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Review

Brief Review of Minimum or No-Till Seeders in China

Shan Jiang, Qingjie Wang *, Guangyuan Zhong, Zhenwei Tong, Xiuhong Wang and Jing Xu

College of Engineering, China Agricultural University, Beijing 100083, China; m13324090855@163.com (S.J.); zgydmail@163.com (G.Z.); tongzhenwei917@163.com (Z.T.); s20203071278@cau.edu.cn (X.W.); xujing_xx@163.com (J.X.)
* Correspondence: wangqingjie@cau.edu.cn

Abstract: Minimum or no-till seeding technology is the core of conservation tillage, which can effectively reduce soil degradation by water and wind erosion. It is an essential part of agricultural modernization. The anti-blocking technology is the key to realize minimum or no-till seeding technology. According to the principle, it can be divided into three types: straw-flowing type, gravity-cutting stubble type, and power-driven type. Emphasis is placed on the anti-blocking principle, technical characteristics, and development trends of minimum or no till seeders based on three different anti-blocking principles. In view of analyzing and summarizing the advantages and disadvantages of three technologies and typical machines, the future development trends of minimum or no-till seeders were prospected as follows: (1) strengthening research on basic theories and integration mechanisms; (2) building a big data-sharing platform for seeding operations; (3) establishing and improving specific systems of minimum and no-till seeders with China character.

Keywords: conservation tillage; minimum or no tillage; seeders; anti-blocking technology

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1. Introduction

The fundamental difference between conservation tillage and conventional tillage is that the soil surface is not plowed and covered with many residues, and seeding operations are carried out on the residue-covered land [1]. Minimum or no-till seeding technology is the key to the implementation of conservation tillage technology. Long-term data monitoring confirms that minimum or no-till seeding operations have a positive effect, which can effectively reduce soil erosion by wind and water, expressively ameliorate soil microbial communities' composition, and improve soil's ability to fix nitrogen and carbon [2–7]. It is a modern planting technology that revolutionizes the planting system and realizes the sustainable development of agriculture [8]. In the areas where the minimum or no-till seeding technology is implemented, due to poor surface flatness and a great quantity of straw residue covering, the trafficability of machines cannot be performed excellently. In addition, the tillage tool is easily entangled by grass and blocked by straw piles, affecting the quality of seeding and the effect of seedling emergence. Therefore, an effective anti-blocking mechanism matters to the efficient implementation of minimum or no-till seeding technology.

At present, countries that implemented conservation tillage earlier are more focused on the study of the benefits of conservation tillage [9–12]. The United States is the first country in the world to implement conservation tillage. The mature system of conservation tillage machines has been formed. The famous agricultural machinery production companies have been established, such as Caseih [13], John Deere [14], and Maschio [15]. However, multi-beam structures are the main way for the foreign minimum or no tillage seeders, which are not suitable for domestic agronomic requirements. In recent years, the research on the minimum or no-till seeding in China has mainly focused on anti-blocking technology and developed a series of anti-blocking devices with environmental adaptability. On this basis, theoretical innovation and structural optimization are carried out. This paper expounds on the three anti-blocking principles and research status of the straw-flowing type of minimum or no-till seeders, gravity-cutting stubble type of minimum or no-till seeders, and power-driven type of minimum or no-till seeders, and typical machines are listed. Under the development of technology and machines, the minimum or no-till seeders are summarized and analyzed. Finally, this review points out the development directions of the minimum or no-till seeders in the future.

2. Minimum or No-Till Seeding Anti-Blocking Technology and Machine

The central part of minimum or no-till seeding is anti-blocking technology, ensuring that the tools can smoothly ditch on the ground covered with straw mulch. The seeds are fully contacted with the soil to absorb nutrients, and solve the distribution of seeds reasonably in the field. As a result, the level of soil fertility can be guaranteed to keep consistent with the standard required for the growth of crops at various stages to create good conditions for crop growth [16]. Since the 1960s, experimental research on the minimum or no-till seeding has been carried out in China [17]. After decades of research and development and promotion, the application area of minimum or no-till seeding shows a rapidly expanding trend. As of 2018, it has reached 8242 kha, an increase of about 810% compared to 2002 (Figure 1). The promotion of minimum or no-till seeding technology and the process of agricultural mechanization have been expressively accelerated.

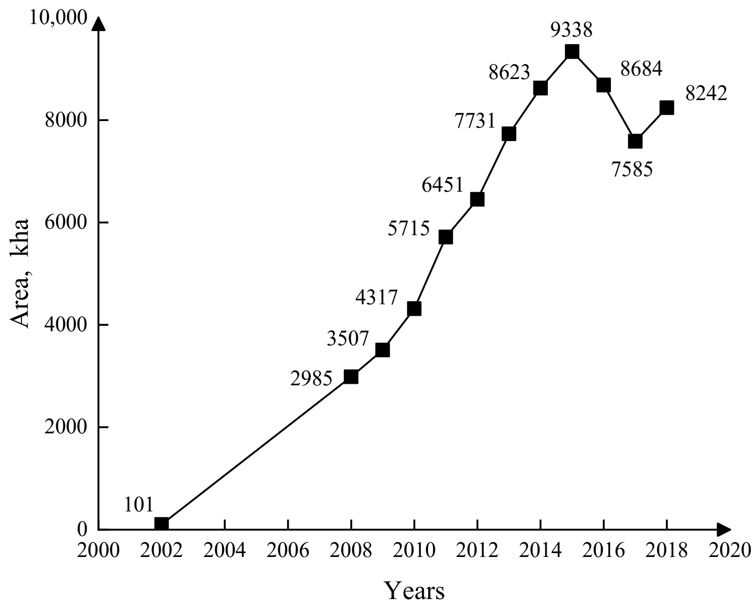


Figure 1. Application trend of minimum or no tillage in China (Data resources: *Annual Report of National Agricultural Mechanization Statistics* [18]).

