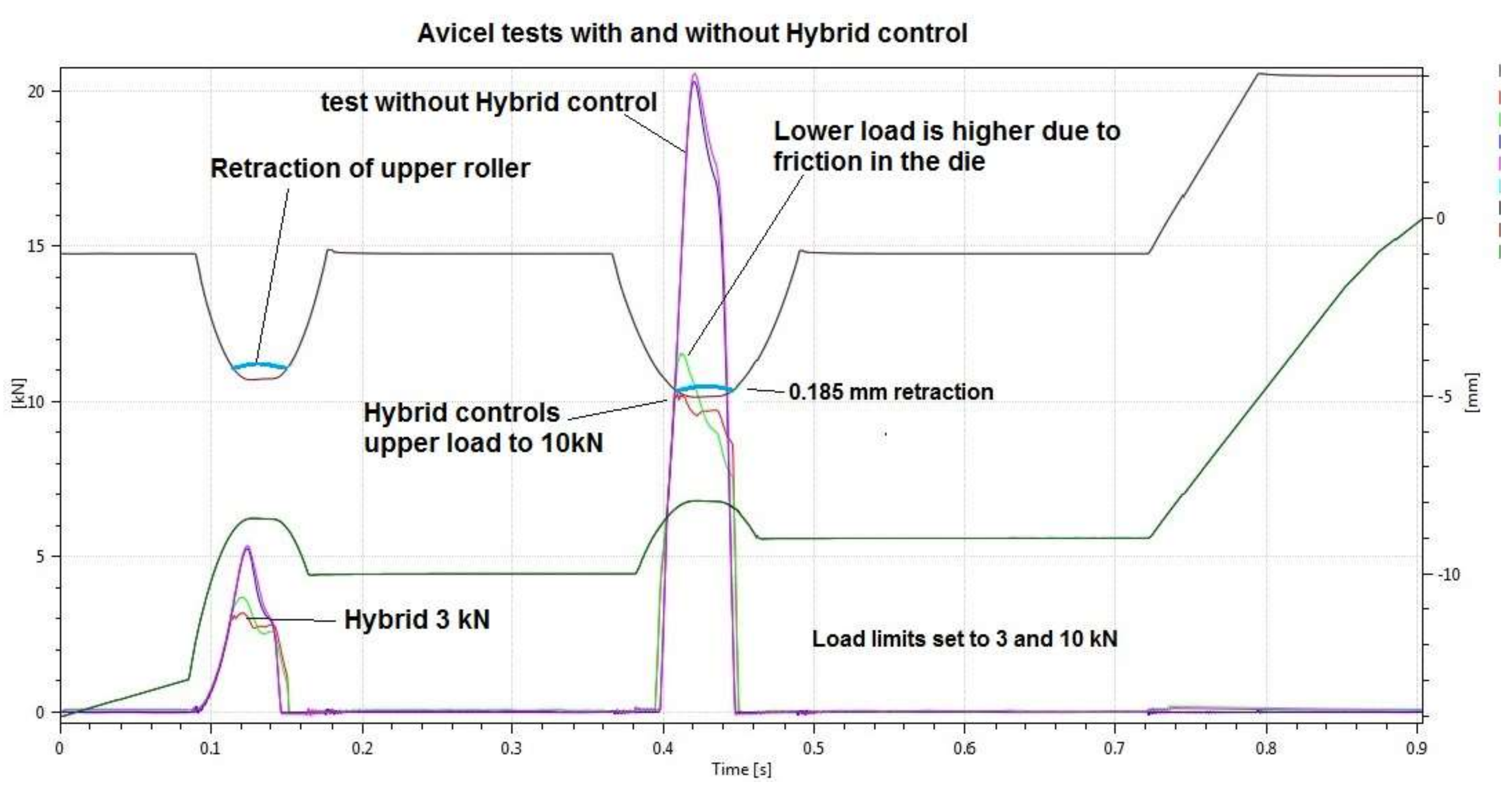
Simulating a load limiting tablet press is complex. A normal compaction simulator can perform tests in Position Control or Load Control. Simulating a tablet press compression profile is normally performed in Position Control, but if part of the compression is conducted under a regulated load, the simulator must switch into Load Control mode, and then back into Position Control when appropriate. The change-over occurs just when load is at its peak and values are changing quickly, so the change must be seamless to avoid large shocks.

