Development of Electronic Opening and Shutting Device for One-Ton Wing-Body Truck

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Abstract: The wing-body trucks are special vehicles that are designed to provide large carrying space and to protect the freights from outside impacts and bad weather. They are constructed to the structure opening and shutting three-layered aluminum top.

In the middle- and large-size(above one-ton) wing-body trucks, wing-body is opened/closed by opening and shutting device of oil pressure type. But one-ton truck is constructed that its wing-body is opened/closed in manual to use helping of stay-dampers. So, we developed an electronic opening and shutting device for one-ton wing-body trucks to improve the inconvenience of usage for manually operated wing-body.

The developed device is consisted of two connected links and a dc motor combined with an worm gear. The worm gear changes the rotation axis of the dc motor to a right-angled direction and transfers the torque of dc motor to the links. The two connected links open/shut the wing-body using the torque transferred from the dc motor. When the wing-body starts to be opened, the biggest torque is required from the dc motor for opening the wing-body. And as the wing-body is opened more and more, the required torque is smaller for opening the wing-body. Thus, the structure of two connected links are designed to locate at the center of worm gear so that maximum torque of the dc motor is transferred the links at the initial time starting to open wing-body.

The controller of the device with open and closed buttons also is designed to protect the device from over-opening and over shutting operations. The developed device is accomplished for many experiments using actual vehicle. Those experiments show that the device has more excellent performance than the oil pressure type.

Keywords: wing body, special vehicle, link, worm gear, geared motor

1. INTRODUCTION

The wing-body trucks are special vehicles that are designed to provide large carrying space and to protect the freights from outside impacts and bad weather. They are constructed to the structure opening and shutting of three-layered aluminum top. The thing that an aluminum top is opened like the wings of the bird is called the wing-body. In the middle- and large-size (above one-ton) wing-body trucks, wing-body is opened/closed by opening and shutting device of oil pressure type. But one-ton truck is constructed that its wing-body is opened/closed in manual to use helping of stay-dampers.

The manual type consists of stay damper of gas cylinder. Stay damper has been utilizing for opening and shutting the wing-body as connecting wing-body and aluminum-body. In case of wing-body special vehicle which has only stay damper, it is necessary that load must be taken into consideration on the damper installation. The existing manual wing-body truck has a gas cylinder of maximum repulsive force. But it is not enough to reduce a load of wing-body, so wing-body is fast closing. So, when wing-body is closed, torsion spring has been used for reducing wing-body load. But, while it is possible that wing-body can be stable on opening and shutting, it occurs to operators that they should close the wing-body with more external force.

Nowadays when opening and shutting device of oil pressure type used on middle- and large-size wing-body applies to small special vehicle, competitive power of price goes down because wing-body total cost is rising with power unit consisted of oil pressure device is too expensive. The damage of baggage may be happened when oil is spilled out from oil pressure cylinder by its deterioration or wear. In addition to the alternative way has been discussing due to environment problem.

Therefore, we developed an electronic opening and shutting device for 1t wing-body trucks to improve the inconvenience of usage for manually operated wing-body. As a result, the electronic opening and shutting device is shown marked in effectiveness. It provides an economic cost and excellent durability, and guarantees convenience of loading working and maximum carrying capacity.

Fig. 1 1t Wing-Body Truck

2. DESIGN AND IMPLEMENTATION

The electronic opening and shutting device for 1t wing-body special vehicle consists of three components of mechanic part, actuator part and control part.

In the mechanical part, we analyze the physical modeling of stay damper where is attached 1t special vehicle for side opening. For loading and unloading on one-side, we designed wing-body that it can be opening and shutting to the way. As new mechanical part which is not the type of existing oil pressure is desired, we designed new mechanical part based on previous physical modeling.

In the actuator part, we calculate physical requirements needed to operate mechanical part after finishing the design of mechanical part according to the decision of operation pattern of mechanical part. When actuator part is required the motor, those procedure is illustrated if Fig.2.

