Journal of Theoretical and Applied Information Technology
20th February 2013. Vol. 48 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

TRAJECTORY OF THE PUNCHING QUICK AIRDROP AIRBAGS IMPACTED BY THE GUST

[1]MINGSI QI, [1,2]WEI YANG, [3]SUOPING DENG, [4]WEI WEI [1,2]WENDONG ZHANG, [1,2]JUN LIU,
[1]Key Laboratory of Instrumentation Science & Dynamic Measurement
（North University of China）, Ministry of Education, Taiyuan 030051, Shan-xi, China
[2]Science and Technology on Electronic Test & Measurement Laboratory, Taiyuan 030051, Shan-xi, China
[3]Department of Computer Science and Technology, College of Electronics and Information Engineering, Tongji University, Shanghai 201804, China
[4]China Changfeng Electromechanic Research and Design Institution, Beijing 100854, China

ABSTRACT

How to make the effect of the airdrop equipments affected by the turbulent airflow minimum, and realize the fixed-point and precise airdrop, is a problem that has been plagued by the domestic and foreign experts.The article makes the mesh generation of the airdrop airbag model, builds the finite element simulation models, and uses finite element analysis software ANSYS/LS-DYNA to study the falling process of the punching quick airdrop airbags. Through the simulation of the falling process, the paper gets the status parameters of the airbags, and analyzes whether the airbags meet the falling demands or not. Then this article researches the airdrop trajectory of the airbags with gust and no gust, and researches the airdrop trajectory of the airbags under horizontal and vertical gust. In order to reduce the effect of the gust on the airdrop trajectory, the paper puts forward the controlling strategy.

Keywords: *Airbag, Punching, Quick Airdrop, Airdrop trajectory, ANSYS/LS-DYNA*

1. INTRODUCTION

In a variety of the harsh environments, how to make the effect of the airdrop equipments affected by the turbulent airflow minimum, and realize the fixed-point and precise airdrop, is a problem that has been plagued by the domestic and foreign experts.

The falling process of the punching quick airdrop airbags mainly researches the airdrop objects' airdrop trajectory, the status parameters of the airbag and seeks the precise airdrop method. Before the introduction of modern mathematical simulation technology, the falling process research of early airdrop depended on the experimental methods entirely, and it often needed to pay a high price and was limited by the time and cost. The emergence of the computer makes it possible that people used mathematical simulation method to study the falling process.

American engineering computer simulation and emulation society was established in 1998, other countries had also set up similar organizations. In recent years, many countries have invested a lot of manpower and material resources. People attached great importance to the study of simulation technology at home and abroad. Headquarters department of the army department of the air force Washington has researched airdrop of supplies and equipment: humanitarian airdrop. Scholars Ming-si Qi and Wei Yang, etc have researched ram airbag of punching and quick airdrop[1,2]. Huiyuan Zhang, Zhongke Shi have researched variable structure control of catastrophic course in airdropping heavy cargo[3]. And many other scholars have researched the correlative airdrop technique[4-12]. For the airdrop models, many countries have developed a lot of simulation softwares, but there are few models of the airdrop airbags. And there is few research technology about the punching quick airdrop airbags.

2. SIMULATION ANALYSIS

This research topic is one of the outstanding innovative projects in Shan-xi Province. Based on the airbag model established by teacher Ming-si Qi, this article makes mesh generation of the airdrop airbag model, builds the finite element simulation model, and uses the finite element analysis software ANSYS/LS-DYNA to study the falling process of the punching quick airdrop airbags. Through the simulation of the falling

Journal of Theoretical and Applied Information Technology
20th February 2013. Vol. 48 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

process, the paper gets the status parameters of the airbags and analyzes whether the airbags meet the falling demands or not.

This article researches the airdrop trajectory of the airbags with no gust, and researches the airdrop trajectory of the airbags under horizontal and vertical gust. In order to reduce the effect of the gust on the airdrop trajectory, on the basis of the simulation results, the paper puts forward the controlling strategy.

