Performance of waterjet on cutting maize stalks:
A preliminary investigation

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Abstract: Large amounts of crop stalks left in the field as a result of conservation agriculture cause blockage during no-till planting. To solve this issue, pure waterjet was used to cut off the maize stalks so that the rear furrow opener could pass through without blockage. In this investigation, an experimental study on depth of cut, which was the main performance indicator of pure waterjet on cutting maize stalks, was presented. A full factorial design with 200 tests was implemented with respect to three operation parameters, that is traverse speed, waterjet pressure, and standoff distance were considered as variables. An analysis of variance (ANOVA) was carried out in order to determine the statistical significance of individual operation parameters. Using multilinear stepwise regression analysis, a model to predict the cut of depth from the predicted pure waterjet operation to cut maize stalks was then developed. All three operation parameters significantly influenced the cutting performance. Moreover, the results indicated that depth of cut increased with the increase of waterjet pressure, the decrease of traverse speed, and decrease in standoff distance. Waterjet pressure provided major contribution to depth of cut, followed by traverse speed, then standoff distance, which was demonstrated by both ANOVA and regression analysis. The experimental results showed that when the standoff distance was closer than 10 mm and waterjet pressure was 280 MPa, all maize stalks specimen could be cutoff thoroughly. With the consideration of field operating conditions, waterjet pressure of 280 MPa or higher and 10 mm to 15 mm standoff distance were recommended for maize stalks cutting. This analysis provided a realistic approach for the optimization of the ultra-high pressure pure waterjet parameters in maize stalks cutting, which could be used to relieve the occurrence of straw blockage in no-till planting.

Keywords: waterjet, ultra-high pressure, conservation tillage, maize stalks, cutting, traverse speed, standoff distance
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1 Introduction

Conservation agriculture (CA) advocates no or minimum soil disturbance, biomass mulch soil cover, and crop species diversification in agricultural practices[1]. CA is capable of mitigating the concerns of land resource degradation, as well as reducing the contribution to climate change by reducing greenhouse gas emissions and contributing to carbon sequestration in soil. Thus, one of the key operations of CA is no-till direct seeding on biomass mulch cover land, which consequently creates higher demands on seeding machinery[2,3]. In the North China Plain, the most popular cropping system is to grow two successive crops[4], maize as summer crop and wheat as winter crop, within

the same year. Winter wheat should be directly drilled into the stubble of summer maize. Furrow opener could affect soil bulk density, cone index, sowing performance, and seed emergence[5,6], thus the performance of furrow opener of a no-till seeder for winter wheat has great influence on crop growth. To ensure sufficient a growth period, wheat must be seeded immediately after maize harvesting. However, a large amount maize stalks/residue is relatively fresh and hard to cut following the maize harvest. This poses a dilemma in the summer maize and winter wheat cropping system, such that large amounts of maize residue could cause plugging of furrow openers and metering devices[7].

To tackle the dilemma, researchers designed several kinds of furrow openers or anti-blocking devices with different working principles. Rolling coulter was used on seeders to clean the seedbed before the furrow opener engages soil[8] Also, double discs furrow opener are designed to improve the ability of soil penetration and residue cutting[9]. Coulters are the least intrusive yet effective vertical tools to slice soil and cut residue[10]. Despite this, coulters are large in diameter and the vertical cutting force is mainly provided by gravity, which means seeders with such furrow openers usually are large in scale, heavy in weight, and of great demand in draft force. Specifically, in two crops a year areas in China, maize has only been harvested while its straw is tough, and may therefore be pressed into the soil rather than being cut by the discs. Meanwhile, strip-chop and strip-till[4,8], which cut straw by rotary blades, are also put forward. On the other hand, straw may wind around the blade roller, and straw cutting quality does not always meet seeding requirements. Therefore, a new form of furrow opener needs to be developed to cut fresh straw residue

easily, especially in the two crops a year areas. Hu et al.[12] proposed an ultra-high pressure (UHP) waterjet pre-opener for no-till seeder and attempted to solve aforementioned problems.

