Design on Direct Crushing Garbage in the Garbage Dump Truck: A Case Study for Denpasar City, Bali, Indonesia

I Ketut Adi Atmika, I D. G. Ary Subagia, and Tjokorda Gde Tirta Nindhia

***Abstract*—In transporting of garbage, a phenomenon that often occurs is spilled garbage on the street. Aside from cause traffic, congestion and air pollution pose a unpleasant odor to the environment, either directly or indirectly have an impact also on public health. This study examines and assesses the performance of traction and vehicle stability performance of trucking garbage crusher which is integrated with screw operated at various conditions / field operations. The analysis is focused on analyzing the behavior of the vehicle rolling. Analysis of vehicle traction performance model is able to overcome various obstacles, with a capable pass climbs up to 24 degrees, with the traction needed up to 52000 N and the minimum prediction engine power of 142 hp. On the road conditions turn up the speed of 60 km / h, the magnitude of the normal force on each wheel is still positive, then the vehicle is still safe for the rolling conditions.**

***Index Terms*—Screw crusher, traction performance, behavioral directions, Rolling analysis.**

I. Introduction

Garbage often interferes with comfort because it smells unpleasant and unfavorable views. Increasing number of garbage today lead processing becomes imperfect and sometimes not transported by the local department because too many industries and households. This problem is experienced by one of the provincial capital of Bali, Denpasar. Denpasar city generated garbage every day at this time of 2200 m^3 to 2500 m^3. The Department is responsible for the cleanliness of the environment, namely Denpasar city and Sanitation Department (DKP), DKP currently has a vehicle of 96 units with a number of feasibility level as garbage that can be said is inadequate, especially in terms of comfort and performance of traction and rolling behavior.

In transporting garbage, a phenomenon that often occurs is spilled garbage on the street. Aside from the cause traffic, congestion and air pollution which is pose a less pleasant odor to the environment in its path, either directly or indirectly have an impact also on public health. The phenomenon of garbage transport vehicle in Denpasar, Bali, Indonesia shown in Fig. 1.

The purpose of this study is to test and assess the performance of traction, stability and security performance models of vehicles carrying garbage. While the final phase of the overall activities of the research design and mechanization of garbage transport vehicle integration crasher (screw crusher) is expected to generate a mechanism of transport vehicles and construction waste that meets the eligibility standards of operation. The design vehicles haul trucks garbage crusher is integrated with the screw shown in Fig. 2. Process on garbage transport vehicle started by including garbage organic into waste hopper to the system crusher step by step where in it there are system of sieve and receptacle water waste.

Fig. 1. The phenomenon of garbage transport vehicle in Denpasar, Bali, Indonesia. Spilled garbage on the street is often occurs.

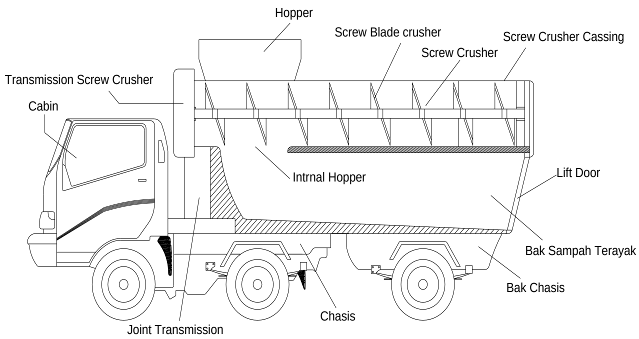

Fig. 2. The prototype design garbage transport vehicle integrated crusher.

Some researchers have expressed motor vehicle other than have a definite ability to transport goods and people also should have quality in terms of stability and comfort and safety.

Research entitled advance Automotive Control System in the Future to develop a concept vehicle directional stability control which is essentially still based on braking and torque control [1]. The research has developed a 4-wheel drive system (4WS) that can have multiple parameters to improve directional stability and the ability to turn the vehicle [2], [3].

Research and study with the topic design of mechanical hidroulis Semilock Brake System with Load Sensing Proportioning Valve combination and Membranes to develop

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the concept of semi-lock brakes which can improve the ability to turn the vehicle and directional stability of the vehicle [4].

The research have developed a control system of the vehicle directional stability by providing or reduction of force on the brake wheel by utilizing ABS, and controlling the torque with a CVT and integrated harness system with 4-wheel steering [5] and study with Smart Handling with Gyroscopic Component [6].

From predecessor automotive technology development focuses just only on the issue of security, stability, and comfort. Furthermore, to be able to answer the problem of transporting garbage transportation technologies, in this research will be developed prototype vehicle with the integrated trash integrated with crasher (screw crusher), which begins with the testing and assessment of the performance of traction and roll behavior of the vehicle's performance.