Due to the particularity of the application of the technology, the soil volume is large, and moisture content is high, and the surface residues are much more [19]. Furthermore, with the implementation of minimum or no-till seeding technology, the ditching and anti-blocking performance of the machine is required to be compatible with different treatment methods for straw in the field. Hence, it is the main and challenging point to improve the anti-blocking performance of the machine effectively. According to the mechanical structure characteristics and the anti-blocking principle of seeders, and the classification of anti-blocking devices, the machines are divided into straw-flowing type, gravity-cutting type, and power-driven type.

2.1. Straw-Flowing Anti-Blocking Technology

The principle of the straw-flowing anti-blocking technology is to expand the straw-flowing space, generally by increasing the ground clearance, adopting a multi-beam structure, or enhancing the straw fluidity devices, such as rollers, grass dividers. The stubble is easy to accumulate between the adjacent working parts of the seeder. When the instantaneous straw amount is larger than the minimum space formed between adjacent tillage parts, the clogging degree of the seeder will be affected by the amount, length, and decay of straw [1]. The principle of increasing the ground clearance is to extend the distance between the opener and the ground in the vertical direction. The principle of adopting a multi-beam structure is to increase the distance between the two adjacent openers on the beam of the seeder in the horizontal direction. The straw-flow enhancement device is installed in front of the opener or in the area prone to block. The compactness of this seeder depends on the arrangement of beams and openers and the design of the reinforcement device. It is primarily applied in areas of one crop a year, such as the Northeast Plain.

At the beginning of the implementation of minimum and no-till seeding technology in China, the first idea was straw-flowing anti-blocking technology. The Conservation Tillage Research Center in China [20] designed a double beam wheat no-till fertilizer seeder arranged in front and back of the trenches (Figure 2), with 40 cm long between the front and rear beams, ensuring sufficient straw-flowing space between the openers and improving the anti-blocking performance. At present, on account of the current situation and development needs of Chinese arable land, domestic scholars have done less research on the straw-flowing machine, and it is more common to design and install grass dividers and rollers on machines. Liu et al. [21] designed a new corn no-tillage precision seeder, of which the grass divider with involutes tooth structure was hung before the ditching disc. It can effectively remove weeds and straws from the seedling belt and effectively prevent the opener from being clogged and the seed spilling on the straw. In addition, based on the advantages of straw-flowing anti-blocking technology, other auxiliary devices were mainly innovated to enhance the straw fluidity and make the anti-blocking performance of the machine more superior. Gao et al. [22] designed a rotary drum-type anti-blocking mechanism with the parabolic drum. The drum was installed in front of the opener and rotated forward at a certain speed to continuously separate the straw in front of the opener and pull it away to both sides of the opener. The simulation experiment showed that the drum parameters were 1.24-speed ratio and 150 mm diameter, which met the requirements of dividing grass.

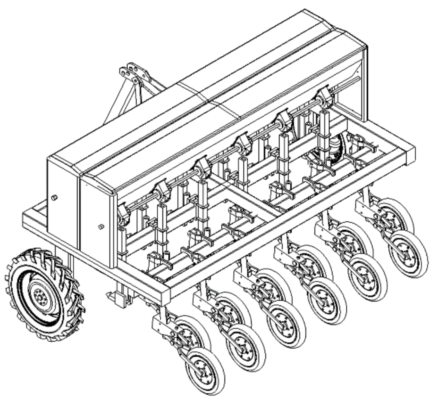


Figure 2. Schematic of a double beam wheat no-till fertilizer seeder.

The auxiliary anti-blocking devices were manufactured to attempt to improve the straw fluidity in China. For example, the rollers were used as a fluidity-enhancing device on Huinong 2BJFG-4 no-tillage fertilization precision seeder [23] (Figure 3a). Both seeding depth and fertilization depth were adjustable. The seeding row spacing is 400–600 mm, the maximum operating speed is 8 km/h, the working width is 160–240 cm, and whole machine weighs 290 kg. The front-mounted residue-throwing wheel was installed on Zhaofeng 2BFM-2 no-tillage fertilizer seeder [24] (Figure 3b). It is convenient to break soil and adjust the depth of fertilization with the double-disc opener. The seeding row spacing is 400–700 mm, the number of working rows is two, and the whole machine weighs 1000 kg.

(**a**) (**b**)

Figure 3. Examples of typical machine. (**a**) Huinong 2BJFG-4 no-tillage fertilization precision seeder [23]. (**b**) Zhaofeng 2BFM-2 no-tillage fertilizer seeder [24].

Satisfactory anti-blocking performance is showed in the demonstration application of the straw-flowing type of minimum or no-till seeders. However, the acreage per capita cultivated land is small in China, and the planting area is mainly composed of small plots. The structure of the machine is too large to adapt to the requirements. Due to the lack of research on the relationship between straw and contact parts, it is not suitable for the working environment with a large amount of straw on the surface. Thus, it is not easy to promote and implement comprehensively.