Hybrid control is the Huxley Bertram name for a control mode that can switch between load and position control seamlessly. This is very different from a simple capping of the demand when a load limit is reached, as the servo system will need a predictive element and the ability to generate a maximum reverse drive to stop the overshoot.

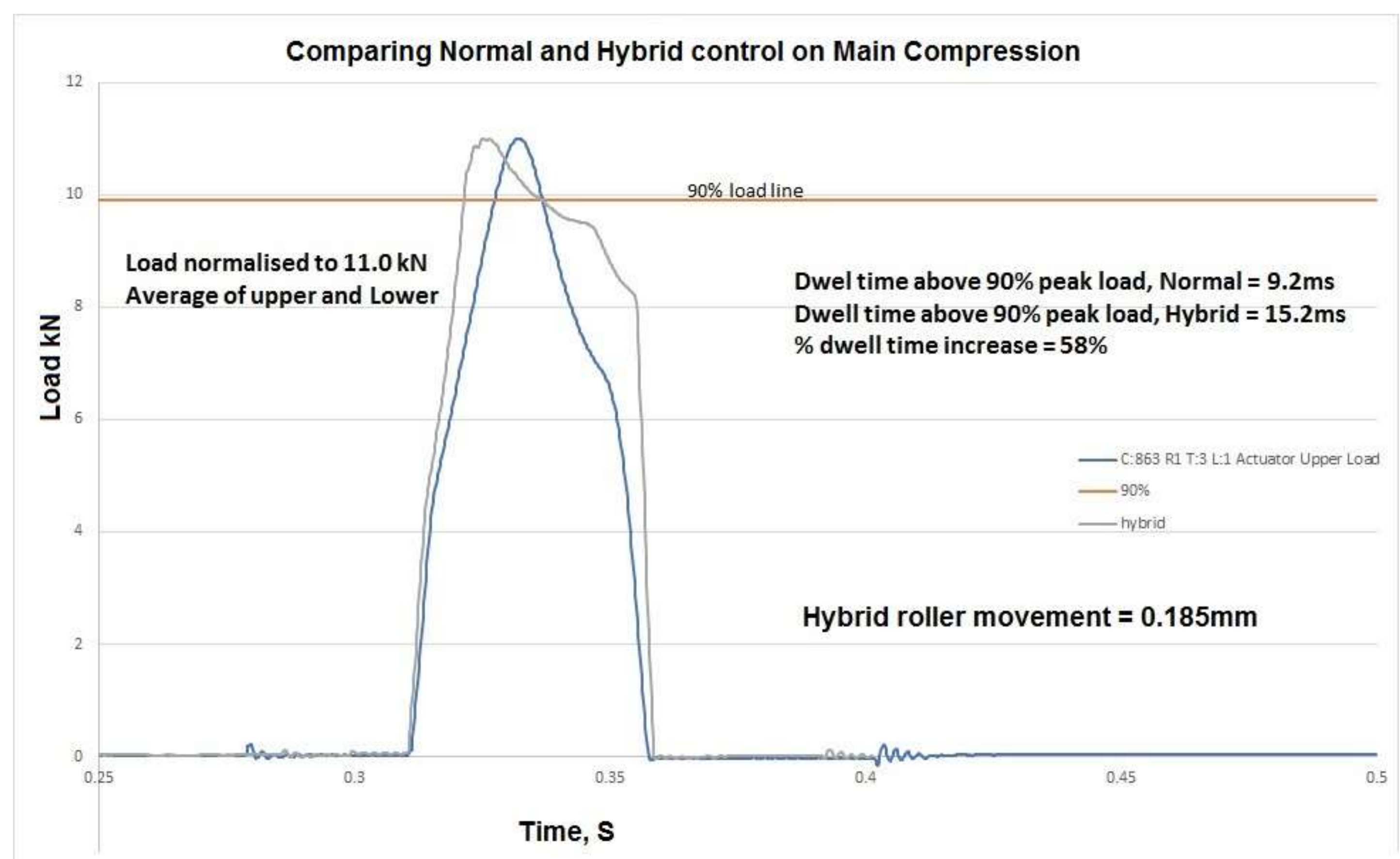
Real-world mechanical systems have their own dynamics caused by mass, friction and elasticity, and the simulator needs to be adaptable to imitate any particular machine. For this reason the predictive element of the control algorithms can be set by the operator to generate more or less overshoot to match machine load data.

