Development of a Revolutionary Advanced Auto-shackle, A Construction Equipment

Keon Young Yi* *Associate Professor*
Jong Eun Lee* *Graduate student*
Sam Yong Chung** *Team Leader*
Song Soo Han** *Senior Researcher/Ph.D*

*Dept. of Electrical Engineering
Kwangwoon University, Seoul 139-701, Korea

**Research Institute of Technology,
Samsung Corporation
270-1 Seohyun-dong, Bundang-gu,
Sungnam-si, Gyonggi-do 463-824, Korea

Telephone : +822-940-5142
Fax : +822-942-0107
E-mail : keonyi@daisy.kw.ac.kr

Abstract : In the field of construction work, shackle is one of the most essential tools to build up a structure on the foundation. The process of setting up the beam to its up-right position starts from linking the end of the beam and the shackle by a construction worker. Then the beam is carried to the proper place by a crane. After fixing up the beam, according to the old-style process, a construction crew climbs up the beam to release it from the shackle. This step is hazardous and very inefficient, which is needed to be automated. For this reason, the auto shackle controller with two shackles, which can release the beam through a wire-less command, was developed. The auto-shackle controller makes the work safer and more efficient. However, the early auto-shackle controller itself was heavy and had some sorts of problems in safety and durability.

In former research, the advanced auto shackle controllers solved the problem of the durability by reducing the height and the internal mechanical structure of the shackles; the control wires were damaged easily by steel chain hits when the shackles were released. However it is still heavy because the controller uses an automotive battery for a power source. Now, we present a super miniaturized high-performance auto-shackle controller which has no exterior controller using state-of-the-art technologies. Furthermore mechanical structures are changed to ensure the safety of the shackle.

Keywords : Auto-shackle, construction tool, shackle, clamp, revolutionarily advanced auto shackle.

1. INTRODUCTION

For the construction of higher-storied buildings, composing a steel-frame structure is a basic task and a very important step [1]. Figure 1 shows the process of setting up steel frames. In old- style processing, a construction crew binds an iron beam (‘a’ in the Figure 1) to the shackle equipped under the working crane (‘b’ in the Figure 1) and then moves it to the proper place for temporary assembling [2] [3]. Last, the construction crew climbs up to the top of the iron beam to unbind it from the existing bolts and nuts at the shackle (‘c’ in the Figure 1). It is a very hazardous work because of the falling accidents. In addition, it is inefficient because of the climbing time and the increasement in operation loads. It is a serious problem so we need automation in the working processes.

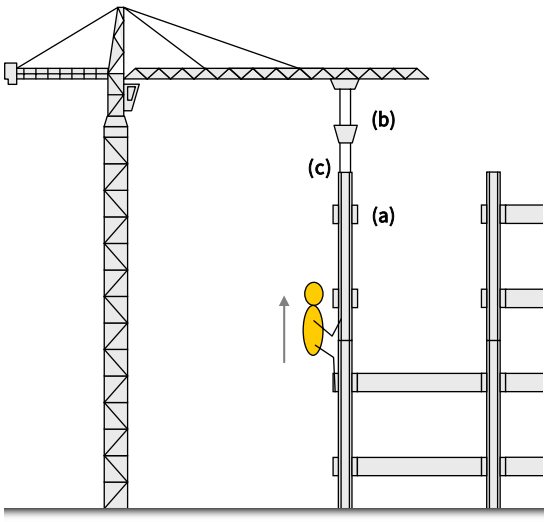

Figure 1. The process of building an iron beam

For this reason, the auto shackle controller with two clamps, which can be operated to release the iron beam through the wireless remote controller, was developed by Research Institute of Technology, Samsung Corporation [4] [5]. Hereby, the auto shackle controller removed the danger of the operation radically. In addition, it reduced cycle time of the iron beam assembly so the work became more efficient.

However, the early auto shackle controller is heavy and has some sorts of problems in safety and durability. To solve these problems, the advanced auto shackle was developed [6] through changing and miniaturizing the structure of the clamp as well as developing a durable controller. Nevertheless, the advanced auto shackle was still heavy because of its power supply which was a vehicle battery. Another problem was breaking of the signal wires. As battery technology makes progress, the super miniaturized high-performance advanced auto shackle controller which has no external controller is designed to solve these problems radically. As battery technology advances, the auto shackle miniaturizes revolutionarily. Because of structural change, safety and durability increases. Thus, the super miniaturized auto shackle will be used commonly.