2.2. *Gravity-Cutting Stubble Anti-Blocking Technology*

The principle of the gravity-cutting anti-blocking technology is to use a disc opener, which relies on its own gravity to exert positive pressure on the ground and rotates at high speed while cutting and ditching operations (Figure 4). The trafficability of seeders working on the straw-covered land can be improved, and the rate of seeds on the surface and missed seeding can be reduced markedly. Because of the anti-blocking performance of the machine, it is suitable for the field environment with less straw coverage than usual. It is characterized by simple structure, low cost, heavy weight, and high soil compaction. There is a long fallow period in areas of one crop a year in China. After a certain degree of decomposition, the moisture content and toughness of straw are expressively reduced and cut off simply. Given these features, it is widely used in this area.

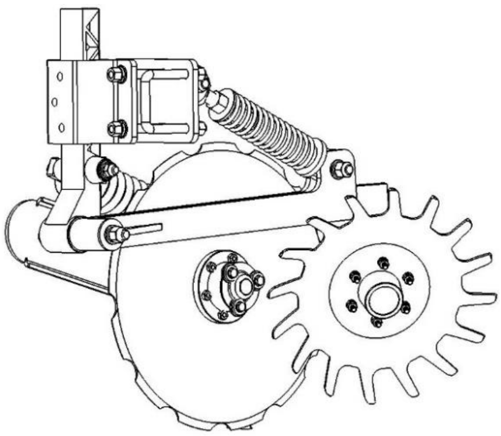


Figure 4. Schematic of row cleaner with side cutter and stubble clean disk [25].

According to the structural characteristics of the disc opener, the working principle and typical machine of flat discs, ripple discs, and notched discs are explained.

The working principle of the flat disc (Figure 5a) is that the disc is driven by a shaft rotating at high speed. It is in point contact with the surface of the working soil and exerts an enormous pressure on the residue to cut the straw. Subsequently, the quality of ditching and sowing can be ensured. The anti-blocking performance of straw cutting will be affected by the diameter of the disc, the cutting speed, and the working deflection angle [26]. When the depth and diameter of the disc into the soil are constant, the force of the flat disc on the straw can be improved by a proper working deflection angle to increase the straw cutting rate.

(**a**) (**b**) (**c**)

Figure 5. Types of discs. (**a**) Flat disc. (**b**) Ripple disc. (**c**) Notched disc.

Corrugated grooves are distributed on the ripple discs [27,28] (Figure 5b). The working principle is that under the power traction, it relies on gravity and spring to open ditch and cut stubble. The swing in the soil is conducive to breaking the soil and accelerating the decomposition rate of straw. In the case of a certain depth of soil, the cross-sectional profile of the furrow will be influenced by the width of the corrugated disc cutter and the number of corrugations directly. The side surface area of the disc in contact with soil and the blade length of cutting soil and stubble are larger than those of the plane disc [29,30].

The notched disc [31] (Figure 5c) is derived from the flat disk, which is cut out according to a certain number and shape at the edge of the disk. The shape of the cutting edge can be divided into sliding knife shape and arc shape. The working principle is that the disc moves forward with the machine driven by the power. While rotating, the edge gap is used to get the surface straw pressed and cut the stubble smoothly. As a result, the straw slippage can be inhibited, and the blocking performance is improved. The forward resistance of the disc is affected by the cutting-edge angle, edge type, and quantity of notches. The performance is shown that the less the number of disc cutter notches, the more excellent the forward resistance, and the more inferior straw cutting effect.

Table 1 summarizes advantages and disadvantages of the above three types of discs. Among them, notched discs are widely used because of the better anti-blocking performance.

In recent years, domestic scholars have made theoretical innovations for minimum or no-till seeders based on the gravity-cutting anti-blocking technology. In addition, relevant experimental optimizations on the structure have been carried out to improve trafficability. Lin et al. [32] optimized the notched disc knife based on the Archimedes spiral theory and designed the stubble breaking ditching device and stubble breaking anti-blocking device, which were up to the requirement of agricultural technology. Wang et al. [33] designed an asymmetric large-small double-disc ditching device for corn seeding. The two discs were arranged asymmetrically. Results of field experiments showed that the device could realize relatively stable and reliable ditching effect. Wang et al. [34,35] designed a concave disk row cleaners with a star-tooth of straw cleaning device. Through analyzing a kinematic pattern of straw particles at the surface of the disc row cleaner during the operation, the main structural parameters affecting the operational quality of the row cleaners were clarified. Furthermore, based on the concave disk, he put forward an automatic width control system by using an S-type pressure sensor and an electric linear actuator. The system monitored the pressure of the row cleaners on the soil and adjusted its depth into the soil in real-time, which effectively improved the stability of the width. Table 2 shows the key anti-blocking device of the above studies.

Table 1. Performance comparison of three types of discs.

Disc Type	Advantages	Disadvantages
Flat disc	1. Smooth edges and simple structure [26]. 2. Reduce the resistance of ditching, and the soil disturbance is small [26,28].	Low straw cutting rate under high-strength soil and high straw quantity environment [28,29].
Ripple disc	1. Edge corrugation can improve the loosening effect of the machine [29,31]. 2. Straw fluidity enhancement [29].	Compared with a flat disc, the greater disturbance to the soil is shown under the same conditions, and the higher material technology levels are required [29,31].
Notched disc	1. The straw can be fixed by the notches on the edge, and the straw cutting effect is good [31]. 2. Enhanced penetrability [31].	Greater traction, complex processing technology, and high production cost are required [29,31].

