R. R. McHenry

USER'S MANUAL FOR THE CRASH COMPUTER PROGRAM

By
Raymond R. McHenry

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FINAL REPORT

PART 2

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From (14), (15) and (12), these velocity changes (approach period) can be expressed as

$$\Delta V_1 = \sqrt{\frac{2(E_1+E_2)}{M_1\ (1+{}^{M_1}/_{M_2})}} \quad \text{in/sec} \tag{16}$$

$$\Delta V_2 = \sqrt{\frac{2(E_1+E_2)}{M_2\ (1+{}^{M_2}/_{M_1})}} \quad \text{in/sec} \tag{17}$$

Non-Central Collisions

In the more general case of non-central collisions, a common velocity is achieved at the regions of collision contact rather than at the centers of gravity. For example, in the offset frontal collision depicted in Figure 10, a common velocity is reached at point P.

In Figure 10, the collision force acting on Vehicle 1,

$$F_x = -M_1\ddot{X}_1 = -M_1\ (\ddot{X}_p - h_1\ddot{\psi}_1) \tag{18}$$

The corresponding moment acting on Vehicle 1,

$$F_x h_1 = -I_1\ddot{\psi}_1 = -M_1 k_1^{\,2}\ddot{\psi}_1 \tag{19}$$

where k_1^2 = radius of gyration squared of Vehicle 1 in yaw, in^2.

From (19), the angular acceleration of Vehicle 1,

$$\ddot{\psi}_1 = -\frac{F_x h_1}{M_1 k_1^{\,2}} \tag{20}$$

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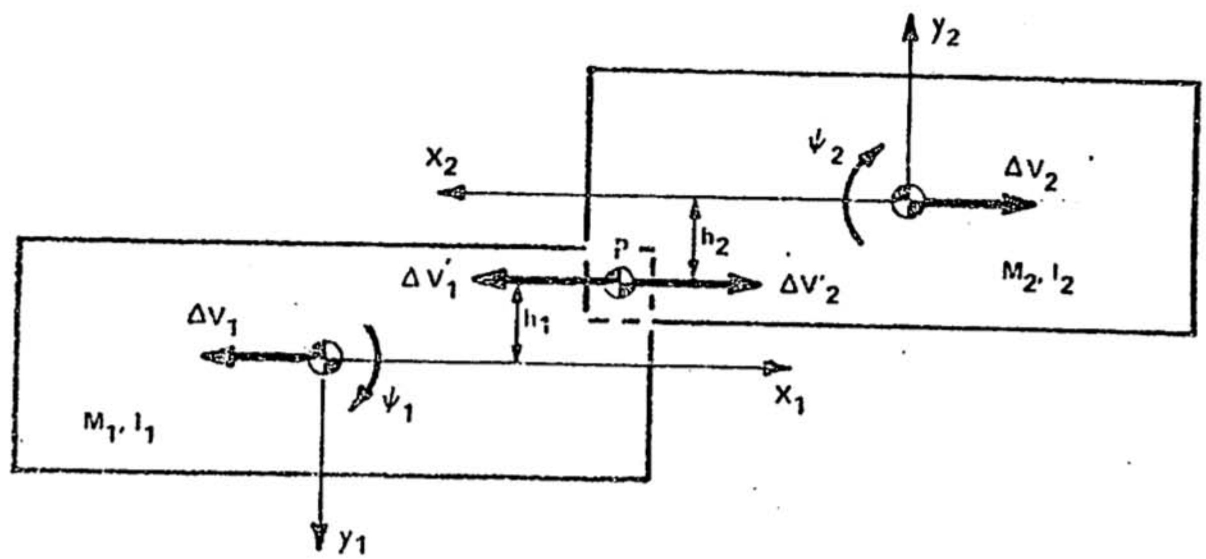

Figure 10 OFFSET FRONTAL COLLISION

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Substitution of (20) in (18) yields

$$\ddot{X}_p = -\frac{F_x}{M_1}\left(\frac{k_1^2+h_1^2}{k_1^2}\right) \tag{21}$$

$$\ddot{X}_1 = -\frac{F_x}{M_1} = \left(\frac{k_1^2}{k_1^2+h_1^2}\right)\ddot{X}_p \tag{22}$$

Let $\gamma_1 = \dfrac{k_1^2}{k_1^2+h_1^2}$, then from (22),

$$\ddot{X}_1 = \gamma_1 \ddot{X}_p \tag{23}$$

Integration of equation (23) over the time interval during which a common velocity is reached at point P yields

$$\Delta\dot{X}_1 = \gamma_1 \Delta\dot{X}_p\text{, or} \tag{24}$$

$$\Delta V_1 = \gamma_1 \Delta V_1' \tag{25}$$

where $\Delta V_1'$ is the velocity change during the approach period of the collision at point P.

