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Modelling and Intelligent Control Based Damping System for Smart No-Till Seed Planter's Assembly

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Abstract- **Providing a precise Mathematical Model for a perfect damper and damping control is a leading issue in all mechanical Systems. This research is about the modelling of a damper and using it to control the damping system of an intelligent no-till seed planter. In a no-till seeding planter, there is a significant influence of variations in soil conditions regarding inconsistency in seeding depth. Inappropriate and unwanted dynamic responses of the seed planter's assembly are the main cause of such an inconsistent situation. In this research paper, the fluctuation and the dynamics of a seed planter's assembly, featured with a mono-tube hydraulic damping system, will be modelled and controlled regarding the ground impact and vertical movement. Modelling will cover the system's linearities and non-linearities. After a model is proposed, then the damping system's control of the seed planter in an intelligent manner will be required. Adaptive Proportional Integral Derivative (PID) is a very powerful control technique that will result in precise and accurate control.**

Index Terms-- **Seeding Depth, Damper, Seed Planter, Mathematical modelling, control, PID**

I. INTRODUCTION

The modelling and control of vibrations concern the vibratory motion of the associated forces and components. All components having elasticity and mass are capable of oscillations. Thus, most structures and engineering machines go through vibration to some degree and hence have some vibratory behaviour. However, as deformability is possible in all real materials, the mechanical system always creates deformation motion and rigid-body motion. Although there can be a small and negligible motion of deformation in many instances, it may be of great importance in other occasions. There are various ways of expressing the damping forces observed at the wheel. For example, dividing the weight of the vehicle, not mass, by the total damping coefficient at the wheels in the bump provides a characteristic speed of order 10m/s representing an effect at which the vehicle would settle on its suspension when resisted by its dampers without spring support. However, the dependence on appropriate damping is not just on a vehicle's damping ratio. This may not be a good approximation for two different damping coefficients of the direction, but it has its qualitative benefits.

The criteria traditionally depend on various parameters (used to measure) and experimental measurements to describe dampers' damping properties.

To achieve adequate seed germination and seedling emergence during no-tillage sowing, consistency in the depth of seeding is crucial. Since both ultimately affect crop growth and, generally, the yield of the produced goods [1][2]. Because of the furrow components' imbalanced and improper dynamical behaviour, uneven depth of seeding generally occurs. The dynamic performance of the seeding machines is significantly impacted by soil harshness, including soil surface roughness, residual effects, fluctuating soil density, etc. Variation in their dynamic response is caused by the coulter assembly's vertical dynamics' incapacity to regulate reaction forces and displacements [3]. The forces generated by the interaction of the coulter tine with the soil can be used to describe the motion behaviour of the assembly [4][5]. The assembly parts stimulated by the forces brought about by the soil reaction will determine how this works out. The assembly may include an additional packing component, in which case the impact forces that occur must also be considered [6].

A. MODELING OF MECHANICAL SYSTEMS:

Methods of Modeling Linear Systems include the Transfer Function Method (only linear systems) and State-Space Method (both linear and nonlinear systems). The motion of a Mechanical system may be Translational motion, Rotational motion, or Complex motion (A combination of the mentioned). In Our Case, the motion is Translational, and we will use the mono-tube hydraulic damper for the damping control.

Hydraulic Dampers: Some significant properties of hydraulic operating dampers comprise of Employs pressurized liquid as fluid, Low Operating Costs, Capable to move heavier loads, lubrication, cooling, and power transmission at a time, Lesser control than MR Dampers, Foaming Phenomenon, Complex design, High Initial Cost, Less damping in case of leakage. Twin tube hydraulic dampers have two cylinders, one for piston movement and the other works as an extra oil reservoir.

