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Simulation helps eliminate tractor seat stimulation

By Gary Alcorn

A group of agricultural machinery researchers from the University of South Australia is using computer modelling to help refine the design of a vibratory subsoiler and reduce tractor seat vibration so it can be commercialised successfully.

They found the prototype unit transmitted some of the generated energy as vibration back through the PTO shaft and drawbar into the tractor and the operator giving 'hot seat' a whole new meaning.

Their research paper 'Simulation of the Dynamic Behaviour of a Tractor-Oscillating Subsoiler System' has been submitted for presentation at the 2007 Society for Engineering in Agriculture Conference in September (see box this page).

This article gives an outline of the methodology and findings of the lab and fieldwork using Cosmos-Motion 2005 software. The team's aim was to determine how closely the computer-generated simulation fitted with actual field observations of the subsoiler's performance characteristics.

They found close agreement between measured and simulated results which

gives confidence in refining the subsoiler design on the computer to further reduce damaging vibrations and energy losses.

Research supervisor Dr Chris Saunders from the Agricultural Machinery Research & Design Centre, Mawson Lakes Campus, University of South Australia believes his student is well on the way to solving the vibration dilemma.

"Soil compaction in Australian vineyards is a major problem in some areas of the country with significant impact on yield and quality. Previous research in this area showed the potential for low frequency, high amplitude vibratory technology to provide a solution to the limited tractive power available from the common vineyard tractors when high draft subsoiling operations were required. The side effects of this original research were the additional vibrations that were transmitted to the tractor and the operator.

"The current research we are undertaking allows us to understand the cause and effect of these vibrations and isolate and reduce or remove them from the system.

"Although much research had been carried out in the past in relation to vibratory

tillage and subsoiling, modern computer techniques and software allow us to carry out many more virtual tests where the impacting variables are changed to highlight the improved operation of the system.

"A key aspect of this computer modelling is the validation of the results with actual field experiments. This is an important area in which AMRDC has a strong and experienced background," Chris said.

For fracturing the compacted layers of soil between grapevines using small vineyard tractors, a two-tine vibratory subsoiler

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was developed at the University of South Australia.

But the soil forces exerted on the tines were unbalanced, so torque peaks through the power-take-off (PTO) and the inertia of the tines transferred considerable vibration to the tractor and its driver.

These vibrations currently prevent the use of optimum soil loosening settings and commercialisation of the design.

“Past research has shown the most important parameters affecting the performance of vibrating tillage were frequency, amplitude and velocity ratio of the vibrating tines,” says Chris.

The tractor-subsoiler system considered in this study is shown in the photo on page ?? and comprises a trailed oscillating subsoiler developed at the University of South Australia and a Massey Ferguson 390 4WD tractor. The driver’s seat was a KAB 303 model, joined to the tractor body by a spring of stiffness 5.5 kN/m and a damper with a damping coefficient of 1.14 kNs/m. The performance of the oscillating subsoiler was measured over a range of settings and field conditions.

Data measurements included implement draft, PTO torque and speed, tractor forward speed and three -dimensional vibrations transmitted to the tractor seat. A simulation model was subsequently developed aiming to:

- Validate its accuracy against field data; and,
- Optimise the tractor-subsoiler system characteristics to minimise vibrations to the tractor seat.

The prototype test subsoiler used tractor power via a PTO shaft through a 76



AMRDC subsoiler researchers Dr Chris Saunders (left), Gholamhossein Shahgoli, Dr Jack Desbiolles (top inset) and Assoc Prof John Fielke.

kg flywheel to a fixed ration gearbox and chain-sprocket arrangement to a crank-shaft unit driving the two subsoiling tines via connecting rods.

Precise adjustments were made across a wide range of settings from tine tip oscillation amplitudes, frequency, and tine tip velocities — at a constant working depth of 400 mm and working speed of three kph. Cutting, backing off and catching up phases of the tines was calculated and applied to various dynamic equations in the simulation.

To generate the simulation in Cosmos-Motion, the following basic steps were taken:

- Define the rigid bodies and their properties of mass and centre of mass;
- Select the components participating in the simulation by defining them as moving or grounded parts;
- Add motion, joints and contacts between rigid bodies to represent the mechanism;

- Add external loads from the soil cutting forces to the soil engaging tines;
- Generate a solution, with the software generating the equations of motion and solving them at the required time steps; and,
- Review the simulation results by producing plots, spreadsheets and animations, and analyse comparisons with measured data obtained in field conditions.

Over a period of 18 months the team observed, analysed and refined the simulation study based on field measurements.

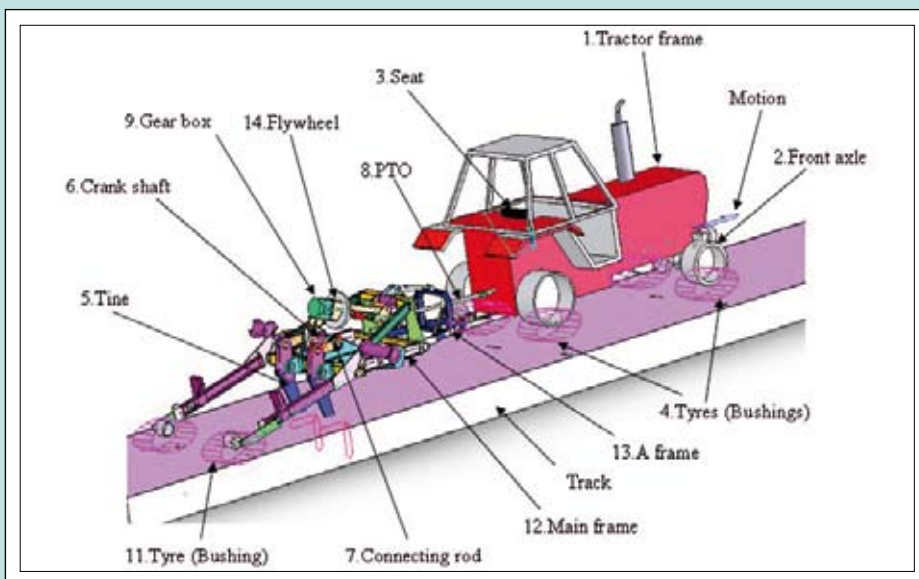
“Close agreement was found between the peak levels and trends of vertical accelerations for the simulation and measurements as frequency, amplitude and vibration angle were changed,” says Chris. “For higher frequencies, amplitudes and negative vibration angles soil cutting force change was large and at maximum values it created large pitching moment which increased vertical vibration.”

The team concluded that the computer model could simulate the dynamic behaviour of the tractor-vibratory subsoiler system. Work is continuing to further refine the simulation, in particular the modelling of the tyres and to evaluate the effect of increasing the number of tines and their arrangement so as to reduce the acceleration of the tractor and driver.

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Dr Saunders believes these research findings could be applied to subsoiler performance across other areas of intensive agriculture where soil renovation is required.



The tractor-vibratory subsoiler system.