In the control part, according to input signal that is received from operator by switching, motor is rotating forward and backward for opening and shutting wing-body. When wing-body is totally opened and closed, motor does not operate even though it gets input signal. So, we can prevent safety accident by inattention.

The basic steps in the motor selection procedures are as following diagram :

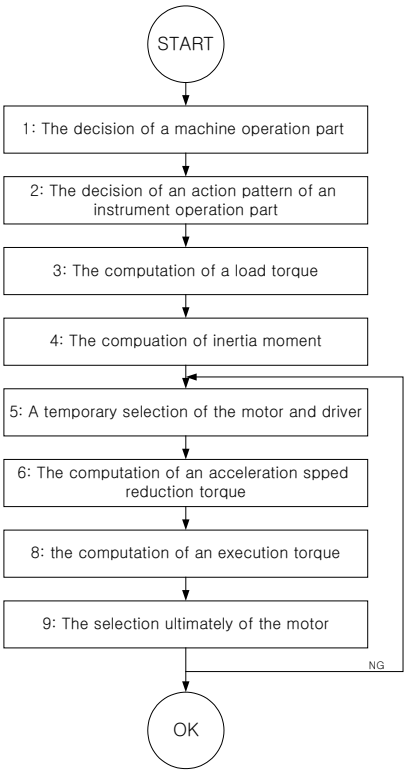

Fig. 2 The motor selection procedures

2.1 Mechanical parts

First of all, we calculated wing-body's distributed load, concentrated load and moment with using basic theorem of dynamics and statics to derive operation pattern of torsion spring and damper from existing manual wing-body. Fig.3 shows open form of wing-body.

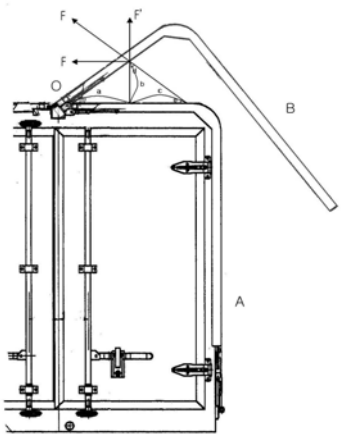

Fig. 3 The opening form of wing-body

In the first place, each variable is assigned on the Fig. 3 and moment of point O on each of A and B is calculated. A is a condition when wing-body is totally closed. B is other condition. The calculated moment is applied to needing torque when the motor is installed on point O. The quantity of moment variation according to angle change of the stay damper is that shown in the Table 1. The moment of stay damper is shown in Fig. 4

Table 1 The moment about an angle change of a stay damper

Angle	a	b	c	d	e	F'	F''	Mo=F''*a
5	0.4	0.03	0.4	85.04	4.96	1095.9	95.15	37.92
10	0.39	0.07	0.41	80.29	9.71	1084.3	185.5	73.06
15	0.39	0.1	0.41	75.95	14.1	1067.1	267.1	103.2
20	0.38	0.14	0.42	72.12	17.9	1046.9	337.7	126.9
25	0.36	0.17	0.44	68.87	21.1	1026.1	396.5	143.7
30	0.35	0.2	0.45	66.21	23.8	1006.5	443.8	153.7
35	0.33	0.23	0.47	64.09	25.9	989.45	480.6	157.5
40	0.31	0.26	0.49	62.48	27.5	975.57	508.2	155.7
45	0.28	0.28	0.52	61.32	28.7	965.09	527.8	149.3
50	0.26	0.31	0.54	60.56	29.4	957.94	540.7	139
55	0.23	0.33	0.57	60.13	29.9	953.9	547.8	125.7
60	0.2	0.35	0.6	60	30	952.63	550	110
65	0.17	0.36	0.63	60.12	29.9	953.78	548	92.64
70	0.14	0.38	0.66	60.46	29.5	956.98	542.4	74.2
75	0.1	0.39	0.7	60.98	29	961.9	533.6	55.24
80	0.07	0.39	0.73	61.67	28.3	968.21	522.1	36.26
85	0.03	0.4	0.77	62.49	27.5	975.62	508.1	17.71
90	0	0.4	0.8	63.43	26.6	983.87	491.9	1E-14