Table 2. Key working units of gravity-cutting anti-blocking minimum or no seeders.

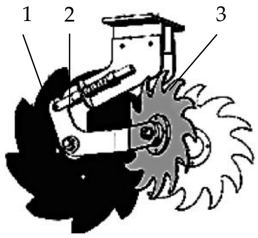
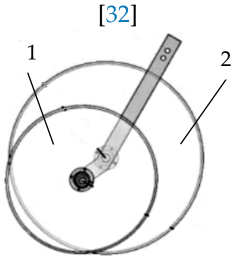
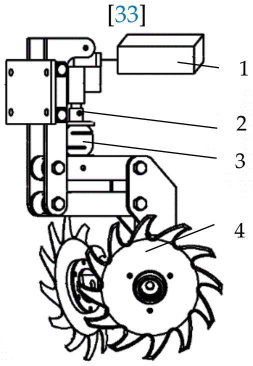
Anti-Blocking Device	Structure	Structural Composition	Features
Residues break and anti-blocking device [32]	 [32]	1. Nine tooth broken stubble plate 2. Double arm lever 3. Stubble clean plate	The stubble cutting resistance of the device is small, and the machine mass is reduced. The ridge shape is maintained while avoiding the formation of new furrows.
Asymmetric large-small double discs ditching device [33]	 [33]	1. Small disc 2. Double arm lever	The straw is cut by the large disc in advance, and the seed furrow is cleaned by the small disc. A stable effect of ditching operation can be achieved under the condition of the medium corn straw mulching.
Star-toothed concave disk row cleaners [34,35]	 [34,35]	1. Automatic width controller 2. Electric linear actuator 3. S-type pressure sensor 4. Star-toothed Concave 5. Disc	Each star tooth is cut in sequence to ensure the stability of the working depth. Its performance is better than that of the flat claw wheel type anti-blocking device. The leakage area between the straw cleaning discs can be eliminated by the two discs. The working width can be controlled and adjusted in real time.

Table 3 shows part of gravity-cutting anti-blocking minimum or no seeders in China.

Table 3. Part of gravity-cutting anti-blocking minimum or no seeders.

Disc Type	Seeder Type	Structure	Technical Characteristics
Ripple disc	Dongfanghong 2BMQZ-2 trailed finger clip no-tillage seeder [36]	 [36]	The machine adopts reinforced seeding unit, metal finger-clamp type seed metering device and powerful spring. An intelligent monitoring system is used to monitor the seeding quality in real time. Working row spacing is 400–700 mm (adjustable), using double disc opener, working speed varies from 6–10 km/h.
	DEBONT 2BMG-4 (1405-Z) no-tillage precision seeder [37]	 [37]	The machine adopts the rippled disc used to loosen the soil and break the stubble. It is equipped with a two-way involute tooth type grass divider, an upper double-side synchronous transmission mechanism, and a six-in-one monitor. The operating speed ranges from 6–8 km/h.
	Mu Shen 2BMF-20 split type no-tillage fertilizer seeder [38]	 [38]	The machine adopts a central pivot suspension structure to connect the turbo ripple disc stubble-breaking mechanism with the seeder matched with a high-power tractor. It is suitable for arid and semi-arid areas, which stubble-breaking ditching, sowing, fertilizing, soil covering, suppression, and other functions can be completed at one time. Working width ranges from 3.81–4.57 m.
Notched disc	Jilin Kangda 2BMZF-6 no-till finger clamp precision fertilizer seeder [39]	 [39]	The machine adopts double discs and notched discs used for ditching and breaking the stubble. The positive pressure ranges from 400–900 N and the seeding row spacing is 400–650 mm. The whole machine weights 1400 kg, and the number of operating rows is 2–6.

Compared with the straw-flowing type of seeders, the gravity-cutting anti-blocking minimum or no-till seeders have a broader scope of application. Combined with automatic control technology, a complete set of mechanical and electrical integration systems of minimum or no-till seeders has been initially established, which is compatible with agricultural machinery and agronomy. However, due to the reliance on gravity, straw clogging still occurs on condition that the amount of straw is too large, which is not suitable for all-regional applications. Moreover, the dynamic operation data in the seeding process has not yet been fully integrated. The realization of interconnection and sharing of seeding operation information is delayed.

2.3. *Power-Driven Anti-Blocking Technology*

Unlike the passive stubble-breaking and anti-blocking method, the core of the power-driven anti-blocking technology is to actively prevent the aggregation and accumulation of stubble around the opener from the source. Generally, cutting, throwing, crushing, and other methods will be adopted to avoid straw entanglement and stacking. The anti-blocking components of this seeder are directly driven by the engine power. It has the advantage that a large amount of straw can be actively cut rapidly. The trafficability and the anti-blocking performance superior. The disadvantage is the high power consumption, operating cost, and soil agitation rate. Because of these factors, this seeder is mainly used in areas of double-crop a year in China, such as Huanghuaihai Plain, the middle and lower reaches of Yangtze River, and North China Plain.

Domestic scholars have done numerous studies on power-driven minimum or no-till seeders. Moreover, considering the regions of crop growth determined by the distribution of domestic unique planting systems and the reasonable working conditions of the machine, this type of seeders is mainly used to process corn straw and wheat straw covering the ground in China. Combining the physical characteristics of the two types of straws in different periods and the interaction between the straws and the anti-blocking mechanism, from the perspective of power-driven and the movement state of the straw during the operation, researchers innovated the mechanical structure of the anti-blocking device and developed the design optimization.

