Research on Weighing Method Innovation and Device Development for On-Board Sensors of Logistics Vehicle

En Fang[1,2](✉), Yuchao Zhou[1], and Delu Li[3]

[1] School of Electrical and Control Engineering, Xuzhou University of Technology, Xuzhou 221018, Jiangsu, China
fangen@cumt.edu.cn

[2] Jiangsu Key Construction Laboratory of Large Engineering Equipment Testing and Control Technology, Xuzhou 221018, Jiangsu, China

[3] Jiangsu Vocational Institute of Architecture Technology, Xuzhou 221018, Jiangsu, China

Abstract. In this paper, both ends of the on-board weighing devices are not fixed simultaneously to prevent the force constraints from affecting the measurement accuracy of the sensor. According to the test results with analysis and the market feedback on small batch production and sales of prototype, a weighing method innovation and device development for on-board sensors of logistics vehicles are proposed The base end of the sensor is fixed with the axle, and the other end can work in two states with a safety device. The safety device can be lifted in the upper position to keep the sensors off the carriage without weighing for safe transportation. In the lower place, the carriage and the on-board sensors are in uniform contact to realize weighing without restriction. The influence of random interference factors is eliminated, and the bottleneck problem of on-board dynamic weighing technology is solved.

Keywords: Weighing with on-board sensor · Weighing method innovation · Research and development of weighing device

1 Research on Weigh-in-Motion at Home and Abroad

The foreign dynamic weighing system research was focused on in some developed countries in the 20th century. The United States has been studying the dynamic weighing technology of vehicles since the mid-19th century because of the earlier situation of over-limit transportation. In 1974, the earliest research on vehicle dynamic weighing was the earliest reference of vehicle dynamic weighing system (Gvvacs Company) at IMEK0/TC3 conference in Hungary, which laid a solid foundation for developing dynamic measurement technology. At present, due to the different use of the dynamic weighing system, the average error of the world's advanced dynamic weighing system for axle weight measurement can be controlled within 30%, and its confidence can reach 90%. The most advanced dynamic weighing system can handle the error of axle weight

D. Jiang and H. Song (Eds.): SIMUtools 2021, LNICST 424, pp. 473–487, 2022.
https://doi.org/10.1007/978-3-030-97124-3_35

measurement within 5%, and the confidence degree reaches 90%. Because of its high cost, it can only be used on some special occasions.

The first research on the dynamic weighing system in China was done by the research institute of highway science of Chongqing. They have developed a new dynamic vehicle weighing technology, which was applied in model SM2000 and SM3000 sensors. Later, Shanxi Institute of Measurement and Testing cooperated with Taiyuan institute of engineering to research axle-metering weighing devices for vehicles. Especially in recent years, the demand for dynamic weighing of vehicles has been dramatically increased in the domestic industry. Many manufacturers and companies have launched their dynamic weighing products, taking BDZ-AE portable dynamic axle weight tester produced by Defeng Precision Machinery Co., Ltd as a typical example. With the improvement of science and technology, China has developed various dynamic weighing systems for many years. It is mainly used in weight calculation and law enforcement inspection, which plays an essential role in highway traffic management.

The sensor weighing is divided into dynamic weighing and static weighing. The static weighing accuracy mainly depends on the sensor itself. The accuracy of dynamic weighing results is related to the precision of sensors and the installation and using methods, working conditions, and other factors of sensors. If the improper installation or operating approach is adopted, the impact of interference on the system is difficult to detect and estimated in advance. And it is challenging to realize error compensation through algorithms and improve measurement accuracy. The crucial problem of dynamic weighing technology is inaccurate results. The weighing error exceeds while the average error should generally be controlled within 30%. Dynamic weighing can be divided into direct dynamic weighing and indirect dynamic weighing. Vehicle weighing is divided into weighing with the vehicle and weighing on the platform (ground weighing).

2 Research and Development Background

There are some problems with the dynamic weighing devices of logistics vehicles using sensors. At present, when using sensors to weigh heavy objects in the market, the connecting threaded holes at both ends of the sensor structure are commonly provided. Thus, both ends are fixed with threads. One end is connected with the vehicle bridge through the mounting base of the sensor device, and the other end is associated with the carriage or the weighing objects. After joining, the weighing products, carriage, sensor, mounting base, and axle become whole through connection. Because two ends of the sensor are fixed with threads, the restrictions on both ends of the sensor device increase. The interference factors are random and unpredictable. Under the effect of gravity, which acts not only through the weighing center, the bending moment also deviates from the center, which directly affects the weighing accuracy. The crucial problem feedback from the market of dynamic weighing devices for logistics vehicles is inaccurate. The carriage weighing results measured by sensors at different positions are inconsistent. The difference between the weighing result and the actual weight is too significant. The reason is that in theory, only when the resultant force of the gravity of the object and the supporting power of the thread on both ends of the sensor connected by screw thread is vertically downward and passes through the weighing center, the bending moment generated by the resultant force vanishes to zero. Thus, the weighing results can be accurate, which is impossible to realize in practice.