2.1 Research Method

The paper firstly adopts Arbitrary Lagrangian-Eulerian (ALE method for short, Arbitrary Lagrangian-Eulerian) fluid-structure coupling method. When the change of the flow field affects the structure shape greatly, the airbags simulation of the inner flow field is extremely important. The method can actually describe the shape of the airbags and the change of the flow field. It is more accurate to simulate the initial deployment stages, but the computation time and the computational efficiency of this method is not better than the control volume method.

Finally the paper adopts Arbitrary Lagrangian - Eulerian method to simulate the fluid-structure interaction working process of the aeration process of the airbags, the control equation is composed of the mass equation, the momentum equation and the energy equation. They are as follows.

$$\rho\ddot{\chi}+\rho\nabla\dot{\chi}\left(\upsilon-\dot{\chi}\right)=\rho f+div\sigma \qquad (1)$$

$$\rho\dot{\mu}+\rho\nabla\left(\upsilon-\dot{\chi}\right)=\sigma D+\rho r-\nabla q \qquad (2)$$

In equation 1 and equation 2: υ——the airflow velocity; $\dot{\chi}$——the grid speed; ρ——the density of fluid; f——the external volume force; σ——Cauchy stress tensor; μ——the represents internal energy of the material; D——the material strain rate; r——the unit mass of the heat generating rate; q——the flux density. The grid movement speed $\dot{\chi}$ is determined by the speed of fluid motion and the speed of movement of the membrane material. Equation 3 can be get from equation 1and equation 2.

$$\dot{\chi}=\upsilon-\omega \qquad (3)$$

Material movement speed is determined by the structure of the membrane dynamics, and the control equation is equation 4.

$$M\ddot{\omega}+C\dot{\omega}+K\omega=F \qquad (4)$$

In equation 4, M, C and K are respectively the element mass, the damping modulus and the elastic modulus. F are suffered resultant force effected on the membrane unit .

The paper adopts the model established by scholars Ming-si Qi, Wei Yang, etc. The single airbag size is 400mm×400mm×400mm. The surface of the rigid airbag has one controllable air inlet and four exhaust holes. And the particular parameters can be found in reference 1.

2.2 Basic Assumptions

During the airbag deployment process the paper hypothesis as follows. The inner pressure of the airbags is equal. The inner gas in the airbags is ideal gas and the heat capacity is constant. The inflation process of the airbags is an adiabatic process, and it has no external heat exchange with outside space. The temperature and pressure in the airbags are uniform. The unfolded tensile and bending deformation are ignored.

Table 1: Airbag Model Parameters

Airbags size（mm）	600*600（Before the commencement ）
airbag wall thickness（m）	0.030（shell thickness）
the airbags density（kg /m^3）	972
airbag elastic modulus（Pa）	2.3e+9
airbag Poisson's ratio	0.3
airbag folding size（mm）	1
model finite element type	four shell elements
model total number of finite element	2742

The internal pressure of the airbags is constant. The lift force of the parachute is large, so the paper does not consider the air resistance, and the heat exchange is not considered during the falling process.

Table 1 is the ramjet fast airdrop hard airbag material type.

During the following process after the airbags are full of gas, the airbags are affected by two forces in the vertical direction: one is a downward force, i.e. the gravity of the load and the airbag and its parachute; the other is an upward force, i.e. parachute has speed and buoyancy. Airbag stress analysis is shown in Figure 1. Airbag forces satisfy equation 5 and equation 6.

$$G=mg \qquad (5)$$

$$F=kSv \qquad (6)$$

Wherein, m——the mass of the load and airbag and its parachute, g——theacceleration due to

Journal of Theoretical and Applied Information Technology
20th February 2013. Vol. 48 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

gravity; k——the air resistance coefficient; s——the Sanmian area of parachute airbag; v——the instantaneous velocity of airbag. The area of parachute umbrella is determined by the radius of the umbrella, $S = 2\pi r^2$, but the length of the rope is decided by the radius of the parachute, as shown in Figure 2. Therefore equation 7 is the parachute Sanmian area.