Based on the supporting straw-cutting mechanism, Wang et al. [40] introduced a mixed type and grid-guided hob straw chopping device, which provided a mechanical structure design idea with supported cutting straw. Zhao et al. [41] designed a supported roll-cutting type anti-blocking device with both active and passive horizontal rotating parts. The Design-Expert software and field tests showed the optimal operational parameters, including the combination of the rotating speed and the turning radius for active rotating blade and passive rotating blade. Lu et al. [42,43] designed a new anti-blocking device of rotary cutting with slide plate pressing straw taking characteristics of passive and active anti-blocking devices. Motion Simulation Analysis by Creo Parametric was conducted to explore the regularity of rotary blade accelerations. The coefficient of friction between slide plate and straw and the coefficient of friction between soil and straw are the main problems of whether the straw can pass through the device. After testing the coefficient of friction between four kinds of slide plate and straw and the coefficient of friction between three kinds of different soil moisture, the result showed that Q235 steel was suitable for maize straw, and stainless steel was suitable for wheat straw. Table 4 shows the key anti-blocking device of the above studies.

Table 4. Key working units based on the supporting straw-cutting mechanism.

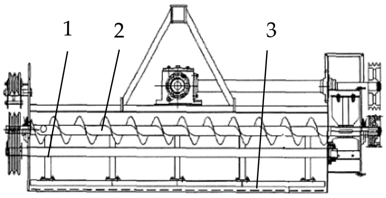
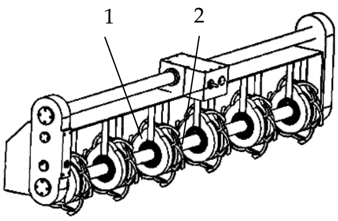
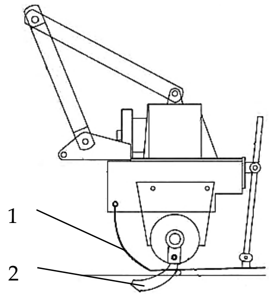
Anti-Blocking Device	Structure	Structural Composition	Features
Hob field straw chopping device [40]	 [40]	1. Hob 2. Screw conveyer 3. Stationary knife	This machine is limited to cotton straw. The problems of large power consumption, dust and bad working condition are solved.
Supported roll-cutting anti-blocking mechanism [41]	 [41]	1. Passive horizontal rotating parts 2. Active horizontal rotating parts	The machine is designed for cutting corn residues effectively. Compared with the unsupported anti-blocking device, the cut-off rate is higher, and the power consumption is more minor.

Table 4. *Cont.*

Anti-Blocking Device	Structure	Structural Composition	Features
Anti-blocking device of rotary cutting with slide plate pressing straw [42,43]	 [42,43]	1. Slide plate 2. Rotary cutter	The cutting speed is low. The safety performance of the device is guaranteed. The trafficability of the machine is improved.

Based on the operating principle of active straw-cutting, Shi et al. [44] designed a new type of trapezoidal combination cutterhead, avoiding blockage of the opener, hybrid of grass and soil, and hybrid of dry and wet soil. The test showed that when the stalk cover rate was less than 1.2 kg/m^2, the coefficient of grass and soil separation was 95%, coefficient of dry and wet soil separation is 91.7%. Wang et al. [45] designed the blade sawing star style no-till seeder for wheat. It was driven by star gear type blades to cut off straw and stubble on the surface. Field tests showed that the machine could solve the residue entangling and blocking effectively. Yu et al. [46] designed a spiral-split sowing strip cleaning device. The cut straw was transported to both left and right sides under the action of the stubble cleaning knife arranged in a spiral. The sowing strip straw removing rate was 92.55% with the optimal combination of parameters. Based on the principle of straw shifting and anti-blocking, Zhu et al. [47,48] put forward an active stalk-to-line cleaning non-tillage direct seeding technology and designed a vertical surrounding active driving device. The field experiments showed that the machine seeded smoothly under the condition of straw mulching with 1.5–2 kg/m^2, and the straw removal rate of the row reached 87.91%. Table 5 shows the key anti-blocking device of the above studies.

Table 5. Key working units based on the operating principle of active straw-cutting.

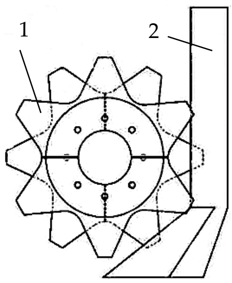
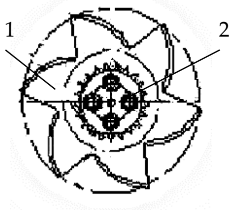
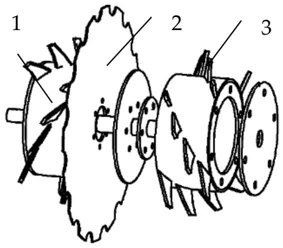
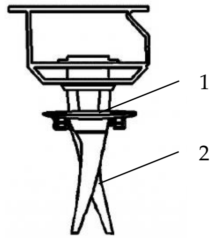
Anti-Blocking Device	Structure	Structural Composition	Features
Mechanism for broken stubble blockades [44]	 [44]	1. Trapezoidal combination cutterhead 2. Opener	The straw is cut by a pair of angled trapezoidal cutter, which creates favorable conditions for subsequent seed germination and emergence.
Star-gear blade type of anti-blocking device [45]	 [45]	1. Star-gear blade 2. Axle	The blade is driven by power to cut the straw covering the ground. It has the characteristics of strong sliding ability.

