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ERGONOMIC ANALYSIS OF THE EFFECTS OF THE INTRODUCTION OF ELECTRONIC DISPLAYS IN THE COCKPITS OF LIGHT SINGLE-ENGINE PISTON AIRCRAFTS

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Abstract. *This paper sublimates previous experience and results of certain studies related to the introduction of glass cockpit(GC) in the light piston aircraft.It considers the influence of the replacement of analog, conventional displays with the glass cockpits, on the safetyof thelight piston aircrafts, primarily from the aspect of reducing human (pilots) errors. Certain design solutions that were proposed with the introduction of the new technology in the light aviation are evaluated, including also into the consideration the results of studies that have not confirmed the expected increase of safety, in comparison with airplanes equipped with the conventional instruments.*

Key words*: aircraft, glass cockpit, analog instruments, digital displays, ergonomics*

INTRODUCTION

This paper in brief summarizes specific experiences gained by the research related to the introduction of glass cockpit in light piston aircraft. In connection with that, it will be evaluated the influence of the replacement of analog, conventional displays with the glass cockpits, on the safety of light piston aircrafts.

This paper specifically focuses on the analysis of the design solution of a display (as a part of glass cockpit equipment) that shows the speed and altitude of the aircraft.For this purpose, the guiding line will be reduction of pilot´s overload and improvement of the performance and safety.

THE HUMAN FACTORS AND DESIGN OF COCKPIT INSTRUMENTS AS A CONSEQUENCE OF THE ACCIDENTS IN AVIATION

Although some of the research (mentioned in subheading) in the domain of human factors are related to the late 19th and early20th centuries, the human factors, as an area of scientific research and practice, was fully recognized during World War II. During the first two years of World War II, over2000 multi-engine US aircraftsexperienced accidents. They were caused by controls for the landing gear and flap leversthat were identical in shape, size, and the method of operation, and located too close together to allowidentification through kinesthetic feedback. Because of that, during the landing of the aircraft, a pilot relying on the touch and kinesthetic feedback information rather than on the visual inspection often caused the mistake, changing one control for the other[1].Another possible cause of errors were inadequate design solutions of displays and their arrangement in the cockpit.

The engineering psychologists were called upon to investigate militaryaircraft accidents in the United States. They triedto explore why so many of these accidents were being attributed to "pilot error" and what "pilot error" really mean from acausation standpoint.They discovered that the "pilot error" was in fact error created as a result of inadequate design[1].Namely,controls and displays werebeing designed in ways that were not compatible with human capabilities and limitations. Accordingly, these designs were initiators for making errors by the pilots. For example, thetransition from one aircraft to another, with a different arrangement of the instrumentswould lead tomisperceptions and pilot´s error - especially in conditions of flight under stress.

Thes discoveries initiate investigations which were initially focused on the human perception and reactions, and later the central focus moves to the design aspect. The studyof US Air Force tried to determine the best combination of control shapes to use in cockpit for the various flight functions. The results were the control shapes associated with the function where possible.This led to the standardization of aircraft controls that are used worldwide today. Similar research in the late 40s and 50s led to the identification and standardized arrangement of the instruments most critical to flight, that remains in use for a long time. These efforts have resulted in reduction of pilot´s errors and improvements in aviation safety[1]. Similar researches have led to the development of standards in the domain of displays, such as the British standard BS3693 [3].

ARRANGEMENT OF COCKPIT INSTRUMENTS IN THE FUNCTION OF REDUCING HUMAN ERRORS

The cockpit of an aircraft must be designed in the way that enables the pilot to control the aircraft without errors and excessive effort. This meansthat the pilot needs the comfortable work space, easy access to controls,intuitive handling and high level of readability, legibility and visibility of the displays. According to the current standards of the FAA, all kinds of visual displays (navigation, motor, etc.) which are intended for use by pilot must be clearly visible from the pilot's seat, in his field of view when he looks ahead during the flying, with minimal body movements in the pilot's seat and with the minimal need for the eye movements. In aviation,especially in a military aviation, when it comes to security, decisions must be maked in a very short period of time. So, quick scan of displays must give the pilot unequivocal generic impression of the situation during the fly. If the display and its position in the cockpit are not compatible with the human sensibility and perception(s) ability, so it is difficult to scan, or scanning lasts longer, there is a high probability that the pilot will make an error inreading or interpretation of data, and consequently he will react in an unacceptable way.

INTRODUCTION OF GLASS COCKPIT INTO LIGHT AIRCRAFTS

During only a few years, the cockpits of light piston aircrafts were in most cases have undergone a transition from conventional analog flight instruments to the panel integrated electronic displays that are usually called "glass cockpits" (GC). Glass cockpit first started to appear in light aircrafts.Data from the General Aviation Manufacturers Association (GAMA) point out that by 2006, more than 90 percent of new piston-powered, light airplanes were equipped with full glass cockpit displays[4].

Separate displays that were designed to show individual states more frequently are merged in order to improve the management of the fly. The accuracy and reliability of the instruments are improved by the introduction of electronics, the quantity of information and data which are available to the pilot during flight significantly increases, and a pilot's panelthat was designed to accommodate the analog displays now is more economically used. With the introduction of these advanced aircraft systems, there was a hope that they would eliminate pilots' errors. However, experience has shown that, at the same time, while these advanced systems help to reduce many types of errors, they at the same time increase the risk of new, unexpected errors[6].

