The gait analysis on the sloping walking of goat

Fu Zhang[1,2*], Yakun Zhang[1], Binbin Yue[1], Guoying Zhang[1]

[1] *College of Agricultural Engineering, Henan University of Science and Technology, Luoyang, 471003, P R China*

[2] *Henan Haofeng Machinery Manufacturing Co, LTD, Xuchang, 461103, P R China*

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Abstract

The 18° sloping walking state and movement rules of the goat was researched by the high-speed video camera system. The movement process and the imaging results of goat in 18° sloping fields were recorded in the computer. The experiment imaging results of goat movement process were analysed by SigmaScan software and Matlab software, the results showed that gait parameters and angle change curve of each leg on 18° slope was obtained. The research will provide the basis of the experimental data for bionic design of agricultural machinery of goats sloping walking mechanism.

Keywords: Goat, High-speed camera, Sloping fields, Gait

1 Introduction

The walking gait is a useful biometric that is the most commonly used of the nature quadruped, is the base of study on ground walking mechanism [1-3]. In recent years, the researches on walking state and movement rules has been reported a lot at home and abroad, which concerned on all kinds of quadruped, while less on the goat which has small body, firm limb bones, the ability of walking gait agile brisk and walking on the uneven surface of the ground, slopes, steep and mountainous freely and neatly, and can endure long-distance walking. The goat can be used as the base research of the gait walking mechanism [4-11]. In this study, it was shot by the high-speed camera that the movement state of goat in 18° sloping fields, and the obtained images were analysed by SigmaScan software and Matlab software.

2 Experiment equipment and methods

The walking process of a goat in the slope has been shot by a high-speed camera (up to 10,000 per second) in the experiment. The high-speed camera was adjusted to ensure that the shooting speed was adapted to the movement of the goat in different sloping fields. The moving sequence images of the goat in slope fields were recorded and saved to the computer. Subsequently, the data of the goat key point body were collected and analysed by SigmaScan software. The characteristic parameters and curves of the corresponding series, which were on the movement of goat in different sloping fields, were obtained.

2.1 EXPERIMENT EQUIPMENT AND OBJECTS

2.1.1 Experiment equipment

It was consisted of a high speed camera (FASTCAM - Super 10KC), a lamp (MODEL10000), a mechanical scale (XSJ 2 x 1300 w - 20), a microcomputer (P4—3.0 G), a tape and a inclinator, and so on (Fig 1) that were used in this article. The high-speed camera equipment was mainly composed of the host processor, laptop, monitors, lenses, lighting device and data lines, etc. [4, 5].

FIGURE 1 High-speed camera equipment

2.1.2 Experiment sites and objects

The sloping fields, which were measured by inclinator, were 18 degrees in the experiment. The data parameters of spatial movement of the key points, which were on the movement of the goat in sloping fields at any time, were obtained by high-speed camera.

Goats (Goat) belong to artiodactyla, were mainly composed of the head, neck, torso and limbs. They have

[*] ***Corresponding author*** e-mail: zhangfu30@126.com

solid head, good combination of the neck, body and forelimb, broad and deep chest, open ribs, generous and straight back waist, wide, long and plump hindquarters, strong limbs, well-balanced structure, moderate height. a female goat (1.5 years old) was analysed in the test (Fig. 2). The main posture characteristic was showed (Table 1). The test was operated on the outskirts of Luoyang City in Henan province, and the temperature was 32~35℃.

FIGURE 2 The photos of the goat

TABLE 1 The photos of the goat

Body length (cm)	**Body height (cm)**	Taller than	Weight (kg)
138±0.5	90±0.5	1.53	42±0.5
The length of first calf (cm)	The length of first thigh (cm)	The length of latter calf(cm)	The length of latter thigh (cm)
16±0.5	30±0.5	23±0.5	23±0.5

2.2 EXPERIMENT PROCEDURE

In order to reduce the photography error and make the processing of image datum easily, the high-speed camera was used to shoot the whole moving process of the goat, which was towed to ensure it always walked in a straight line on the sloping fields.