Table 5. *Cont.*

Anti-Blocking Device	Structure	Structural Composition	Features
Spiral-split sowing strip cleaning device [46]	 [46]	1. Double helical roller 2. Notched disc 3. Stubble blade	The straw can be cut and transported to the left and right sides of the seed belt, which is beneficial to the rise of ground temperature and the germination of seeds.
Straw-removing anti-blocking device [47,48]	 [47,48]	1. Rotating cutter head 2. Dual vertical blade	The straw is shifted to one side of the seed bed along the tangent direction of the rotary knife tip. It is suitable for the situation of high stubble of wheat and full amount of straw returned to the field.

Based on the principle of "plowing, shifting and throwing", Zhao et al. [49] designed a strip-tillage inter-row residue side-throwing device with a fixed blade seeding and fertilizing opener and other supporting parts. The field experiment showed that that the seedbed cleaning rate of the device was 82.7% without blocking and entanglement. Fang et al. [50] designed seven types of anti-blocking devices with round roller and claw according to the proportion of claw height accounted of total device's height. The soil bin experiment showed that the optimal working parameters of two-third type were rotation speed of 400 r/min and forward speed of 5 km/h for cutting the straw on Huanghuaihai Plain.

Niu et al. [51] designed a cleaning device on account of Archimedes spirals, which guided the straw to move up along with the outline to the vertical space on both sides of the seedling belt. The experimental results showed that there were no blockage and exposed seeds 7 km/h of forward speed and 600 r/min of rotational speed. The performance is better than that of the previous one. Shi et al. [52] designed a straw crushing and seed-belt classification machine under full straw mulching aimed at rice and wheat rotation regions in the middle and lower reaches of the Yangtze River. The compound operation was completed by the function of power high-speed reverse picking and crushing. Three-factor and three-level orthogonal performance test was carried out to show that the average stubble cleaned rate was 90.54% under optimum parameter combination. Shi et al. [53] designed a stubble prevention device added to the 2BMFJ series of precision seeders developed by Northeast Agricultural University. The experiments showed that the straw removal rate of the bed was 95.5% under the optimum parameters. Chen et al. [54] designed a kind of no-tillage seeder based on air blowing utilizing a fan and shallow rotary knife to blow the straw away. Field experiments showed that the cleaning rate of the straw was 80.55%, and the rate of seeds on the surface was 0.95%. In addition, data monitoring systems for the seeding process has been designed and developed by domestic companies. For example, an intelligent conservation tillage platform has been developed by Jiangsubeidou Technology Company. The operation data can be obtained in real-time, and agricultural machinery operation process management can be completed through the human-machine interface. Table 6 shows the key anti-blocking device of the above studies. Table 7 shows part of power-driven minimum or no-till seeders in China.

Table 6. Key working units based on the operating principle of active straw-cutting.

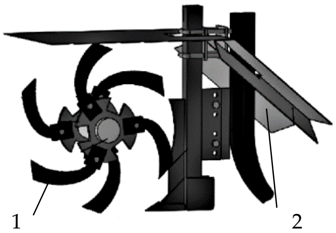
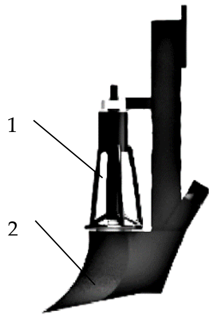
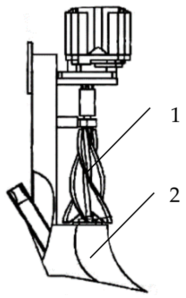
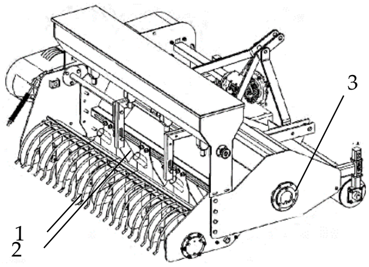
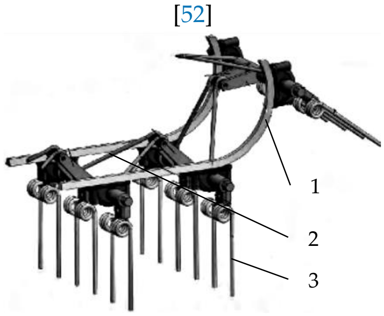
Anti-Blocking Device	Structure	Structural Composition	Features
Strip tillage inter-row residue side-throwing device [49]	 [49]	1. Tilted blade 2. V-type board for soil guidance	A secondary cutting is formed by the tilted blade and the arc-shaped fixed blade. The amount of soil backflow can be increased by the V-type board for soil guidance.
Round roller-claw anti-blocking mechanism [50]	 [50]	1. Round roller-claw 2. Stub-runner opener	The device has an auxiliary guiding effect on the straw at a higher position above the surface, and the lower end of the mechanism can quickly pull out a large amount of surface straw at a relatively high linear speed.
Cleaning mechanism on account of Archimedes spiral [51]	 [51]	1. Archimedes spiral clearing wheel 2. Stub-runner opener	The device guides the stalks to climb, making them rise and stack. It alleviates the local concentration of stalks caused when the stalks are pulled out of the seedling belt in parallel.
Equipment for strawcrushing and seed-belt classification [52]	 [52]	1. Barrier 2. Straw guider 3. Crushing blade shaft	The straw is shifted to one side of the seed bed along the tangent direction of the rotary blade. It is suitable for the situation of high stubble of wheat and full amount of straw returned to the field.
Spring-tooth stubble cleaning device [53]	 [53]	1. Driving belt 2. Spring-tooth angle adjusting rod 3. Spring tooth	The device has the advantages of a small amount of soil tillage and overload protection. While ensuring the quality of stubble removal in the working width, it can effectively reduce the stubble returning.

