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Research on Optimization of Structural Parameters of Electromagnetic Vibration Seeding Apparatus

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Abstract:

As the core working part of the electromagnetic vibration rice direct seeding machine, the performance of the electromagnetic vibration seeding apparatus directly affects the seeding quality, and its performance is determined by its structural parameters. In this paper, with the help of virtual prototype technology and orthogonal test method, the structural parameters that affect the overall performance of the seeding apparatus system are optimized. The results show that when the stiffness of the connecting spring is 634N/m, the height is 38mm, and the length is 38mm; the total stiffness of the main vibration spring is 57600N/m and the inclination angle is 62°; the total stiffness of the rear leaf spring is 35080N/m and the inclination angle is 66°, the seeding apparatus is not easy to be blocked, and the performance of the rice direct seeding machine meets the agronomic requirements.

***Keywords**: Electromagnetic vibration seeding apparatus, Optimization, Simulation, Orthogonal test.*

I. INTRODUCTION

The electromagnetic vibration seeding apparatus is the core working part of the electromagnetic vibration rice direct seeding machine, and its working performance directly affects the seeding quality of the rice direct seeding machine. The electromagnetic vibration seeding apparatus has many components, and is a multi-degree-of-freedom and complex system. If the parameters are not properly designed, the relative movement of the seed plate and the vibration upper plate will be unreasonable, which will cause seed clogging and will also affect the consistency of the seeding amount of the seeding apparatus in each row. Therefore, in order to achieve uniform seeding, no clogging, reduce the amount of backflow seeds and meet the seeding requirements, it is of great significance to optimize the structural parameters affecting the seeding performance of the electromagnetic vibration seeding apparatus [1]. The

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traditional mechanical structure parameter optimization research is carried out by physical experiment, which is time-consuming, labour-intensive and costly. In this paper, the ADAMS-based virtual prototype technology and orthogonal test method are used to perform parameter optimization research, so that the seeding apparatus can meet the agronomic requirements of seeding quality [2].

II. STRUCTURE AND WORKING PRINCIPLE OF VIBRATION SEEDING APPARATUS

The structure diagram of the electromagnetic vibration seeding apparatus is shown in Fig 1. When working, the electromagnet is activated, and the main seed plate and the vibration upper plate are supported by the springs, thus generating vibration. Under the action of vibration, the seeds from the seed box fall through the funnel and the vibration upper plate into the V-grooves of the main seed plate. At this time, the seeds in the main seed plate are pushed forward under the action of vibration. When the seeds move to the shunt holes of the shunt plate, the overhead seeds fall from them into the seed collector for recycling, and the remaining seeds continue to move forward. When the seeds reach the outlet of the shunt plate, it falls into the inoculator and the seeding tube and is sown into the field, so as to achieve a large-scale discharge and small-scale seeding.

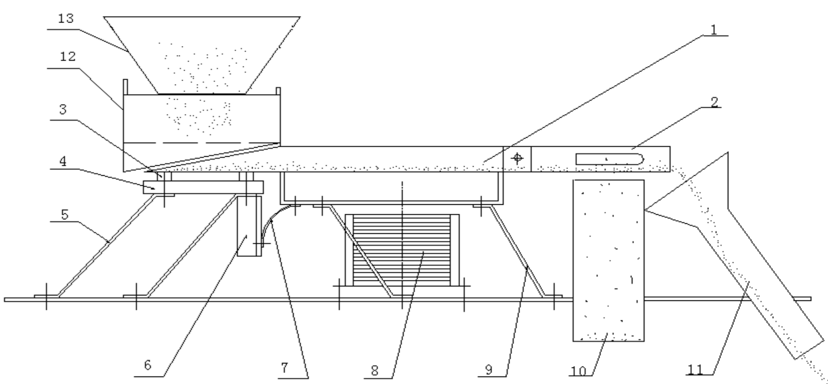

Fig 1: Schematic diagram of electromagnetic vibration seeding apparatus (1) Seed plate (2) Shunt plate (3) Connecting cylinder (4) Vibration rear plate (5) Rear leaf spring (6) Connecting steel plate (7) Connecting spring (8) Electromagnet (9) Main vibration spring (10) Seed collector (11) Inoculator (12) Vibration upper plate (13) Funnel

