Vehicles Weight Ratio V. Initial Velocity of Vehicle in Chain Accidents on Highways

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ABSTRACT:
The objective of this study is to determine the influence of vehicles weight ratio on the initial velocity of the first vehicle in a chain accident on highways involving three vehicles. Regression analysis on the results of these variables was conducted. Excellent correlation coefficient was found for the relationship at α = 0.05 significance level. The influence of Vehicles Weight Ratio on the Initial Velocity is shown by a quadratic equation (Initial velocity = 9.4313 Vehicles Weight Ratio ^{2} – 45.94 Vehicles Weight Ratio +143.52) with R = 0.91.

KEYWORDS: *Accident Reconstruction, Chain Accidents, Highways, Initial Velocity, Regression Analysis, Reconstruction engineering, Vehicles Weight Ratio.*

I. INTRODUCTION

Accident reconstructing engineering is the planning, surveying, measuring, investigating, analyzing, and report making process on the intricate engineering details of how accidents occurred. The analysis and conclusions are based on the extensive application of fundamental principles of physics and engineering including Newton's Laws of Motion [1] and First Law of Thermodynamics [2]. The first law of thermodynamics when applied to accidents states that the total energy before and after the accident will be the same. The input variables include roadway, vehicle, driver and environmental conditions. Accident reconstruction engineering studies can be utilized by the industry, city and state governments for modifying the structural facilities such as roads. The modifications may include obtaining improved friction factors, increased number of lanes and lane widths and better site distances. Vehicle manufacturers use the results of the studies for developing better designs of vehicles. Some of the recent vehicles may use event data recorder containing information on the speed of the vehicle before and at the time of the accident. Some manufacturers, such as GM and Ford, allow downloading the information from these boxes after an accident [3]. The results of the accident reconstruction studies are also used for producing better navigations aids to assist the drivers.In this study the guidelines of Accreditation Commission for Traffic Accident Reconstruction (ACTAR) [4] are used. There are many research studies on the application of accident reconstruction engineering principles. One of the most important one is that of Hurt's [5]. Hurt found that motorcyclists needed to develop their capabilities on controlling skids and proper use of helmets significantly reduced head injuries. Hurt further found that out of all the turning movements, the left turners were the most involved ones in the accidents while turning in front of the oncoming motorcycles.

II. SCOPE OF THE STUDY

The study is limited to the accidents caused by negligent drivers of cars hitting the parked cars [6,7,8]. All the accidents caused elastic deformations only [9,10]. There are no significant plastic deformations [11,12,13].

III. METHODOLOGY

C1 was travelling at certain speed, feet per second and skidded s feet before hitting C2. One half of the energy was transmitted from C1 to C2. C2 was travelling at certain speed, feet per second before the accident. C2 picked up the energy from C1 and hit C3. The weight ratios of C1/C2 and C2/C3 are noted. Again one half of the energy of C2 was transmitted to C3.
The following equations were used.

[1] The total product of mass and velocity of Car2 is equal to that of Car 3 as shown in the following equation.

[2] $M_2u_2 = m_3 u_3$ (2)

Where, m_2= mass of vehicle C2 and u_2 is the velocity of C2. M_3= mass of C3 and u_3 = velocity of C3.

[3] Deceleration was calculated by using Equation1.

a. Final velocity was calculated by the following equation.

$$u = \sqrt{v^2 - 2 \cdot a \cdot s} \quad (3)$$

Where, u= initial velocity of the vehicle, ft/sec
v=final velocity, ft/sec
a= deceleration of the vehicle, ft/sec^2
s= skidded distance, feet

IV. RESULTS AND DISCUSSION

The following assumptions were made in this study

[1] The energy lost in sound produced by the accident is negligible.

[2] The energy lost in causing the slight angular movement of the vehicle is negligible.

Professional engineering principles allow the application of the above two assumptions in the appropriate engineering calculations.

Table I shows the Engineering Calculations for Mixed Variables for Case 1 through Case 5 for Determininig the Initial Velocity while Table II gives the Engineering Calculations for Mixed Variables for Case 6 thorugh 10 for Determininig the Initial Velocity.

Engineering Calculations for Case 1 through Case 5; Case 6 through Case 10; and Case 11 through Case 15 for Determininig the influence of Vehicles Weight Ratio on the Initial Velocity are given in Tables III, IV, and V respectively.

The following regression relationship was found with statistically significant correlation coefficient for predicting the performance of the engineering variables. The relationship was significant at $\alpha = 0.05$ significance level [14,15,16].