During the experiment, the frequency of high-speed camera was adjusted to 10000 frames per second. The high-speed camera equipment was set on the basis of the test purpose. The camera was fixed on a tripod and the lens was set at the forward side of the goat motion. The hardware conditions of the camera, which including space position, point range, shooting range, aperture, focal length and so on, were adjusted to ensure that the main lens optical axis focused on the range centre of the goat movement. The main lens optical axis was adjusted to the goat moving plane as close as possible in order that the goat was clearly imaged. Then the whole sequence images that the goat walked along the straight line in the sloping fields were recorded and saved into laptop through image capture card. The trajectory of the goat walking process was shot expediently and completely under the condition that the goat walked normally.

2.3 EXPERIMENT DATA PROCESSING METHODS

2.3.1 The use of SigmaScan software

SigmaScan software was installed and the icon of the software was clicked directly. A new worksheet was created under the SigmaScan software environment. Then the picture was opened (Figure 3).In the image measurement, the lateral displacement values of the key marked points in the goat body were defined as the X-axis value (along a particular path direction), and the longitudinal displacement values were defined as the Y-axis.

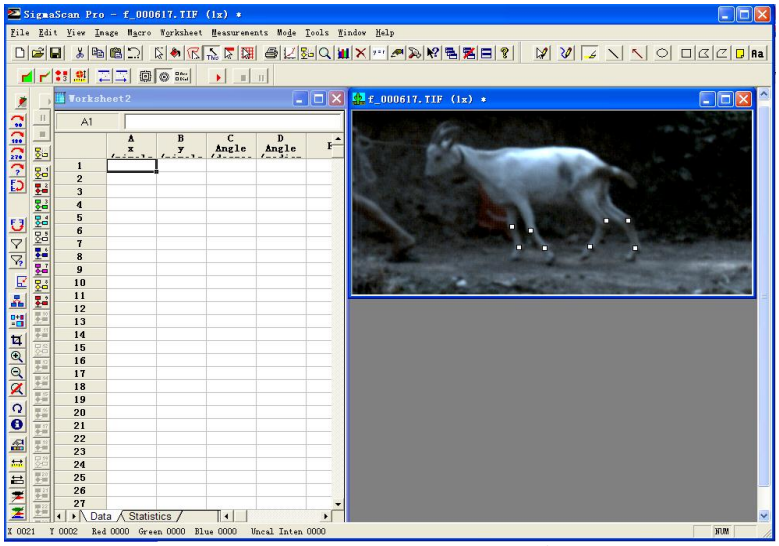


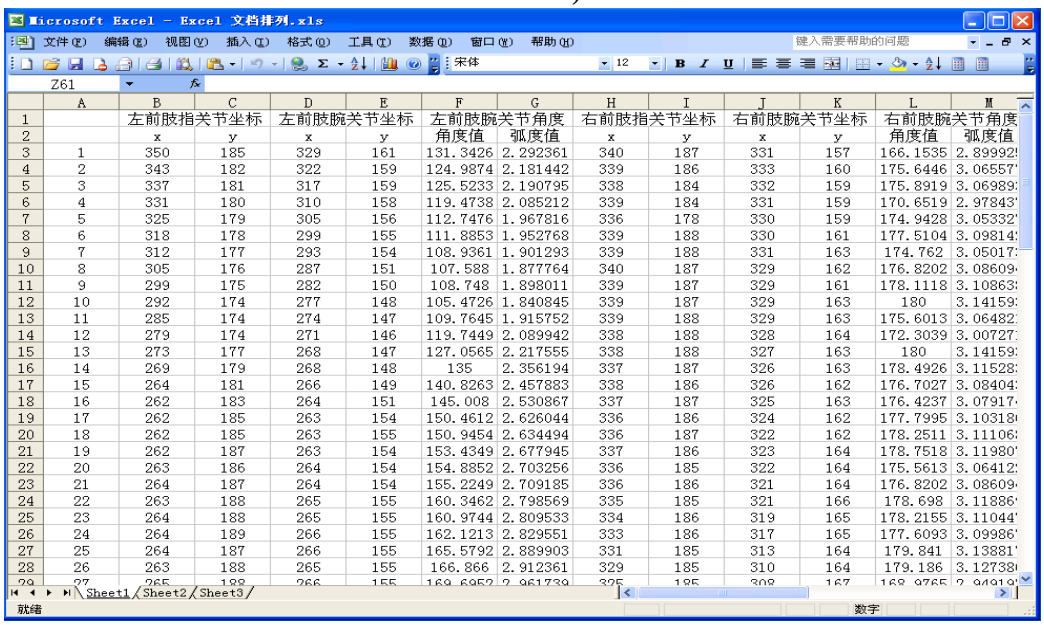
FIGURE 3 The joint marked point position of the goat

The size of the pixel value was equal to the coordinate size. The quadrant maximum values were limited by the resolution of high speed camera (i.e. the pixel size of image). The resolution values of high speed camera in this test were 512 (horizontal direction) ×240 (vertical direction), so the quadrant maximum value was 512 (X axes) ×240 (the Y axis) in the experiment. Therefore the data values ranged from 0 to 512[6-8]. The relative coordinate values of the key points of the goat movement in the slope fields were obtained when the key points of

the goat limbs of in the gait cycle image sequences were clicked. The data were preserved in the Excel document format.