Therefore, we get a new research idea which is described as follows. The two ends of the on-board dynamic weighing sensors should not be fixed with thread simultaneously.

In principle, it can be divided into two states. One is that the carriage and the weighing object works in the vehicle transportation state. In this state, the weighing products, carriage, sensor, mounting base, and axle are connected into a piece of equipment with high rigidity to ensure safe transportation. The other is to descend in the weighing state. In this state, the car stops, and the weighing devices of the logistics vehicle fall without restrictions of forces outside the vertical direction. The weight or carriage contacts with the upper end of the sensor by the spherical point in the center of the weighing communication. The weight is weighed in a free state of being affected by gravity and support. The lower end of the sensor device is fixed or welded with the axle through the sensor mounting base. That is to say, the pan or dish of a steelyard is specified. The weighing object and the carriage are not connected with the upper end of the sensor by a thread. And there is no restriction on the upper end of the sensor to realize weighing. There are two possibilities for these weighing devices with poor accuracy. One is that the weight's center of gravity exceeds the weighing area (rollover phenomenon may occur). And the other is that the sensor has problems.

To innovate and discover the use methods of the on-board sensors of logistics vehicles solves the bottleneck problem of on-board weighing problems in principle. Because the weighing time of the on-board weighing device is relatively short compared with the whole working time, the weighing sensors are disconnected in the transportation state, which effectively improves the service life of the sensor weighing device.

3 Weighing Method Innovation and Device Development for On-Board Sensors of Logistics Vehicle

Independent weighing method innovation and device design for on-board sensors of small and medium-sized logistics vehicles are studied in this paper. Also, the weighing sensor protection device and control method are discussed. The principle of the on-board weighing device is that the gravity of the weighing object acts on the sensor body and is transferred to the internal chip to produce micro elastic deformation. The gravity is always vertical downward, and the micro elastic deformation of the sensor chip is one-dimensional linear. According to the micro elastic deformation, the stress and strain are calculated. The signal is collected, processed, amplified, and calculated. The weight value is sent to the display instrument of the vehicle terminal and then to the system management server through mobile communication. According to the test report "Beijing Institute of Aerospace Metrology and Testing Technology (authorized by the state administration of science, technology and industry for national defense, authorized certificate No.: National Defense Military Industry-JLJG-1-003) - Certificate No.: TJ1C2019-04-07386, calibration certificate of force sensor FYXZ-07" for the force sensor of Xuzhou university of engineering, the calibration results meet the technical requirements of JJG 455-2000 (verification regulation of working dynamometer). In this report, if the test pressure value of the sensor is 500N, the measured value is 500.1. The indication error is –0.20%, and the repeatability is 0.01. If the test pressure value of the sensor is 7000N, the measured value is 7000.1. The indication error is –0.01%, and the repeatability is 0.01. The weighing accuracy of the sensor device is high enough to meet the weighing requirements on logistics vehicles.

The weighing test and analysis during prototype trial production are as follows.

(1) Start the weighing system and adjust the sensor output to zero when the car is empty.
(2) Stand with the same person in different positions (such as middle or four corners) of the carriage and observe and record the results displayed by the instrument.
(3) Stand with varying weights in different positions (such as middle and four corners) of the carriage, and observe and record the results displayed by the instrument (Table 1).

Table 1. Prototype test weighing results.

Tester	Position				
	Upper Left	Upper Right	Center	Lower Left	Lower Right
A	55.0	56.5	57.5	52.5	54.0
B	60.0	61.0	62.5	62.0	59.5
C	70.5	71.5	75.0	72.0	72.5

The test found that when the same weight load is applied to different parts of the car, the instrument output will display different weight values. The test results show that the sensor's installation mode, orientation, and load distribution have other effects on the measurement results. The following problems can also be found after the market research.

(1) The connection between the sensor and the car is rigid. During the installation of the sensor, the fixing bolt will add a specific interference force to the sensor in the non-gravity direction. In principle, four sensors should be in the same plane. Ideally, the flat surface should be perpendicular to the gravity direction. Limited by the installation conditions, it is difficult for the four sensors to be in the same plane after installation. Even if there is no load in the car, there will be a particular output signal of the sensor under the action of the mounting bolt, forming a "zero correction error". When the loads are in different positions in the car, the interference force of the fixed bolt on the sensor will also change, so an unstable "system error" is formed. Zero adjustments cannot solve the unstable system error.

(2) It is found that the supporting frame of the experimental car body is not entirely rigid. When the vehicle load is in different positions, the structure drives the load cell to shift. At the same time, the stress of the weighing system is changed, which makes the stress of the load cell extremely complex. The load is no longer the only factor affecting the output of the load cell. Therefore, the weighing is not accurate.

