BIOMECHANICAL MODEL OF HUMAN-LIKE ARM FOR A CRASH TEST

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ABSTRACT
Safety of the occupant during the crash is very essential design element. Many researches have been investigated in reducing the fatal injury of occupant. They are focusing on the development of a dummy in order to obtain the real human like motion[1]. However, they have not considered the arm resist motion during the car accident. In this study, we would like to suggest the importance of the reactive force of the arm in a car crash. The effects of reactive force acting on the human upper limb were investigated using the biomechanical model of upper limb and a Hybrid III dummy. A three-dimensional computer model using Pam-Crash/Safe was developed that estimates the influence of a arm resist motion. Also, human arm muscle model was developed in order to verify the biomechanical model of upper extremity. Through the experimental sled test of the dummy equipped human-like arm, the theoretical arm model developed in this paper was compared. The results showed that without seat belt, the reactive force of human arm reduced the head, chest, and femur injury, and the flexion moment of the neck is higher than that of the conventional dummy.

1 INTRODUCTION
In automobile manufactures consider design factors that are of a performance improvement, cost reduction, reliability. Especially, Safety of occupant during the crash is very important design requirement for the vehicle industries. An efficient method to estimate safety for crash injury is dummy test, which can surrogates the human. The Hybrid III 50th Percentile male crash test dummy has been widely used for the crash test for the evaluation of automotive safety restraint system in the automobile industries across the world.
According to the traffic accidents data from NASS/CDS for the years 1993~2000, Face injury is 22.2%, lower limb injury is 21.5%, and upper limb injury is 17.0%, upper limb injuries from vehicle crash are third most common injury. Upper limb injuries are classified at minor (AIS=1) or moderate (AIS=2) severity level. These injuries appear to have little or no influence on mortality but are associated with impairment and loss in functional capacity due to the crash injury.

The purpose of this research is to investigate the influence of active human arm in crash injury and to develop the biomechanical model of human upper extremity. A three-dimensional computer model was developed by using Pam-Crash/Safe software that estimates the influence of an arm resistance motion. Also, a human arm muscle model was developed in order to verify the biomechanical model of upper extremity. Through the experimental sled test of the dummy equipped human-like arm, the theoretical arm model developed in this paper was compared and verified.

2 BIOMECHANICAL MODEL OF HUMAN ARM
2.1 Hill-type muscle model
Central nervous system transmits a neural excitation signal to the muscle, which in turn activated. The muscle produces a force due to this active state. We use the common Hill-type muscle model. Figure 1 shows the common Hill-type muscle models. Hill muscle model are consisted of an active Hill contractile element, a passive element and a series elastic element. Hill contractile element depends on the activation level, length and velocity of the muscle.

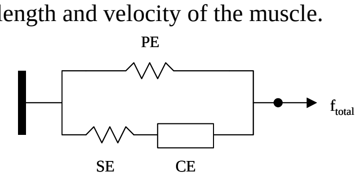

Figure 1. Common Hill-type muscle model

2.2 Biomechanical model of upper extremity
Upper extremity model consists of muscles that can move the forearm, wrist, and hand[2,3]. The muscle origins and insertions were defined on the base of anatomical datum. There are two types of muscles in human arm: one is flexors muscles, the other is extensor muscles. Flexor muscles are Biceps, Brachialis, Brachioradialis, flexor carpi ulnaris, flexor carpi radialis, palmaris longus, flexor digitorum superficialis, flexor digitorum profundus. And extensor muscles are Triceps, extensor carpi radialis longus, extensor carpi radialis brevis,

extensor carpi ulnaris, extensor pollicis longus, extensor pollicis brevis, Abductor pollicis longus, extensor indicis proprius, extensor digitorum communis, extensor digiti minimi. The above muscles are used to build the biomechanical model, which is performed in this paper. Hill-type model is used to define the characteristic behavior of the each muscle. Figure 2 shows the biomechanical model of upper limb.

Figure 2. Biomechanical model of upper limb

Biomechanical model of upper limb was implemented using Pam-Crash/Safe software (ESI). Figure 3 shows the Pam-Crash/Safe model of crash dummy.

Figure 3. Pam-Crash/Safe model of crash dummy

3 DESIGN AND CONTROL OF HUMAN-LIKE ARM

3.1 Design of human-like arm

Human like arm is developed in order to verify the effects of active arm response during the car accident. Figure 4 shows the assembly parts of human-like arm. Upper arm contains the motor. The length between the shoulder and the elbow joint is 260mm, and between the elbow and the wrist joint is 260mm. Wrist joint is composed of the passive friction bolt. The friction of wrist joint is adjusted by varying bolt screw displacement. Hand is capable of grasping and releasing the handle depending on the force allowance. That is, a force is applied at the hand over the human grasping force, the hand is automatically released from the handle. This is a very important to the human-like motion in the car collision.

Figure 4. Human-like arm

3.2 Control interface system

After we designed the human-like arm, we controlled the elbow joint with DC motor. Controller interface is part for connecting between motor and motor driver, and computer. Controller interface consists of input driver, interface board and power supply. We can measure motor angle through encoder attached at motor. Encoder signal is delivered from encoder to computer through controller interface. Computer reads motor angle with Lab card, PCL-833. And input signal for driving motor is determined by control program. This data is transmitted to motor driver through DA card, PCL-726. Motor driver generates the voltage signal according to control input.

4 CRASH TEST AND RESULTS

4.1 Test condition and method

Our test model is Grandeur XG made by Hyundai Motor. Frontal crash velocity is 20.0 km/h. We test the Hybrid III dummy with conventional arm and human-like arm.

4.2 Test results

Table 1 describes the experimental results of sled test. We test the dummy without the seat belt. In this case, we obtain the different trend of the conventional dummy and dummy with human-like arm. First, Head injury is 34% down in case of human-like arm. Flexion moment of the neck is 167% higher than conventional dummy. Chest acceleration and deflection are 32%, 55% lower than conventional dummy.

Table 1. Experimental results of frontal crash

	HIII+No Belt	Human-like Arm+No Belt	Remarks
Head Injury (HIC)	47.89	31.77	34%(↓)
Neck: Flexion Moment (Nm)	15.76	42.15	167%(↑)
Neck: Extension Moment (Nm)	46.42	16.57	64%(↓)
*N_{TF}	0.238	0.244	3%(↑)
*N_{TE}	0.531	0.256	52%(↓)
*N_{CF}	0.088	0.154	75%(↑)
*N_{CE}	0.381	0.165	57%(↓)
Chest Acceleration (G)	13.35	9.07	32%(↓)
Chest Deflection (mm)	-16.96	-7.58	55%(↓)
Femur: Compression (N)	L) 3792.90 R) 3081.80	L) 3621.02 R) 2678.85	L) 29%(↓) R) 23%(↑)
Femur: Tension (N)	L) 166.46 R) 174.65	L) 118.45 R) 214.95	L) 5%(↓) R) 13%(↓)

*$N_{ij}=F_z/F_{int} + M_y/M_{int}$

Where, F_z: normal force, M_y: neck moment, F_{int}: critical intercept value for load used for normalization, M_{int}: critical intercept value for moment used for normalization

5 CONCLUSIONS

We developed the biomechanical model of human upper extremity and human-like arm in order to verify the influence of the active human arm response during the car accident. In our study, the arm resistant motion reduces almost injuries of occupant.

6 REFERENCES

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