III. ESTABLISHMENT OF VIRTUAL PROTOTYPE SIMULATION MODEL

The deformation of the main seed plate, shunt plate, vibration upper plate, vibration rear plate and main vibration spring of the electromagnetic vibration seeding apparatus is relatively large, which has a greater impact on the uniformity of the seeding of the seeding apparatus, so they are regarded as flexible bodies. The remaining components are deformed less, which have little effect on the working performance of the seeding apparatus. They are regarded as rigid bodies and directly modelled in ADAMS [3,4]. The ADAMS/Flex module can create a flexible

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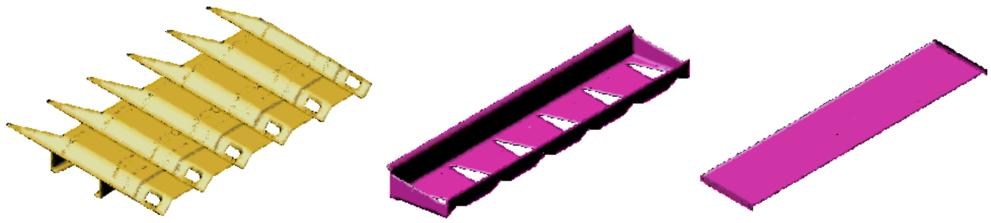
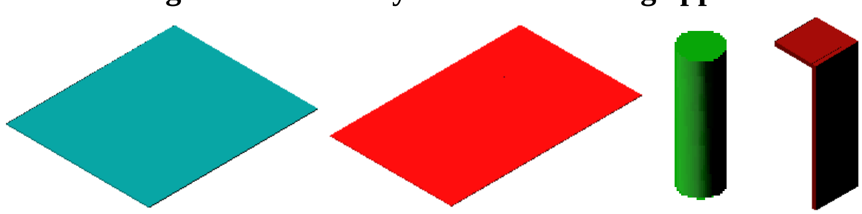
body model, but this module is not suitable for building component models with complex geometric shapes, and the generated flexible body has low accuracy, so it is necessary to build a flexible body in the finite element analysis software ANSYS, divide the mesh, and generate modal neutral file (i.e. mnf file), and then use ADAMS/Flex module to import it into ADAMS [5,6]. The virtual model size and structure are determined with reference to the 2BD-6 rice direct seeding machine in the laboratory. The flexible body models and rigid body models of the seeding apparatus are shown in Fig 2 and Fig 3.



(1) Main seed plate (2) Vibration upper plate (3) Vibration rear plate

(4) Main vibration spring (5) Connecting spring (6) Rear leaf spring

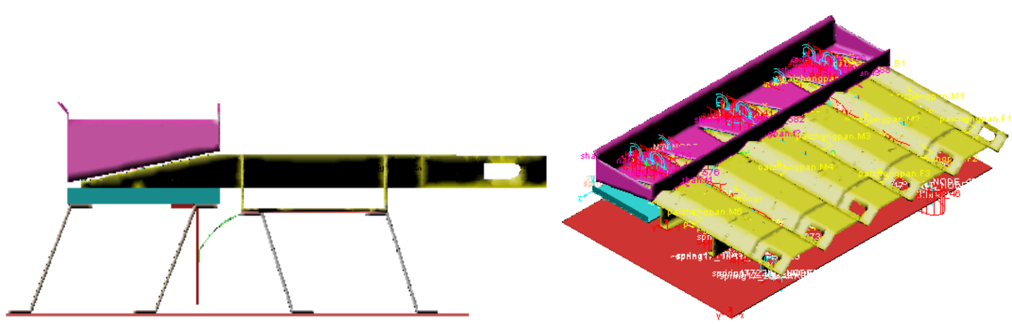
Fig 2: Flexible body models of seeding apparatus



(1) Fixed floor (2) Spring bottom plate (3) Connecting cylinder (4) Connecting steel plate

Fig 3: Rigid body models of seeding apparatus

The flexible body and rigid body models of the seeding apparatus are assembled into a whole according to the assembly relationship to obtain the simulation model of the virtual prototype, as shown in Fig 4.



