

# **Crash 3**

## **Technical Manual**

U.S. DEPARTMENT OF TRANSPORTATION  
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#### 2.2.4 Moment Arms of Resultant Collision Force on Vehicles 1 and 2

The moment arms  $h_1$  and  $h_2$  of the resultant force on the two vehicles determine the effective masses acting at those vehicle points that achieve a common velocity at the damage centroid during the collision. Thus, the accuracy of the  $\Delta V$  results corresponding to given damage patterns is directly affected by the moment arm approximations.

The basis for the procedure is depicted in Figure 2.6, in which the following relationships may be seen to exist. The moment arm,  $h_1$ , depends on the assumed location of the average force, which is taken to be at the centroid of the damage area.

(1) Side Contact, Figure 2.6a

$$\text{TEMP1} = Y_S - \left(\frac{1}{N}\right) (C_1 + C_2 + \dots C_n) \quad (2.51)$$

$$h = \left( D^2 + (\text{TEMP1})^2 \right)^{1/2} \cos \left\{ \arctan \left( \frac{\text{TEMP1}}{D} \right) + \alpha \right\} \quad (2.52)$$

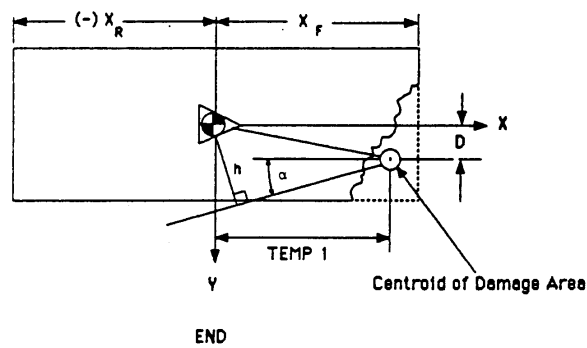
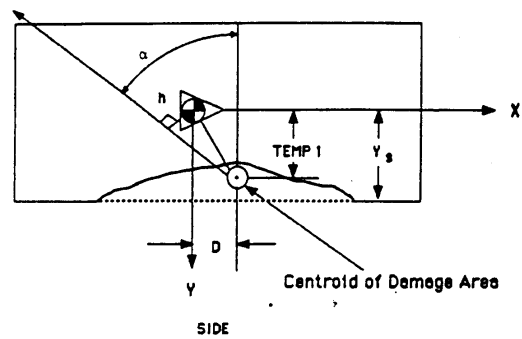


FIGURE 2.6 MOMENT ARMS OF RESULTANT COLLISION FORCES

(2) End Contact, Figure 2.6b

$$\text{TEMP1} = X_F - \left(\frac{1}{N}\right) (C1 + C2 + \dots C_n) \quad (2.53)$$

or

$$\text{TEMP1} = -X_R - \left(\frac{1}{N}\right) (C1 + C2 + \dots C_n) \quad (2.54)$$

$$h = D \cdot \cos \alpha + \text{TEMP1} \cdot \sin \alpha \quad (2.55)$$

The angles  $\alpha$  are based directly on either the specified clock directions (columns 1, 2 of CDC) or the supplementary inputs of direction angles of the principal force on the two vehicles. Thus, the user should understand that the direction of  $\Delta V$  is determined by these input data and not by the program, which only calculates the magnitude of change in velocity,  $\Delta V$ .

#### 2.2.5 Damage Interpretation in Oblique Collisions Correction Factor for Crush Resistance

The fitted empirical crush characteristics apply to the intervehicle force component perpendicular to the involved side or end. For cases in which the principal force is not perpendicular to the involved side or end, the analytical relationship defining the maximum relative displacement must

make use of the crush resistance and deflection along the line-of-action of the resultant force. In other words, the effective peripheral crush resistance that is used in the derivation of the foregoing equations is in the direction of the resultant force. Therefore, the calculation of absorbed energy must reflect this fact.

If the specified direction of the principal force is assumed to be approximately correct, a corresponding tangential force component must have existed during the deflection. In Figure 2.7, the components of a resultant intervehicle force are depicted. In the figure, it may be seen that

$$F_R = F_N / \cos \alpha \quad \text{and} \quad (2.56)$$

$$C_R = C_N / \cos \alpha \quad (2.57)$$

where  $F_R$  = Resultant force.

$F_N$  = Normal force.

$C_R$  = Crush in the direction of  $F_R$ .

$C_N$  = Normal crush.

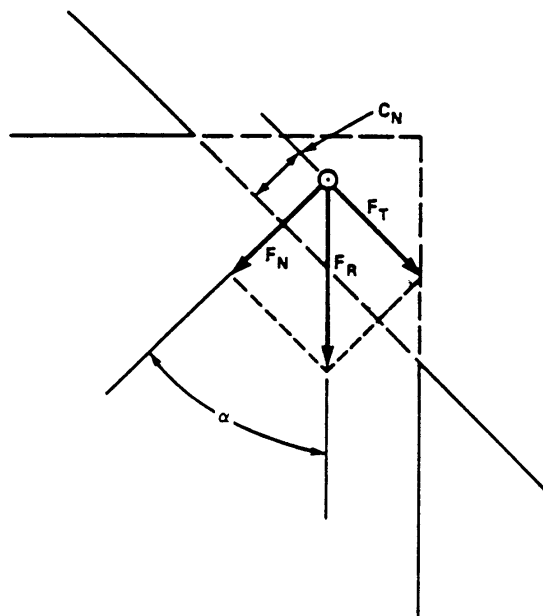


FIGURE 2.7 FORCE COMPONENTS IN OBLIQUE COLLISION

The work done in the direction of the resultant force may be determined from

$$\int_0^{C_R} F_R dC_R = (1 + \tan^2 \alpha) \int_0^{C_N} F_N dC_N \quad (2.58)$$

Application of (2.58) to the calculation of absorbed energy yields the correction factor,  $(1 + \tan^2 \alpha)$ , for the effective crush stiffness in oblique collisions. Some<sup>17</sup> have claimed that the  $(1 + \tan^2 \alpha)$  correction factor is much too large, reaching a maximum value of 2.

The tangential force,  $F_T$ , however, cannot increase without bound.  $F_T$  represents the frictional forces acting perpendicular to the normal force,  $F_N$ . The tangential force is given by

$$F_T = F_N \tan \alpha \quad (2.59)$$

As stated above,  $F_T$ , is limited to some maximum value which is given by

$$F_{T-\max} = \mu_f F_N \quad (2.60)$$

where  $\mu$  is a coefficient of intervehicular friction. If equations (2.59) and (2.60) are set equal to each other and solved for  $\mu_f$ , the

following expression results

$$\mu_f = \tan \alpha \quad (2.61)$$

It is to some degree academic to argue about what value of  $\mu$  is appropriate. What the CRASH3 program implies by limiting  $\alpha$  to  $\pm 45$  degrees is that  $\mu$  can get no larger than 1. The assumption that the tangential friction force cannot grow larger than the normal force is a reasonable boundary assumption. For this reason, the maximum value of  $\alpha$  is limited to  $\pm 45$  degrees.