Table 6. *Cont.*

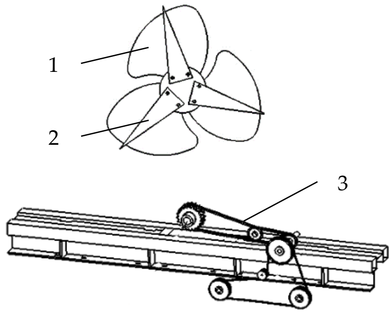
Anti-Blocking Device	Structure	Structural Composition	Features
Gas blowing anti-blocking device [54]	 [54]	1. Fan blade 2. Triangle fork 3. Transmission chain	The device is suitable for covering the land with straw length less than 10 cm after cleaning the stubble. The shallow-rotating stubble knife is combined with a fan to prevent blocking by air blowing.

Table 7. Part of power-driven minimum or no-till seeders.

Device Type	Seeder Type	Structure	Technical Characteristics
Disc + Straw Throwing board	Xinle Xinglong 2BMQF-6/12 full return to field anti-winding no-tillage fertilizer seeder [55]	 [55]	The machine adopts the new technology that a furrow opener is with a guillotine blade. The anti-blocking part adopts the combination of disc serrated blade and grass throwing board, which can realize multiple processes such as side cutting, separation, and furrowing of the straw and rhizome on the planting seedling belt at one time. The operating speed ranges from 2–5 km/h, and the corn plant spacing is 135–269 mm, which can be adjusted in 6 levels.
Rotary Knife	Haofeng 2BXS-12A no-tillage fertilizer seeder [56]	 [56]	The machine adopts full-disc openers and double-row staggered openers to break stubble by rotary tillage. Operations such as rotary tillage, soil cutting, straw chopping, and stubble removing can be completed at one time. The number of operating lines is 12, and the supporting power ranges from 51.5–66.2 kW.
	Dahua Bora 2BMYFC series no-tillage precision seeder [57]	 [57]	The machine adopts a driving rotary seed belt cleaning device, which one operation can complete multiple processes such as seed belt cleaning, fertilization under the seed side, precision seeding, and suppression. A newer independent profiling mechanism is installed on both the seeding legs and the suppression wheel, equipped with a precision seed metering device of the finger-clamp type.

Table 7. *Cont.*

Device Type	Seeder Type	Structure	Technical Characteristics
Spindle-through shaft type anti-wrapping auger mechanism	Hebei Nonghaha 2BYFSF-4 power anti-wrapping corn no-tillage fertilizing seeder [58]	 [58]	The machine adopts a shovel opener, which grain-like fertilizers can be applied in a row. The processes of ditching, fertilizing, and planting can be completed at one time. The plant spacing is adjustable from 80 to 360 mm. The row spacing is 600 mm, and the supporting power is from 29.4 to 58.8 kW.

Compared with the former two types of seeders, this kind of seeder has the power to directly drive the straw cutting, which can be applied to the situation with heavy straw. However, the research on the mechanism of machinery in the field working environment is still not dived deeply. At present, an automatic control system for stand-alone operations has been initially formed in China. The seeding process will be realized by the monitor, and the operation data will be uploaded to the cloud platform. Nevertheless, the data circulation chain has not yet been established between the various platforms leading to the lack of support for theoretical development. In such cases, the planting equipment system has not been completely formed.

3. Discussion

In recent years, minimum or no-till seeders have developed rapidly in China. In addition, differing from the anti-blocking technology mentioned above, some scholars have put forward new methods for stubble and straw cutting based on other anti-blocking principles to provide ideas for improving the trafficability of machines. The following is an example of a non-connect stalk cutting by the ultra-high-pressure waterjet method proposed by Hu Hongnan [8]. Inspired by the new industrial waterjet cutting technology, the researcher developed a new anti-blocking device through dynamic analysis, ALE-FEM simulation, and high-speed camera by applying existing theoretical methods and technical means (Figure 6). Field tests showed the device had a low disturbance rate and no blocking, which effectively cutting corn stalks.

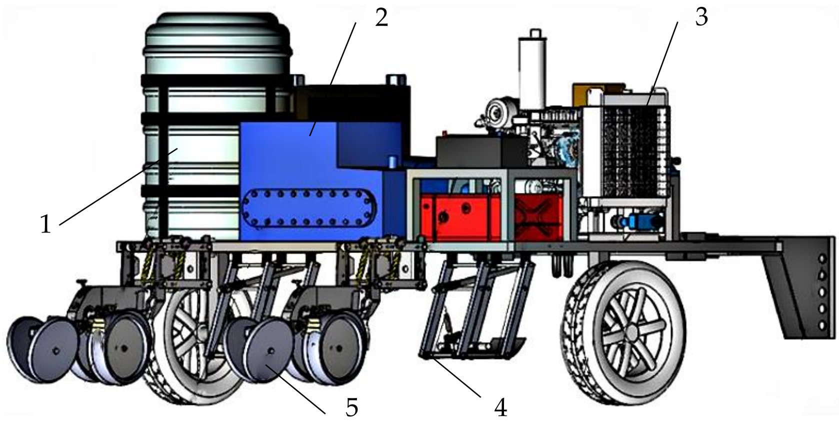


Figure 6. Schematic of ultra-high pressure water jet cutting stalk anti-blocking device [8]. (**1**) Water tank. (**2**) Hydraulic tank. (**3**) Diesel engine system. (**4**) Cutting execution system. (**5**) Opener unit.