2.3.2 Data processing

The Excel data documents (Fig 4)which were processed by the SigmaScan software were arranged in chronological (if the shooting speed was 200 frame per second, then the time series was 0ms, 20ms, 40ms and so on).



Microsoft Excel - Excel 文档排列.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		左前肢指关节坐标		左前肢腕关节坐标		左前肢腕关节角度		右前肢指关节坐标		右前肢腕关节坐标		右前肢腕关节角度	
2		x	y	x	y	角度值	弧度值	x	y	x	y	角度值	弧度值
3	1	350	185	329	161	131.3426	2.292361	340	187	331	157	166.1535	2.89992
4	2	343	182	322	159	124.9874	2.181442	339	186	333	160	175.6446	3.06557
5	3	337	181	317	159	125.5233	2.190795	338	184	332	159	175.8919	3.06989
6	4	331	180	310	158	119.4738	2.085212	339	184	331	159	170.6519	2.97843
7	5	325	179	305	156	112.7476	1.967816	336	178	330	159	174.9428	3.05332
8	6	318	178	299	155	111.8853	1.952768	339	188	330	161	177.5104	3.09814
9	7	312	177	293	154	108.9361	1.901293	339	188	331	163	174.762	3.05017
10	8	305	176	287	151	107.588	1.877764	340	187	329	162	176.8202	3.08609
11	9	299	175	282	150	108.748	1.898011	339	187	329	161	178.1118	3.10863
12	10	292	174	277	148	105.4726	1.840845	339	187	329	163	180	3.14159
13	11	285	174	274	147	109.7645	1.915752	339	188	329	163	175.6013	3.06482
14	12	279	174	271	146	119.7449	2.089942	338	188	328	164	172.3039	3.00727
15	13	273	177	268	147	127.0565	2.217555	338	188	327	163	180	3.14159
16	14	269	179	268	148	135	2.356194	337	187	326	163	178.4926	3.11528
17	15	264	181	266	149	140.8263	2.457883	338	186	326	162	176.7027	3.08404
18	16	262	183	264	151	145.008	2.530867	337	187	325	163	176.4237	3.07917
19	17	262	185	263	154	150.4612	2.626044	336	186	324	162	177.7995	3.10318
20	18	262	185	263	155	150.9454	2.634494	336	187	322	162	178.2511	3.11106
21	19	262	187	263	154	153.4349	2.677945	337	186	323	164	178.7518	3.11980
22	20	263	186	264	154	154.8852	2.703256	336	185	322	164	175.5613	3.06412
23	21	264	187	264	154	155.2249	2.709185	336	186	321	164	176.8202	3.08609
24	22	263	188	265	155	160.3462	2.798569	335	185	321	166	178.698	3.11886
25	23	264	188	265	155	160.9744	2.809533	334	186	319	165	178.2155	3.11044
26	24	264	189	266	155	162.1213	2.829551	333	186	317	165	177.6093	3.09986
27	25	264	187	266	155	165.5792	2.889903	331	185	313	164	179.841	3.13881
28	26	263	188	265	155	166.866	2.912361	329	185	310	164	179.186	3.12738

Sheet1 / Sheet2 / Sheet3 / 就绪 / 数字

FIGURE 4 Excel document data

The obtained data sequence can be analysed and calculated by Excel directly, and it also can be processed by Matlab software when the data were imported. The corresponding series of movement characteristic curve were obtained, such as the joints point motion curve of goat leg, the range of motion and so on.

3 Test results and analysis

3.1 THE ANALYSIS OF GOAT GAIT CYCLE

A complete gait cycle goat figure (Figure 5) was selected at the time interval between every two pictures 240ms (12 frame). Besides a complete gait cycle that the goat walked on this sloping fields, was 904ms (452 frame).