2. THE FIRST AUTO SHACKLE CONTROLLER

Equipments like a tower crane is usually used for setting up an iron beam for the foundation of high-storied structure. The crane equipped with a shackle and sling wires carries the beam to the proper place for the foundation. The old process is that a crew climbs up to the top of the iron beam and releases the clamps by hand. This step is very dangerous. The first auto shackle which was developed by Samsung Corporation, releases a steel beam automatically with wireless communication controller instead of the old process. It makes the working process more automatic, efficient and also prevents falling accidents. It is an epochal equipment to the new working process.

Figure 2. Setting up a vertical beam

Figure 2 is using the first auto shackle in the construction site of the Hopping power plant in Taiwan. In this figure, there are clamps of the auto shackle on the top of steel beam. The arrow points at the main body of the auto shackle.

2.1 Sturcture of the first auto shackle

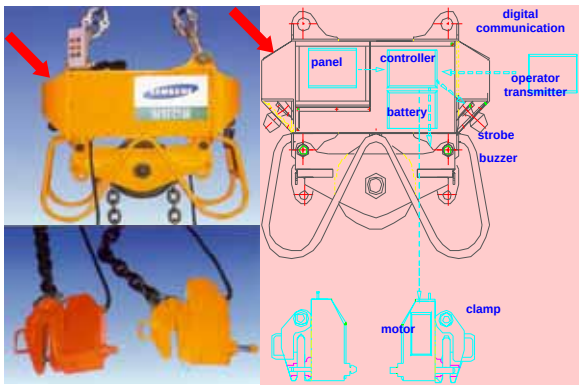

Figure 3. The first auto shckle

The first auto shackle controller primarily consists of the main body and two clamps. Each of the structure is like Figure 3.

2.1.1 The main body of the first auto shackle

The main body which is pointed by an arrow has a rechargeable battery for the power supply of this system, wireless communication module and system control board are built in it. The main body prevents damage from the outside impact and humidity like the function of a cabinet and transmits the weight of suspended steel frame to the crane. Also, it gives sounds and lights alarms of its operation states to surrounding crews.

Table 1. Properties of plates

Material	Elastic constant	Tensile strength	Yield point	Remark
SM45C	2.1×10^4	42.5	35.0	$v = 0.29$
SCM415	2.7×10^4	85.0	39.0	
SNCM439	3.7×10^4	75.9	48.1	

A steel plate is attached inside of the main body because the wrapping material of the main body can not stand the weight of a steel frame. The steel plate is made of SM45C [7]. Thirty millimeter of armature is welded into the parts which can break down because of concetration of the stress of the frame. In the edge which is an expectable concentration of the stress, breakdown stress is $35kgf/mm^2$ and the stress state of Von Milses [8] is $11.3kgf/mm^2$. Table 1 is the summarized properties of plates.

In the part of bolts and chain linking, the sectional stress concentration is likely to happen so the SNCM

bushing is installed and heat treatment has done. Thus, the possibility of breakdown is reduced.

2.1.2 System controller

The controller consists of wireless communication module, a digital indicator for expressing operation state and input device to command digital and analogue input.

The wireless module of auto shackle is BIM-433-HP manufactured by RadioMatrix, using this module interfaces with a microcontroller. Also, to communicate by wire, a port is made up with MAX-232.

A limit switch is used for the crews to detect the locking state of the shackle pin. The control program interprets and analyzes operation state with the limit switch signal.

2.2 The clamp of the first auto shackle

The clamp is the actual part of linking the shackle to a steel beam. It performs two major roles in the whole system. The first role is hanging an iron beam. During that time, the clamp pin has to stand the high pressure of the steel beam's weight so the pin is made from the strong material SNCM. Except the pin, expectable parts of high stress transmission is made from SCM in the whole clamp.

