Rudder Pedal Force and Seat Relation for Optimal Efficiency with Different Leg Geometry

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Force exerted on the rudder pedal and the leg geometry of eleven healthy male subjects for different seat/rudder pedal adjustments were recorded. Maximum force on rudder pedal is exerted when the seat reference point (SRP) and the rudder reference point (RRP) were in the same horizontal plane. During maximum exertion of force knee angle of 145.3° ±9.8° and angle between thigh and horizontal (alpha angle) 13.1° ±4.5° were observed. On increasing vertical separation of SRP above the RRP there was progressive decline in maximum force exerted on the rudder pedal.

A critical factor affecting the operator's performance in man-machine system is the layout of his workplace[6]. The pilot should be able to operate all his controls in the cockpit efficiently and accurately with speed and safety. Location of the rudder pedals is one of the important design considerations from the point of view of reach, comfort and efficiency of operation[4]. The force required to operate the rudder pedals in routine flying is less than 100 Lbs. During certain emergencies (such as hydraulic failure), the force required to operate the rudder pedal may be as much as 100-300 Lbs depending upon the class of the aircraft[1]. The amount of force which can be exerted on the rudder pedal depends upon the location of the rudder pedal in relation to the seat and the leg of the operator. In this study the relationship between the force exerted on the rudder pedal and the leg geometry during different seat and rudder pedal adjustments is correlated.

Leg Geometry in relation to rudder pedal and seat is shown in Fig. 1.

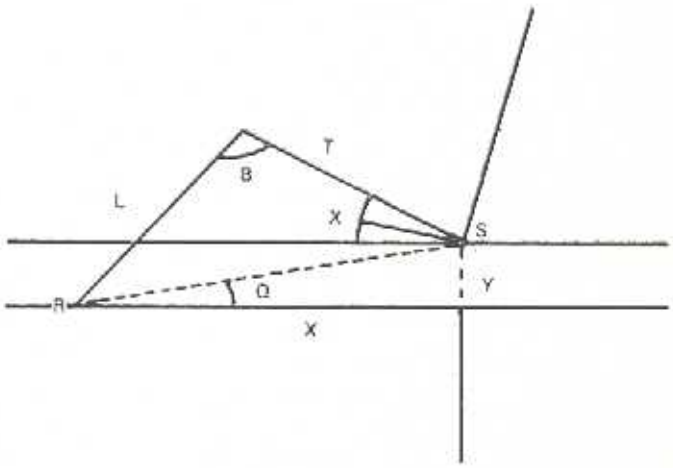

Fig 1. Leg geometry

S—Seat reference point (SRP)
R—Rudder reference point (RRP)
T—Thigh length
L—Leg length
Y – Vertical separation of SRP from RRP
X—Horizontal distance between SRP and RRP
Alpha—Angle between thigh and horizontal
Beta—Angle between thigh and fore leg.

Material and Methods

The universal cockpit alongwith its universal seat and rudder pedal assembly located at Institute of Aviation Medicine, Bangalore was used for this study. Seat pan angle of 6° up and seat back angle of 20° behind the vertical was chosen for this study as these values are quite close to angles of different aircraft seats. HT-2 rudder pedal assembly having 28.5 cms range of horizontal adjustability mounted on a platform was used. Electronic load cells of 100 kg rating attached at RRP were used to record rudder pedal force. The signal output from electronic load cell was amplified and recorded on encardiorite recorder.

Eleven healthy males in the age 23-50 years having leg length varying from 5th to 95th percentile of Indian pilot population were selected for this study[8]. Subjects, wearing flying overall and shoes, were fully strapped in the universal seat. The equipment was first calibrated for 100 kg force and the linearity of the equipment was tested with the help of spring balance. Rudder pedal force for various Y distances ranging from 0-30 cms at 5 cms intervals were simulated. For each Y-distance, the horizontal distance was changed from 84 to 112 cms depending upon the leg length of the subject and each time rudder pedal force and joint angles of lower limb were recorded.