Currently, waterjet (WJ) cutting is one of the fastest growing non-conventional technologies among manufacturing machinery[13]. During the cutting process, water is pumped at a sufficiently high pressure (200-400 MPa) and discharged through a small diameter orifice (0.2-0.4 mm dia.). The potential energy of water is converted into kinetic energy, yielding an ultrasonic velocity jet. The WJ cutting technology has various distinct advantages, and is widely used for cutting applications. In agriculture, cutting is used in various operations, such as slashing weeds, chopping straw, reaping crops, and opening soil or slicing stubbles. The cutting of various agricultural materials using high pressure water jet thus presents a promising approach. With the objective of revealing the cutting process of agricultural materials under WJ, investigation of the effects of water jet parameters on cutting performance is extremely important and highly desirable. Somjet et al.[14] used WJ with a specific cutting energy of 8.7×10^{-3} J/mm^3 to cut sugarcane of 30-mm diameters at a traverse speed of 4.4 km/h; Dennis et al.[15] used WJ with 150 MPa cutting pressure and 0.6 mm nozzle diameters to cut sugar beet of 75 mm diameters at a cutting speed of 1.5 m/s; Wang et al.[16] used WJ to cut meat with bone at a traverse speed of 1200 mm/min; John et al.[17] used 206.8 MPa WJ with 0.127 mm diameter diamond orifice nozzle to cut strawberry calyx. It can be deduced that cutting maize stalks using waterjet is achievable, environmentally friendly, and quality guaranteed. Furthermore, it has become a potential option for anti-block utilization in no till seeding.

The cutting performance of WJ can be predicted based on complex and interacting parameters[18], including both the operation parameters of WJ technology and material characteristics to be cut. Previous studies which were related to WJ cutting agricultural materials evidently showed that there were numerous parameters which have been identified and considered, such as orifice diameters, water pressure, standoff distance and traverse speed. There is a lack of analysis data on the performance of WJ on cutting maize stalks and this information is highly desirable and crucial to guide the design of ultra-high pressure WJ pre-opener equipment.

This study aimed to deal with the blockage issues encountered while seeding winter wheat after summer maize harvest in a no-till field of CA, using waterjet to cut through heavy maize stalks, thus guaranteeing the working quality of furrow opener. For this purpose, the depth of cut represented cutting performance, for there was no requirements for surface quality or kerf profile.

In this preliminary study, a full factorial experimental method was utilized to investigate performance of waterjet on cutting maize stalks. The objective was to examine the effects of operation parameters on the cutting performance, and a multilinear regression model for depth of cut was proposed to effectively control and ultimately optimize the maize stalks cutting process. Furthermore, this study will form a guideline for the design of no-till seeder with WJ pre-opener and the settings of operation parameters.

2　Materials and method

2.1　Materials

2.1.1　Maize stalks

Maize stalks specimen was the fresh maize (*ZhengDan 958*) planted at Zhuozhou (115°59′E, 39°29′N) in a two crops a year

area of the North China Plain. It was harvested in October 4, 2018 and stored indoors for 7 d until the experiments carried out. Using the drying method, the average moisture content of the maize stalks was 54.7%. Both long axis diameter and short axis diameter of maize stalks specimen were measured by a vernier caliper with ±0.01 accuracy and recorded with 3 times repetition of each position. Short axis diameter ranged from 13.22 to 15.33 mm, while long axis diameter ranged from 28.67 to 31.23 mm. 50 maize stalks specimens were cut into 20cm in length for test and cutting points of specimens were all within the internodes. Even though specimens were selected carefully, there were still differences in scales of diameters due to natural variations in growth characteristic.

2.1.2　Ultra-High pressure (UHP) pure waterjet machine

This study was conducted on a three-axis pure WJ machine produced by Anhui Aoyu CNC Technology Co., Ltd., driven by a mono intensifier pumping system with continuous operating pressure of up to 360 MPa. The highest traverse speed of this machine was 5000 mm/min and the maximum flow rate was 3.7 L/min. The energy resource of this WJ machine came from a 37 kW electromotor, and tap water was used as cutting medium after triple filter. In this study, pure waterjet aimed to cut off maize stalks to let the rear furrow opener move forward without blockage, and without any quality requirements for the cutting kerf, a large orifice diameter was selected to provide better cutting ability[19]. To clarify, orifice diameters are standard parts in different sizes, and a diameter of 0.3 mm was selected for maize stalks cutting in order to match the intensifier pump and be suitable for material cutting character. The water pressure originated from the intensifier pump was measured with a pressure gauge in real time. The scheme of maize cutting device was shown in Figure 1.
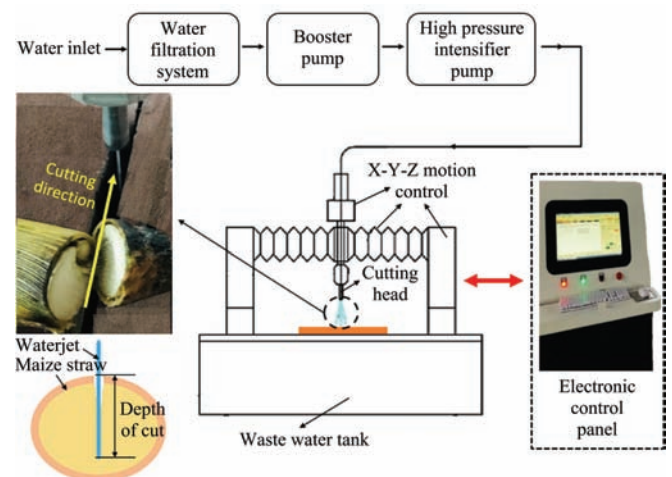