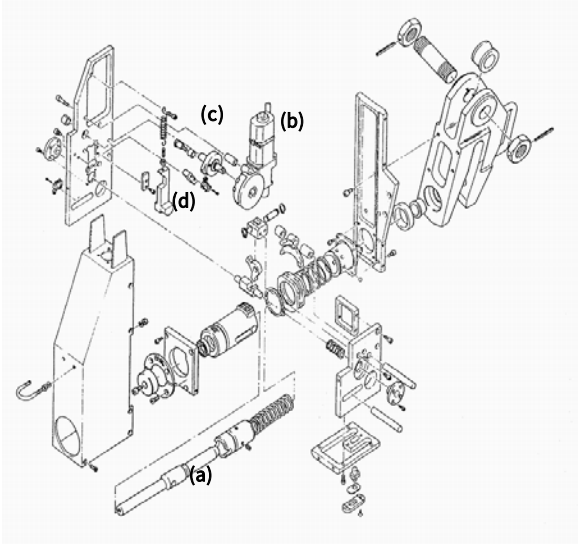

Figure 4. Deal drawing of the first auto shackle clamp

Figure 4 is the deal drawing of the first auto shackle clamp. The pin ('a' in Figure 4) receives elastic force of the spring, to the outside of the clamp, which is the position open. To lock the shackle, a crew has to press the pin inside the clamp. The auto shackle operates automatically for the unlocking process to minimize its power consumption so the locking process is manual. The DC motor ('b' in Figure 4) in the clamp is served to release the clamp. The cam ('c' in Figure 4) is moved with dynamic force of the motor to press the trigger. Then, the pin is released by the elastic force of the spring. The method of the locking tool is double lock for safety.

The main body links two clamps with chain. Two signal lines along with the chain let clamps communicate with the controller in the main body. In the whole processing of the first auto shackle controller, there is danger of breaking the signal line because the signal line gets tangled with the chain. For this reason, Figure 4 shows that the motor part leans twenty degree form the locking part to protect the breaking the wire.

2.3 Wireless communication

In 2.1, the auto shackle consists of two major parts which are main body and clamps. In addition, the wireless communication part is one of the auto shackle parts. In general, the kernel of wireless communication technology is to minimize noises and jamming. The first auto shackle controller removes the possibilities of noises and jamming with digital telecommunication method.

The wireless communication module of the auto shackle consists of two major parts. They are transmitting and receiving parts. The transmitting part is built in the remote controller to make it easy to manipulate. The transmitting part receives and analyzes digital signals and then it transmits the signal to the PCB for control input.

The remote controller has six buttons and three indicating lamps. They are power ON/OFF buttons and releasing A and B buttons, each of that works to release A and B clamp. The A and B buttons work when they are pressed at the same time to prevent incorrect controls. The indicating lamps consist of power ON/OFF state lamps and battery recharge state lamp.

Table 2 is specified summary of the wireless communication.

Table 2. RF modem specification

RF - Modem Description	TX - UNIT	RX - UNIT
Frequency	447.8625 ~ 447.9875 kHz	
Channel Frequency	12.5 kHz, 11 chn	
Modulation	FSK	
Communication Speed	2400 bps	
Service Distance	100 m	

2.4 Effects of the first auto shackle

The first auto shackle controller secures safety of the crews and gives economical effects as shown in Table 3 under nomal working environment.

In Table 3, Safety of crews is remarkably increased and the time cycle of processing is decreased using the auto shackle. As a result, productivity is increased.

The economical efficiency can change from twenty

to forty percent by the working environment. In Table 3, the data does not include immaterial effects of supporting equipment like tower crane and prevention of accidents.

Table 3. Comparence of processing time

Item	Crew handling	Using auto shackle	Effects
Standard operation hour	8.5 hour/Day		
Time Cycle (min/cycle)	30	23	Reducing 7
Number of operation/Day	17	22	Reducing 5
Construct period (T site : 500 operations)	29 Day	22 Day	Reducing 7 days (Reducing about 24%)
Safety	Danger	Safe	Removing danger source

3. THE ADVANCED AUTO SHACKLE CONTROLLER

3.1 Problems of the first auto shackle controller

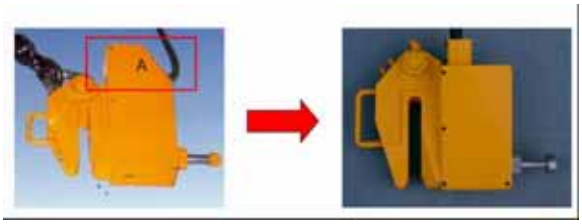

Figure 5. Formal change of clamp

The first auto shackle does not have enough distance between connecting part and operation equipment as the Figure 5 area A. When a crew unlocks the auto shackle, he should worry about damage of signal line due to crash with the chain by strong elastic force and inertia of the clamp. The motor position of the first auto shackle controller is controlled by limit switch so it is not durable. The weight of clamp is heavy so the restoration elastic force of the clamp is strong too. Thus, a crew sometimes needs supporting equipment when he locks the clamp. In the wireless communication part, the operator of the shackle does not know the present position of motor. If the limit switch is broken, motor works continuously. That could be a cause of motor breaking.

These problems are possible to solve by reconstructing the motor parts position that reduces the size of the clamp and developing of reliable controller. Also, operator of the shackle can know the present motor position through wireless communication when the limit switch is broken.

3.2 Advanced auto shackle controller

Figure 5 shows miniaturization of the clamp to cut the upper motor part. The structure of motor part is changed too.