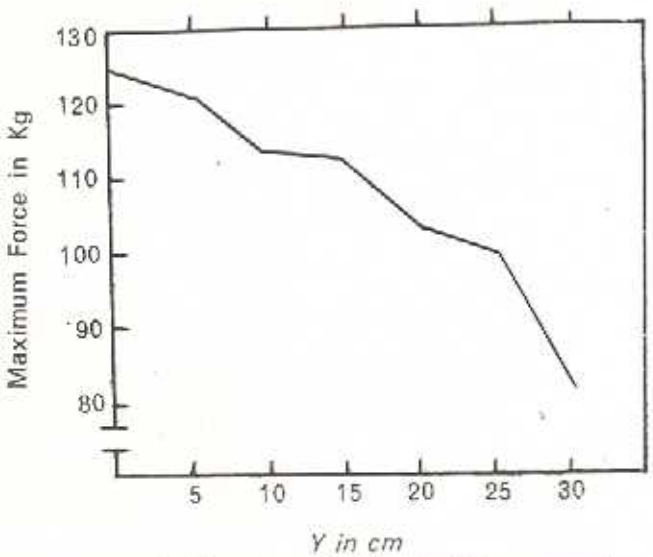

Fig. 2 *Maximum Rudder Pedal Force and Y Distance (n=11 Subjects)*

Results

The maximum rudder pedal force at various Y distances and joint angles are shown in Table-I. Maximum force on the rudder pedal was exerted when the SRP, and RRP were in the same horizontal plane (Y=O cms). On increasing the Y distance above RRP, the force gradually decreased as shown in Fig. 2.

TABLE - I

Maximum Rudder Pedal Force at Different Y Distances (n=11 Subjects)

Y in cms	Force in Kg	Angles in degree		Correlation co-efficient between maximum force and knee angle
		Alpha	Knee	
0	124.0	13.1	145 3	+0.10
5	119.5	12 1	144.3	+0.20
10	112.9	9.7	144.3	−0.04
15	111.8	7.0	146.0	−0.11
20	103.0	5.6	145.3	+0.23
25	100.2	4.6	137.5	−0.15
30	81.0	4.5	131.7	+0 47
Mean	107.5	8.1	142.3	
±SD	4.5	3.6	5.3	

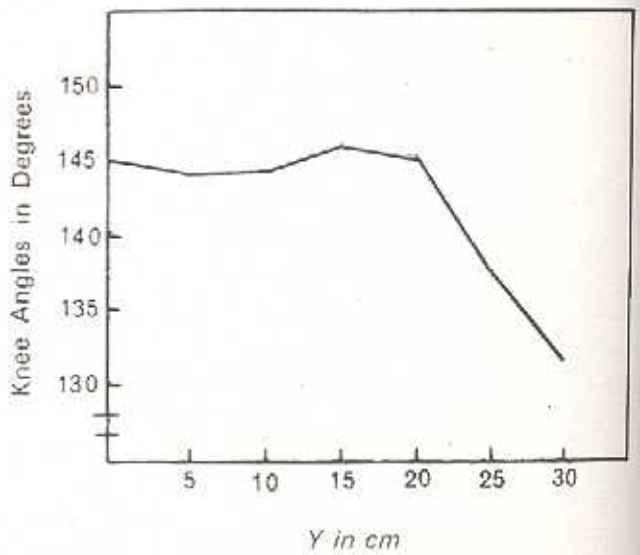

Fig. 3 *Knee Angle on Maximum Exertion of Force at Various Y Distances*

The mean knee angle at the time of maximum exertion of force on rudder pedal is shown in Fig. 3. It ranged from 146° to 131.7° for 0 to 30 cm Y distance.