The mono-tube hydraulic dampers can bear more load as it has one large cylinder, due to which the piston head size is more than the twin tube. Some significant properties of the mono-tube hydraulic operating dampers consist of a single fluid reservoir and piston rod, good for heavy loads, good for curve damping, more control (bigger piston), Costly, most popular, compact size, Reliability and proper functioning, Accumulator to avoid fluid lock, pressurized to avoid cavitation, up to 150-350 psi.

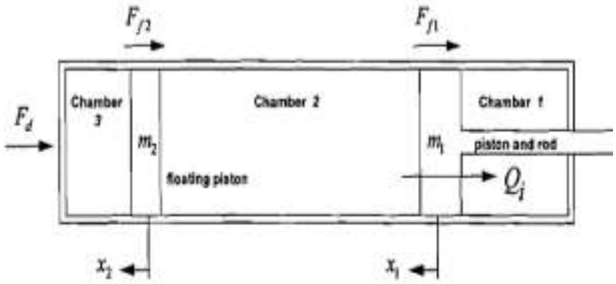

FIGURE 1: Schematic of a Mono-tube Damper [7]

From Fig. 1, by incorporating cavitation into the cylinder of a mono-tube hydraulic damper, the effects can be studied, and the efficient model of the damper can be used for the enhancement and simulation of dynamic vehicle response [7]

Because of the clear advantages, such as assessing the performance of a well-defined model for future optimization in the machine's performance, farm machinery's dynamic behaviour has attracted machine engineers' attention. The machine's dynamic response to soil undulations causes excessive vertical oscillations of the seeding components. This has been reported about modelling the dynamical reaction of a semi-mounted seeding implement to surface undulations. By modelling its dynamics, the impact of force and soil undulations on the motion behaviour of the subsoiler has also been investigated [8–10]. Additionally, an active control mechanism for residue-free field conditions with minimal tillage seed drilling was thoroughly researched and investigated [11]. The control systems developed for regulating the seeding component's vertical movement could also be added to the broadly used ISO 11783 standard, commonly designated as ISOBUS.

The communication infrastructure required in agricultural machinery for uniform control and reception of feedback signals could be provided by ISOBUS [12][13]. Numerous studies have been done to improve the dynamics of no-tillage sowing devices to prevent or lessen the inconsistent seeding depth [14]. The coulter assembly's employed downforce control may be the best option for improving performance [15], but devising an effective control strategy might be difficult due to the nonlinear properties of the spring and damping elements, which govern the depth control system. These issues could be resolved by constructing a dynamic downforce control system, where the elements for regulation are actively managed by various control approaches [17].

II. Control Technology

Adaptive Proportional Integral Derivative (PID) and Adaptive Fuzzy controls are two very powerful techniques, so combining such a hybrid technique will result in precise and accurate control. The Adaptive fuzzy control will accelerate the precision of Adaptive PID, and combinedly these two results in a more surprisingly amazing damping control.

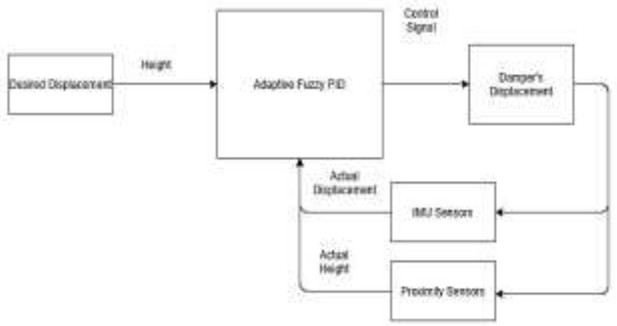

FIGURE 2: Block Diagram when sensors are to be added

Figure 2 shows the block diagram for the system. Sensors will sense the actual displacement and send the data to the controller and the controller will send a control signal to the damper, and the process will go on until the desired height is achieved. But here, we have focused only on PID implementation in MATLAB