II. Methode

Traction characteristics on motor vehicles principally covers the vehicle's ability to accelerate, and overcome the obstacles that occur, including rolling resistance (rolling resistance), climb obstacles, as well as aerodynamic resistance. From the concept of inertia force, traction and derived equations written in general [7]:

$$F = R_a + R_r + R_d + R_g + \frac{W}{g}.a \tag{1}$$

F= total traction force required (N)
R_a = aerodynamic resistance (N)
R_r= Rolling resistance (N)
R_d = barriers for pulling loads (N)
R_g = barriers ramp (N)
W = total vehicle weight (N)
a = acceleration of the vehicle (m/dt^2)

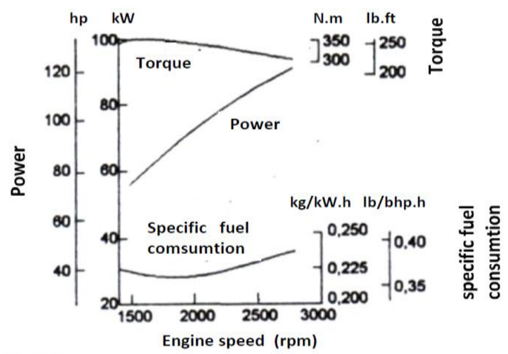

Fig. 3. Graph of Power-Torque Characteristics vehicles in general for each speed [8].

For application in motor vehicles, the characteristics of an ideal power source for propulsion is generated constant power at all speed levels. With the availability of constant power, at low speeds will be available torque is large enough, will be used to generate enough traction on the wheels to accelerate the vehicle. With increasing speed, engine torque will decrease hyperbolic. This is in accordance with the needs traction on vehicles, where the speed is high enough, no longer needs huge traction. Power-Torque Characteristics Graph vehicles in general for each speed (rpm) is shown in Fig. 3.

When a drive train system is characterized by the parameters of the drive train system efficiency η_t and the reduction gear ratio i, the traction on the drive wheels can be formulated [7]:

$$F_k = \frac{M_e(v).i_k.i_d}{r} \eta_t \tag{2}$$

F_k= traction force on the k-th level (N)
M_e= engine torque to speed v (Nm)
R= the radius of the driving wheels (m)
i_k =. gear ratio of the k-th
i_d= Differential gear ratio

The study begins with a literature review on previous studies and supporting various theories relating to the traction vehicle. Then determine the type of vehicle to be tested, followed by the collection of data necessary vehicle models. The initial step is to test the power-torque characteristics of the engine model vehicles. Then do the analysis of the traction capabilities are able to produce models of vehicle transmission system in various conditions / field operations, also analyzed the behavior of the direction (analysis bolsters) vehicle models.

III. Result and Dicussion

Characteristics of power - engine torque model vehicle is shown in Fig. 4.

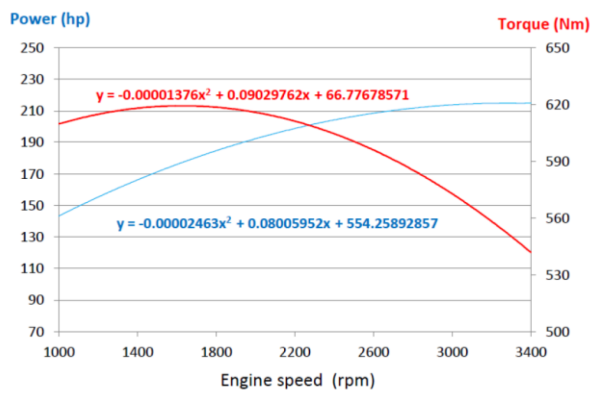

Fig. 4. Characteristics of power - engine torque model vehicle.

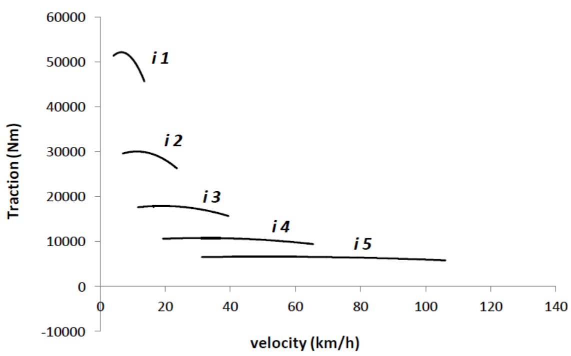

Fig. 5. Characteristics of traction Vehicle model.

Calculation and Analysis of Performance Traction (at engine speed 1500 rpm) vehicle speed (V) shown in Fig.