Figure 1　Cutting process of maize stalks under UHP waterjet

2.2　Experimental procedure

2.2.1　Experiment setup

Although performance of waterjet on cutting maize stalks involves a large number of variables that may somehow affect the results, only major variables were concerned in this study. Based on the previous studies[12-15], three key parameters were selected as water pressure, traverse speed and standoff distance, and a full factorial experimental design was applied. Each parameter was assigned different levels, 10, 5 and 4 levels for water pressure, traverse speed and standoff distance, respectively. The range of parametric conditions is described in Table 1. So that total of 200 combinations were conducted.

Table 1   Experimental conditions

Fixed parameters	Values
Diameter of orifice	0.3 mm
Jet impingement angle	90°
Maxim operation pressure of the machine	360 MPa
Maxim flow rate	3.7 L/min
Variable parameters	**Levels**
Water pressure (P)/MPa	120, 140, 160, 180, 200, 220, 240, 260, 280, 300
Traverse speed (v)/mm·min^{-1}	1,000, 2,000, 3,000, 4,000, 5,000
Standoff distance (SOD)/mm	5, 10, 15, 20

2.2.2   Depth of cut measurement

Meanwhile, physical mechanics properties of maize stalks under UHP waterjet were difficult to estimate due to the heterogeneous and anisotropic nature of organic crop straw. It is therefore necessary to set up an evaluation index for the cutting performance. The depth of cut (D_C) represents the capability of waterjet to penetrate into the maize stalks, and was defined as the length from the highest point of maize stalks surface to the deepest point cut by waterjet. The single maize stalks specimen was placed on a soil bin and both ends of the specimen were pinned down; the start position of cutting process was at one side of maize stalks. The cross section of maize stalk was considered as oval shape and waterjet cut through the maize stalks along the direction of long diameter and waterjet injected parallel to the short diameter (as shown in Figure 1). The long diameter (D_L) and short diameter (D_S) of cutting position were measured by electrical vernier caliper at least three times for every cutting operation, and each combination (with the same operation parameters) was repeated three times and the average was taken as the final value for the depth of cut.

In this study, cutting depth was selected to reflect the relationships between operation parameters and cutting performance. *Revealer 5F01* high-speed camera was used to record the whole cutting process and cutting depth could be obtained in the photos. For the full frame resolution (1280×1024),
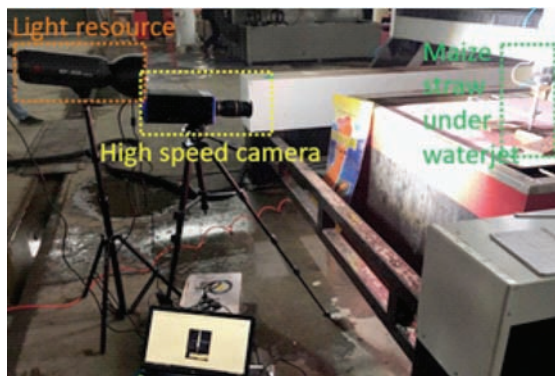
high frame rate of 2000 fps can be obtained, while in 1024×64 format, the maximum frame rate is 32 000 fps. High-speed camera system was placed at orthographic projection direction (as shown in Figure 2). The exposure time was set as 1 ms, meaning pictures were shot every 1 ms. In particular, threshold time T_t was defined as the time that waterjet was away from the maize stalks and not applied on the maize stalks. The threshold time equation was expressed by Equation (1):

$$T_t = \frac{D_L}{v} \tag{1}$$

The pictures were taken right at the threshold time could reflect the depth of cut, and were selected to calculate D_C. The feature points' image coordinates of these selected high-speed photographs were extracted with MATLAB 14.0. As shown in Figure 3, featured points T, B and, J represented the top point of the maize stalks, the bottom point of the maize stalks and the deepest point of waterjet, respectively. The differences of vertical coordinates could represent the length between two points. With that, the depth of cut could be calculated by Equation (2):

$$\frac{L_{TB}}{L_{TJ}} = \frac{D_S}{D_C} \tag{2}$$

where, L_{TB} and L_{TJ} are the length of the short axis diameter and depth of cut in high-speed photographs.