In a complete gait cycle, the walking speed of the goat was 31.4cm per second and the footstep was 66.0cm on 18° sloping fields. It was discovered that the walking speed and walking step were decreased and then increased with the slope gradually increased.

In a complete gait walking cycle, the corresponding single leg span, single leg step and load factor of the goat in 18 ° sloping fields were shown in table 2. It is discovered that the single leg span and step of the goat left hind leg were the smallest, which were smaller than the other three legs, while the load factor of each leg was the same. It was the reason why the goat can walk on sloping fields stably.

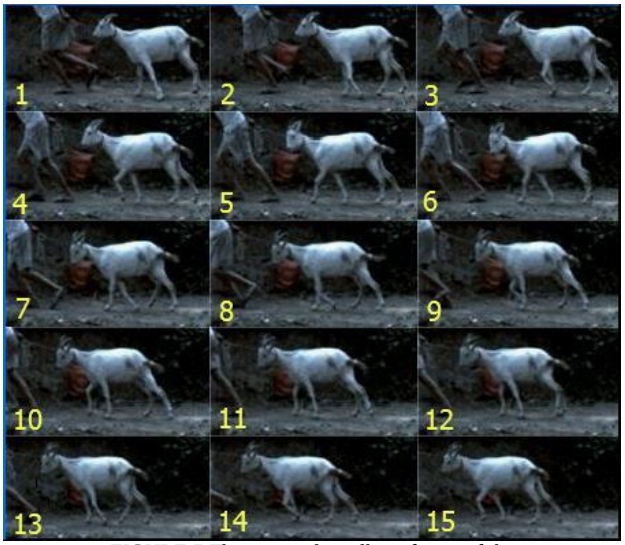


FIGURE 5 The gait cycle walking figure of the goat

TABLE 2 The single leg span distance of the goat

	single leg span distance (cm)	single leg step distance (cm)	load factor
The left front leg	61.0	17.0	0.75
The left hind leg	45.5	9.0	0.75
The right front leg	54.5	14.0	0.75
The right hind leg	58.5	13.5	0.75

The state diagram of the goat legs were shown in Fig 6 when the goat was climbing in 18° sloping fields. The period of three-legged support had emerged a total of four times during a complete transformation gait cycle of the goat walking. 520ms had been taken by the period when

the left hind leg was hanging and other three legs were at the support condition. 496ms had been cost by the period when the left hind leg was on the ground, the left front leg lifted off the ground, and other three legs were at the support condition. 512ms had been cost by the period when the goat body gradually moved forward, the left front leg took a step and was on the ground, the right hind leg lifted off the ground and was at the hanging condition, and the other three legs were at the support condition. 544ms had been spent by the period when the right hind leg took a step and was on the ground, the right front leg lifted off the ground and was at the hanging condition, and the other three legs were at the support condition. 512ms had been spent by the period when the body gradually moved forward, the right front leg took a step and was on the ground, the left hind leg lifted off the ground and was at the hanging condition, and other three legs were at the support condition. So far, the whole transformation gait cycle of goat had been completed. Then, 416ms had been spent by the period when the left front leg was at the hanging condition and the other three legs were at the support condition. 400ms had been cost by the period when the right hind leg was at the hanging condition and the other three legs were at the support condition. 500ms had been taken by the period when the right front leg was at the hanging condition and the other three legs were at the support condition. Walking repeatedly as mentioned above, the goat's body was supported by the cyclical alternation of the front and hind leg. The body centre of gravity was projected on the triangle stent which was supported by the three legs, thus the balance and stability of the goat has been guaranteed during goat walking.

In a complete gait cycle, the proportion of each goat leg's support period of the whole gait cycle was shown in Table 3. It is discovered that the condition of three goat legs common support always existed during the walking in 18° sloping fields.

FIGURE 6 The state chart of each leg of the goat

TABLE 3 The proportion of the leg support period of the whole gait cycle

Type of Support	The number of occurrences of a single-cycle
Common support of the diagonal legs	0
Common support of the ipsilateral legs	0
Common support of the three legs	1
Common support of the four legs	0

The reason why there were a total of four times period of three legs common support were that the hind leg lag behind the front leg which was diagonal to the hind leg when the legs were on up and down during the goat walking. The hanging time of hind leg was longer than the front leg when the goat started moving at the base of slope. However, the hanging time of the front and hind legs had a sudden reduction compared with the initial movement at the base, and the hanging time of hind legs was lower than the front.