III. Mathematical Model and Control Equation

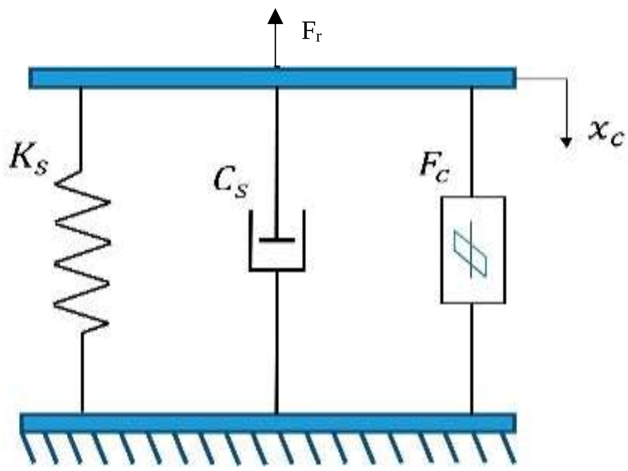

FIGURE 3: Schematic view of the model for the mono-tube hydraulic damping system

From Fig. 3, the resulting force from the mono-tube hydraulic damping model was expressed by the following formula

$$Fr = m\ddot{x} + b\dot{x} + kx + Fc \quad (1)$$

In (1);

Fr [N] is the reaction force acting on the wheel

b is the damping coefficient [N s m^{-1}]

k is the stiffness coefficient [N m^{-1}]

m is the mass

Fc is the Control Force

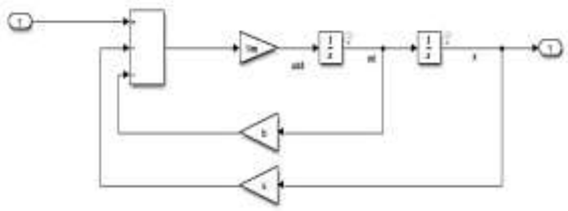

FIGURE 4: Simulink block view of the spring mass damper

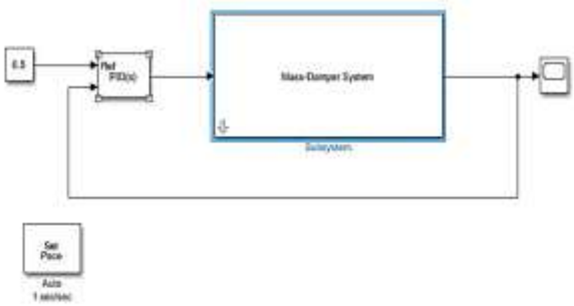

FIGURE 5: PID-tuned Mass damper system (Simulink)

Figure 4 shows the simple Simulink model for the spring-mass system, and Fig. 5 PID control technique is applied to tune the referred damping system.

IV. MATLAB SIMULTION RESULTS

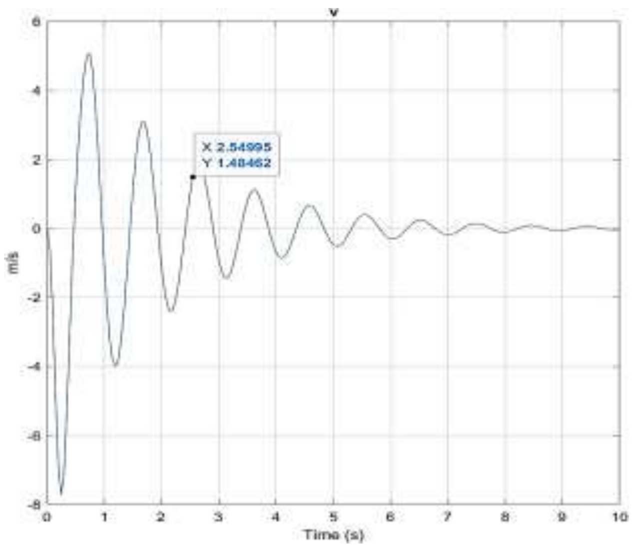

FIGURE 6: Velocity of mass

Figure 6 shows the damper's balancing after the impact force removal. The whole shock is absorbed, and the system settles within 5 seconds.