3.2.1 Structural change of advanced auto shackle clamp

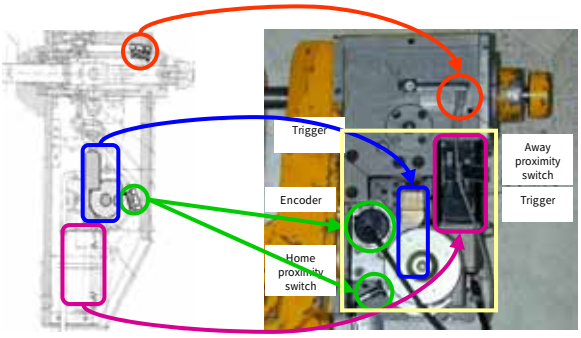

Figure 6. Structural change of advanced auto shackle clamp

In Figure 6, we can see that not only the appearance but also the structure of main body is changed in order to solve the problem commented in 3.1. In the first auto shackle, motor power was transmitted through the cam. However, the advanced auto shackle transmits motor power through the crank. An encoder is used to detect the present position of motor, which prevents the motor from excessive working even though the switch detecting locking state is broken.

The type of switch which indicates locking state is proximity switch instead of limit switch. Proximity switch is a metal detecting senor. It is durable and operates well.

3.2.2 Development of a reliable controller

The reliable controller board is developed. It can check the states of wireless communication, encoder and proximity sensor by itself. It can also report the present state of the auto shackle with a buzzer and alarm lamps. In addition, developing the remote controller which notifies the state of the auto shackle makes the auto shackle more reliable.

3.3 The shackle open process of the advanced auto shackle controller

The shackle open process is as presented next. There is a big load to begin initial operation so motor is controlled with full power instead of PID control. At first, unlocking angle is chosen to be 110 degrees and then, controller commands the motor to rotate 110 degrees. If the motor rotates less than 90 degrees it means the clamp at the shackle is still locked. At that time, controller commands that the motor rotates 10 degrees counterclockwise. And then the controller commands that the motor rotates clockwise again. This process repeats 15 times.

When the clamp is unlocked, “Away proximity switch” turns ON. If the switch doesn’t turn ON,

controller regards that the clamp is lock and gives the switch error.

After finishing the unlocking process of the clamps, the motor returns to the original position then, the “Home proximity switch” turns ON. After finishing the unlocking process, motor turns ON the buzzer to notify working state.

4. THE REVOLUTIONARY ADVANCED AUTO SHACKLE CONTROLLER

4.1 Problems of the advanced auto shackle controller

After developing the advanced auto shackle controller, some sorts of problems of the first auto shackle controller was solved. However, some problems of safety and durability which, the first and the advanced auto shackle controller have still remained.

Early auto shackle controllers have structural problems. The pin of clamp protrudes from the inside clamp. When crews lock the clamp, they should push the pin inside of the clamp. If the clamp is broken, the pin is pushed outside by the elastic force of the spring. It became a problem of stability. Also, the signal line between main body and clamp is rubber cable. It made possible the danger of the wire breaking because of a strong elastic force during unlocking process.

The reason of heavy weight of early auto shackle controller is the power supply in its main body. It is a vehicle battery and it is large so the main body is made to exist. The main body has a steel plate because it has to withstand the weight of hanging steel beam. Main body weighs 500kg. Each clamp weighs 30kg. Thus, the weight of early auto shackle controller including linking chain is approximately 600kg. Because of that crews can not link it to a tower crane by themselves. Because of the weight of auto shackle controller, the crew sometimes needs some equipment.

For this reason, the revolutionary advanced auto shackle controller is designed.

4.2 The structure of revolutionary advanced auto shackle controller

Figure 7 compares early auto shackle controller with revolutionary one. In appearance, there is no exterior controller but only chain and two clamps. The signal lines disappeared because controller is placed in the interior of clamp. Also we can remove the steel plate which withstands the weight of the steel beam.

As the main body disappears, the whole weight of the auto shackle controller becomes approximately 60kg. As a result, crews can link the auto shackle controller to a crane without any equipment.

One of the reasons why the auto shackle is revolutionarily light is changing battery. Lithium-Polymer battery [9] is used for power supply instead of vehicle battery. In the case of motor, motor controller and other devices in the main body are miniaturized and organized in the clamp.