$$S=\pi L^2 \qquad (7)$$

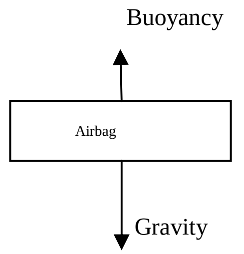

Figure 1: Airbags stress analysis

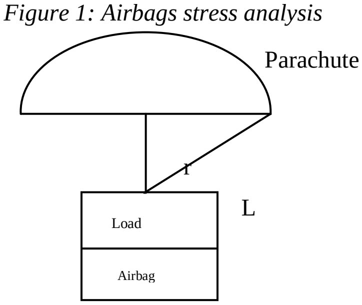

Figure 2: Parachute Size Sketch

Therefore, the airbag will go through a transition acceleration phase, until the acceleration is reduced to zero, and then go through an uniform stage, until it touches the ground. Airbags are commenced with the level of early speed V_x and vertical initial velocity V_y, and the varying vertical initial velocity of the accelerated phase V_{y0}, vertical final velocity V_{y1}.

2.3 The Variable Acceleration Phase Of The Punching Quick Airdrop Airbags

The change acceleration phase satisfies equation 8.

$$S=\pi L^2 \qquad (8)$$

$$mg - kSv = ma \qquad (9)$$

Wherein, the initial data are as follows.

In X direction: $V_x = 9m/s$

In Y direction: $m = 917kg$

$g = 9.8m/s^2$, $k = 2.9577$, $L = 11m$

$v_{y0} = -2.94m/s$, $v_{y1} = -8m/s$

2.4 The Uniform Phase Of The Punching Quick Airdrop Airbags

The uniform stage satisfies equation 10.

$$mg = kSv \qquad (10)$$

Wherein, the initial data are as follows.

In X direction: $v_x = 9m/s$.

In Y direction: $v_{y1} = -8m/s$.