5-Fig. 7, characteristics normal force shown in Table I, and skid condition on type of road and some variation of speed shown from Table II up to Table VIII. Road type taken for example calculation is the wet concrete, wet asphalt and wet land. While the variation of the simulated vehicle speed is 40 km/h, 50 km/h and 60 km/h.

Curve achieved, as shown in Fig. 5, almost obtain ideal condition where the higher of speed the lower of traction needed. The maximum traction (5200 Nm) achieved can through any road conditions that exist in the city of Denpasar, so based on vehicle traction performance it is feasible for use [7].

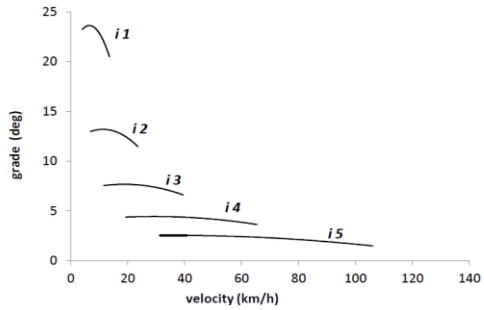

Fig. 6. Characteristics of grade.

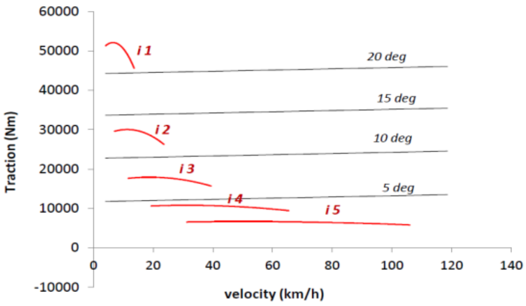

Fig. 7. Characteristics of traction and grade.

TABLE I: CHARASTERISTICS NORMAL FORCE

Steer angle (deg)	fzf (N)	fzr (N)	rolling	
			front	rear
4.5	9236.5	11140	no	no
5	9240	11145	no	no
5.5	9238.5	11140.5	no	no
6	9237.5	11139	no	no
6.5	9241	11137	no	no
7	9240	11140	no	no
7.5	9243.5	11138	no	no
8	9242.5	11136	no	no

TABLE II: CHARASTERISTICS OF SIDE FORCE AT 40 KM/H ON WET LAND

Steer angle	Fyf	Fyr	Fycf	Fycr	Skid condition	
deg	N	N	N	N	front	rear
4.5	905.6	3426	5080.5	6128	No skid	No skid
5	1172.5	3811.5	5080.5	6128	No skid	No skid
5.5	1433.5	4188.5	5081.5	6127	No skid	No skid
6	1687	4555.5	5081.5	6127	No skid	No skid
6.5	1933	4912	5082	6127	No skid	No skid
7	2171	5256.5	5082.5	6126	No skid	No skid
7.5	2399.5	5588	5082.5	6126	No skid	No skid
8	2618	5906	5084.5	6126	No skid	No skid

The vehicle is able to overcome the grade resistance of 24 degree, as shown in Fig. 6, so it can operate well due to the maximum grade resistance in Denpasar City is 20 degree [7], [8]. From Fig. 7, it is shown the grade resistance ability of vehicle at various transmission levels. It can be seen that grade resistance of 5 and 10 degree can be overcame by use of transmission ratio of 3 and 2 respectively. Meanwhile, grade resistance of 15 and 20 degree can be through by using transmission ratio of 1 [7].

All of the front and rear normal forces have positive value for all of steer angle, as shown in Table I, so that the condition does not affect vehicle rolled [5], [8].

TABLE III: CHARASTERISTICS OF SIDE FORCE AT 50 KM/H ON WET CONCRETE

Steer angle	Fyf	Fyr	Fycf	Fycr	Skid condition	
deg	N	N	N	N	front	rear
4.5	2271.5	5637	7391.5	8906.5	No skid	No skid
5	2606	6129	7395	8904	No skid	No skid
5.5	2929.5	6605.5	7398.5	8901	No skid	No skid
6	3240	7064.5	7397	8903.5	No skid	No skid
6.5	3536.5	7505	7400.5	8901	No skid	No skid
7	3818.5	7926	7399	8898	No skid	No skid
7.5	4086	8325.5	7402.5	8895.5	No skid	No skid
8	4338	8704	7482.5	8897.5	No skid	No skid

Table II and Table III shows the side force both front and rear happens to the vehicle is still smaller than the side force that is capable of being held by the wheel, so does not happen skid of all steer angle [8]. Table II shows the skid condition at a speed of 40 km/h which is operated on a wet land, while Table III shows the skid condition at 50 km/h on wet concrete road.