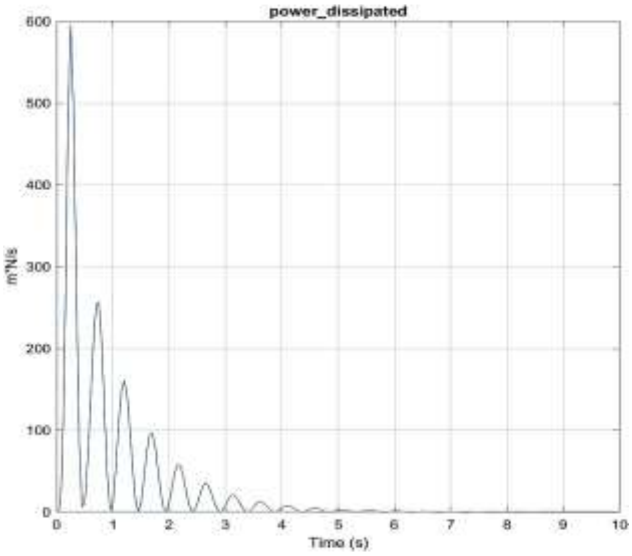

FIGURE 7: Power dissipated w.r.t time

Figure 7 shows power dissipation. The time, i.e., 4 seconds, is for the energy/power absorption and dissipation.

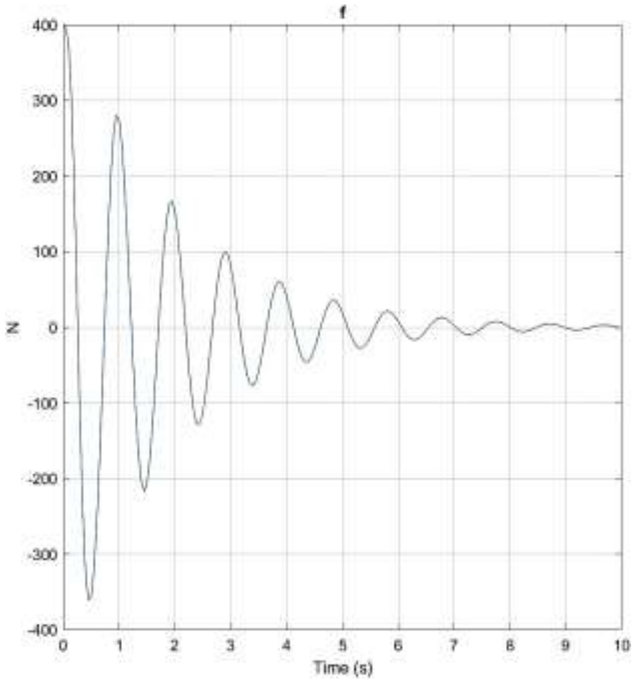

FIGURE 8: Spring oscillation frequency when a constant force is applied

The nitrogen gas in the shock absorber is modelled as a spring (see Fig. 8), and the oscillation frequency for a constant force application and removal causes the above damper's frequency to act like mass velocity.

Figure 9 shows the step response after tuning the PID controller, having time along the x-axis and amplitude along the y-axis. The graph shows the root locus plot for the damper.