(1) Front view (2) Isometric view

Fig 4: Simulation model of seeding apparatus

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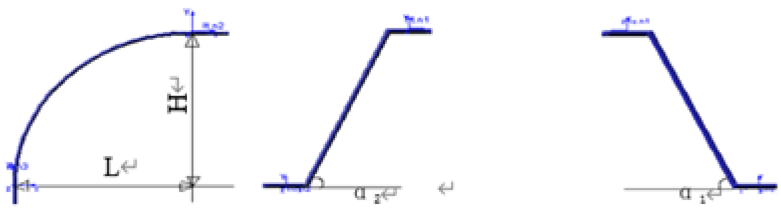
IV. ORTHOGONAL TEST

In this research, the orthogonal test method is used to simulate the virtual prototype to find out the better plan of the main parameters that affect the working performance of the seeding apparatus.

4.1 Determination of Factors and Levels

The parameters that affect the performance of the system mainly include the stiffness and inclination of the main vibration spring, the stiffness and inclination of the rear leaf spring, the stiffness, height and length of the connecting spring. The structure diagram of the three springs is shown in Fig 5.



(1) Connecting spring (2) Rear leaf spring (3) Main vibration spring

Fig 5: Physical parameters of the three springs

In the orthogonal test design, these parameters are used as factors, and each factor is selected at three levels. The factor levels are shown in TABLE I. The L_{27} (3^{13}) orthogonal table is used to arrange the simulation test.

TABLE I. Factor level table

Factors / Levels	Factor A Connection spring stiffness K(N/m)	Factor B Main vibration spring stiffness K_1(N/m)	Factor C Rear leaf spring stiffness K_2(N/m)	Factor D Main vibration spring inclination α_1(°)	Factor E Rear leaf spring inclination α_2(°)	Factor F Connection spring height H(mm)	Factor G Connection spring length L(mm)
1	228	45648	35080	62	62	23	23
2	634	57600	46268	66	66	38	38
3	1242	70188	57988	70	70	52	52

4.2 Modal Analysis of Seeding Apparatus System

In the seeding apparatus system, under the combination of different levels of various factors, the modal frequencies and vibration modes of the virtual prototypes are also different, so first of all, the normal modal analysis of each virtual prototype must be performed to find their natural frequency and Main mode [7,8]. The modal analysis results are shown in TABLE II.

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TABLE II. The natural frequency of the virtual prototype under the combination of different levels of various factors

Test number	Natural frequency f(Hz)	Excitation frequency 0.9f(Hz)	Test number	Natural frequency f(Hz)	Excitation frequency 0.9f(Hz)	Test number	Natural frequency f(Hz)	Excitation frequency 0.9f(Hz)
1	26.6	24.0	10	33.3	30.0	19	41.3	37.2
2	27.0	24.3	11	41.1	37.0	20	40.9	36.8
3	28.3	25.5	12	38.4	34.6	21	64.4	58
4	31.3	28.2	13	51.6	46.4	22	40.7	36.6
5	29.8	26.8	14	34.4	31.0	23	41.9	37.7
6	32.1	28.9	15	35.6	32.0	24	42.4	38.2
7	32.0	28.8	16	38.7	34.8	25	57.4	51.7
8	30.2	27.2	17	36.1	32.5	26	49.7	44.7
9	32.0	28.8	18	37.6	33.8	27	44	39.6

In the simulation test, the excitation force is square wave excitation, and the waveform is shown in Fig 6. The frequency of excitation is taken as 0.9 times the natural frequency of each virtual prototype [9].