The depth of cut represents the capability of the waterjet to penetrate into the maize stalks, and the depth of cut was defined as the longest line from the edge of the maize stalks to the bottle of kerf (as shown in Figures 1 and 3). Natural maize stalks has differences in shape and size; nevertheless, they were carefully selected to be as similar as possible for this experimental test. To access the fairer results, cutoff ratio (R_c) was defined to measure the performance of waterjet cutting as well, R_c could be calculated by Equation (3):

$$R_C = D_C/D_L \tag{3}$$

where, R_c is the cutoff ratio; D_c is the depth of cut calculated by high-speed photographs; and D_L is the long diameter of the maize stalks specimen measured by vernier caliper.

Figure 2   Placement of the experiment
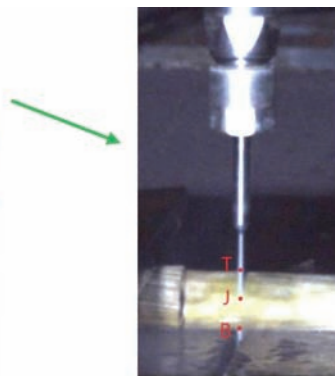
Note: T: top point of the maize stalks; B: bottom point of the maize stalks; J: the deepest point of waterjet.

Figure 3   High speed photograph of maize stalks

2.3   Statistical analysis and regression modeling

ANOVA was utilized (at 95% confidence interval) to find out the factor's significance for depth of cut as described in Table 1. Design-Expert V8.0.6 was used to calculate the results for the analysis.

A regression model was developed after comprehensively discussing the impact of operation parameters on depth of cut. The equation could help to find out the causal relationships between variables. The value of dependent variables could

predict the value of independent variables by using suitable regression models[20]. The cutting process is complicated and also some unknown parameters which will influence the cutting performance[21]. The knowledge and data are limited based on current researches. To simplify the model, depth of cut and operation parameters (P, v and SOD) were taken as the dependent and independent variables, respectively. These parameters can be measured easily and a multilinear stepwise regression model was proposed for the quantification of the depth of cut. Therefore, the
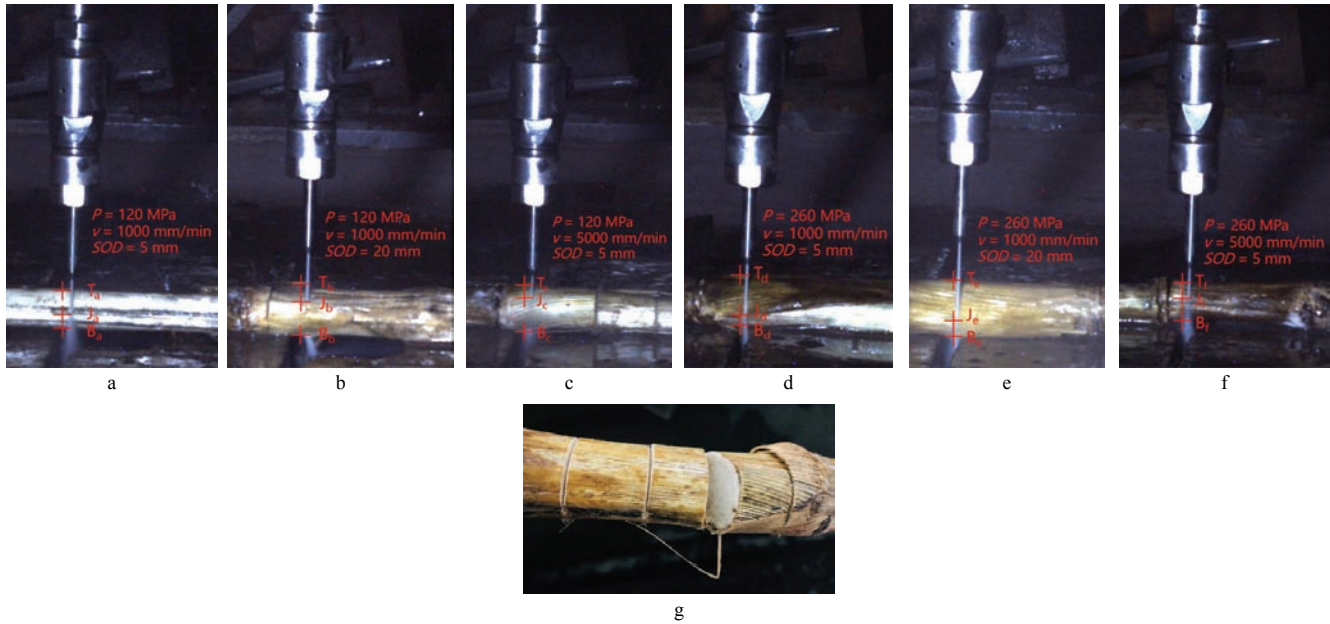
regression model can be convenient and quick for practical use, and the regression model could be expressed as follows[22]:

$$Y=b_0+b_1X_1+b_2X_2+\ldots b_nX_n \qquad (4)$$

where, Y is the dependent variable; $X_1 \ldots X_n$ are independent variables; b_0 is the constant and $b_1\ldots b_n$ accounts for the estimated change in average value of performance feature per unit change in the forecaster value. The statistical analysis was carried out using Statistical Package for Social Sciences (SPSS).

3　Results and discussion

High-speed photographs with different operation parameters

were acquired and selected, and D_c was automatically calculated by MATLAB software as shown in Figure 4. Overall, deeper depth of cut/higher cutoff ratio was expected for higher waterjet pressure, lower traverse speed, and closer standoff distance. All three parameters significantly influenced depth of cut. More specifically, P (waterjet pressure) was the most significant factor followed by the parameter v (traverse speed) and SOD (standoff distance). Moreover, the model for depth of cut prediction from operation parameters was established by multilinear stepwise regression analysis.

Note: T represents the top point of the maize stalks; B represents the bottom point of the maize stalks; J represents the deepest point of waterjet.

Figure 4　High speed photographs of maize stalks with different operation parameters(a-f), and (g) maize stalks after waterjet cutting

3.1　ANOVA analysis of the experimental results

All the selected operation parameters were observed to be significant for the cutoff ratio (R_c) and interactions ($P*v$, $P*SOD$, and $v*SOD$) were statistically significant. Furthermore, larger F value indicates that the variables of operation parameters greatly contribute to R_c[23]. In this study, waterjet pressure (P) leadingly contributed with the F value of 640.08 with regard to the cutoff ratio followed by traverse speed (v) and standoff (SOD) distance with F value of 381.69 and 147.39, respectively, as shown in Table 2.

Table 2　Results of analysis of variance (ANOVA) for the cutoff ratio

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	10.77	91	0.12	87.93	<0.0001
P	7.75	9	0.86	640.08	<0.0001
v	2.06	4	0.51	381.69	<0.0001
SOD	0.60	3	0.20	147.39	<0.0001
$P*v$	0.26	36	0.007264	5.40	<0.0001
$P*SOD$	0.073	27	0.002719	2.02	0.0060
$v*SOD$	0.031	12	0.002584	1.92	0.0396
Residual	0.15	108	0.0010346		
Cor total	10.92	199			

Note: The Model F-value of 87.93 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant.

Ishfaq et al.[15] found that abrasive waterjet cutting performance was also affected by P, v and SOD, with the percentage contributions of 14.2, 22.5 and 9.3%, respectively. Study on surface roughness in waterjet machining[24] also found that P was the most dominant parameter, the following were v and SOD, respectively. It could be stated that the contributions of P and v were different between pure waterjet and abrasive waterjet, however, it could be explained that higher v decreased the striking time of abrasive particles and higher P might aggravate the springback of abrasive particles[21], which would obstruct cutting performance of abrasive waterjet. Arola et al.[25] studied the differences of peening performance between pure waterjet and abrasive waterjet and the results were opposite. However, cutting performance of pure waterjet mainly depends on kinetic energy of water flow[16], which makes the waterjet pressure the most important operation parameter for the cutting performance in this study.