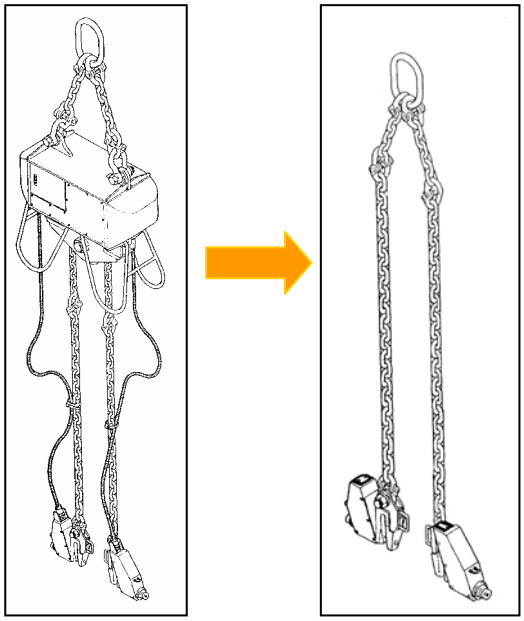

Figure 7. The revolutionary advanced auto shackle controller

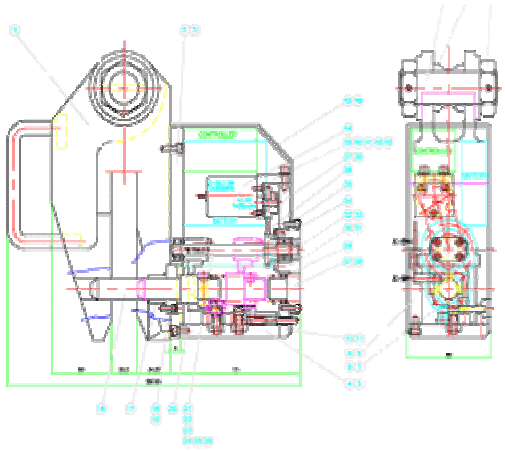

Figure 8. The drawing of the super miniaturized auto shackle

Figure 8 is the drawing of the super miniaturized auto shackle. It shows miniaturized battery. Motor controller is also minimized. It shows the initial state of the revolutionary advanced auto shackle pin that is locked. If the clamp is out of order, the pin does not unlock by itself.

The unlocking operation is changed structurally. The early auto shackles use the elastic force of the spring. However, the revolutionary advanced auto shackle has a different working structure. Rotary motion of the motor is converted into rectilinear motion then the pin is moved slowly instead of using elastic force. The early auto shackles are automatic only on the unlocking process. The revolutionary one

locks and unlocks automatically when the motor rotates clockwise or counterclockwise. The motor part of the clamp is parallel with the locking part. There is no necessity to lean the motor parts because the signal lines disappeared. The side view of Figure 8 shows it.

5. CONCLUSION

In this paper, we presented the background of developing the auto shackle controller which influences automation in the construction field. We presented what is the first auto shackle controller and analyzed the problem of it. We also presented the advanced auto shackle controller which solved the problems of the first auto shackle. However, the advanced one still has problems. Finally, we introduced the design of the super miniaturized high-performance auto shackle controller.

The revolutionary one is developing commonly. Through further research, we can study how to make work in construction fields more efficient and safe.

REFERENCES

[1] Kim. Sangbum, Choi. Sung mo, Yoon. Sung won, “Develpoments and Demand Strategies for Steel Framed Residential Buildings”, *Journal of Korean Society of Steel Construction*, Vol. 15, pp. 33-39, 2003.

[2] Harris, Cyril M, *Dictionary of Architecture & Construction*, McGraw-Hill., 2000

[3] Butler, Robert Brown, *Architecural Formulas*, McGraw-Hill., 2002.

[4] Samsung Corporation, *The remote controller of shackle for clamping of “H” beam*, No. 149141, Korea Intellectual Property Organization, 1998.

[5] Samsung Corporation, *Shackle for clamping*, No. 0193956, Korea Intellectual Property Organization, 1998.

[6] Intelligent Lab. Electrical Engineering, Kwangwoon University, *Development of the auto shackle controller (Final report)*, Kwangwoon University, 2000.

[7] Kim. Hyun-Chul, Park. Yong-Shick, Lim. Byeong-Soo, “Influence of grain size and inter-particle spacing on the fatigue crack propagation in SM45C steel”, *Proceedings of 6th international Pacific Conference on Automotive Engineering*, pp. 719-725, 1991.

[8] Kim. Jin-Woo, *On the Computation for Elastic-Plastic Finite Deformation Process*, Korea Military Academy, 1983.

[9] Brodd, R.J., Lundquist, J.T., Morris, J.L., Shackle, D.R., "New rechargeable polymer battery system", *Battery Conference on Applications and Advances*, pp. 135-139, 1994.