AI 3401 TRACTORS AND ENGINE SYSTEMS

UNIT IV NOTES

TRACTOR CHASSIS MECHANICS

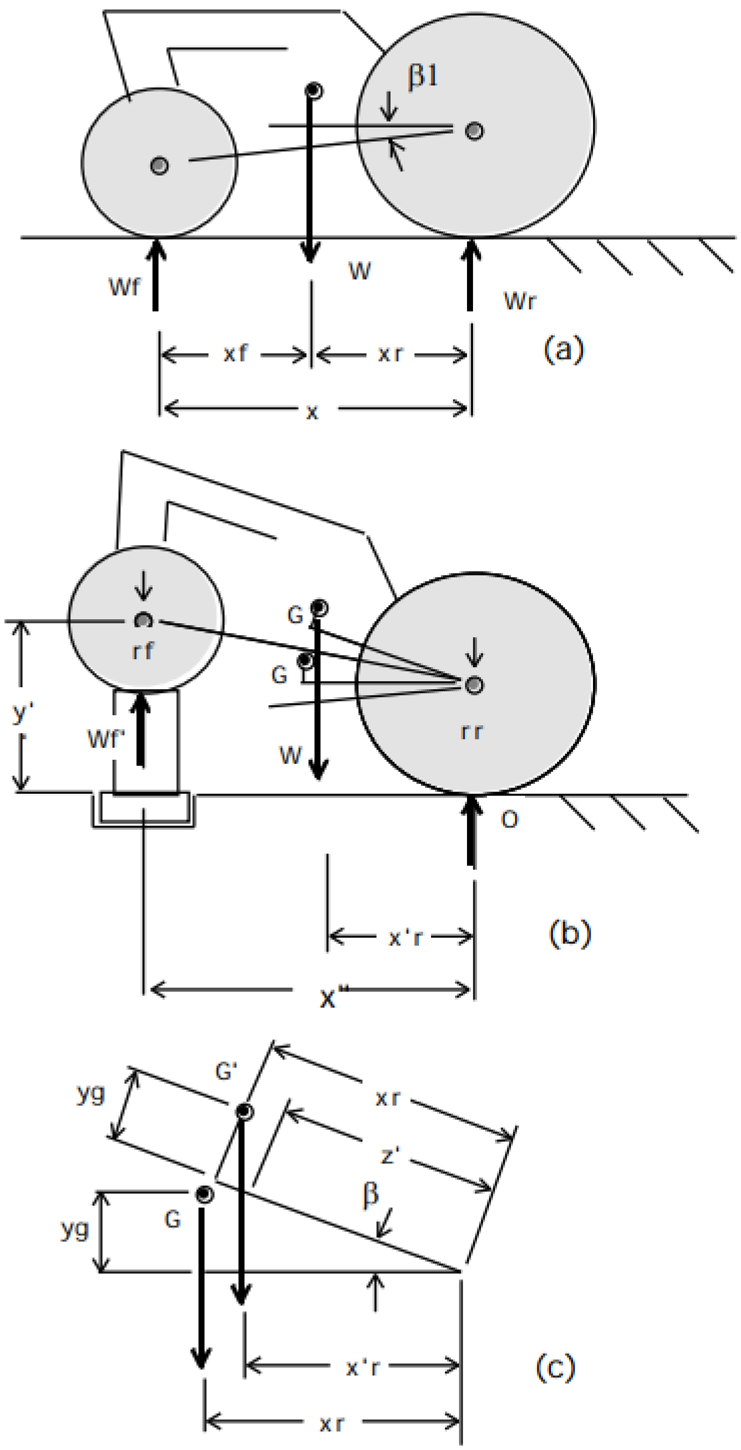
The term 'mechanics' here refers to an analysis of the forces that act on the tractor chassis. The major force is that of gravity and is known as the weight. This is sometimes (loosely) given, and spoken of, in units of mass (kg); in engineering analysis (concerned with statics) all such 'weights' should be converted to force units (kN).