3.2　Influence of operation parameters

The results of experimental data indicated that R_c and D_c increased as waterjet pressure increased, and R_c had an approximately linear relationship with P. Figure 5 demonstrated that as waterjet pressure increased from 120 to 300 MPa, R_c and D_c increased from 0.202 to 1, and 3.8 to 21.5 mm, respectively, under different traverse speeds and standoff distances. When the standoff distance was closer than 10 mm, maize stalks specimen could be cut if the waterjet pressure was higher than 280 MPa. When the standoff distance was further than 10mm, 300 MPa or

higher was required to cut through maize stalks. This phenomenon might be related to the larger amount of water flow striking on the cutting surface of maize stalks, which brought higher water energy. This being said, velocity and volume of water striking the maize stalks directly determined cutting performance. To be precise, a certain 0.3 mm orifice diameter was selected for these experiments, therefore a certain relationship among velocity, water volume, and waterjet pressure was confirmed[26]. Assuming water is incompressible, the relationship between the waterjet pressure and the velocity was expressed Bernoulli's Equation (5):

$$v_{pwj} = \mu_v \cdot \sqrt{\frac{2P}{\rho}} \qquad (5)$$

where, v_{pwj} is waterjet velocity, m/s; μ_v is velocity coefficient, which depends on waterjet and is usually between 0.86 and 0.97; P is waterjet pressure, N/m²; and ρ is water density, kg/m³. As the μ_v and ρ were constant in this study, the water velocity only depended on waterjet pressure. The kinetic energy of waterjet is directly related to waterjet velocity, so that higher waterjet brought higher kinetic energy.

It was noticed that immediately before the maize stalks were thoroughly cut off, in other words, cutoff ratio attained to 1, D_c increased rapidly with the increase of P. For instance, when the standoff distance was 10 mm, the maize stalks specimen could be fully cut off with a 280 MPa or higher. Meanwhile the difference of D_c under 260 MPa and 280 MPa became larger than the lower P (Figure 5b). This might be attributable to the characteristic of waterjet, which could cause the loss of energy when the specimen with crop fiber could not be cut through promptly[27]. That is to say, when pure waterjet was subject to resistance from the maize fiber growing along the axial direction, it might wedge into the crack of vascular tissue and finally deteriorated cutting efficiency. Due to this reason, 280 MPa or higher waterjet pressure was recommended as the optional operation parameter for maize stalks cutting.

The influence of the traverse speed on cutting performance was plotted in Figure 5, and demonstrated that increasing traverse speed from 1000 to 5000 mm/min effectively reduced R_c and D_c. Under the same P and SOD, each decrease of 1000 mm/min in traverse speed resulted in a value nearly equal to that of the decline range of R_c and D_c. On that note, the decline range was from 0.6 to 3.4 mm under operation parameters of 140 MPa waterjet pressure, 15 mm standoff distance and 240 MPa, 5 mm standoff distance, respectively.

Traverse speed somehow relates to striking time of maize stalks under waterjet. When the traverse speed increased, there was fewer water flow striking the maize stalks specimen at a given point. On the other hand, as shown in Figure 5, the rising trend of R_c and D_c started to level off with the decrease of v. For example, under 5 mm standoff distance, D_c increased from 11.6 to 20.1 mm at a traverse speed of 1000 mm/min, while D_c increased from 5.3 to 20.1 mm at a traverse speed of 5000 mm/min. This phenomenon might be attributed to the reduced energy loss. Specifically speaking, the air damping and friction effect on the waterjet decreases as the striking time decreases[28], such that higher v results in less energy loss. In other words, when the waterjet travels fast through the maize stalks, the waterjet cutting efficiency is higher than when it travels slowly. As a result, the rate of decrease in R_c and D_c will reduce, and the curves consequently level off as v increase.