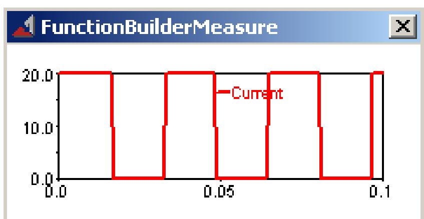

Fig 6: Waveform of square wave excitation force

4.3 Determination of Test Index

According to agronomic requirements, the speed of the rice seeding machine in field operations is about 400-500mm/s, the average plant spacing is 100mm, the length of each seed is about 6 mm, and each V-shaped groove of the seeding apparatus needs to discharge 4-5seeds per second [10]. In addition, because the seeds will be superimposed before and after moving in the V-shaped grooves, in order to achieve this amount of discharged seed, the forward speed of the seed relative to the seed plate, that is, the speed of the centre of the seed plate in the horizontal direction must reach 20 mm/s or more. In order to better disperse the seeds on the vibration upper plate and fall in the grooves of the seed plate, the vertical speed of the vibration upper plate should be at least 5 mm/s or more [11].

At the same time, the speed difference between the centre point of the seed plate and the vibration upper plate in the horizontal direction is preferably in the range of 20mm/s-40mm/s. If the difference is too large, the displacement of the two in the horizontal direction will be too large, which is easy to damage the buds of the germinating seeds. If the difference is too small, it will not help the germinating seeds to fall from the vibration upper plate into the seed plate.

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The vertical speed difference between the centre point of the seed plate and the vibration upper plate should be no more than 25 mm/s. If the speed is too large, the energy consumed is too large. In order to achieve the necessary amount of vibration, a large excitation force is required [12]. At the same time, because the gap between the vibration upper plate and the seed plate in the model is 1.6 mm, and the diameter of the seed is about 3mm, when the displacement difference exceeds 1.4 mm, the seed will leak from the gap between the two.

In order to prevent the seeds from jumping too much in the vertical direction of the seed plate, the displacement of the seed plate in the vertical direction cannot be greater than the gap between the bottom of the seed plate and the top of the electromagnet. Otherwise, the bottom of the seed plate may easily collide with the top of the electromagnet, damaging the seed plate and the electromagnet, and affecting the seeding of the seed plate.