Centre of gravity

The centre of gravity is the point at which the whole of the mass and the weight of the tractor may be considered to act. Its location depends on the disposition of the various masses that comprise the tractor. Any analysis of the tractor chassis requires the location of the centre of gravity to be known. It is usually specified in relation to the rear axle as shown by point G in Figure

(a) Longitudinal location The location of the centre of gravity in the longitudinal (x) direction may be found by measuring the weight on the front (W_f) and rear (W_r) wheels. Application of the force equilibrium condition gives the tractor weight, W: $W = W_f + W_r$

Application of the moment equilibrium condition gives the required longitudinal location, x_r as shown in Figure



Location of centre of gravity of tractor (a) horizontal location (b) tractor raised to find vertical location (c) geometry of position of centre of gravity

For the tractor take moments about O

$$W \cdot x_r = W_f \cdot x$$

$$x_r = \frac{W_f}{W} x$$

The wheel base (x) between the front and rear axles is usually given in the manufacturer's specification or can be measured directly. For most common rear wheel drive tractors x r is approximately 30 % of x; this is also the % of the static tractor weight that is on the front wheels. (b) Vertical location The location of the centre of gravity in the vertical (y) direction is more difficult. The common method is to lift the front (or rear) of the tractor (as shown in Figure and measure the weight on the front wheels (W'f) in the raised condition

Application of the moment equilibrium condition gives the required vertical location, y_g.

For the tractor take moments about O:

$$x'_r = \frac{W'_f}{W} x''$$

The geometry of the positions of the centre of gravity (Figure 6.1(c)) gives:

$$z = \frac{x'_r}{\cos\beta}$$

$$y_g = \frac{x_r - z}{\tan\beta}$$

Substituting for z gives

$$y_g = \frac{x_r - \frac{x'_r}{\cos\beta}}{\tan\beta}$$

where x'_r is as calculated from Equation 6.2 above.

and $$\beta = \beta_1 + \beta_2$$

$$= \operatorname{atan} \frac{r_r - r_f}{x} + \operatorname{atan} \frac{y' - r_r}{x''}$$

Inspection of Equation 6.3 shows that if the difference between x_r' and $\frac{x_r'}{\cos\beta}$ is to be accurately calculated, β needs to be relatively large and / or accurately determined.

Instability Instability occurs when the weight transfer is sufficient to cause the tractor to tip over rearwards. Impending instability (where the front wheels leave the ground and the tractor is on the point of becoming unstable) is considered here because it is a limiting case of the weight transfer and hence of tractor operation. It is an undesirable situation because it represents loss of steering control and may lead on directly to actual instability. Such a situation is partly avoided by inherent features of the design of the tractor-implement system and partly by its operation in a way that avoids reaching that condition. Usually the wheels slip before instability occurs. An understanding of the actual process of tipping over in the vertical longitudinal plane which may follow requires a different, more complex dynamic analysis that includes, among other matters, the inertia of the tractor chassis and of the implement, also the inertia and stiffness of the transmission to the rear wheel.

Analysis and assumptions The following analysis of the tractor in the longitudinal, vertical plane is limited to the calculation of wheel weight during steady state operation in normal work (Section 6.4) and to the prediction of the conditions for impending instability (Section 6.5). Although the tractor and implement are moving, the assumption of steady state operation implies that there are no inertia forces; the forces are doing external work but are not causing any acceleration. Hence the principles of statics and the conditions for static equilibrium of rigid bodies can be applied. Three independent equations of equilibrium (chosen from the following) can be written: (i) the sum of the forces in any two perpendicular directions are zero.

The two directions usually chosen are those parallel to and perpendicular to the ground surface. (ii) the sum of the moments about any two points in the vertical longitudinal plane are zero. The two points usually chosen are the wheel / ground contact points or the centres of the wheels. In simple situations it may be sufficient to consider the whole tractor as a rigid body. Where the external forces are known the weights on the wheels can be calculated directly. However it is sometimes convenient to consider the tractor as composed of two rigid bodies. One, the drive wheels, rotate about a centre located in the other - the chassis of the tractor. This occurs under the action of the torque acting on them which is internally produced by the engine. Any such analysis must apply appropriate constraints ie, that the forces and moments on each are equal and opposite.