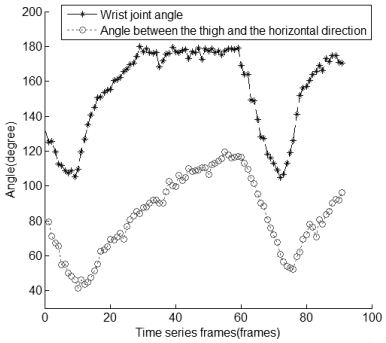
3.2 THE ANGLE ANALYSIS OF THE GOAT LEGS

The angle change range value of each leg measured was shown Tab.4 during the walking in 18° sloping fields.

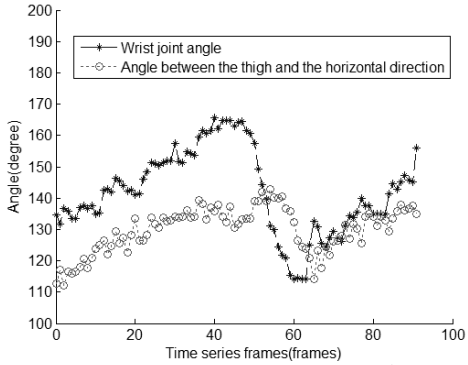
TABLE 4 The angle change range value of each leg

Slow walking in sloping fields	Angle range
α angle (front legs)	100°~185°
β angle (hind legs)	46°~139°
α angle (hind legs)	103°~169°
β angle (front legs)	111°~158°

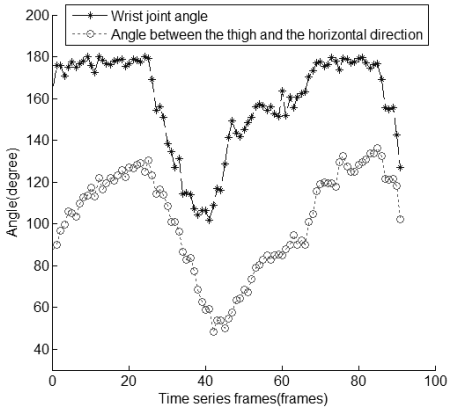
Processing with the experimental data of the whole gait cycle, and the angle change curves of goat four legs were obtained during the walking in sloping fields. (the frame number between angle and time series of the goat left forelimb, the frame number between angle and time series of the goat left hind limb, the frame number between angle and time series of the goat right forelimb, the frame number between angle and time series of the goat right hind limb were shown in a, b, c and d of figure 7 correspondingly). Among them, the angle between the things and the calfs was always presented by the α angle when the goat walking, namely the wrist angle. The angle between the things and the forward direction was always presented by β angle, namely the angle of thigh and horizontal direction.



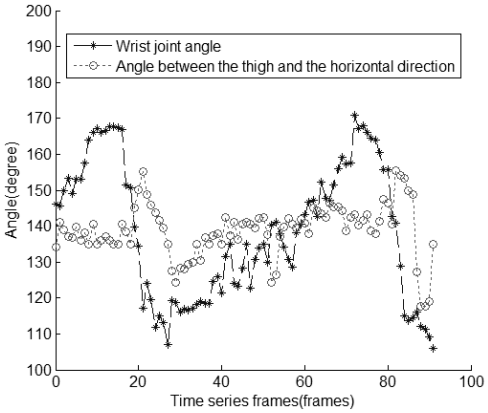
a) The frame number between angle and time series of the goat left forelimb



b) The frame number between angle and time series of the goat left hind limb



c) The frame number between angle and time series of the goat right forelimb



d) The frame number between angle and time series of the goat right hind limb

FIGURE 7 The frame number curve between angle and time series of the goat in 18° slope fields walking.

The legs angle changes of the goat walking in 18° slope fields were as follows.

The left forelimb: the α angle reached the minimum firstly when the leg was bending and lifting, and achieved the maximum after a forward stretching out and stride, then attained the minimum after falling off again and again. The β angle reached the minimum when the α angle was the minimum firstly (the leg was bending), and achieved maximum when the α angle was the minimum secondly (the leg was on a forward stretching out and stride).