The analysis of on-board weighing test is consistent with the feedback information of market users, which is described as that the error of weighing value exceeds the limit. The scientific research found that both ends of the sensor of the on-board sensor weighing device can not be fixed with thread at the same time.

The load cell structure is designed, and the technology of sticking stress-strain sensor chip is used flexibly. The weighing accuracy of the on-board weighing device is improved by testing and calibrating data on the prototype many times. Design and enhance the connection stiffness of the sensor weighing device of logistics vehicles in the transportation state. The safety device can lock and protect the weighing device in the transportation state. The development of intelligent controller and supporting software includes the design and debugging of controller development board, information interaction among sensors, controllers, network terminals and human-computer interaction interface, terminal display and control software design, etc. The system solves the problems of logistics vehicle weighing, vehicle terminal displaying net weight and total weight, mobile communication video monitoring in material transportation. It is suitable for logistics transportation and storage, large wholesale market, both sides of commercial trade, and self-proof reading of Expressway weight charge.

4 Structural Innovation Technology I: Innovation of Weighing Device and Method for Medium and Small Logistics Vehicles

The on-board sensor weighing device and method innovation of small and medium-sized logistics vehicles are as follows. In the small and medium-sized logistics transportation vehicle without a hydraulic transmission system, the on-board sensor weighing device is designed. The carriage and weighing object are lowered to the weighing position when weighing. A thread fixedly connects the connecting end of the sensor and the mounting base. The other end of the sensor is in an unrestricted free state so that the weighing object can be weighed freely without any restriction. When weighing is not needed or the vehicle is in transportation, the carriage and the weighing thing rise to the vehicle transportation state. The carriage and the weighing object are connected with the vehicle bridge through the vehicle weighing device to form a highly rigid body to ensure vehicle transportation safety.

The working principle of the on-board weighing device for medium and small logistics vehicles is shown in Fig. 1 and Fig. 2.

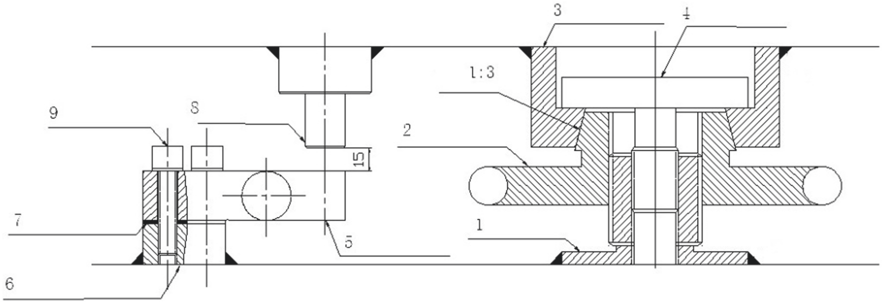

Fig. 1. Upper lifting position - vehicle transportation status.

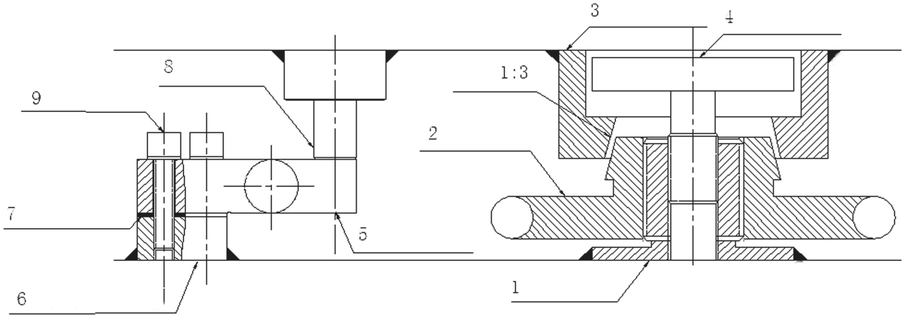

Fig. 2. Lower lifting position - weighing status.

1-bolt base, 2-lifting handwheel, 3-cars with a tapered hole, 4-up limit plate, 5-bar sensor, 6-sensor connection base, 7-assembly adjustment pad, 8-weighing contact, 9-hexagon bolt.

(1) The weighing device for medium and small logistics vehicles is composed of: the axle is connected with bolt base 1, the upper end of lifting handwheel 2 is provided with a tapered shaft, and the taper of 1:3 is used to match with the connecting plate of cars with a tapered hole 3. up limit plate 4, bar sensor 5, sensor connection base 6, assembly adjustment pad 7, weighing contact 8, hexagon bolt 9.