The effect of increasing X distance on rudder pedal force is shown in Fig. 4. As the X distance

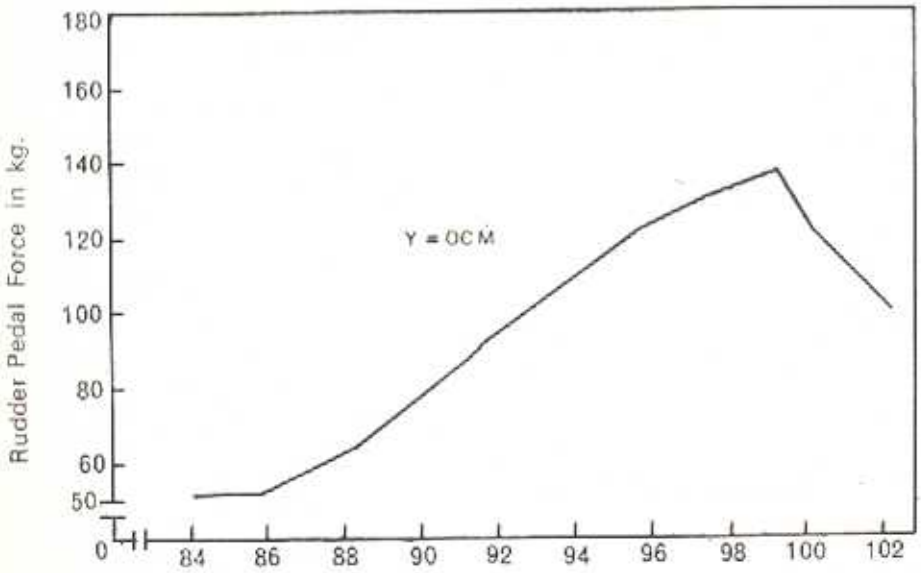

Fig. 4 *Horizontal Distance of SRP to RRP (X) In cm*

increases the force also increases till it reaches a maximum. If the X is further increased rudder pedal force starts declining rapidly. This is due to lack of adequate support to pelvis and back.

Discussion

Maximum force on the rudder pedal is exerted when the SRP and RRP are in the same horizontal plane. During maximum exertion of force the knee angle of 130° to 160° is observed. As per Muller[2] and WADC report[5] also, the maximum force on rudder pedal is exerted when the SRP and RRP are in the same horizontal plane and the knee angle is 135° to 155°. The position of rudder pedals should be within the range of limb movements and the force required to operate them must be within the power of operator under all circumstances. The various factors which have to be taken into account, in location of rudder pedals are sitting, height, leg length, thigh length, fore leg length, contour of seat back, design of rudder pedal and the adjustabilities of seat and rudder pedal.

The line of vertical adjustment of ejection seat is inclined slightly backward with the result any vertical adjustment of seat will affect both horizontal as well as vertical distance between the SRP and pedals. In extreme cases any extent of fore and aft rudder pedal adjustment may remain inadequate unless the pedals were also designed to shift up and down to compensate for changes in vertical separation[4].

Conclusion and Recommendations

From performance point of view the location of the rudder pedal, range of seat and rudder pedal adjustabilities and the human body anthropometric parameters are to be considered while designing and locating rudder pedals. Maximum force on rudder

pedal is exerted when the SRP and RRP are in the same horizontal plane. As the vertical separation of SRP and RRP is increased, the force applied on the rudder pedals decreases progressively. On increasing X distance the force on rudder pedal increases till it reaches maximum; if the X is further increased force decreases rapidly due to less support to pelvis and back. In different aircraft the Y distance ranges from 5 to 30 cms; so the design of instrument panel also needs consideration from this point of view, if the pedals are to be brought in line with SRP. Knowledge of rudder pedal force and leg geometry can be used to evaluate cases of lower limb disabilities in aircrew.

References

1. A V P - 970 chapter 207 para 2. 5. 1.
2. Muller, EA. Optimum arrangement of pedals to be operated from sitting position. Air Technical Intelligence Centre Wright Patterson Air Force Base Ohio.
3. Ram, D, Rai, PM and Kapoor, KS. Anthropometric survey of Air Force Personnel. Technical report DSL and DIPAS. Madras, 1964.
4. Verma, SP and Verghese, CA. A Nomogram for aircraft rudder pedal design. Journal of Aviation Medicine 11 : 15-21, 1968.
5. WADC technical report 56.171. Layout of work places PP 32-41, 1956.