THE PROBLEMS AND THE POTENTIAL RISKS CAUSED BY USING GC DISPLAYS

It is undisputed that GC displays (Figure 1) can present more information in the planned area compared to the conventional instruments, but many information require at the same time focusing pilot´s attention on the position of data while he controls the flight. That creates a risk of mental overload. There is a difficulty with understanding data from the displays and danger of dropping the attention that is necessary to work with the control devices. A preliminary NTSB study [4] found that between 2002 and 2008 light single-engine aircrafts equipped with glass cockpit displays experienced higher fatal, but lower total accidents, than the same aircrafts fitted with traditional cockpit displays. This suggests that the complexityof GC integrated information can practically reduce the functionality of thesystem, which proved to be fatal in certain situations.

Figure 1. Example of GC displays in the Lasta light single-engine piston aircraft.

Pilots in practice are facing one problem, which refers tothe vertical linear tape on the flight display used to show airspeed and altitude [2], whereas traditional cockpits represent airspeed and altitude on circular analog displays.Analysis of this problem was given by the study (Hiremath et al. 2009) which researched pilot´s unusual attitude recovery ability using either traditional or glass cockpits. The results showed that pilots using the glass cockpit spand much more time to recover from unusual attitudes than pilots using the cockpitwith traditional (analog) instruments. The authors indicated that in the traditional cockpit the position of the airspeed and altitude indicator needles can be recognized at the first sight. As opposed, glass cockpit tape displaydoes not represent the whole scale. To get an idea of the airspeed or altitude, the pilot has to focus longer on the numerical values[5], which contributes to the reduction of awareness of thesituation.

Another problem related to the electronic displays was observed on the basis of interviewing the pilots who fly on the glass cockpit aircrafts.The practice of the test pilots indicates a problem with the moving of the vertical marks on the scale of the display during the execution of the specific tasks.For example, when the pilot increases the angle of attack at a constant engine power when the reduction of speed is required, thealtitudedecreases i.e. becomes unstable. The marks on the altitude display are changing in both directions (up and down) and the pilot needs more attention and time to monitor the altitude change tendency and a rate of this changes. The reason is because the glass cockpit altimeters use a fixed pointer and the moving scale. Furthermore, higher altitudes are shown at the top of the display and the scale with marks moves downwards to indicate increasing altitude. Presenting higher altitudes at the top of the linear tapeis consistent with the pictorial realism. But, a downward tape movement to represent increasing altitude violates the logical principle and confuses the pilots[5].

Thus, it can be seen a double problem concerning the GC displays. The first refers to the increased mental workload that arises due to the increased number of information that are presented on the GC. The second appears as a consequence of the transition from circular analog display to the linear tape display (regarding the altimeter).

One of the possible design solutions for this problem is an electronic display with analog appearance that would be placed on the same panel with linear altitude display. This solution is in agreement with previous experience of pilots and it would significantly improve and facilitate reading of the data.

The wide variability in cockpit instruments design has influence on pilot´s ability to identify system malfunctions. For example, visually scan the analog displays for many experienced pilots is a routine, due to standardization of the instrument apperiance, operating range, marking and position on the pilot˙s desk. Unfortunately, traditional instrument scanning procedures are not in compliance and do not apply to glass cockpit aircraft.

CONCLUSION

The research of the properties and improvement of analog displays last more than half a century[3]. A certain number of accidents that were caused by inadequate design of this type of displays initiated an increased number of experimental studies.This researches have focused on examining the characteristics of this type of displays and their individual components, and has led to the determination of certain recommendations [7-8], as well as standards that are related to the analog displays.

The analog displeys are still in useinvarious branches of industries, so their research and testing are not finished yet. Nevertheless, it can be concluded that more time was invested in development of analog displays compared to the development of the electronic displays (such are the primary flight displays in aircrafts).

The experimental studies of the GC displays are very rare, and it is extremely difficult to find some in the literature. This applies particularly to researchesin controlled laboratory conditions. However, there are some recommendations that can be found in the literature relating to the use of electronic displays in aviation.These recommendations should be taken as a starting point for the design of future GC displays. The conclusion is that the scope for improving the safety of the aircraft should be sought in the redesigning of displays, as well as in the training of pilots and insisting on their full understanding of the GC system (before they get the permission to fly independently).

Regular training and simulators, as well as a periodic testing of pilots who have completed training related to the use of GC displays in different situations, may improve and strengthen their flying skills. In addition, the NTSB concluded that due to the complexity of GC and the differences in the operation and design, pilots are not always provided with all the information they need[4]. According to that, it is necessary to make a thorough analysis of the information that will be presented on the GC displays.

Improvements of the properties of GC displays,above all,we should look in the implementation of experimental researches. Considering that some of the conducted researches have shown that in practice there is no advantage of GC displays over analog displays, one of possible design solutions could be found in the combination of analog and electronic displays, where it is justified in terms of usability and safety. Also, good communication with the manufacturers of the devicescan contribute to the supply with information about the potential disadvantages of the system. Exchange of experiences with other users of the same devices, making of internal studies, global studies, the establishment of guides and publications on this topic, can also contribute to the improvement of the flight safety in terms of GC displays, and lead to decreasing of pilots' errors.

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