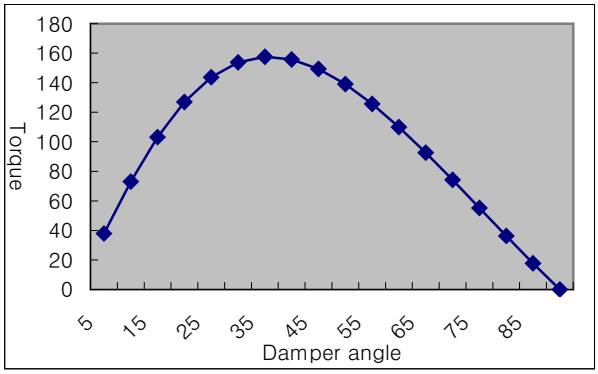

Fig. 4 The moment about an angle change of a stay damper

The maximum repulsive force of a stay damper which is currently installed to the manual wing-body has a 1100N. It is that length of the stroke is most short time. The repulsive force comes to be weak as the length of the stroke comes to be long. Namely, the damper acts to a maximum repulsive force when the wing-body shut down.

So, the stay damper decreases constant value of vertical load to be produced by the wing-body load and moment value which is derived from vertical load F'' become small. But the repulsive force of the damper is reduced at the wing-body is opened gradually and it does not diminish vertical load F''. The moment value is reduced again from the situation which the wing-body is opened 35° . Because it is that the moment of a force about a point is defined as the force times the perpendicular distance from the point to the line of action of the force[1].

Next, after stay damper removed, we compute moment for wing-body open at the point O. The moment table is shown below.

Table 2 The motor requirement torque about wing-body angle

Angle	F''	F'	d=0.7* F'	Mo= F''*d
5	585.76	51.248	0.6973	408.473
10	579.07	102.11	0.6894	399.189
15	567.96	152.19	0.6761	384.028
20	552.54	201.11	0.6578	363.452
25	532.91	248.5	0.6344	338.086
30	509.22	294	0.6062	308.7
35	481.66	337.26	0.5734	276.188
40	450.43	377.96	0.5362	241.537
45	415.78	415.78	0.495	205.8
50	377.96	450.43	0.45	170.063
55	337.26	481.66	0.4015	135.412
60	294	509.22	0.35	102.9
65	248.5	532.91	0.2958	73.5143
70	201.11	552.54	0.2394	48.1481
75	152.19	567.96	0.1812	27.572
80	102.11	579.07	0.1216	12.4113
85	51.248	585.76	0.061	3.12656
90	4E-14	588	4E-17	1.5E-30

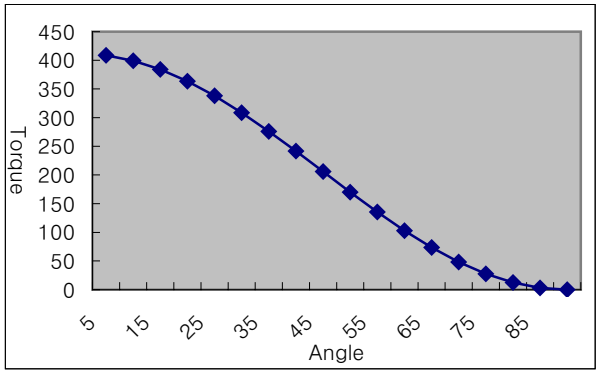

Fig. 5 The motor requirement torque about wing-body angle

According to the Fig. 5, we can know that motor's torque which needs for a wing-body open is maximum at the wing-body shut down and the torque comes to be small as the wing-body is opened gradually. Because it does not has a stay damper to decrease the vertical load. Also, moment is only calculated at vertical load and activity distance in O.

Based on all data in the above mentioned, we developed the structure which is opening form of link structure on the basis of worm gear to substitute the stay damper.