However, based on the analysis of the current research status of minimum or no-till seeders, there are still some problems in this field in our country in China. Most of the studies are focused on the structural design and performance improvement of the anti-blocking device. By integrating the advantages of different anti-blocking technologies, better anti-blocking performance has been achieved successfully by the innovative optimization design in the specific field environment. Due to insufficient and immature research on the flow properties of straw and the interaction between straw and machinery during operation, it is difficult to make breakthroughs in technical principles. Additionally, anti-blocking devices perform poor generality in the application, which the machines have not been entirely universal on different crops and different operating conditions. Few studies are conducted on the agronomic process under minimum or no-tillage and the changes of soil biological characteristics under different operation modes. The lack of long-term monitoring data also matters seriously [59–62]. At present, intelligent systems have formed initially, such as seeding quality inspection, seeder trajectory traceability, and tillage depth control. Operation quality detection system has still not developed perfectly. The seed-dropping situation can only be detected probabilistically, while the soil data under the operation cannot be transmitted in real time, and the seeding process cannot be controlled in a closed loop. However, much more limited, and controversial problems exist about the application of minimum or no-till seeders. As a result, the actual production conversion rate of the machine is restricted severely. Hence, it is urgent to improve the consistency and coordination between technical research and machine application.

4. Conclusions and Prospect

Minimum or no-till seeding technology is a modern farming technology that occupies an essential strategic position in the continuous promotion of agricultural rationalization development in China. For the past many years, researchers have been committed to promoting the technology. The minimum or no-till machine is the core of this technology and primary equipment for the green development of China's agriculture. The anti-blocking technology is the crucial and challenging point in the application of the seeders. Based on the status of minimum or no-till seeders in different forms in China, the future development directions for minimum or no-till machines are proposed in order to enhance the core competitiveness of agricultural machinery and equipment. The cost-saving, efficiency, and sustainable development of China's agriculture will be realized in this way.

4.1. Strengthening Research on Basic Theories and Integration Mechanisms

Minimum or no-till seeding technology requires that the machine has high-efficiency anti-blocking performance, determining whether the technology can be effectively implemented. In the future, in addition to stepping up efforts on machine structure research, it is also necessary to strengthen the relationship between straw and soil and research on changes in soil physical and chemical properties under long-term minimum or no-till seeding conditions to improve anti-blocking performance. An extensive and comprehensive theoretical basis should be developed deeply, providing clear guidance for the design of machinery.

4.2. Building a Big Data-Sharing Platform for Seeding Operations

Smart agriculture is one of the pioneering trends of China's agriculture. Therefore, the optimization of a single machine can no longer meet the needs of current planting operations. When miss-seeding, reseeding, and inconsistent tillage depth occur, the status parameters of crop seeds in the soil, the flowing status of surface straws, and the working parameters of the working parts need to be monitored during minimum or no-till seeding working process. Based on modern technology, informatization, and visualization of the seeding process are crucial means to improve the seeding quality. The navigation technology and image processing technology should be used to collect the operational data and field environment parameters of the minimum or no-till machine, which are uploaded to the integrated data space to form a large domestic database for subsequent analysis. The information-sharing platform of sowing operation will be built to provide data support for the research of anti-blocking machines and the formation of appropriate agronomic modes, and technical support for the intelligent optimization and automatic control of sowing machines and the development of intelligent agriculture.

4.3. Establishing and Improving Specific Systems of Minimum and No-Till Seeders with China Character

China has been committed to independently research the minimum or no-till seeders suitable for the China's agriculture development. As a result, a series of types of machines compatible with regional agronomic requirements have been initially formed. However, due to complex and diverse planting areas, the regional differences determine the planting systems and agricultural technical requirements of different crops and regions, so the planting methods are also adapted to local conditions at the regional scale. It is urgent to establish and refine specific systems of minimum and no-till seeders with China character. The integration of agricultural machinery and agronomy should be strengthened. Modern technology must be utilized sufficiently to develop and form an organic and unified whole of sowing operation with high standardization, strong universality of sowing mode, and large data abundance.

In short, China's minimum or no-till seeders are gradually meeting the requirements of regional adaptable agronomic operations. The research on anti-blocking technology is continuously deepening, with independent and innovative design capabilities. The agricultural mechanization has begun to scale, and high-end technology research still has potentially infinite space. It is the inevitable trend to strengthen basic theoretical research, couple different mechanisms, and internal effect mechanisms. There is also a need to build a complete agricultural data link and take the road of intelligent agricultural development. Under multi-level and high-level integrated development, an agricultural mechanization system with Chinese characteristics could be built gradually; and thus, domestic agricultural machinery will be promoted in the direction of intelligent, informative, and environmentally friendly green development.

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