TABLE III. Test results

Test index	Speed of Seed plate centre V_1(mm/s)		Speed of vibration upper plate centre V_2(mm/s)		Displacement of seed plate centre S_1(mm)		Displacement of vibration upper plate centre S_2(mm)		Difference between V_1 and V_2 (mm/s)		Difference between S_1 and S_2 (mm)	
Test number	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	horizontal direction	Vertical direction
1	51.78	36.51	17.08	11.86	0.64	0.45	0.23	0.16	61.06	32.99	0.41	0.29
2	49.42	30.66	17.64	10.67	0.61	0.38	0.23	0.14	48.54	34.32	0.38	0.24
3	56.20	30.26	0.06	0.03	0.75	0.40	0.00	0.00	56.15	30.26	0.75	0.40
4	35.30	21.82	13.53	8.30	0.37	0.23	0.16	0.10	45.13	17.66	0.21	0.13
5	37.80	20.27	1.92	0.99	0.41	0.22	0.02	0.01	38.52	19.84	0.39	0.21
6	35.95	25.37	17.87	12.37	0.38	0.27	0.20	0.14	40.17	28.70	0.18	0.13
7	33.11	17.79	4.86	2.54	0.34	0.18	0.06	0.03	36.85	16.29	0.28	0.15
8	40.82	28.80	9.80	6.80	0.44	0.31	0.12	0.08	44.99	27.27	0.32	0.23
9	35.78	22.19	2.76	1.67	0.37	0.23	0.03	0.02	36.40	21.81	0.34	0.29
10	35.52	24.89	2.19	0.99	0.35	0.25	0.02	0.01	34.44	26.04	0.33	0.24
11	18.76	11.22	15.52	8.03	0.17	0.11	0.14	0.07	28.13	10.94	0.03	0.04
12	21.03	11.27	12.55	8.78	0.19	0.11	0.12	0.08	28.09	11.64	0.07	0.03
13	11.75	7.33	11.49	6.03	0.10	0.07	0.09	0.05	19.21	8.81	0.01	0.02
14	29.76	15.91	1.61	1.21	0.28	0.17	0.02	0.01	30.70	15.42	0.26	0.16
15	30.59	21.52	8.84	5.43	0.28	0.20	0.09	0.06	35.33	19.37	0.19	0.14
16	23.06	12.38	7.50	5.33	0.20	0.11	0.07	0.05	27.86	9.40	0.13	0.06
17	28.51	20.11	12.18	7.47	0.26	0.19	0.12	0.08	36.50	16.40	0.14	0.11
18	24.79	15.38	13.18	6.73	0.22	0.14	0.13	0.07	32.13	14.28	0.09	0.07
19	23.60	16.50	6.64	3.77	0.19	0.14	0.06	0.04	28.53	14.07	0.13	0.10
20	22.89	14.07	4.71	3.47	0.19	0.12	0.04	0.03	26.20	12.15	0.15	0.08
21	7.98	4.62	7.97	4.94	0.07	0.04	0.06	0.039	11.24	7.43	0.01	0.001
22	21.78	13.50	9.45	6.74	0.18	0.11	0.09	0.06	28.68	9.92	0.09	0.05
23	17.48	9.36	9.46	5.85	0.15	0.08	0.09	0.05	23.66	7.84	0.06	0.03
24	19.33	13.62	14.70	7.61	0.16	0.12	0.13	0.07	28.77	12.60	0.03	0.05
25	49.52	26.57	27.98	18.46	0.29	0.16	0.20	0.13	72.24	15.44	0.09	0.03
26	14.09	9.99	11.18	5.91	0.11	0.08	0.10	0.05	22.13	8.44	0.01	0.03
27	19.84	12.27	2.86	1.87	0.15	0.10	0.02	0.02	18.42	13.61	0.13	0.08

Carry out simulation test according to the test plan arranged by $L_{27}(3^{13})$ orthogonal table

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[13]. The test results are shown in TABLE III. Because the vertical speed of the seed plate and the horizontal speed of the vibration upper plate are not specifically required, they can be reflected by the difference between the horizontal and vertical speeds of the seed plate and the vibration upper plate. Moreover, from the data in the table, it can be seen that the displacement of the centre point of the seed plate and the vibration upper plate and the displacement difference between the two are within the required range, so they are not listed as test indexes when performing range analysis, only for reference. There are four test indexes in this test, namely, the speed of the centre of the seed plate in the horizontal direction, the speed of the vibration upper plate in the vertical direction, and the speed difference between the seed plate and the vibration upper plate in the horizontal direction and the vertical direction.

4.4 Test Plan and Result Data Analysis

Based on the four test indexes set above and orthogonal test plan, a range analysis of the test results is performed. The results are shown in TABLE IV. From the range analysis in TABLE IV, it can be seen that with the different test indexes, the order of each factor is different, and the optimal level is also different.