A worm and worm gear is used to transmit motion between nonparallel and noninteracting shafts[2]. The worm gear has a various advantages. It generates a big operation power and noise is small. The gear ratio that it can't be combined with gear head by high reduction ratio is possible combination using the structure feature of the worm gear. Merely, worm gear revolves worm rubbing against gear. Because of the wear of surface and noise can be happened. But if it is uses the additive of a lubrication role, such problem are solved easily.

In the case of using the general gear oil, mechanic part must seal. However if it should use the grease, the completion sealing of the mechanical part will be unnecessary.

The opening and shutting angle on the basis of top frame must become the 90° for complete opening and shutting of the wing-body. It needs 10 second time for opening and shutting. We made the worm gear to be satisfied such condition. The worm and gear is shown in Fig. 6.

Fig. 6 The worm and gear

The link structures are converted rotation movement of worm gear into vertical movement for opening and shutting

wing-body. It is method that one of link that was geared into worm gear does a rotation movement and then other link opened wing-body by its movement. The torque is affected by length of link with connecting worm gear. Therefore the length of the time that wing-body is completely opened and relation of the torque at that time are important.

The distance of link which is fixed point from hinge support and the length depend on initial state of link should be considering together in the length calculation of link1 and link2. The link length satisfying both installation location and torque condition is Link1 = 200mm, Link2 = 300mm.

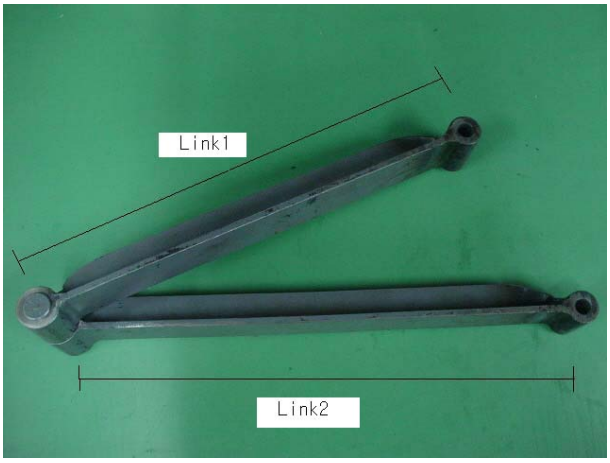

Fig. 7 The link structures

We know that motor requirement moment is most big when the wing-body is opened and it is reduced as grow bigger a open angle. So, the worm gear begins in the center so that the initial link structure can take a maximum power transmission.

In other word, the link structures open wing-body with using its full moment at the beginning. As the wing-body is opened gradually, the moment to get from link structure is going down. The moment that is required wing-body is occurred from structure as angle as it opens. Fig. 8 shown the whole configuration of wing-body's opening and shutting device. It consists of worm and worm gear, gear head and motor.

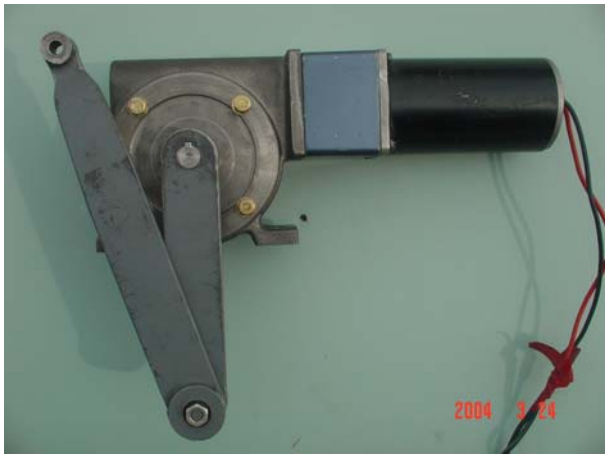

Fig. 8 The wing-body opening and shutting device

2.2 Actuator part

The actuator parts are composed with gear head and motor. Actually, it is regarded as a monolithic geared motor rather than consider each device to be separate. The specification of the geared motor is shown in Table 3.