In this analysis and the worked examples, the following simple assumptions are made: (i) forward motion is uniform; this assumes constant implement forces and no acceleration (ii) lines of forces on wheels are either tangential or radial or may be resolved as such; wheel sinkage and tyre distortion (but not normal tyre deflection) are neglected (iii) the tractor is symmetrical about the longitudinal vertical plane; all the forces and moments may be considered to act in this plane (iv) other forces, such as the change in position of the fuel and oil in the tractor on sloping ground, air resistance and other minor forces are neglected.

Spatial, visual and control requirement of the operator

i. Work place layout: The layout of workplace should be compatible with not only system performance requirement but also with the user. It should also ensure safety and comfort of operator and controls must be within the reach to minimize errors. Proper workplace layout requires consideration of workplace dimensions, controls and operations being controlled with due regard to:

- The operator’s size
- His position and the directions in which he can most easily work.
- The optimum spaces in which he can manipulate the controls
- Arrangement of controls and displays
- Visual requirement for maximum operator efficiency
- Working posture of the operator viz. Sitting, standing or squatting
- Special influence such as protective clothing.

To decide about proper workplace layout following important factors must be considered:

- Anthropometric parameters of operators
- Placement of operator on tractor for optimum work task vision or vision of displays
- Placements of controls in optimum areas for the operators.

ii. Anthropometric Data: Human being must not only fit spatially in a man task system, but must also be able to move in the work space. With the aid of anthropometric data we can provide an optimum work space layout, including good posture, contributing to considerable decrease in work load and an improvement in the performance. In design of work space and other facilities various considerations need to be taken. In particular, the type of people and their body dimensions are given in Table. Normally, during collection of human engineering data skip the first and last five percentile. Thus while designing a seat, it should be designed to accommodate a reasonable range of individuals, usually from 5^{th} to 95^{th} percentiles.

The seat must be adjustable in a fast, easy and safe way-in horizontal and vertical direction to realize an adoption to the measurements of various population groups. Seat should be designed to take maximum weight expected. In order to realize a good performance, it is necessary that the movements of the body members are in synchrony, simple and logical motions are made, which can be performed almost automatically by the central nervous system. Lower percentile values of seat height and seat depth should be taken. Layout studies can be carried out to find maximum and optimum work space area.

S. N.	Dimensions	Percentile		
		5th	50th	95th
1	Height, cm	162	173	185
2	Seating height erect, cm	84	91	97
3	Seating height normal, cm	80	87	93
4	Knee height, cm	49	54	59
5	Popliteal height, cm	39	44	49
6	Elbow rest height, cm	19	24	30
7	Thigh clearance height, cm	11	15	18
8	Buttock knee height, cm	54	59	64
9	Buttock Popliteal length, cm	44	50	55
10	Elbow to elbow breadth, cm	35	42	51
11	Seat breadth, cm	31	36	40
12	Weight, Kg	58	75	98

Placement of operator for optimum vision

The seat of tractor must give the operator an optimum field of vision and be in a position on the tractor which helps give him comfortable and safe operating conditions. Tractor operator may require vision to front and rear, or front and sides. A wide field of vision is required for both short and long ranges. Moreover close range vision is required during handling of mounted implements. These visibility requirements are satisfied by upright seating posture in order to permit easy movements of head and upper body from the front, to side, or rear as required for gathering necessary visual information. Good visibility for the operator is more important than excessive number of displays, especially when the machine is operating satisfactorily. The display area has to be close to the operator's line of vision which requires only minimum eye movements away from his task. Below Table would be quite helpful in designing the location of displays of tractor in relation to the operator.

Optimum vision of operators

Type of movement	Direction	Lateral		Direction	Vertical	
		Opt.	Max.		Opt.	Max.
Head rotation only	Left and right	0	60	Up and down	0	50
Eye rotation only	-do-	15	35	-do-	0 30	25 35
Head and eye rotation	-do-	15	95	-do-	0 30	75 85