Simulation for Pilot's Capability of Target-Pointing Operation

Hongjun Xue and Xiaoyan Zhang

School of Aeronautics, Northwestern Polytechnical University, Xi'an Shaanxi 710072, China
xuehj@nwpu.edu.cn, zxyliuyan@sina.com

Abstract. Target-pointing operation of the pilot is of importance for the information interaction in the cockpit, and the accuracy, rapidness and effectiveness of the operation is critical for the flight safety. The design and layout of human-machine interface in the cockpit cannot be implemented perfectly through static reach and visual zone, due to neglect the dynamic effect, such as plane vibration. In order for the optimization of layout of human-machine interface, the affect of the target-pointing operation due to multi-acceleration and vibration in cockpit is studied by manikin dynamic simulation based on both of muscle-skeleton model of LifeMOD platform and pilot motion captured data under normal condition. The results suggest that emergency operation equipment can be positioned in the area in which the acceleration and vibration has least impact to ensure that pilot can operate timely and accurately in emergency and eventually to promote flight safety.

Keywords: Cockpit, lifeMOD, target-pointing, pilot capability.

1 Introduction

Cockpit is a kind of important interface between pilot and aircraft. Pilot can respond to the information from the aircraft by control equipments. Although autopilot may reduce workload from pilots there is still much work for pilot to operate manually. Especially during takeoff or landing, or in emergency pilot would be the last decision-maker to guarantee flight safety. Usually, pilot limb's movement time, track or speed, acceleration is always used to represent the performance of nominal operation. Generally, the flight of aircraft is often affected by vibration and acceleration of engine or airflows [1, 2, 3, 4]. Sometimes, this vibration and acceleration may make the pilot's operation performance to be lower or even failure [5, 6, 7, 8]. The operation of pressing or dialing the buttons on the panel in the cockpit is defined "target-pointing". "Target-pointing" operation is also of importance for flight safety. This paper focuses on the performance of target-pointing operation from pilot muscle-skeleton model in LifeMOD. Taking experimental operation data as the basis data and the driven data, we built a manikin model to simulate various accelerations and swings influence for pilot operation. The result has given a principle of design for the man-machine interfaces in cockpit, and improvements in flight emergency to guarantee flight safety.

2 Kinetics Model of Target-Pointing Operation

Kinetics Model of Pilot. Kinetics model in the LifeMOD includes 122 muscle units modeled by spring and damp elements and can bear and produce pull force. The forces from the muscles act on the skeleton system [9, 10, 11]. The muscle unit is originally "un-trained". During the anti-kinetics simulation, the capture data can be used to drive the manikin and the action of muscles are recorded, after once simulation, the muscle is "trained". During the later kinetics simulation, the trained muscles has now the performance as same as before.

The equation of muscle is:

$$F = \begin{cases} F_{max} & F \geq F_{max} \\ P_{gain} \cdot P_{error} + D_{gain} \cdot D_{error} & F < F_{max} \\ 0 & L_{desired} < L_{actual} \end{cases} \quad (1)$$

where, $F_{max} = p_{CSA} \cdot s_{max}$, p_{CSA} is the area of muscle transect, s_{max} is the maximum tissue stress; $P_{error} = L_{desired} - L_{actual}$, $L_{desired}$ is the force of the expected muscle motion mode, and L_{actual} is the actual force. $D_{error} = \dot{P}_{error}$. P_{gain} and D_{gain} represents scale plus coefficient and differential plus coefficient respectively. Generally speaking, D_{gain} is one tenth of P_{gain} .

Model of Pilot-Seat. Taking the ADAMS to simulate the pilot posture. In this simulation, coefficient of rigid is 10kN/m, and damp is $0.1\text{kN} \cdot \text{s/m}^{[9]}$.

3 Kinetics Simulation of Target-Pointing Operation

Operation Target. The operation target in the cockpit is the vertexes and centre of rectangle on the shield, top panel, MCD and central control panel. The optics capture system has been used to capture the motion data of pilot in the operation experiment.

Influence of Acceleration. As for civil aircraft, the direction of acceleration is always +Z, -Z, and +X (where X axis is along the fuselage and the direction of flight is +X, and Y axis directs left, Z axis directs up.). According to the CAAR 25, the range of acceleration is within +Z (0, 2.5g), -Z (-1g, 0), +X (0, 1g).

Influence of +Z-axis Acceleration. Applying +Z acceleration ranged from 0 to 2.5g to the pilot-seat model and increment is 0.1g. The movement and displacement of the finger compared with which of basis is analyzed for the four areas and shown in figure 1. The simulation result in figure 1 suggests that +Z-acceleration influences the top panel area most, central control panel least. the biggest displacement is 864mm in top panel at 2.2g acceleration.