Table 3 The specification of geared motor

Output		150 [W]
Voltage		DC 12 [V]
Gear Ration		1/30
No load	Revolution	3000 [rpm]
	Current	2.0 [A]
At Rated load	Torque	6.0 [kgfcm]
	Revolution	2450 [rpm]
	Current	17.0 [A]
Run Duty		2000 [Hr]
Weight		2.8 [kg]

2.3 Control part

The opening and shutting operation is running using a open/close push button. When wing-body is fully opened and closed, although operator is pushing an operation button continuously at wing-body opening/closing fully, we are configured the circuit that motor does not driven.

The motor driving circuit consists of power relay and simple wiring. Therefore, product cost can be reduced.

3. SIMULATION

We verified a theoretical calculated value to make use of ADMAS(Automatic Dynamic Analysis of Mechanical Systems). ADAMS Full Simulation Package is a powerful modeling and simulating environment that lets our build, simulate, refine, and ultimately optimize any mechanical system[3].

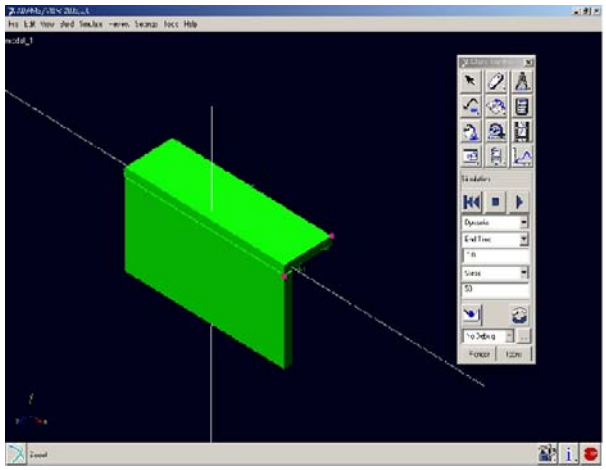

Fig . 9 ADMAS view model of wing-body

The simulation values are shown Table 4. The vertical axis is torque and the horizontal axis is angle in Fig. 10.

Table 4 The torque value according to simulation

Angle	0°	45°	90°	Avg
Torque [Nm]	432.47	305.80	22.63	282.45

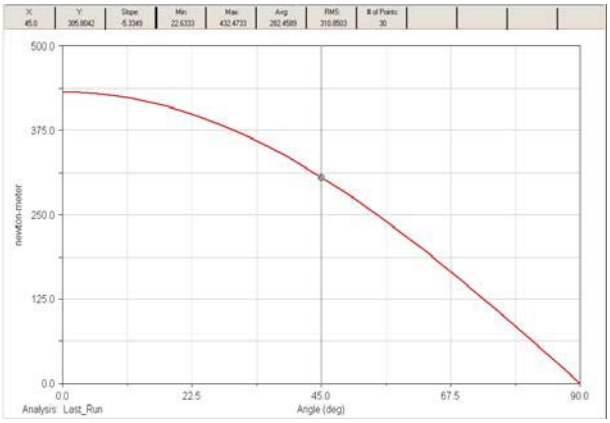

Fig. 10 The Torque at the hinge support of wing-body

We know that the transition of requirement torque that is needed to opening wing-body is same to compare Fig. 5 with Fig. 10. It is some difference in numerical values. Because the simulation was included a center of gravity to torque calculation and theoretical computation value is assumed 3 -dimension model to 2-dimension.

The operation time and current consumption is shown Table 5. The time which wing-body takes to open is 15 second and time to shut is 10 second. This is because gravity acted when wing-body shut.

Table 5 The operation time and current consumption

	time	current
Open	15 [sec]	max 17 [A]
Close	10 [sec]	max 10 [A]

4. CONCLUSION

In this paper, we described the link structure and motor driving circuit for electronic wing-body opening and shutting device. As a result, we has been made a preproduction that it can be stable control. Through many experiments, we mastered the technique about more specific driving method to compare with parameter which we got while we designed wing-body device.

The developed equipment was certified that it is a stable and excellent product on field. It was also shown more excellent competitive power than exiting oil pressure type on performance.

The future work is to add protect equipment on opening and shutting wing-body to give us more convenience and high stability. And we could do miniaturization and good performance if a high efficiency motor is developed.

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