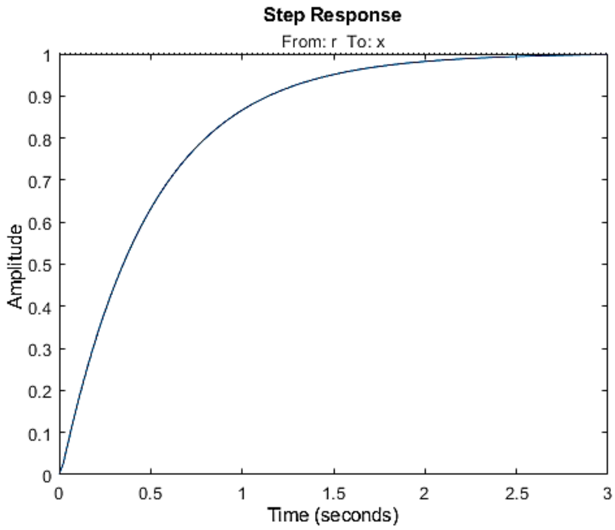

FIGURE 9: Step Response with respect to time

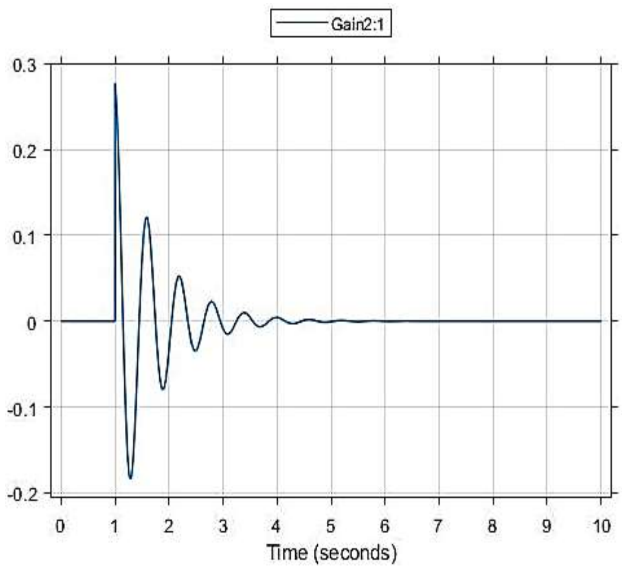

FIGURE 10: Gain at Step input

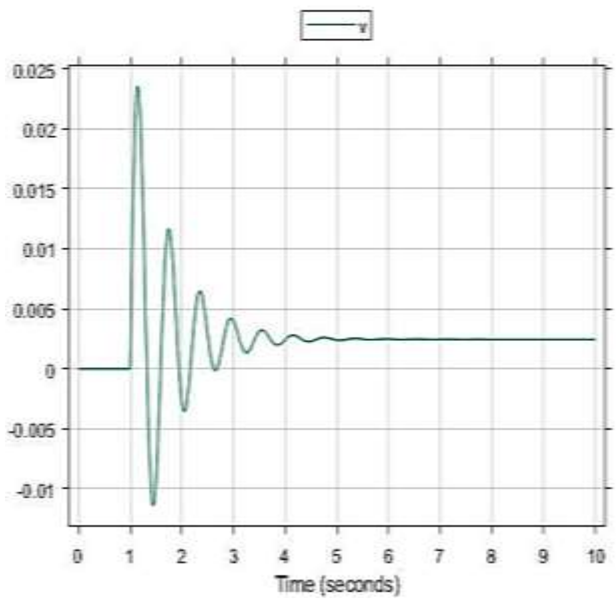

FIGURE 11: Velocity at Step input

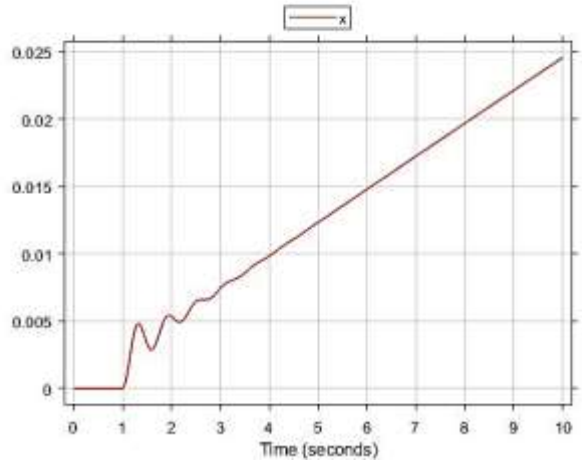

FIGURE 12: X at step input

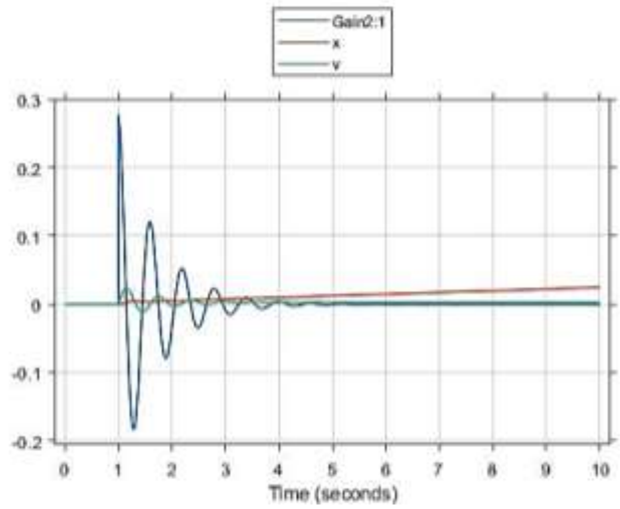

FIGURE 13: Combine analysis of gain, velocity and x at step input

Figures 10-13 show the different variable responses at Constant and Step input forces, e.g., the velocity of mass at a constant input of 0.5. The power dissipated w.r.t time at a constant input of 0.5, Spring oscillation frequency when a constant force of 0.5 is applied, the velocity of spring at a constant input of 0.5, Step Response concerning time, Gain at Step input, Velocity at Step input, X at step input and Combine analysis of gain, velocity and x at step input respectively.

V. CONCLUSION AND FUTURE WORK

A mathematical model of the coulter assembly with a mono-tube hydraulic damper's vertical motion dynamics was created. MATLAB Simulink was used to model the dynamic response in terms of the gain and speed of the assembly's vertical motion. The tuning of PID for constant and step input shows very different results with a difference of 2 to 3 seconds (can be observed in the figures) of stabilization during and after impact force application. PID controller tuning enhanced the simulation results during the application of step input force. These results lead to a very proper plantation by the no-till