From (21), the effective mass of Vehicle 1 acting at point P may be expressed as $\gamma_1 M_1$. Similarly, the effective mass of Vehicle 2 acting at point P may be expressed as $\gamma_2 M_2$. Substitution of the effective masses into equations (16) and (17) yields expressions for the velocity change (approach period) at point P.

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$$\Delta V_1' = \sqrt{\frac{2(E_1+E_2)}{\gamma_1 M_1 (1+\gamma_1 M_1/\gamma_2 M_2)}} \text{ in/sec} \tag{26}$$

$$\Delta V_2' = \sqrt{\frac{2(E_1+E_2)}{\gamma_2 M_2 (1+\gamma_2 M_2/\gamma_1 M_1)}} \text{ in/sec} \tag{27}$$

From equation (25) and the corresponding expression for Vehicle 2, the velocity changes (approach period) at the center of gravity of the two vehicles are obtained.

$$\Delta V_1 = \sqrt{\frac{2\gamma_1 (E_1+E_2)}{M_1 (1+\gamma_1 M_1/\gamma_2 M_2)}} \tag{28}$$

$$\Delta V_2 = \sqrt{\frac{2\gamma_2 (E_1+E_2)}{M_2 (1+\gamma_2 M_2/\gamma_1 M_1)}} \tag{29}$$

It should be noted that when $\gamma_1 = \gamma_2 = 1.00$, equations (28) and (29) reduce to the central-impact relationships of equations (16) and (17).

In Figure 11 and Figure 5, further relationships required to approximate the effects of intervehicle friction are depicted. The dimensions h_1 and h_2 are approximated on the basis of (1) the midpoint of the collision contact region and (2) the existence of a tangential velocity (columns 1 and 2 of the VDI).

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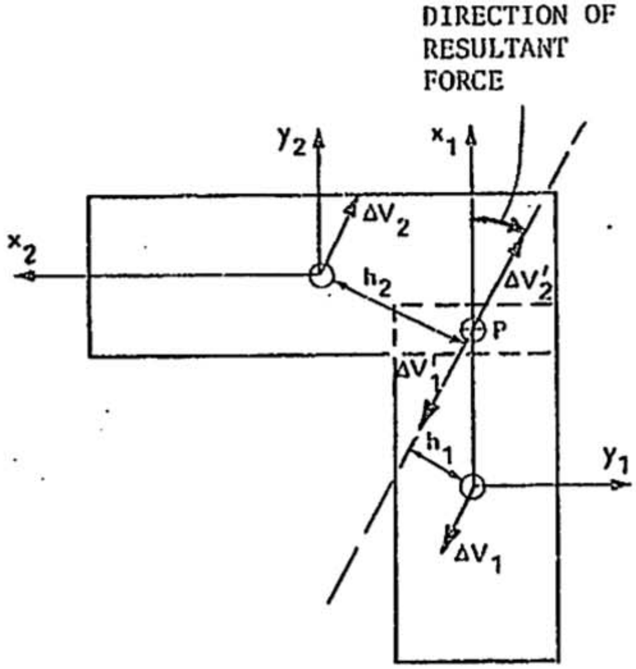

Figure 11 INTERSECTION COLLISION

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In the cited study by Emori (Reference 6) and in the SMAC program (Reference 2) a simple friction coefficient has been shown to yield reasonable approximations of collision responses. Inherent in the present analytical treatment is the assumption that the residual crush provides a direct measure of the energy absorbed by compressive forces between the two vehicles and that the additional work done by tangential shear forces does not provide directly measurable damage evidence. It should be noted that the front end of the impacting vehicle in an intersection collision is generally distorted laterally, but that corresponding measurement techniques have not been established.

Absorbed Energy

The calculation of absorbed energy is based on residual crush and is patterned after that developed by Campbell (Reference 7). The only significant difference is in the treatment herein of the energy absorbed without residual crush as being proportional to the contact width rather than a constant. The following relationship is applied.

$$E_i = \int_0^{W_0} \left(A_i C + \frac{B_i C^2}{2} + G_i\right) dw \quad \text{in lbs} \tag{30}$$

where E_i = Energy absorbed by vehicle i, inch lbs.

$C = f(w)$ = Residual crush of vehicle i, inches.

w = Width dimension of damaged region, inches;

A_i, B_i, G_i = Empirical coefficients of unit width properties obtained from crash test data.

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