(2) Principle: when the carriage and the weighing object are in the lower position, they can be weighed without any restrictions to realize free weighing; There is no gap between the tapered shaft and the taper hole, and the automatic alignment can be realized; The lifting thread is self-locking under the action of the vertical downward force of the weight, and the thread lifting thrust is significant when the lifting handwheel is rotated; When the vehicle is in the transportation state, the tapered shaft and hole are matched without clearance, and the bolt is fastened with double safety.

(3) Working process:
The working process in the upper lifting position is shown in Fig. 1. When vehicles are in transportation status, the lifting handwheel is rotated clockwise to loosen the

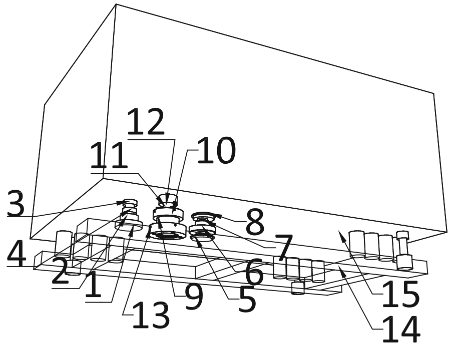

Fig. 3. Layout of 4 groups of on-board weighing devices for medium and small logistics vehicles between axle and carriage.

clamping from top to bottom. The lifting hand wheel continues to be turned, and the carriage will descend with the weighing object. When descending 15 mm is obtained, the weighing contact (the spherical point in the center of the weighing contact) will encounter the strip sensor. When the lifting handwheel continues to be rotated and another descending 15 mm is reached, there is a 10 mm gap between the tapered shaft and the tapered hole in the diameter direction. The lower lifting position is achieved in the weighing state, as shown in Fig. 2.

The working process in the lower lifting position is shown in Fig. 2. When the vehicles are in weighing status, the lifting handwheel is rotated counterclockwise from top to bottom to rise 15mm. And then, the tapered shaft contacts with the tapered hole and the position is automatically aligned. The lifting handwheel continues to be rotated to drive the carriage and the weighing object to rise. When it rises 15 mm again, it meets the rising limit plate. The lifting handwheel continues to be rotated to achieve clamping. The gravity will press down more and more tightly. The upper lifting position is performed in vehicle transportation status, as shown in Fig. 1.

As shown in Fig. 3, four groups of on-board weighing devices for small and medium-sized logistics vehicles are arranged between the two axles and the carriage pad, and the weighing center and weighing area are delimited in the carriage.

5 Structural Innovation Technology II: G2152 [Australia] Load Cell Protection Device and Control Method of for Logistics Vehicle (International Patent)

The invention independently innovates and designs the weighing device and method innovation of the logistics vehicle on the logistics vehicle with a hydraulic transmission system. The invention discloses the protection device of the weighing sensor of the logistics vehicle, including the axle, the lifting cylinder, the cylinder connecting plate, the lifting and lowering center cone shaft, the lifting and lowering center cone hole, the carriage backing plate, the weighing contact (contact with the center spherical point), the weighing sensor Assemble adjustment pad, sensor base, lifting limit plate, reinforcement, positioning safety plate, positioning safety cone shaft, positioning guide support, positioning cylinder connecting plate, placing safety cylinder, hydraulic control module and electrical control module; When the carriage and weighing object are in the weighing state, the load cell can weigh freely without any restriction, which improves the weighing accuracy; When the carriage and weighing object are in the transportation state, the load cell is separated from the carriage and weighing object, and the load cell weighing device of the logistics vehicle sensor is protected and controlled under the transportation condition. The device has a novel and reasonable structure, high efficiency, and broad application scope.

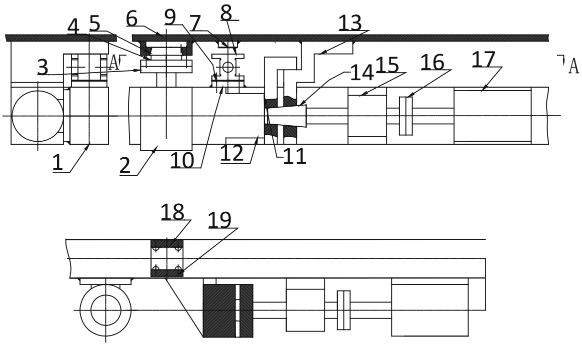

Fig. 4. Transportation status diagram of load cell protection device of logistics vehicle.

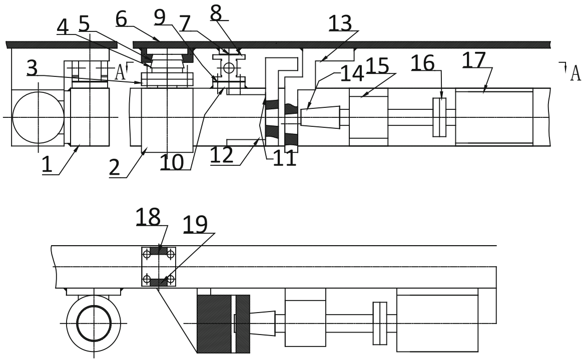

Fig. 5. Weighing status diagram of load cell protection device of logistics vehicle.