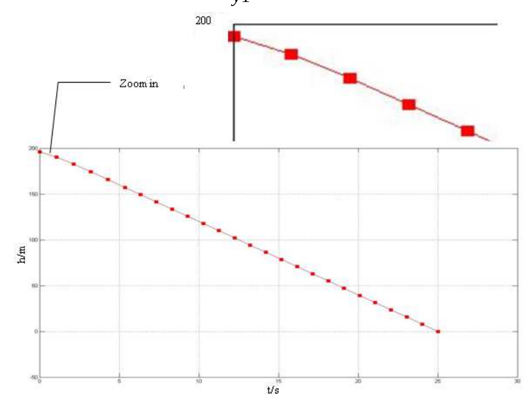

Figure 3: The H-T Diagram Of The Airdropped Objects With No Gust

3. ANALYSIS OF THE TRAJECTORY OF THE AIRDROPPED OBJECTS WITH NO GUST

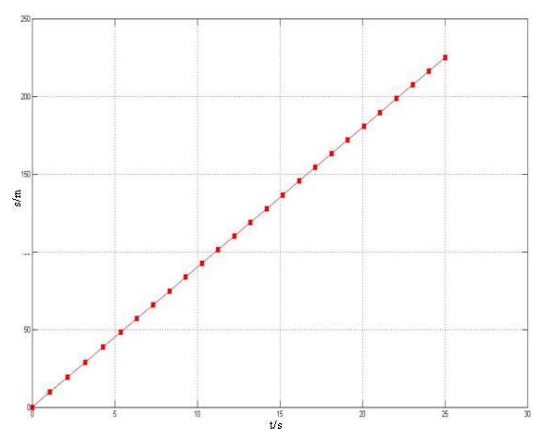

Figure 4: The S-T Diagram Of The Airdropped Objects With Gust

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

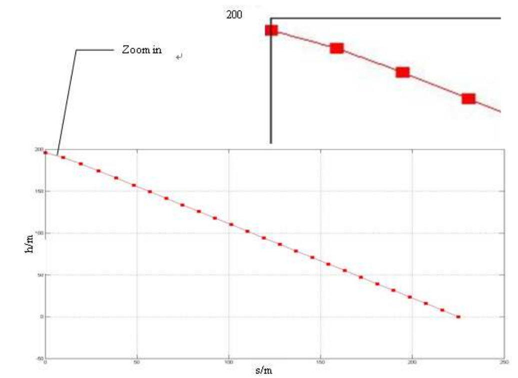

Figure 5: The H-S Diagram Of The Space-Time Cast Objects With No Gust

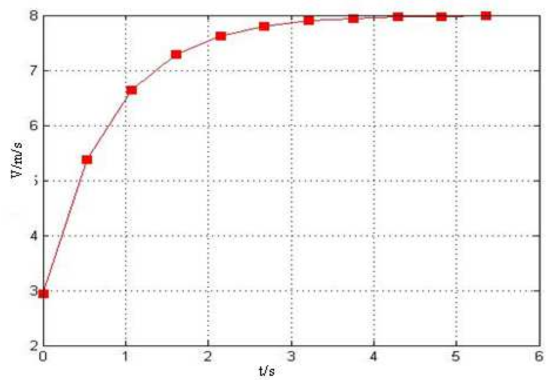

Figure 6: The V-T Diagram Of The Airdropped Objects With No Gust

Figure 3, figure 4 and Figure 5 shows the h-t diagram, s-t diagram and h-s diagram with no gust respectively.

The data are programmed by ANSYS, Figure 6 and figure 7 are respectively the v-t diagram and the a-t diagram with no gust.

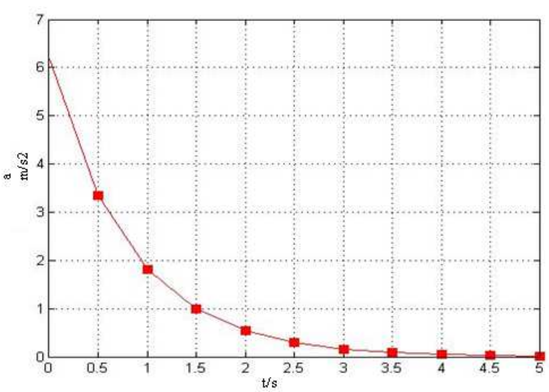

Figure 7: The A-T Diagram Of The Airdropped Objects With No Gust

4. THE FALLING TRAJECTORY OF THE AIRDROPPED OBJECTS WITH GUST

In reality, it is difficult to eliminate the impact on the whereabouts of the airbags from the wind field, especially gust. Therefore, variables are introduced in the horizontal direction and numerical direction and contrast simulation experiments are made based on MATLAB software. The wind field variables are introduced for comparison, using the MATLAB software.

4. 1 The airdrop trajectory of the space-time cast objects with vertical gust affect

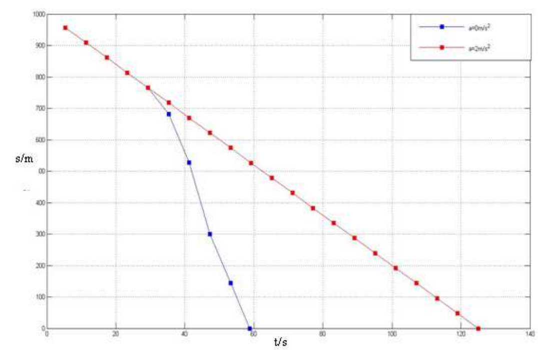

Figure 8: The Objects' Vertical Displacement Comparison Chart Of The Space-Time Cast With Vertical Gust Affect

Taking the actual airdrops process of the airbags into account, the up wind is rarely existing, so only down gust is studied. Since the direction of the vertical velocity is downward, taking vertically downward as a positive direction. With the introduction of the vertical downward wind, v = 2m/s, comparison (Fig. 8) can be obtained to the vertical displacement and the track contrast (Figure 9).