TABLE IV. Test plan and result analysis

Factors / Test number	A	B	A×B	A×B	C	A×C	A×C	D	E	F	G	A×G	A×G	Horizontal speed of seed plate centre (mm/s)	Vertical speed of the vibration upper plate centre (mm/s)	Speed difference between the seed plate centre and the vibration upper plate centre (mm/s)	
																Horizontal direction	Vertical direction
1	1	1	1	1	1	1	1	1	1	1	1	1	1	51.78	11.86	61.06	32.99
2	1	1	1	1	2	2	2	2	2	2	2	2	2	49.42	10.67	48.54	34.32
3	1	1	1	1	3	3	3	3	3	3	3	3	3	56.20	0.03	56.15	30.26
4	1	2	2	2	1	1	1	2	2	2	3	3	3	35.30	8.30	45.13	17.66
5	1	2	2	2	2	2	2	3	3	3	1	1	1	37.80	0.99	38.52	19.84
6	1	2	2	2	3	3	3	1	1	1	2	2	2	35.95	12.37	40.17	28.70
7	1	3	3	3	1	1	1	3	3	3	2	2	2	33.11	2.54	36.85	16.29
8	1	3	3	3	2	2	2	1	1	1	3	3	3	40.82	6.80	44.99	27.27
9	1	3	3	3	3	3	3	2	2	2	1	1	1	35.78	1.67	36.40	21.81
10	2	1	2	3	1	2	3	1	2	3	1	2	3	35.52	0.99	34.44	26.04
11	2	1	2	3	2	3	1	2	3	1	2	3	1	18.76	8.03	28.13	10.94
12	2	1	2	3	3	1	2	3	1	2	3	1	2	21.03	8.78	28.09	11.64
13	2	2	3	1	1	2	3	2	3	1	3	1	2	11.75	6.03	19.21	8.81
14	2	2	3	1	2	3	1	3	1	2	1	2	3	29.76	1.21	30.70	15.42
15	2	2	3	1	3	1	2	1	2	3	2	3	1	30.59	5.43	35.33	19.37
16	2	3	1	2	1	2	3	3	1	2	2	3	1	23.06	5.33	27.86	9.40
17	2	3	1	2	2	3	1	1	2	3	3	1	2	28.51	7.47	36.50	16.40

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18	2	3	1	2	3	1	2	2	3	1	1	2	3	24.79	6.73	32.13	14.28
19	3	1	3	2	1	3	2	1	3	2	1	3	2	23.60	3.77	28.53	14.07
20	3	1	3	2	2	1	3	2	1	3	2	1	3	22.89	3.47	26.20	12.15
21	3	1	3	2	3	2	1	3	2	1	3	2	1	7.98	4.94	11.24	7.43
22	3	2	1	3	1	3	2	2	1	3	3	2	1	21.78	6.74	28.68	9.92
23	3	2	1	3	2	1	3	3	2	1	1	3	2	17.48	5.85	23.66	7.84
24	3	2	1	3	3	2	1	1	3	2	2	1	3	19.33	7.61	28.77	12.60
25	3	3	2	1	1	3	2	3	2	1	2	1	3	49.52	18.46	72.24	15.44
26	3	3	2	1	2	1	3	1	3	2	3	2	1	14.09	5.91	22.13	8.44
27	3	3	2	1	3	2	1	2	1	3	1	3	2	19.84	1.87	18.42	13.61
$(k_1)_1$	41.8	31.9	32.5	34.8	31.7	27.9	27.2	31.1	29.7	28.8	30.7	30.9	26.9	Primary and secondary order: A,AB,E,AG,B,G,AC,D,F,C Excellent combination:$A_1E_2B_1G_2D_1F_3C_1$			
$(k_2)_1$	24.9	26.6	29.8	26.7	28.8	27.3	33.3	26.7	32.2	27.9	31.4	28.0	26.7				
$(k_3)_1$	21.8	30.0	26.3	27.1	27.9	30.7	28.1	30.7	26.6	31.8	26.4	29.5	34.9				
R_1	20	5.3	7.15		3.8	4.75		4.4	5.6	3.9	5.0	5.55					
$(k_1)_2$	6.1	5.8	6.9	6.8	7.1	6.5	6.0	6.91	6.5	9.0	3.9	7.4	5.7	Primary and secondary order: F,G,E,AB, AC,AG,C,D,A,B Excellent combination:$F_1G_2E_2C_1D_1A_3B_3$			
$(k_2)_2$	5.6	6.1	7.3	5.9	5.6	5.0	7.6	5.95	7.1	5.9	8.2	5.8	6.6				
$(k_3)_2$	6.5	6.3	4.0	5.4	5.5	6.6	4.6	5.35	4.6	3.3	6.1	5.0	6.0				
R_2	0.9	0.5	2.35		1.6	2.3		1.56	2.5	5.7	4.3	1.65					
$(k_1)_3$	45.3	35.8	38.2	40.4	39.3	34.5	33.0	36.9	34.0	37.0	33.8	38.6	32.1	Primary and secondary order: A,AC,AG,AB,C,E,G,D,B,F Excellent combination:$A_2C_2E_1G_1D_3B_1F_3$			
$(k_2)_3$	30.3	32.2	36.4	31.8	33.3	30.2	39.7	31.4	38.2	32.9	38.2	31.7	31.1				
$(k_3)_3$	28.9	36.4	30.0	32.2	31.9	39.7	31.8	36.1	32.3	34.6	32.5	34.2	41.2				
R_3	16.4	4.2	8.4		7.4	8.7		5.5	5.9	4.1	5.7	8.5					
$(k_1)_4$	25.5	20.0	18.7	19.9	16.7	15.6	15.9	20.7	17.9	17.1	18.4	16.9	15.6	Primary and secondary order: A, D ,B, AB ,E ,G, AC, AG, F, C Excellent combination:$A_2D_2B_3E_1G_2F_1C_2$			
$(k_2)_4$	14.7	15.6	16.9	15.5	17.0	17.7	18.5	15.9	18.5	16.2	17.7	17.9	16.9				
$(k_3)_4$	11.3	15.9	15.9	16.0	17.7	18.1	17.1	14.8	15.1	18.2	15.3	16.7	19.0				
R_4	14.2	4.4	3.6		1.0	2.55		5.9	3.4	2.0	3.1	2.3					