As shown in Fig. 4 and 5, the invention provides a load cell protection device for logistics vehicles, which includes: axle 1, lifting oil cylinder 2, oil cylinder connecting plate 3, lifting centering cone shaft 4, lifting centering cone hole 5, carriage base plate 6, weighing contact 7, weighing sensor 8, assembly adjustment pad 9, sensor base 10, lifting limit plate 11, reinforcing rib 12, positioning safety plate 13, positioning safety cone shaft 14, positioning guide mount 15, positioning oil cylinder connecting plate 16, positioning safety oil cylinder 17, oil cylinder hydraulic control module 18 and electric control module 19. The lifting cylinder 2 is welded and fixed with the outside of axle 1. The cylinder connecting plate 3 is associated with the piston rod end of the lifting cylinder 2. The cylinder connecting plate 3 and the lifting centering cone shaft 4 are fixed and secured by bolts. The taper of the lifting centering cone shaft 4 and the lifting centering cone hole 5 is 1:3, and the base of the lifting centering cone hole 5 is welded and fixed with the carriage base plate 6. The weighing contact 7 is welded and fixedly connected with the carriage base plate 6. The sensor base 10 is placed on the axle 1 and welded and the assembly adjustment pad 9 is installed between the weighing sensor 8 and the sensor base 10 by bolts. The lifting limit plate 11 is welded and fixed with the outside of the axle 1 and fastened with the reinforcing rib 12. The positioning safety plate 13 is welded and settled with the carriage base plate 6. The lifting limit plate 11 and the positioning safety plate 13 have taper holes with a taper of 1:12. The positioning safety oil cylinder 17 is welded and fixedly connected with the outside of axle 1. The piston rod end of the positioning safety oil cylinder 17 is provided with a positioning oil cylinder connecting plate 16. The push rod of the positioning safety cone shaft 14 is associated with the positioning oil cylinder connecting plate 16 through the positioning guide mount 15. The taper of the positioning safety cone shaft 14 is 1:12, and the lifting limit plate 11 and the positioning safety plate 13 are fixed by the lock.

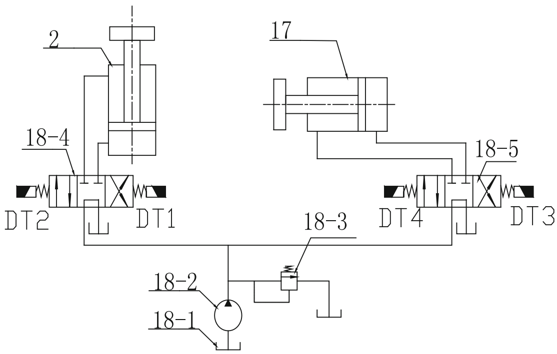

Fig. 6. Hydraulic control module of oil cylinder 18.

Further, as shown in Fig. 6, the hydraulic control module 18 of the oil cylinder includes: oil tank 18–1, oil pump 18–2, relief valve 18–3, three-position four-way electromagnetic directional valve 18–4, three-position four-way electromagnetic directional valve 18–5, first electromagnetic coil dt1, second electromagnetic coil DT2, third electromagnetic coil DT3, and fourth electromagnetic coil DT4. The oil pump 18–2 supplies pressure oil to the oil cylinder system through the relief valve 18–3. The first solenoid coil dt1 and the second solenoid coil DT2 of the three-position four-way solenoid directional valve No.1 18–4 control the piston rod of the lifting oil cylinder 2 to move up and down. The third solenoid coil DT3 and the fourth solenoid coil DT4 of the three-position four-way solenoid directional valve 18–5 control the piston rod of the positioning safety oil cylinder 17 to move left and right.

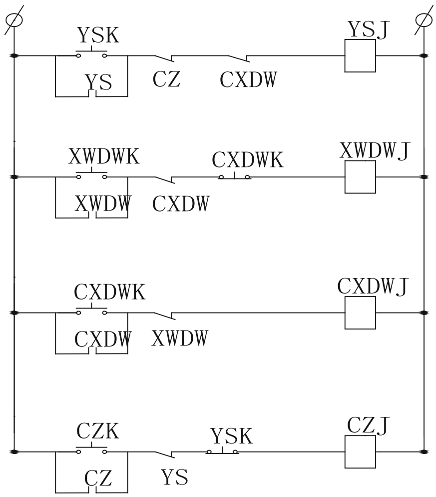

Fig. 7. Electrical control module 19.