As can be seen from Figure 8 and Figure 9, due to the impact of the downward vertical gust, the vertical displacement and trajectory of the punching quick airdrop objects will be influenced, with errors appeared. Moreover, the vertical displacement error caused by the vertical gust is 502m; while the vertical gust trajectory error is about 600m deviations in horizontal leftward direction.

Journal of Theoretical and Applied Information Technology
20th February 2013. Vol. 48 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

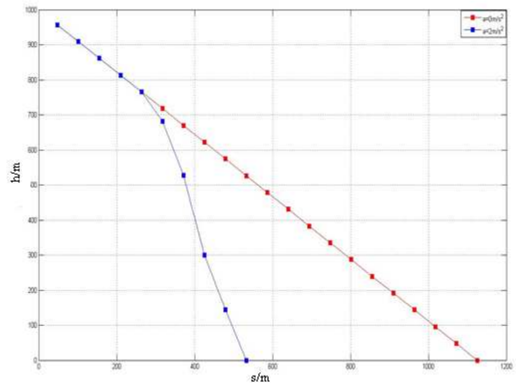

Figure 9: The Object's Trajectory Comparison Chart Of Space-Time Cast With Vertical Gust Affect

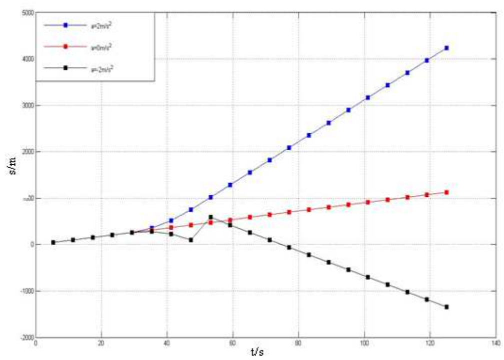

Figure 10: Horizontal Gust Impact Airdrop Horizontal Displacement Of The Object Contrast

4.2 The airdrop trajectory of the space-time cast objects with horizontal gust affect

For horizontal gust, its direction may be rightward or leftward. Since the direction of the horizontal speed is rightward, take the level of the right as the positive direction. With the introduction of the horizontal downward wind, they are respectively 2 m/s and -2m/s, the contrast of the horizontal displacement (Figure.11.) and the track contrast (Figure.12.) can be obtained.

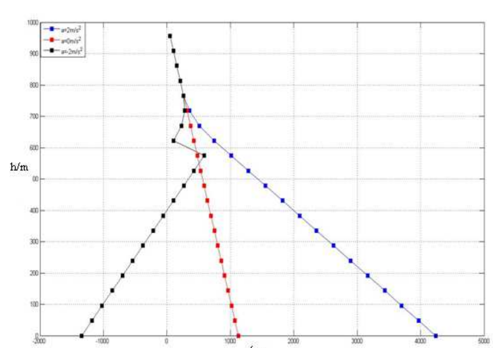

Figure 11: Vertical Gust Affect The Comparison Chart The Airdrop Objects Horizontal Displacement

As can be seen from Figure10 and Figure 11, because of the influence of the horizontal gust, the trajectory of the punching quick airdrop objects will be influenced, with errors appeared. Moreover, the right level displacement error caused by the horizontal gust is over 3000m, while the left level displacement error is over 2000m.

4.3 Trajectory chart of the airdropped objects with gust

When trajectories of the horizontal gust and vertical gus are compared, the trajectory comparison chart can be obtained, as is shown in Figure 12, with the introduction of the gust. As can be seen from figure 12, because of the influence of the gust, the trajectory of the punching quick airdrop objects will be influenced, with errors appeared. Moreover, the trajectory error caused by the vertical gust is horizontal leftward direction, with the deviation 600m. The right level displacement error caused by the right level gust is horizontal rightward direction, with the deviation over 3000m. While the left level displacement error caused by the left level gust is horizontal leftward direction about deviations over 2000m. Visibly, the impact by the vertical gust is less than the right level gust. Therefore, the error must be corrected.