In order to facilitate analysis and comparison, the excellent levels of various factors under different test indexes are listed in TABLE V.

TABLE V. Excellent levels of various factors under different test indexes

Factors / Test indexes	A	B	C	D	E	F	G
Horizontal speed of seed plate centre (mm/s)	1	1	1	1	2	3	2
Vertical speed of the vibration upper plate centre (mm/s)	3	3	1	1	2	1	2
Speed difference between the seed plate centre and the vibration upper plate centre in the horizontal direction (mm/s)	2	1	2	3	1	3	1
Speed difference between the seed plate centre and the vibration upper plate centre in the vertical direction (mm/s)	2	3	2	2	1	1	2

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When the horizontal speed of the centre point of the seed plate and the vertical speed of the centre point of the vibration upper plate meet the requirements, it can be seen from the data in TABLE IV that the speed difference between the centre point of the seed plate and the vibration upper plate in the horizontal and vertical directions basically meets the requirements. Therefore, when selecting the optimal level of various factors, focus on the horizontal speed of the centre point of the seed plate and the vertical speed of the centre point of the vibration upper plate.

As shown in TABLE V, for the horizontal speed of the centre point of the seed plate and the vertical speed of the centre point of the vibration upper plate, the optimal levels of factors C and D are both level 1, and the optimal levels of E and G are both level 2. At the same time, the speed difference between the centre point of the seed plate and the vibration upper plate in the horizontal direction and the vertical direction also meets the requirements, so it is determined to be the optimal level of the simulation tests C, D, E, and G, that is, the length of the connecting spring is 38 mm, the inclination angle of the main vibration spring is 62°, the rigidity of the rear leaf spring is 35080N/m, and the inclination angle is 66°. For the two indexes of the horizontal speed of the centre point of the plate and the vertical speed of the centre point of the vibration upper plate, the optimal levels of factors A, B, and F are all 1 or 3.