As shown in Fig. 7, the electrical control module 19 includes: double contact transport button YSK, transport line relay YSJ, transport protector YS, weighing switch CZ, cancel positioner CXDW, limit positioning travel switch XWDWK, limit positioner XWDW, double contact cancel positioning button CXDWK, limit positioning line relay XWDWJ, cancel positioning line relay CXDWJ Weighing button CZK, weighing line relay CZJ; The double contact transport button YSK and double contact cancel positioning button CXDWK have customarily closed connection and normally open contact. The transport line relay YSJ, limit positioning line relay XWDWJ, cancel positioning line relay CXDWJ, and weighing line relay CZJ have dynamic closing and breaking contact.

Furthermore, as shown in Fig. 4, 5, 6, and 7, the protection and control method of the device is as follows. When the carriage and the weighing object are in the up and down position, which means the vehicles are in the transportation state, the double contact transport button YSK is pressed down. The normally closed contact of the double contact transport button YSK first cuts off the weighing line. Then its normally open contact is closed and stays for 2 s. The transport line relay YSJ receives the electric signal and makes the dynamic contact of the transport line relay YSJ close. The transport line relay YSJ is powered on and self-locking; The oil pump 18–2 is started. The relief valve 18–3 sets the pressure value of the system pressure oil and supplies the pressure oil to the system. The first solenoid coil DT1 of the three-position four-way solenoid directional valve 18–4 is energized, the right position of the three-position four-way solenoid directional valve 18–4 is in the working state, and the pressure oil enters the lower chamber of the lifting cylinder 2 through the right position of the three-position four-way solenoid directional valve 18–4. At the same time, the pressure oil in the upper chamber of lifting cylinder 2 flows back to the oil tank 18–1 through the right position of the three-position four-way solenoid directional valve 18–4. The piston rod of the lifting cylinder 2 moves up, and through the cylinder connecting plate 3, the lifting centering cone shaft 4 moves up and meets the lifting centering cone hole 5. The lifting centering cone hole 5 is aligned. When the positioning safety plate 13 touches the lifting limit plate 11, the resistance of the lifting cylinder 2 increases again. When the system pressure increases to the set value, the pressure is maintained, and the lifting stops. At this time, the limit positioning travel switch XWDWK on the lifting limit plate 11 is pressed. The limit positioning line relay XWDWJ receives the electric signal and makes the dynamic contact of the limit positioning line relay XWDWJ close. The limit positioning line relay XWDWJ is powered on and self-locking. At the same time, the third electromagnetic coil DT3 of the three-position four-way solenoid directional valve 18–5 is powered on, and the right position of the three-position four-way solenoid directional valve 18–5 is in the working state. The pressure oil enters the right chamber of the positioning safety oil cylinder 17 through the right position of the three-position four-way solenoid directional valve 18–5, and pushes the piston rod of the positioning safety oil cylinder 17 to move to the left. Through the connecting plate 16 of the positioning oil cylinder and the positioning guide mount 15, the positioning safety cone shaft 14 moves left to the cone hole on the positioning safety plate 13 and the lifting limit plate 11. When there is no clearance between 13 and 14, the left movement stops. The set positioning safety oil pressure value is maintained, and the taper of 1:12 in the horizontal direction is adopted so that it has a self-locking function in the vertical direction, which plays a protective and control role for the logistics vehicle load cell in the transportation state.

After transportation, when the carriage and the weighing objects are in the lower lifting position, that is, in the weighing state, the double contact cancel positioning button CXDWK should be pressed. In the process of moving down, the normally closed contact of the double contact cancel positioning button CXDWK cuts off the position limit and then closes the normally open connection. After staying for 2 s, the cancel positioning line relay CXDWJ received the electrical signal. At the same time, the fourth solenoid coil DT4 of the three-position four-way solenoid directional valve 18–5 is energized. The left position of the three-position four-way solenoid directional valve 18–5 is in working state, and the pressure oil enters the left chamber of the positioning safety oil cylinder 17 through the left position of the three-position four-way solenoid directional valve 18–5. The piston rod of positioning safety oil cylinder 17 is pushed to the right. At the same time, the pressure oil in the right chamber of positioning safety oil cylinder 17 flows back to the oil tank 18–1 through the reversing valve. The piston rod of positioning safety oil cylinder 17 moves to the right. Through the connecting plate 16 of the positioning oil cylinder and the positioning guide mount 15, the positioning safety cone shaft 14 moves to the right to the beginning of the stroke. The weighing button CZK is pressed, and then, the weighing line relay CZJ is powered on and self-locking. The dynamic contact is closed. At the same time, the second solenoid coil DT2 of the three-position four-way solenoid directional valve 18–4 is charged. The left position of the three-position four-way solenoid directional valve 18–4 is working. The pressure oil enters the upper chamber of lifting cylinder 2 through the left part of the three-position four-way solenoid directional valve 18–4. The piston rod of the lifting oil cylinder 2 is pushed to make the cylinder connecting plate 3. The centering cone shaft 4 and centering cone hole 5 are lifted. The carriage base plate 6 moves downward. At the same time, the pressure oil in the lower chamber of the lifting oil cylinder 2 flows back to the oil tank 18–1 through the left of the three-position four-way electromagnetic directional valve 18–4. The carriage and the weighing body move downward under the vertical downward gravity. The weighing contact 7 is in connection with the upper end of the weighing sensor 8 and then the carriage and the weighing object stop moving down. Weighing is carried out without any restriction. And the piston rod of the lifting oil cylinder 2, the oil cylinder connecting plate 3 and the lifting centering cone shaft 4 continue to move down to the original position. In the weighing state, there is enough clearance in the diameter direction between the tapered shaft of the lifting centering tapered shaft 4 and the lifting centering tapered hole 5, and a certain amount of allowance in the horizontal direction.