Fig. 1 shows the influence of Vehicles Weight Ratio on the Initial Velocity. This relationship is described by a quadratic equation (Initial velocity = 9.4313 Vehicles Weight Ratio ^{2} – 45.94 Vehicles Weight Ratio +143.52) with R = 0.91.

Table I. Engineering Calculations for Mixed Variables for Case 1 through Case 5 for Determininig the Initial Velocity.

	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Car3					
Velocity after the second accident, ft/sec	123.71	121.83	126.35	117.46	116.09
Weight Ratio, C3/C2	0.48	0.60	0.68	0.78	0.92
Velocity before the second accident, ft/sec	70	75	80	72	74
Weight, pounds	3000	3500	3800	4200	4800
Car2					
Weight, Pounds	6200	5800	5600	5400	5200
Weight Ratio, C2/C1	3.10	2.32	1.87	1.54	1.30

Velocity after the first accident, ft/sec	51.98	56.52	62.90	70.71	77.70
Velocity before the first accident, ft/sec	42	44	48	50	52
Car1					
Weight, pounds	2000	2500	3000	3500	4000
Final Velocity (after skidding, and before first accident) ft/sec	61.87	58.10	55.63	63.90	66.81
Skidded Distance, ft	22	26	28	30	32
Pavement Friction	0.28	0.28	0.28	0.28	0.28
Deceleration, ft/sec^2	9.02	9.02	9.02	9.02	9.02
Initial Velocity, ft/sec	65	62	60	68	71

Table II. Engineering Calculations for Mixed Variables for Case 6 through Case 10 for Determininig the Initial Velocity.

	Case 6	**Case 7**	**Case 8**	**Case 9**	**Case 10**
Car3					
Velocity after the second accident, ft/sec	117.41	101.18	103.05	107.60	104.28
Weight Ratio, C3/C2	1.10	1.17	1.32	1.50	1.74
Velocity before the second accident, ft/sec	78	60	63	68	65
Weight, pounds	5300	5400	5800	6000	6100
Car2					
Weight, Pounds	4800	4600	4400	4000	3500
Weight Ratio, C2/C1	1.07	0.92	0.80	0.67	0.54
Velocity after the first accident, ft/sec	87.04	96.69	105.58	118.80	136.91
Velocity before the first accident, ft/sec	54	56	58	60	62
Car1					
Weight, pounds	4500	5000	5500	6000	6500
Final Velocity (after skidding, and before first accident) ft/sec	70.49	74.86	76.13	78.41	80.67
Skidded Distance, ft	20	18	16	14	12
Pavement Friction	0.28	0.28	0.28	0.28	0.28
Deceleration, ft/sec^2	9.02	9.02	9.02	9.02	9.02
Initial Velocity, ft/sec	73	77	78	80	82

Table III. Engineering Calculations for Case 1 through Case 5 for Determininig the Relationship between Vehicles Weight Ratio and Initial Velocity.

	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Car3					
Velocity after the second accident, ft/sec	140.89	133.62	121.33	113.74	106.08
Weight Ratio, C3/C2	1.00	1.00	1.00	1.00	1.00
Velocity before the second accident, ft/sec	60	60	60	60	60
Weight, pounds	1800	2000	2400	2800	3500
Car2					
Weight, Pounds	1800	2000	2400	2800	3500
Weight Ratio, C2/C1	0.30	0.34	0.46	0.58	0.80
Velocity after the first accident, ft/sec	161.77	147.24	122.65	107.48	92.15
Velocity before the first accident, ft/sec	50	50	50	50	50
Car1					
Weight, pounds	6000	5800	5200	4800	4400
Final Velocity (after skidding, and before first accident) ft/sec	67.06	67.06	67.06	67.06	67.06
Skidded Distance, ft	25	25	25	25	25
Pavement Friction	0.25	0.25	0.25	0.25	0.25
Deceleration, ft/sec^2	8.05	8.05	8.05	8.05	8.05
Initial Velocity, ft/sec	70	70	70	70	70

Table IV. Engineering Calculations for Case 6 through Case 10 for Determininig the Relationship between Vehicles Weight Ratio and Initial Velocity.

