ERGONOMICAL ANALYSIS OF PILOT SEAT KM-1

T. Jurčević Lulić[1], O. Muftić[2], A. Sušić[3]
[1] Faculty of Mech. Eng. and Naval Arch., Zagreb, Croatia, tanja.jurcevic@fsb.hr
[2] Faculty of Mech. Eng. and Naval Arch., Zagreb, Croatia, osman.muftic@fsb.hr
[3] Faculty of Mech. Eng. and Naval Arch., Zagreb, Croatia, aleksandar.susic@fsb.hr

Summary: The aim of this study was ergonomical analysis of pilot seat KM-1 which takes place in MIG 21 aircraft. Seat KM-1 is ejection seat with function of accommodation of pilot in cockpit during normal flying task and safe escape in danger situation. We made measurements of characteristic dimensions of seat and comparison with anthropomeasures of Croatian male population for purpose of investigation of whatever range of pilot sizes the seat is designed to accommodate. We have analysed seat′s ergonomic qualities: pilot comfort, efficiency and safety. The three-dimensional digital human modelling can be proposed as a tool for the seat and area of cockpit design.
Keywords: pilot seat, ergonomics, dimensions, percentiles

1. INTRODUCTION

Various guidelines and recommendations exist for aircraft designers to follow in ensuring functional accommodation of pilots. Design requirements for the cockpit layout need to be established early in the design process. The design of the cockpit and numerous mechanical systems is based on presumed pilot postures and capabilities. Various military specifications and design handbooks provide detailed requirements for the layout of the cockpit of fighters, transports, bombers and other military aircraft.
The aim of this study was ergonomical analysis of pilot seat KM-1 which is used in MIG 21 aircraft.
Construction of ejection seat KM-1 (Figure 1) consists of girder frame of seat, head support, back support and many of functional devices that enable ejection of seat. The weight of ejection seat KM- 1 is 135 kg [1].
The KM-1 ejection seat can provide the crew a safe and efficient escape from the aircraft. The seat is propelled from the aircraft by an ejection gun which is assisted by a rocket motor. The seat system includes an automatic ejection sequencing system. The front canopy separates before the rear canopy followed by the pilot in the aft cockpit and the pilot in the front cockpit last in any case when the ejection is initiated by either pilot through the ejection handles. The ejection seat system also includes an emergency oxygen system and a survival kit in the seat pan.
Figure 2. represents measure of hip width (arithmetical average = 36.1 cm, standard deviation = 29.2 mm), sitting height – length from the seat to top of head (arithmetical average = 91.4 cm, standard deviation = 36.5 mm) and sitting length – length from back to below knee (arithmetical average = 50.0 cm, standard deviation = 21.1 mm).

In Figure 2a), on Gaussian curve of hip width of male population is drawn the line x = 40 cm which represent width of sitting area of seat KM-1. Only pilots that have hip width smaller than width of sitting area of seat can comfortably sit. Calculated area under curve shows that seat accommodate down to 91st percentile of pilots.

Figure 1: Ejection pilot seat KM-1

In the front view of seat can be seen the lower harness connections. The foot restraints have a purpose of protection of pilot's legs from acting of air stream and inertial forces.
The lower right side of the seat mounts two mechanical actuators for various functions of the seat sequencing. The upper one is a PPK-1P which is armed by a cable from the first drogue chute which is attached to the red loop of the starter key. This is the primary seat separation initiator. The lover PPK-2P is actuated by seat motion withdrawing its starter key. The cables from both PPK units can be seen leading back to the aft end of the seat pan.
The back view shows many points of interest. To the right of the shoulder of the catapult tube is a green box which is the inertia reel/shoulder harness control. Four cables can be seen entering the top of this unit. They connect to the roller units visible outboard of the springs on the top of the seat. Those springs are used to flip up the headrest/drogue container to release the second stabilization chute. The two green tubes running vertically along the right edge of the rear are the arm restraint extender and retractor units. The arm restraints are extended at seat initiation, and retracted as part of the seat man separation. Outboard of these at shoulder height is the pyromechanism for the canopy release. It also has an interlock to prevent firing the catapult of the seat until the canopy has separated and withdrawn the interlock.
The lower right of the seat contains mechanisms which are used to release the harness at seat separation on command from the PPK mechanism cables. To the left of the base of the catapult/rocket tube is a silver cylinder which is an electrical motor to drive the seat pan up and down for height adjustment. Above it on the outboard left side is a large silver box, which is the KPA-4 Speed/Time computer. Actuated by a key being pulled by a cable in the first meters of seat travel, it determines the "mode" of the seat based on the sensed airspeed. Next to the KPA-4 is a cylindrical structure with a right-angle turn at the top. This is the rocket initiator unit. Above it, horizontally mounted behind the catapult is the initiator for seat man separation. It is fired by a cable from the KPA-4 running up and over the pulley near the top of the seat. The cable is protected by a clear plastic shield running up from the outboard edge of the initiator.

2. ERGONOMICAL ANALYSIS

When analysing ergonomics of an aircraft's cockpit, it is first necessary to determine what range of pilot sizes to accommodate. The task of accommodating all pilots with comfort and safety becomes increasingly complex. For most military aircraft, the design requirements include accommodation of the 5th to the 95th percentile of male pilots. Due to the expense of designing aircraft that will accommodate smaller or larger pilots, the services exclude such people from pilot training. Women are only now entering the military flying profession in substantial numbers, and a standard percentile range for the accommodation of female pilots had not yet been established.
In this study we measured characteristics dimensions of pilot seat KM-1 (width and length of sitting area, width and length of back and head support). Dimensions of seat KM-1 are shown on Table 1.