seed planter. Applying the fuzzy control technique in hybridization with the PID controller (as shown in figure 2) may lead to a much more stabilized damping system and proper seed plantation. Adaptive fuzzy control will tune and accelerate the precision of PID, and combinedly these two results in a much more surprisingly amazing damping control.

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The authors declare they have no conflicts of interest to report regarding the present study.

CONFLICT OF INTEREST

The Authors declare that they have no conflicts of interest to report regarding the present study.

REFFERENCES

[1] A Özmerzi, D. Karayel, and M. Topakci, "Effect of sowing depth on precision seeder uniformity," Biosyst. Eng., vol. 82, no. 2, pp. 227–230, Jun. 2002, doi: 10.1006/bioe.2002.0057.

[2] B A Collins and D. B. Fowler, "Effect of soil characteristics, seeding depth, operating speed, and opener design on draft force during direct seeding," Soil Tillage Res., vol. 39, no. 3–4, pp. 199–211, Nov. 1996, doi: 10.1016/S0167-1987(96)01062-8.

[3] A Abo Al-Kheer, M. Eid, Y. Aoues, A. El-Hami, M. G. Kharmanda, and A. M. Mouazen, "Theoretical analysis of the spatial variability in tillage forces for fatigue analysis of tillage machines," J. Terramechanics, vol. 48, no. 4, pp. 285–295, Aug. 2011, doi: 10.1016/j.jterra.2011.05.002.

[4] A Hasimu and Y. Chen, "Soil disturbance and draft force of selected seed openers," Soil Tillage Res., vol. 140, pp. 48–54, Jul. 2014, doi: 10.1016/j.still.2014.02.011.