	Case 6	**Case 7**	**Case 8**	**Case 9**	**Case 10**
Car3					
Velocity after the second accident, ft/sec	100.97	98.62	97.07	96.51	95.44
Weight Ratio, C3/C2	1.00	1.00	1.00	1.00	1.00
Velocity before the second accident, ft/sec	60	60	60	60	60
Weight, pounds	4200	4800	5000	5100	5300
Car2					

Weight, Pounds	4200	4800	5000	5100	5300
Weight Ratio, C2/C1	1.05	1.23	1.39	1.46	1.61
Velocity after the first accident, ft/sec	81.93	77.24	74.14	73.01	70.88
Velocity before the first accident, ft/sec	50	50	50	50	50
Car1					
Weight, pounds	4000	3900	3600	3500	3300
Final Velocity (after skidding, and before first accident) ft/sec	67.06	67.06	67.06	67.06	67.06
Skidded Distance, ft	25	25	25	25	25
Pavement Friction	0.25	0.25	0.25	0.25	0.25
Deceleration, ft/sec^2	8.05	8.05	8.05	8.05	8.05
Initial Velocity, ft/sec	70	70	70	70	70

Table V. Engineering Calculations for Case 11 through Case 15 for Determininig the Relationship between Vehicles Weight Ratio and Initial Velocity.

	Case 11	**Case 12**	**Case 13**	**Case 14**	**Case 15**
Car3					
Velocity after the second accident, ft/sec	93.54	92.35	91.65	90.68	90.03
Weight Ratio, C3/C2	1.00	1.00	1.00	1.00	1.00
Velocity before the second accident, ft/sec	60	60	60	60	60
Weight, pounds	5500	5700	5800	5900	6000
Car2					
Weight, Pounds	5500	5700	5800	5900	6000
Weight Ratio, C2/C1	1.96	2.28	2.52	2.95	3.33
Velocity after the first accident, ft/sec	67.07	64.71	63.30	61.37	60.06
Velocity before the first accident, ft/sec	50	50	50	50	50
Car1					
Weight, pounds	2800	2500	2300	2000	1800
Final Velocity (after skidding, and before first accident) ft/sec	67.06	67.06	67.06	67.06	67.06
Skidded Distance, ft	25	25	25	25	25
Pavement Friction	0.25	0.25	0.25	0.25	0.25
Deceleration, ft/sec^2	8.05	8.05	8.05	8.05	8.05
Initial Velocity, ft/sec	70	70	70	70	70

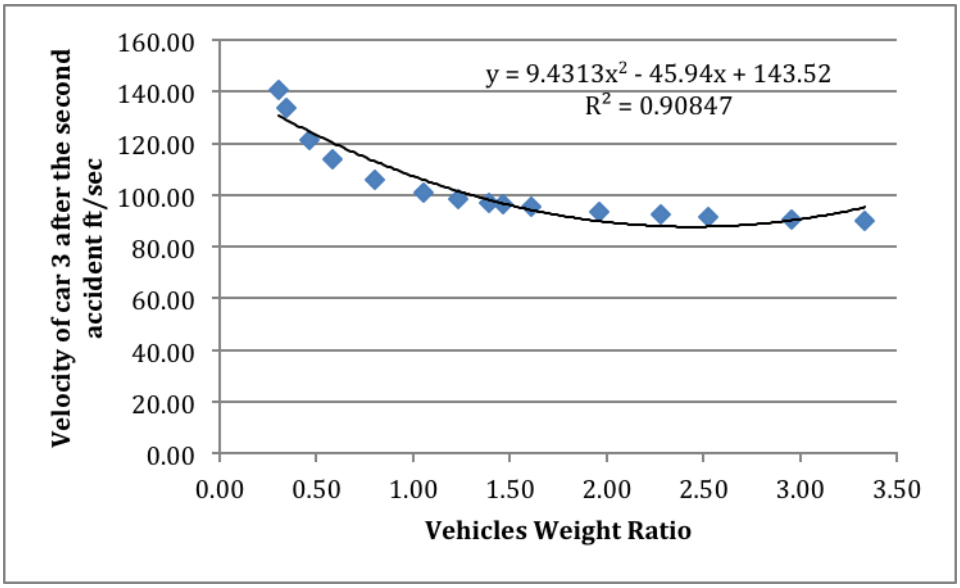

Figure 1 Influence of Vehicles Weight Ratio on the Initial Velocity

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V. CONCLUSIONS

The following regression relationship was found with statistically significant correlation coefficient for predicting the performance of the engineering variables.The influence of Vehicles Weight Ratio on the Initial Velocity is shown by a quadratic equation (Initial velocity = 9.4313 Vehicles Weight Ratio ^{2} – 45.94 Vehicles Weight Ratio +143.52) with R = 0.91.

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