From the Table IV, in the steer angle of 7 deg, rear side force that occurs in a vehicle is greater than the side force that is capable of being held next to the wheel, the skid occurs on the vehicle. So on wet asphalt road at speed of 50 km/h, the vehicle will slip to the right side when turn the left [8].

TABLE IV: CHARASTERISTICS OF SIDE FORCE AT 50 KM/H ON WET ASPHALT

Steer angle	Fyf	Fyr	Fycf	Fycr	Skid condition	
deg	N	N	N	N	front	rear
4.5	2271.5	5637	6469.5	7792	No skid	No skid
5	2606	6129	6470.5	7790.5	No skid	No skid
5.5	2929.5	6605.5	6471.5	7790	No skid	No skid
6	3240	7064.5	6473	7789	No skid	No skid
6.5	3536.5	7505	6474	7787.5	No skid	No skid
7	3818.5	7926	6474.5	7786.5	No skid	Skid

TABLE V: CHARASTERISTICS OF SIDE FORCE AT 50 KM/H ON WET LAND

Steer angle	Fyf	Fyr	Fycf	Fycr	Skid condition	
deg	N	N	N	N	front	rear
4.5	2271.5	5637	5083	6122.5	No skid	No skid
5	2606	6129	5078.5	6127	No skid	Skid
5.5	2929	6605	6471	6444	No skid	Skid
6	3240	7060	6473	6965	No skid	Skid

TABLE VI: CHARASTERISTICS OF SIDE FORCE AT 60 KM/H ON WET CONCRETE

Steer angle	Fyf	Fyr	Fycf	Fycr	Skid condition	
deg	N	N	N	N	front	rear
4.5	3720.2	8127.5	7400.5	8888.5	No skid	No skid
5	4689.9	9697	7408	8888	No skid	Skid
5.5	2955	6605.5	6471	6290	No skid	Skid
6	3240	7064.5	6473	6589	No skid	Skid

From the Table V and the Table VI, in the steer angle of 5 deg, rear side force that occurs in a vehicle is greater than the side force that is capable of being held next to the wheel, the skid occurs on the vehicle. So on wet land road at speed of 50 km/h and on wet concrete road at 60 km/h, the vehicle will slip to the left side when turn the right [8].

TABLE VII: CHARASTERISTICS OF SIDE FORCE AT 60 KM/H ON WET ASPHALT

Steer angle	Fyf	Fyr	Fycf	Fycr	Skid condition	
deg	N	N	N	N	front	rear
4.5	3720.2	8127.5	6477.5	7778	No skid	Skid
5	4535	6765	6425	4772	No skid	Skid
5.5	5350	6243	6425	3788	No skid	Skid

TABLE VIII: CHARASTERISTICS OF SIDE FORCE AT 60 KM/H ON WET LAND

Steer angle	Fyf	Fyr	Fycf	Fycr	Skid condition	
deg	N	N	N	N	front	rear
4.5	3720.2	8127.5	5089.5	6111.5	No skid	Skid
5	4467	7767.5	6055	4256.2	No skid	Skid
5.5	5249	6243	6525	2786	No skid	Skid

In the steer angle of 4.5 deg is shown the Table VII and the Table VIII, rear side force that occurs in a vehicle is greater than the side force that is capable of being held next to the wheel, the skid occurs on the vehicle. So at speed of 60 km/h on wet asphalt and wet concrete road, the vehicle will slip to the left side when turn the right [8].

Analysis of vehicle traction performance model is able to overcome various obstacles, with a capable pass climbs up to 24 degrees, with the traction needed up to 52000 Nm. While inclination of road on Denpasar city not equal to that. So, the minimum prediction engine power of 142 hp. On the road conditions turn up the speed of 60 km/h, the magnitude of the normal force on each wheel is still positive, then the vehicle is still safe for the rolling conditions [8].

Skiding analysis of vehicle model, at speed of 40 km/h the vehicle is not skidding for any variation of steer angle and in any tipe of road, this is because the side-force capable of being held by each wheel. Next on the vehicle speed 50 km/h on wet concrete road do not occur skid too. While on wet asphalt road type has occurred skid at angle steer of 7 deg, on a wet land occurred skid at steer angle of 5 deg, and on the wet asphalt road already skidding at steer angle 4.5 deg. From the analysis of the skid, the vehicle model will be safe if operated at a speed of 40 km/h [7], [8].

IV. CONCLUSSION

Vehicle model is able to overcome various obstacles, with a capable pass climbs up to 24 degrees, with the traction needed up to 52000 N and the minimum prediction engine power of 142 hp. On the road conditions turn up the speed of 60 km/h, the magnitude of the normal force on each wheel is still positive, then the vehicle is still safe for the rolling conditions. From the analysis of the skid, the vehicle model will be safe if operated at a speed of 40 km/h.

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