The base end of on-board load cell is connected with the fixed thread of the vehicle bridge, and the other end is free to weigh without restriction. It is unnecessary to make a connecting thread hole so as to avoid mistakes in using methods. The problem of inaccurate weighing in on-board weighing is solved in principle, and the dynamic weighing sensors are detached. Thus, the service life is effectively improved. The device has a reasonable and compact structure, novel technology and wide application range.

6 Innovation

(1) It is found that the two ends of the load cell can not be connected with a screw simultaneously through scientific research. The end of the load cell base is fixed with the axle by bolts. The other end is recommended that no connection screw holes be made and two working states are used. The weighing device of the vehicle sensor is lifted to the upper position to realize safe transportation. The force on the sensors turns from pressure to tension. The carriage and weighing object are free to contact the upper end of the sensor through the weighing contact to realize free weighing without any restrictions. In principle, the interference and random factors are eliminated, and the bottleneck problem of inaccurate weighing with logistics vehicles is solved.

(2) Apply for Australian international patent “G2151 [Australia] one vehicle weighing device” and “G2152 [Australia] logistics vehicle weighing sensor protection device and control method”. The patent of “one-dimensional angular, linear weighing method of multi-support weighing system ZL201810280073.9” is authorized.

(3) Innovative design of small and medium-sized logistics vehicle weighing device and method innovation is accomplished. The logistics vehicle weighing sensor protection device and two sets of weighing machines are obtained for testing. The experimental results show the correctness and reliability of the research.

(4) The conclusion can be seen in Scientific and technological novelty Report No.: 2017-036. In the current situation and with the development trend of dynamic weighing and force measurement technology, the research and development of key technologies of the one-dimensional linear dynamic weighing device in this project have not been reported.

(5) The calibration results meet the technical requirements of JJG 455-2000 standard force measuring instrument verification regulation, which is proved in the test report of Beijing Institute of measurement and testing technology (authorized by the state defense science and Technology Industry Bureau, authorization certificate No.: National Defense military industry-JLJG-1-003). The Certificate No. is TJ1C9019-04-07386 for force sensor FYXZ-07.

7 Application Examples

7.1 One Dimensional Angle Linear On-Board Dynamic Weighing Device for Logistics Vehicles

Jiangsu Zongshen Automobile Industry Co., Ltd. and Xuzhou University of technology bring their respective industrial and technological advantages into play. The college and enterprise alliance is formed with research cooperation. Through the joint research and development of a new sensor device for 12-point position 12-point force video display, one-dimensional linear wireless sensor network node positioning method and other system software and hardware, multi-support weighing system unified dimension linear weighing method, and so on, scientific and technological achievements are obtained with obvious social and economic benefits. The application demonstration of on-board weighing technologies with patents, such as the utility model relating to a dual-signal and dual-screen cross-type vehicle terminal for logistics vehicles (ZL201310434153.2), non-contact detection device system for mixture parameters of vehicle terminal interaction (ZL201310740127.2), and so on, gains remarkable results and feedback. In Huaihai Economic Zone, 90% of Shunfeng express logistics vehicles and 40% of Jingdong logistics vehicles are provided by Jiangsu Zongshen Automobile Industry Co., Ltd. According to the applicable certificate of Xuzhou Haipai Technology Co., Ltd., Jiangsu Zongshen Automobile Industry Co., Ltd., and Xuzhou Daoge Information Technology Co., Ltd., the total amount of new-increased profit from 2018 to 2020 is 107.44 million yuan. The new-increased tax is 16.885 million yuan. The foreign exchange income is 18.22 million US dollars, and the total expenditure is 40.47 million yuan.

7.2 Video Monitoring Device with Visual Vehicle Terminal for Mobile Communication

Xuzhou Haipai Technology Co., Ltd., as an application and promotion enterprise of scientific and technological achievements, is engaged in the development, sales, use and maintenance of software and hardware of on-board terminal and handheld terminal XGZS001. The technologies of vehicle networking visualization vehicle terminal software, Internet of things parking service and management fees, overload of passenger and freight vehicles on the highway, mobile communication visualization, on-board terminal video monitoring device achieve astonishing results. From 2018 to 2020, the new-increase profit is 3.29 million yuan. The new-increase tax is 435000 yuan. The foreign exchange income is 3.02 million US dollars, and the total expenditure is 1.86 million yuan.