a. Standoff distance – 5 mm

b. Standoff distance – 10 mm

c. Standoff distance – 15 mm

d. Standoff distance – 20 mm
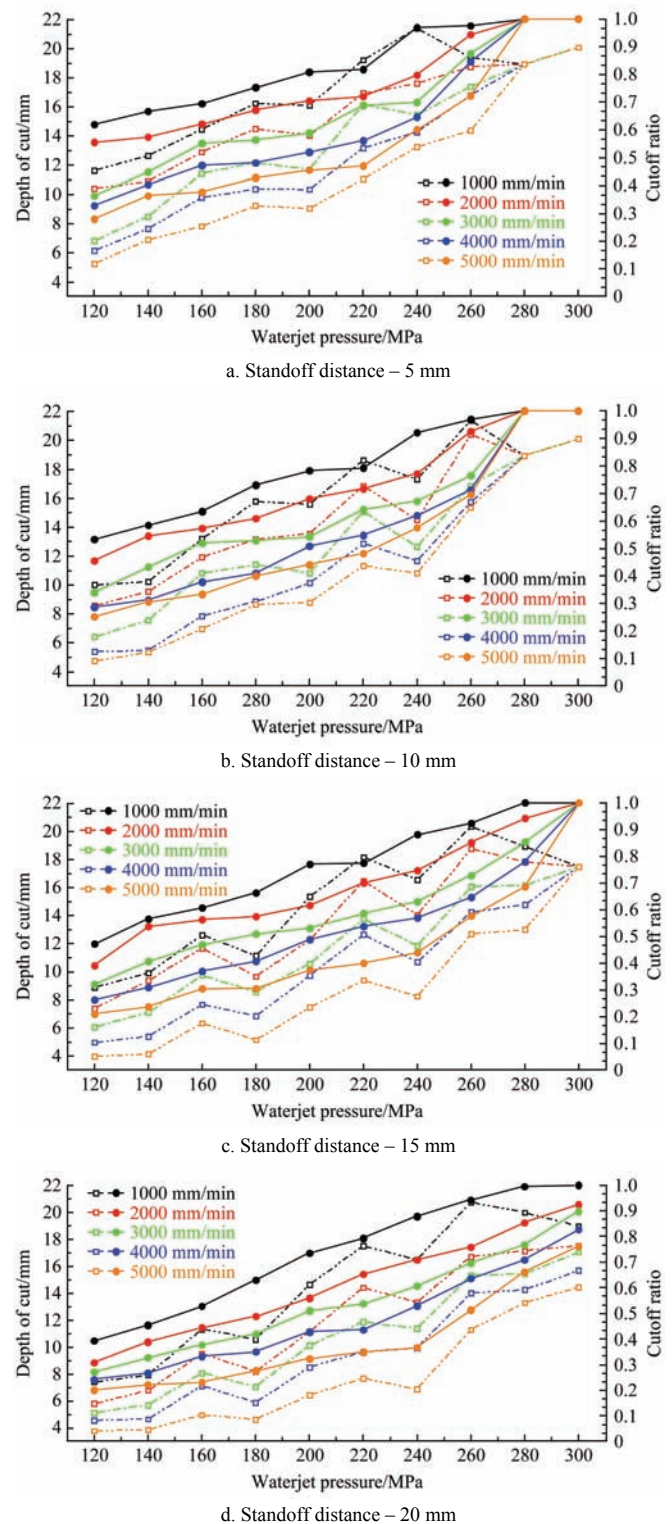
Note: the solid lines represent cutoff ratio and the dotted lines represent depth of cut.

Figure 5   Experimental cutting parameters of maize stalks under pure waterjet

The standoff distance played an inhibiting role in influencing D_c, as shown in Figure 5. When P was 120 MPa and v was 1000 mm/min, R_c and D_c decreased from 0.62 to 0.39 and from 11.64 to 7.63 mm, respectively, with an increase of SOD from 5 to 20 mm. This might be attributed to the wide waterjet diameter produced by high SOD. At higher SOD, the energy density of pure waterjet striking decreases, generating a lower waterjet penetration capability as a result[28]. Furthermore, the outlet waterjet can be categorized into three zones[14], namely, the solid

jet zone, the spray zone, and the droplet zone. The solid jet zone has the highest average kinetic energy among all zones. In this zone, the waterjet has strong concentration ability and jet diameter stays still, therefore, in order to acquire higher cutting efficiency, the standoff distance should be limited in the solid jet zone. With an increased distance away from the orifice, kinetic energy decreases along the axis and jet diameter increases due to droplet diffusion. The spray zone and droplet zone contain small droplets mixed with air, which have lower energy and a dramatic decrease in impact capacity; for this reason, the spray zone and droplet zone are not suitable for cutting utilization. Meanwhile, higher *SOD* led to higher energy consumption caused by the resistance from the water and air mixture[29]. Hood[30] suggested positioning the cutting head at a distance within 1 mm or 2 mm; however, in field application, soil surface is covered with maize stalks, making it hard to keep such little standoff distance. Therefore, to guarantee cutting performance and efficiency, lower *SOD* is recommended. Meanwhile, in the case of impact damage, the cutting head nozzle tube should avoid impact with stone, soil block, and stubble in the field. There is thus a more stringent requirement for the profiling and protection mechanism of the cutting head when the waterjet is

used in the maize stalks mulching field. With this considered, 10-15 mm standoff distance was recommended for maize stalks cutting utilization.
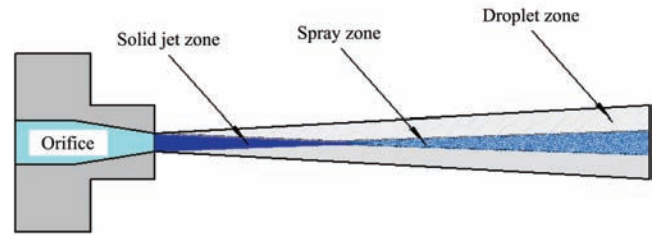

Figure 6   Schematic diagram of waterjet in the air

3.3   Multilinear stepwise regression analysis

The statistical results of regression are shown in Table 3, and the following equation was developed:

Depth of cut (mm) = $5.97+0.068P-0.002v-0.218\ SOD$ (6)

where, P is the waterjet pressure, MPa; v is the traverse speed, mm/min; and *SOD* is the standoff distance, mm.