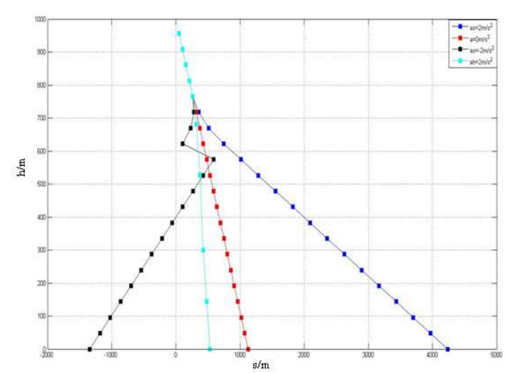

Figure 12: The Comparison Chart Of The Horizontal Displacement Of The Air-Dropped Objects With Horizontal And Vertical Mixed Gust Affect

5. CONTROL STRATEGY

Influenced by the gust for airbags and the airdropped trajectory has a large deviation, the paper proposes a control strategy of the airdrop system, and designs a control structure of the airdrop system. The control strategy is an important part of the controller design. It limits the need to meet the requirements of the controller, and it has important effect on the whole control system. The formulation of the control strategy requires a combination of the flight performance

Journal of Theoretical and Applied Information Technology
20th February 2013. Vol. 48 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

and controllability of the system itself. The following are several control strategies developed for the falling trajectory track of the control system.

First, the wind is one of the important factors to affect the landing performance of the recovery system. The wind farm can be composed by the average wind and the splice of the turbulence or the gust, the two parts are dealed with different control strategies. The speed of the average wind is large, and it changes slowly. It can be obtained by a simple measurement of the wind field in the landing area, and its impact can be eliminated in the trajectory planning. Gust is an obvious oscillation of the wind speed or wind direction in a short time with time passing by. The wind value is usually small, and its influence is fixed as disturbance variable by the control system.

Secondly, during the entire homing process of the system, there are many disturbing factors and random factors. During the range of a certain height, when the deviation value exceeds a certain value, the new plan and design of the track trajectory is needed. This can avoid the continued and substantial manipulation, save the control energy and ensure the system flight stably.

The traditional PID controller is difficult to meet the control requirements of high precision and high performance.

Gain adjustment of the PD control structure with fuzzy PD controller system is shown in Figure 13. The control parameters(KP, KI, KD) of the traditional PD control system is constant, but the control parameters of the PD controller with gain adjustment model is changeable. The control structure of the output response is shown in Figure 14.

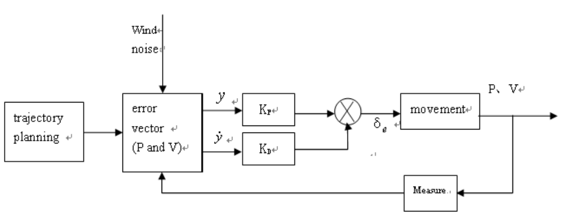

Figure 13: PD Control Structure With Fuzzy PD Controller System

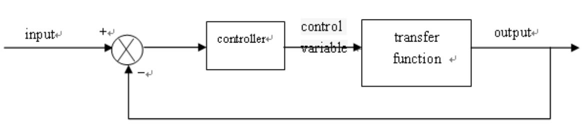

Figure 14: The Control Structure Of The Output Response Of The System

The output of error driven fuzzy PID controller with GS type directly corresponds to the gain parameters, and it adjusts the three gain parameters of traditional PID controller through fuzzy rules.

6. CONCLUSIONS

This paper studies the impact of the wind field in the traditional airdrop systems and the precision airdrop system of the airdrop trajectory, proposes using different control strategies to reduce the influence of the gust. Average wind through the simple measurement of the wind field of the landing area to get better wind measurement precision instrument, whose impact can be eliminated in the trajectory planning. Gust, its influence as the amount of interference by the control system to correct. Qualitative analysis of the impact of the wind farm, and optimization measures. Based on the analysis of the gust, a control system, which can improve the precision airdrop system is proposed.