Table 1: Dimensions of seat KM-1

Sitting area	Width	40 cm
	Length	40 cm
Back support	Width	56 cm
	Length	57 cm
Head support	Width	29 cm
	Length	23 cm

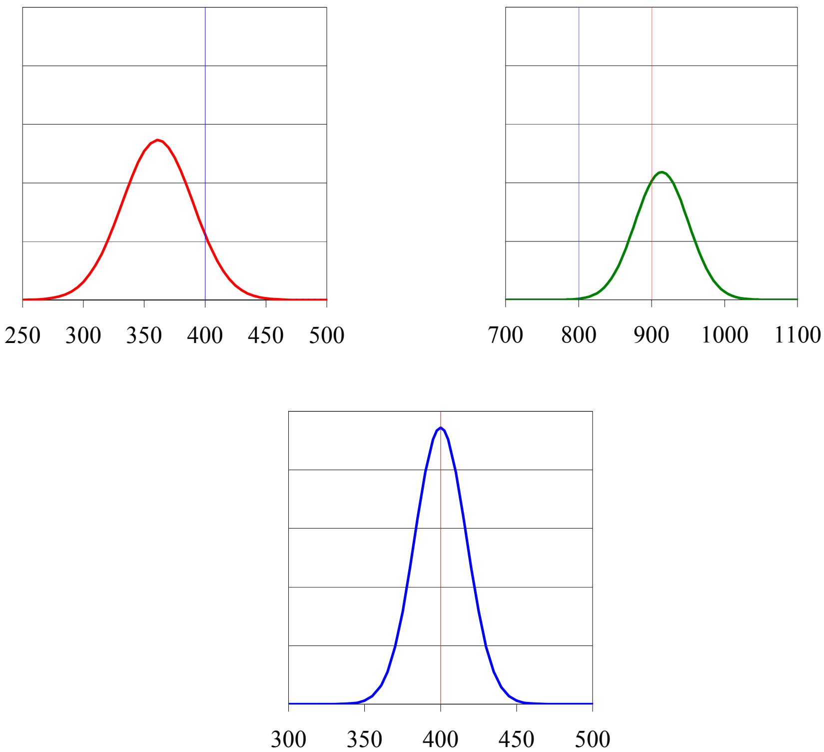

Figure 2: Gaussian curves of characteristic anthropomeasures of male population Ejection pilot seat KM-1
a) Hip width, b) Sitting height, c) Sitting length

Characteristic body dimensions of male population from literature [2, 3], needed for ergonomical analysis of seat, can be plotted on a graph as a bell shaped Gaussian or normal distribution curve. The curves are defined with arithmetical average of values

and standard deviation. The mean and median (50th percentile) coincide, where the mean is the arithmetical average of values and median is the middle number of a series.
We calculated areas under the Gaussian curves to determine accommodation of measures of seat KM-1 to pilot's body dimensions.
Measures of width of back support and head support of seat KM-1 accommodate all male population. Measures of width and length of sitting area and length of back and head support accommodate small part of male population. Gaussian curves of that anthropomeasures are shown on Figure 2.

Figure 2b) shows Gaussian curve of sitting height values with drawn two lines that represent height of the back and head support of seat KM-1. The height of seat support is adjustable from 80 to 90 cm, but height of 80 cm is suitable for only 0.9% male population (down to the 1st percentile of pilots). Height of 90 cm accommodates 35.1%male population (down to 35th percentile of pilots). Other part of male population has greater length of back and head than back and head support of seat.
Gaussian curve of sitting length (distance from back to below knee) is shown in Figure 2c). For comfortable sitting it is necessary that at least 80% of thigh length is on the seat. For that reason, graph 2c) shows Gaussian curve of calculated sitting length (arithmetical average = 40 cm, standard deviation = 16.9 mm) of male population which is equal to 80% of sitting length from anthropological atlas [2, 3]. The length of the sitting area of seat KM-1 is 40 cm, which means that this measure of seat KM-1 accommodate 50% of male population (down to 50th percentile). Other 50 % of male population have higher sitting length and less than 80% of thigh length takes place on seat.

3. CONCLUSION

Seat KM-1 is comfortable only for pilots under 35th percentile of male population (i.e. pilot height under 1683 mm). It is necessary in designing process to change some dimensions of seat (sitting width and length, back and head support length) for better accommodation of larger pilots. A cockpit designed for 95th percentile pilot, included allowances for boots and a helmet, will provide sufficient cockpit space for adjustable seats and controls to accommodate smaller pilots. This will affect the detailed layout of cockpit controls. Pilots require an adequate field-of view external to the aircraft as well as internal, all primary instruments should be placed within a pilot’s primary field of view.
Engineers used the 3D digital human modelling tool for simulating and analyzing interactions between the pilot, seat and cockpit environment.
Difference in proportion (i.e. the relation between body height and torso of sitting height) among people with the same body height may result in significantly different seated postures in a cockpit environment.
Reach envelopes for arms, legs and head have been calculated for each pilot in normal flying position to determine optimal placement for primary controls.

The human modelling studies enable engineers to establish human factors guidelines – reaches, fields of view and design eye points – for the new cockpit.

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