Influence of -Z-axis Acceleration. Applying -Z acceleration ranged from -1g to 0 to the pilot-seat model and increment is 0.1g. The result is shown in figure 2 for the four areas, and suggests that -Z-acceleration influence the shield area most and central control panel least. The biggest displacement is 93mm in shield and least is 48mm in central control panel.

Influence of +X -axis Acceleration Applying +X acceleration ranged from 0 to 1g to the pilot-seat model and increment is 0.1g. The result in figure 3 suggests that when the acceleration is range from 0 to 0.5g, the function of displacement and acceleration is nearly linear in shield and top panel, but when the acceleration is bigger than 0.5, the operation can hardly finished, the biggest displacement is almost 800mm in 1g in shield, and top panel displacement is more than 600mm in 0.8g acceleration. The function is nearly linear in MCD and central control panel, and the influence is less than the other two areas.

Influence of Vibration. The vibration influences pilot operation performance through magnitude of swing and frequency. The magnitude of swing ranged from 10mm to 50mm belongs to low swing, and the frequency ranged from 5 HZ to 50 HZ belongs to low frequency too. The vibration, $S = A \sin(2\pi \cdot f \cdot t)$, imposed on both Z axis and Y axis. The actual movement of right finger is not linear but oscillating around the balance position. The maximum displacement $|E|_{max}$ is used to analyze the degree of influence in vibration.

Influence of Z-axis Vibration. $|E|_{max}$ is shown in figure 4. "Throw-off" means that operation can not be carried out and vibration makes the finger uncontrollable by pilot themselves. The break points in figure 4 and figure 5 represents "Throw-off".

Under identical condition, the vibration influences shield area most, central control panel least. The maximum $|E|_{max}$ is less than 100mm. "Throw-off" has appeared in the MCD area but less influence than shield area.

Influence of Y-axis Vibration. $|E|_{max}$ of Y-axis is shown in figure 5, the contrast of $|E|_{max}$ of Y-axis vibration in four areas. Similarly the vibration influences shield and top panel more than MCD and central control panel. With Y- axis vibration the four areas all appeared "Throw-off" with different magnitude of swings.

4 Conclusions

From the pilot-seat simulation and result analysis, it seems that vibration affect the operation least when pilot operates button in the central control panel. Because the right-upper area as least affected area of pilot operation, the muscle in the model is "operational trained" better and be used to simulate pilot operation in various cockpit environments well. The result of simulation shows that cockpit vibration affects pilot's operation more than that of acceleration, and may leads to operation failure more much. The results also present the fact that the pilots are more adaptable to cockpit

acceleration than vibration. The most important button for safety especially for emergency operation should be positioned in the central control panel to improve the flight safety; and other buttons can be placed in neighbor areas.

Fig. 1. Displacement with +Z acceleration

Fig. 2. Displacement with +Z acceleration

Fig. 3. Displacement with +X acceleration

Fig. 4. Contrast of $|E|_{max}$ in four areas with Z-axis vibration

Fig. 5. Contrast of $|E|_{max}$ in four areas with Y-axis vibration

Acknowledgement. The paper is granted under National Basic Research Program of China (No.2010CB734101).

References

- Adams, J.J.: Application of Human Transfer Functions to a Design Problem. In: Third Annual NASA – University Conference on Manual Control, NASA SP-144 (1967)
- Long, S.Z., Chen, H.: Research on Human Fuzzy Control Model in Man-Machine-Environment Systems. In: The 33rd International Congress of Aviation and Space Medicine, pp. 138–141 (1985)
- Yang, N.: Coordination Analysis and Parametric Description of Human Movements. TsingHua University, Beijing (2001)
- Jiang, M., Wang, R., Jin, D.: Fitts's law for evaluating the recovery from movements of hand-held objects. Journal of TsingHua University 46(11), 1848–1850 (2006)
- Ariff, F.H.M., Rambely, A.S.: Modeling of an Arm Via Kane's Method: An Inverse Dynamic Approach. European Journal of Scientific Research 33(2), 358–364 (2009)
- Wang, R., Zhuang, D.: Simulation and analysis of pilots' manipulation based on SimMechanics. Journal of Beijing University of Aeronautics and Astronautics 33(7), 765–768 (2007)
- Sun, P., Wang, S., Wang, Q.: Calculation for optimized movement trajectories of human multi-joint arm. Inese Journal of Theoretical and Applied Mechanics 42(3), 506–511 (2010)
- Boshi, H., Fumin, C.: Research on Human Body Motion Capture and Motion Control. Computer Engineering and Applications, 60–63 (2005)
- <http://www.lifemodeler.com>
- Li, X., Zhang, E., Lu, C.: Driving Comfort Simulation Based on Human Biomechanics Model Under Vibration. Journal of Xi'an Jiaotong University 42(5), 556–560 (2008)
- Shabana, A.A.: Computational Dynamics. John Wiley & Sons Ltd., United Kingdom (2010)