ACKNOWLEDGEMENTS

This work was financially supported by Chinese Natural Science Funds (50675213) and North University of China Science Funds.

REFERENCES

[1] Y. Wei, Q. Ming-si, Z. Jiao, "Research on Punched Quick Airdrop Cushion", *Packaging Engineering*, Vol. 31, No. 5, 2010, pp. 106-108, in Chinese

[2] Q. Ming-si, Y. Lina, Y. Qiang, Y. Wei, L. Yu, "Stress Analysis on Ram Rigid Airbag for Quick Airdrop Based on ANSYS", *Packaging Engineering*, Vol. 31, No. 15, 2010, pp. 69-72, in Chinese

[3] Zhang Huiyuan, Shi Zhongke,"Variable Structure Control of Catastrophic Course in Airdropping Heavy Cargo", *Chinese Journal of Aeronautics*, Vol. 22, No. 5, 2009, pp. 520-527.

[4] Yanli Feng, Zhongke Shi, Wei Tang, "Dynamics modeling and control of large transport aircraft in heavy cargo extraction", *Journal of Control Theory and Applications*, Vol. 9, No. 2, 2011, pp. 231-236.

[5] Zhi-jie Wang, "Maximizing the probability an aerial anti-submarine torpedo detects its target", *Journal of Marine Science and Application*, Vol. 8, No. 2, 2009, pp. 175-181.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[6] Yu-Hsin Liu, "A genetic local search algorithm with a threshold accepting mechanism for solving the runway dependent aircraft landing problem", *Optimization Letters,* Vol. 5, No. 2, 2011, pp. 229-245.

[7] Michael R. Torry, C. Myers, W. W. Pennington, K. B. Shelburne, J. P. Krong, J. E. Giphart, J. R, "Steadman and Savio L-Y Woo. Relationship of anterior knee laxity to knee translations during drop landings: a bi-plane fluoroscopy study", *Knee Surgery, Sports Traumatology, Arthroscopy*, Vol. 19, No. 4, 2011, pp. 653-662.

[8] Tiago F. Gonçalves, José R, "Azinheira and Patrick RivesInformatics in Control Automation and Robotics", "Vision-Based Automatic Approach and Landing of Fixed-Wing Aircraft Using a Dense Visual Tracking", *Lecture Notes in Electrical Engineering, Springer Verlag, Tiergartenstrasse 17, Heidelberg,* D-69121, Germany, July 2-5, 2011, pp. 269-282.

[9] M. M. Davoodi, N. A. Abu Osman, A. A. Oshkour, M. Bayat, "Knee Energy Absorption in Full Extension Landing Using Finite Element Analysis", *5th Kuala Lumpur International Conference on Biomedical Engineering 2011, Springer Verlag, Tiergartenstrasse 17, Heidelberg, D-69121, Germany,* June 20-23, 2011, pp. 175-178.

[10] Huawen Ye, Liang Sheng, Weihua Gui, Chunhua Yang, "New stabilization design for planar vertical take-off and landing aircrafts", *Journal of Control Theory and Applications*, Vol. 9, No. 2, 2011, pp. 195-202.

[11] Mohammad H. Mahoor, R. Godzdanker, K. Dalamagkidis, K. P. Valavanis, "Vision-Based Landing of Light Weight Unmanned Helicopters on a Smart Landing Platform", *Journal of Intelligent & Robotic Systems,* Vol. 61, No. 1-4, 2011, pp. 251-265.

[12] K. D. Oberländer, K. Karamanidis, J. Höher, G. -P. Brüggemann, "Evidence of Feedforward Postural Adjustments to Reduce Knee Joint Loading in ACL Deficient Patients at Cost of Dynamic Stability Control", *15th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics, Springer Verlag, Tiergartenstrasse 17, Heidelberg, D-69121, Germany,* June 14-17, 2011, pp. 264-267.