The left hind limb: the α angle reached the maximum firstly when the leg was on a forward stretching out and stride, and achieved the minimum when the leg was shrinking and bending, then the leg was on a forward stretching out and stride again. The β angle was little when the α angle was the maximum firstly. However, it increased along with the decreased of α angle gradually, and was the maximum when the leg was ready to fall on the ground.

The right forelimb: the α angle reached the maximum firstly when the leg was on a forward stretching out and stride. After a forward stride, the leg fell on the ground, the body gradually was leaning forward and the gravity centre was moving forward, the α angle reached the minimum when the feet pedalled firmly, and the leg was bending at the same time. The β angle had linearity change with the α angle changes when the leg was on bending and falling on the ground. Namely, the β angle increased with the increased of the α angle, decreased with the decreased.

The right hind limb: the α angle reached the maximum firstly when the leg was lifting, after a forward stride, the leg fell on the ground, the body was gradually leaning forward and the gravity centre was moving forward, the α angle reached the minimum when the feet pedalled firmly, and the leg was bending at the same time. The β angle was on the intermediate state when the α angle was the maximum firstly (the leg was lifting), and was the maximum when the α angle reached the minimum (the leg was bending).

Discoveries were found from Table 6 and graph 11 that, the initial values of β angle of front legs were the minimum, while the final values of α angle of front legs were the maximum, the initial and final values of α and β angle of hind leg were larger than the front legs. The range of α and β angle of hind leg, however, were smaller than the front legs. Some characteristics of leg angular variation, which the goat was walking in slope fields were as follows: The leg angle changing curves between the left front leg and the right front leg had the similarity and regularity, and the leg angle changing curves between the left hind leg and the right hind leg also.

4 Conclusion

1) The test process and the test methods of the goat walking in sloping fields were studied, and the method of SigmaScan software applications in the high-speed camera of was key analysed, and the kinematic data of the key point in goat body were collected and classified at the same time. A more complete kinematic data parameters had been obtained, which provided the research basis for gait analysis.
2) The experimental sequences of image that had been saved in computer were processed and analysed by SigmaScan software, the gait feature parameters of gait and the leg angle changing curves and regulations of the legs were founded when the goat was walking in 18° sloping fields, and the basic experiment data for goat-like design of slope walking mechanism were provided.

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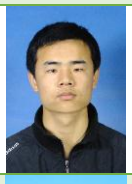
Authors

Fu Zhang, born on June 25, 1978, Xingtai, China

Current position, grades: Doctor of Agricultural Engineering, associate professor and the Deputy Dean in Henan university of Science and technology.
University studies: bachelor degree and master degree from the college of mechanical and electronic Engineering of Hebei Agricultural University in 2001 and 2004 respectively, and received Ph. D. degree from the College of biological and Agricultural Engineering of Jilin University in 2007
Scientific interest: agricultural equipment technology and automation, biomimetic technology of the terrain machinery.
Publications: 40 Patents, 40 Papers, **5 books.**
Experience: a supervisor of master program in agricultural mechanization engineering, the Deputy Dean of agricultural engineering department, member of China agricultural engineering society and youth work committee member of china society for agricultural machinery, 19 research projects including 2 state projects, 4 provincial projects, 9 departmental projects and 4 horizontal subjects.
Research interests: agricultural equipment technology and automation and biomimetic technology of the terrain machinery.



Yakun Zhang, born on February 3, 1991, luoyang, China

Current position, grades: College of agricultural engineering in Henan university of Science and technology.
University studies: Agricultural Engineering in Henan university of Science and technology.
Scientific interest: agricultural equipment technology and automation, biomimetic technology of the terrain machinery.
Publications: 12 Patents, 3 Papers

Binbin Yue, born on September 27, 1989, Jiaozuo , China

Current position, grades: College of agricultural engineering in Henan university of Science and technology.
University studies: Agricultural Engineering in Henan university of Science and technology.
Scientific interest: Agricultural Electrification and Automation.
Publications: 1 Patents, 1 Papers

Guoying Zhang, born on September 27, 1982, Nanyang Henan, China

Current position, grades: Engineer, mainly engaged in the tracto quality supervision and inspection and measurement，as well as the measurement test/calibration work in Luoyang xiyuan vehicles and power institute co., LTD (National Tractor Quality Supervision And Inspection Centre).
University studies: Master's degree in agricultural mechanization engineering, Henan university of science and technology.
Scientific interest: The bionic robot application in mechanical engineering，and the application of the metrology in scientific research.
Publications : 1 Patents, 5 Papers