Therefore, there are three options for the selection of the optimal levels of these three factors : (1) In order to meet the requirements of the two indexes of the horizontal speed of the centre point of the seed plate and the vertical speed of the centre point of the vibration upper plate at the same time, the middle level 2 is taken as the optimal level of factors A, B and F, that is, the stiffness of the connecting spring is 634 N/m, the height is 38mm, the stiffness of the main vibration spring is 57600N/m; (2) Select the optimal level of factors A, B and F according to the horizontal speed of the centre point of the seed plate, that is, the stiffness of the connecting spring is 228 N/m, the height is 52mm, the stiffness of the main vibration spring is 45648 N/m; (3) Select the optimal level of factors A, B, and F according to the vertical velocity of the centre point of the vibration upper plate, that is, the stiffness of the connecting spring is 1242 N/m, the height is 23mm, and the stiffness of the main vibration spring is 70188N/m.

4.5 Comparison of Virtual Prototypes under Three Optimization Schemes

In the above analysis, three different plans have been drawn. In order to compare the advantages and disadvantages of the virtual prototypes built under the three plans, modal analysis and simulation tests need to be conducted on these three virtual prototypes to see if the indexes meet requirements.

The natural frequency of each virtual prototype is obtained through modal analysis: plan 1, 34.2 Hz; plan 2, 27.1 Hz; plan 3, 54.6 Hz. Because the natural frequency of the virtual prototype is preferably between 20 Hz and 40 Hz, too small or too large will affect the discharge of seeds, so plan three will not be considered [14]. The test results of plan 1 and plan 2 are shown in TABLE VI.

It can be seen from the data in TABLE VI that the difference in the horizontal and vertical speeds of the vibration upper plate and the seed plate in scheme 2 reached 54.88mm/s and 30.30mm/s respectively. If the difference is too large, the buds of the germinated seeds will be

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damaged; The simulation results of scheme 1 have met the requirements of the main indexes and reference indexes, so scheme 1 is the better scheme, that is, when the stiffness of the connecting spring is 634N/m, the height is 38mm, and the length in the X direction is 38mm; when the stiffness of the main vibration spring is 57600N/m, and the inclination angle is 62°; when the stiffness of each rear leaf spring is 35080N/m, and the inclination angle is 62°, the seeding of the seeding apparatus is relatively uniform and is not easy to be blocked, and the working performance of the rice seeding machine meets the agronomic requirements.

TABLE VI. Simulation test results of different schemes

Test index	Speed of Seed plate centre V_1(mm/s)		Speed of vibration upper plate centre V_2(mm/s)		Displacement of seed plate centre S_1(mm)		Displacement of vibration upper plate centre S_2(mm)		Difference between V_1 and V_2 (mm/s)		Difference between S_1 and S_2 (mm)	
Test number	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction
Plan1	30.1	18.4	12.4	7.70	0.24	0.17	0.14	0.07	36.07	13.79	0.10	0.10
Plan 2	47.12	33.20	8.49	5.23	0.60	0.42	0.12	0.08	54.88	30.30	0.48	0.34

V. CONCLUSION

In this paper, the virtual prototype technology and orthogonal test method are used to optimize the structural parameters that affect the overall performance of the seeding apparatus system. The research results show that: (1) When the stiffness of the connecting spring is 634N/m, the height is 38mm, and the length is 38mm; the total stiffness of the main vibration spring is 57600N/m and the inclination angle is 62°; when the total stiffness of the rear leaf spring is 35080N/m and the inclination angle is 66°, the seeding of the seeding apparatus is relatively uniform and is not easy to be blocked, and the performance of the direct seeding machine meets the agronomic requirements; (2) The virtual prototype technology based on ADAMS and orthogonal test method are used to optimize the structural parameters of the electromagnetic vibration seeding apparatus, compared with the empirical method and physical test method that have been used all the time. It can simplify the research process, shorten the research time, reduce the research cost, improve the research efficiency, and can provide a useful reference for the use of virtual prototype technology for other agricultural machinery research.

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