[5] J. Liu, Y. Chen, and R. L. Kushwaha, "Effect of tillage speed and straw length on soil and straw movement by a sweep," Soil Tillage Res., vol. 109, no. 1, pp. 9–17, Jul. 2010, doi: 10.1016/j.still.2010.03.014.

[6] W. C. T. C. C. J. Baker, K. E. Saxton, W. R. Ritchie and S. E. J. and P. R. H. D. C. Reicosky, F. Ribeiro, "No-tillage Seeding in Conservation Agriculture," Publ. JOINTLY BY CAB Int. FAO, 2007, Accessed: Apr. 21, 2021. [Online]. Available: http://www.fao.org/3/al298e/al298e00.htm.

[7] K. Lee, "Numerical modelling for the hydraulic performance prediction of automotive mono-tube dampers," Veh. Syst. Dyn., vol. 28, no. 1, pp. 25–39, 1997, doi: 10.1080/00423119708969347.

[8] L. Jugulkar, S. Singh, and S. Sawant, "Mathematical modelling and experimental validation of mono-tube shock absorber," World J. Eng., vol. 13, no. 4, pp. 294–299, Aug. 2016, doi: 10.1108/WJE-08-2016-040.

[9] A M. Mouazen, J. Anthonis, W. Saeys, and H. Ramon, "An automatic depth control system for online measurement of spatial variation in soil compaction, part 1: Sensor design for measurement of frame height variation from soil surface," Biosyst. Eng., vol. 89, no. 2, pp. 139–150, Oct. 2004, doi: 10.1016/j.biosystemseng.2004.06.005.

[10] J. A. Lines and K. Murphy, "The stiffness of agricultural tractor tyres," J. Terramechanics, vol. 28, no. 1, pp. 49–64, Jan. 1991, doi: 10.1016/0022-4898(91)90006-R.

[11] M. E. C. BURCE, T. KATAOKA, and H. OKAMOTO, "Seeding Depth Regulation Controlled by Independent Furrow Openers for Zero Tillage Systems — Part 1: Appropriate Furrow Opener —," Eng. Agric. Environ. Food, vol. 6, no. 1, pp. 1–6, Jan. 2013, doi: 10.11165/EAEF.6.1.

[12] P. Suomi and T. Oksanen, "Automatic working depth control for seed drill using ISO 11783 remote control messages," Comput. Electron. Agric., vol. 116, pp. 30–35, Aug. 2015, doi: 10.1016/j.compag.2015.05.016.

[13] D. S. Paraforos, G. M. Sharipov, and H. W. Griepentrog, "ISO 11783-compatible industrial sensor and control systems and related research: A review," Computers and Electronics in Agriculture, vol. 163. Elsevier B.V., p. 104863, Aug. 01, 2019, doi: 10.1016/j.compag.2019.104863.

[14] S. Kirkegaard Nielsen, L. J. Munkholm, M. Lamandé, M. Nørremark, G. T. C. Edwards, and O. Green, "Seed drill depth control system for precision seeding," Comput. Electron. Agric., vol. 144, pp. 174–180, Jan. 2018, doi: 10.1016/j.compag.2017.12.008.

[15] R. Zhang et al., "Design of depth-control planting unit with single-side gauge wheel for no-till maize precision planter," Int. J. Agric. Biol. Eng., vol. 9, no. 6, pp. 56–64, Dec. 2016, doi: 10.3965/j.ijabe.20160906.2394.

[16] J. Gratton, Y. Chen, and S. Tessier, "Design of a spring-loaded downforce system for a no-till seed opener," 2003.

[17] S. K. Nielsen, M. Nørremark, and O. Green, "Sensor and control for consistent seed drill coulter depth," *Comput. Electron. Agric.*, vol. 127, pp. 690–698, Sep. 2016, doi: 10.1016/j.compag.2016.07.029.