The determination coefficient of this model is 0.935, demonstrating that 93.5% of the variation in the measured data could be explained by the model in Equation (6).

Table 3   Statistical results from the regression model

Independent variables	Unstandardized Coefficients		Standardized Coefficients	t-value	Sig.	Collinearity Statistics	F-ratio	R^2
	B	Std.Error	Beta			Tolerance		
(Constant)	5.973	0.411		14.525	0.000		805.068	0.935
P	0.068	0.002	0.803	40.373	0.000	0.979		
v	-0.002	0.000	-0.545	-27.677	0.000	0.999		
SOD	-0.218	0.015	-0.283	-14.239	0.000	0.980		

The determination coefficient (R^2) of this model is 0.935, indicating that 93.5% of the variation in the measured data could be explained by the model in Equation (6); Figure 7 showed that the measured values of D_c correlated well with the predicted values. Standardized coefficients could represent the contribution of the independent variables to the dependent variable of this regression model. The best model (i.e. with the highest R^2 value) derived from the regression analysis suggests that the most significant parameters were (in order from most to least affecting) waterjet pressure, traverse speed, and standoff distance. This result was consistent with the ANOVA analysis as well, in other words, the regression equation was in good agreement with the experimental corresponding data. Although the interaction of three parameters did not take into consideration, the linear regression model could meet the requirements of prediction in a simple approach. In general, these results show that the regression model was statistically significant and that this model may predict depth of cut.
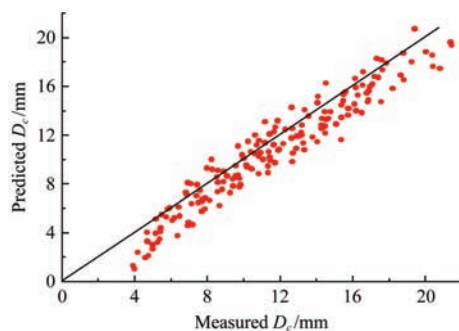

Figure 7   Predicted depth of cut from operation parameters versus measured depth of cut

3.4   Field test

A field moving test stand was developed, and a field test was conducted at Zhuozhou Teaching Experimental Station of China Agricultural University in the autumn of 2019 (as shown in Figure 8). The field tests demonstrate the validity of UHP waterjet cutting maize stalks, and the results of field test are consistent with this preliminary investigation. The field test details will be discussed in the further study.

Figure 8   Field test of UHP waterjet cutting maize stalks

4   Conclusions

This study mainly investigated waterjet cutting performance of fresh (after harvest) maize stalks. The influences of operation parameters, including waterjet pressure, traverse speed, and standoff distance, on depth of cut were studied. On the basis of experimental results, the main conclusions of the study can be summarized as below:

From the experimental data, waterjet pressure of 280 MPa and higher was recommended as suitable operation setting, while higher traverse speed resulted in lower depth of cut. Therefore, to ensure time-effectiveness, intermediate traverse speed combined high waterjet pressure was fitted for field practices. Meanwhile, standoff distance should be within 10-15 mm to ensure the maize stalks were in the region of solid jet zone.

ANOVA analysis showed that all three operation parameters had significant effect on depth of cut as well as cutoff ratio. It was observed that increasing the waterjet pressure resulted in increased depth of cut, while the increase of both traverse speed and cutoff distance led to decreases in the depth of cut. Additionally, based on the results of ANOVA analysis, waterjet pressure made the largest contribution, compared with the other two operation parameters.

A prediction model was derived from a multilinear stepwise regression analysis. The depth of cut was affected by waterjet pressure, traverse speed, and standoff distance. Furthermore, the standardized coefficients showed that waterjet pressure had a great influence on depth of cut, which was consistent with the ANOVA analysis.

With the limitation of experiment equipment and site, the speed of this study was slower than the actual field practice and there will be a further study about the performance of waterjet on cutting maize stalks in fields.

Acknowledgements

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