In May 2018, Xuzhou Daoge Information Technology Co., Ltd. introduced the XGHP001 system software and hardware, which was researched and developed by Xuzhou Institute of engineering, and carried out the application demonstration of scientific research achievements. In the past three years, it has increased profits by 7.15 million yuan and taxes of 910000 yuan. A foreign exchange of 310 US dollars was generated, and a total of 3.86 million yuan was saved. Remarkable social and economic benefits have been achieved.

7.3 Benefits from Core Patented Technology Transfer

In 2019, To realize the transformation of science and technology into productivity and the promotion and application of patented technology, the authorized invention patent rights of the core key technologies were transferred, namely "a dual-signal and dual-screen cross-type vehicle terminal for logistics vehicles (ZL201310434153.2)" and "non-contact detection device system for mixture parameters of vehicle terminal interaction (ZL201310740127.2)", to Jiangsu Zongshen Automobile Industry Co., Ltd.

Acknowledgements. The authors acknowledge the Jiangsu University Natural Science Research Project (18KJB470024) and Provincial Construction System Science and Technology Project of Jiangsu Provincial Housing and Urban-Rural Construction Department (2018ZD088). This work is partly supported by the Natural Science Foundation of Jiangsu Province of China (No. BK20161165), the applied fundamental research Foundation of Xuzhou of China (No. KC17072). The authorized patents for invention are also the research and development of Jiangsu Province Industry-University-Research Cooperation Project (BY2019056).

References

1. Xi, J.: Parking information interaction of global internet of things based on the timer and elastic pressure switch sensor combination. Appl. Mech. Mater. **614**, 497–502 (2014)
2. Xi, J., Han, C.: Parking navigation system based on the double signal double display intersection vehicle terminal and automobile internal information. Appl. Mech. Mater. 803–808 (2014)
3. Xi, J.: Global internet of things garage system wite parking information release of timer control. Meas. Control Technol. **33**(9), 128–130 (2014)
4. Xi, J.: Self-organizing IOV technology oriented vehicle driving and parking service using vehicle terminal. J. Comput. Sci. Technol. **41**(11A), 466–467 (2014)
5. Xi, J.: Parking information release and booking park equipment for garage system on the Internet of things. J. Comput. Appl. **34**(S1), 306–308 (2014)
6. Wang, L., Xi, J., Han, C., Qiao, S.: One dimensional angle linear weighing method for multi fulcrum weighing system. CN108489578A (2018)
7. Huang, W., et al.: Node localization method for wireless sensor networks in one dimensional linear region. CN104703277B (2018)
8. Han, C., Xi, J.: Vehicle terminal space labyrinth module. CN103522963B (2017)
9. Xi, J., Daihong, J., Han, C.: A crossover vehicle terminal with dual channel and double screen. CN103528594B (2017)
10. Liu, A., Xi, J.: Non contact detection system of mixture parameters based on vehicle terminal interaction. CN103674776B (2017)

11. Wang, S., et al.: A logistics dynamic weighing sorting integrated device. CN110252678A (2019)
12. Wang, L., et al.: A dynamic weighing equipment for logistics transportation. CN209727234U (2019)
13. Yu, J., et al.: An electronic driving scale with stable installation and anti-collision. CN110260960A (2020)
14. Fang, E., et al.: A dynamic weighing device. CN210375366U (2020)
15. Wang, L., et al: A kind of vehicle weighing equipment. CN212363390U (2021)
16. Xuzhou University of Technology: Weighing in motion self-calibration algorithm software. 2018SR670312 (2018)
17. Xuzhou University of Technology: Dynamic electronic weighing system software. 2018SR632550 (2018)
18. Xuzhou University of Technology: Intelligent weighing dynamic memory management system. 2019SR1078748 (2019)
19. Xuzhou University of Technology: Dynamic digital weighing automatic management system. 2019SR1078732 (2019)
20. Xuzhou University of Technology: Calibration and optimization software for vehicle weigh in motion. 2019SR1141072 (2019)
21. Xuzhou University of Technology: Key technology research and development of one dimensional linear dynamic weighing electronic device. Science and Technology Novelty Search Report 2017-036, Xuzhou science and Technology Information Institute of Jiangsu Province (2017)
22. Xuzhou University of Technology: Load cell test report. Beijing Institute of aerospace metrology and testing technology (authorized by the State Administration of science, technology and industry for national defense, Certificate No.: National Defense industry-JLJG-1-003), Certificate No.: TJ1c2019-04-07386, Calibration certificate of load cell FYXZ-07 (2019)