Setting up a hybrid controlled test in "Research Mode"

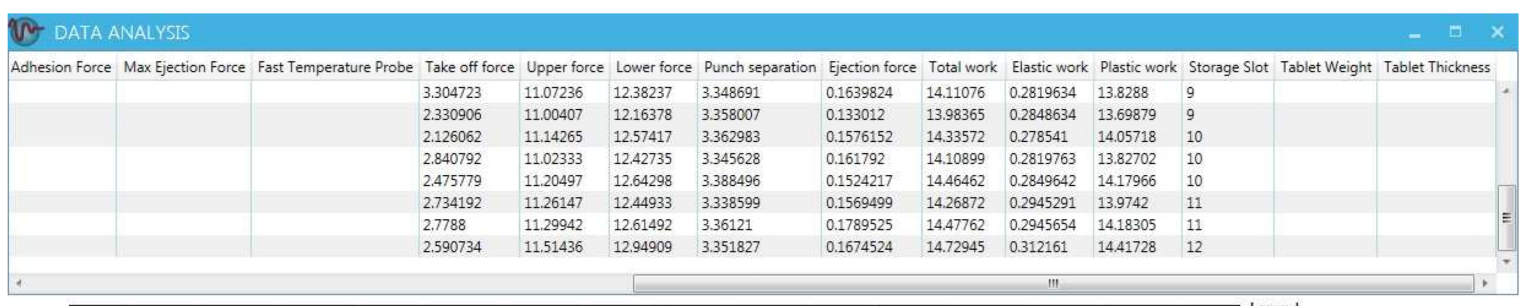
RESULTS



Two identical tests with Hybrid Control switched off and on

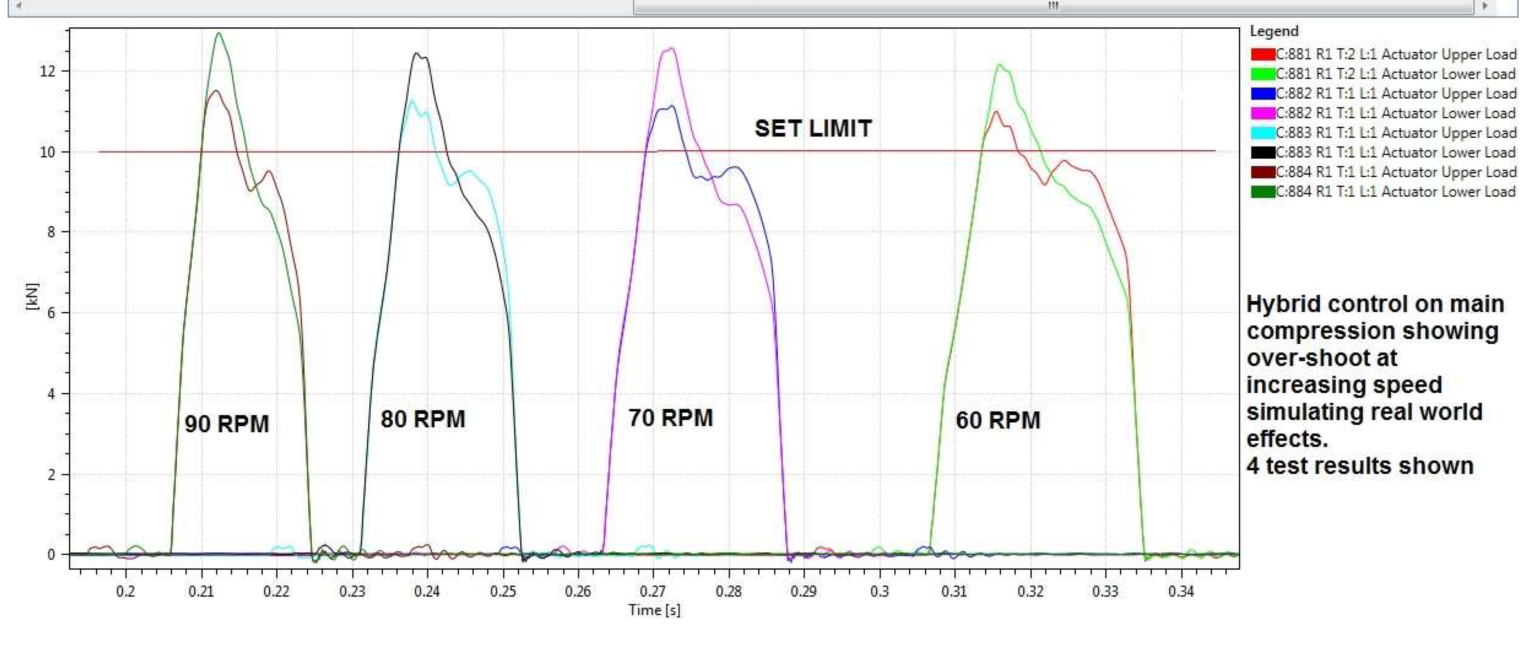


Comparing normal and hybrid compaction with data normalised to a peak of 11kN



DATA ANALYSIS

Adhesion Force	Max Ejection Force	Fast Temperature Probe	Take off force	Upper force	Lower force	Punch separation	Ejection force	Total work	Elastic work	Plastic work	Storage Slot	Tablet Weight	Tablet Thickness
			3.304723	11.07236	12.38237	3.348691	0.1639824	14.11076	0.2819634	13.8288	9		
			2.330906	11.00407	12.16378	3.358007	0.133012	13.98365	0.2848634	13.69879	9		
			2.126062	11.14265	12.57417	3.362983	0.1576152	14.33572	0.278541	14.05718	10		
			2.840792	11.02333	12.42735	3.345628	0.161792	14.10899	0.2819763	13.82702	10		
			2.475779	11.20497	12.64298	3.388496	0.1524217	14.46462	0.2849642	14.17966	10		
			2.734192	11.26147	12.44933	3.338599	0.1569499	14.26872	0.2945291	13.9742	11		
			2.7788	11.29942	12.61492	3.36121	0.1789525	14.47762	0.2945654	14.18305	11		
			2.590734	11.51436	12.94909	3.351827	0.1674524	14.72945	0.312161	14.41728	12		



Main Compression with Hybrid Control showing upper and lower loads (Lower peaks higher)

Conclusion

Load relieving tablet presses modify the compression process in a number of ways. Dwell times increase considerably, load variations are reduced, the tablet is moved vertically under load, and the size of the position correction becomes a variable to study.

The mechanism of a load relieving press is simple, but the simulation of the effect on a servo controlled compaction simulator is complex due to the change in control modes. However, the ability now exists, and study of load relieving presses and their effects can be conveniently completed on a compaction simulator.

Simulation of Roller Compactors and "Load Relieving Tablet Presses" on one Compaction Simulator is particularly useful for developing products for "Continuous Manufacturing" lines.

A successful Hybrid control implementation also allows testing at a controlled strain rate in position control up to a defined and repeatable load.

REFERENCES

Thesis by Elizabeth Peeters, University of Ghent 2014: INVESTIGATION OF THE TABLETING PROCESS IN CONTINUOUS PRODUCTION: INFLUENCE OF FEEDING AND EXTENDED DWELL TIME DURING COMPRESSION ON DEPENDENT PROCESS VARIABLES AND TABLET PROPERTIES.