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Generation of Alternative Solutions for Differential-Less Drive System Applicable to Vehicle Propulsion

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Abstract— Differential is a part of vehicle which offers ability to turn vehicle by distributing energy received from engine to driving wheels. Present basic as well as some of the advanced differentials are subjected to several problems. As vehicle takes a right or left turn differential works easily but when one of the wheel stucks to obstacle it fails to distribute energy. The stucked wheel doesn't receive energy and at the other hand second wheel of the driving wheels rotates freely at its position. When one of the driving wheels is lifted up from the surface, vehicle doesn't move further irrespective of whether it is a FWD, RWD, 4WD or AWD. To overcome this limitation a new system requires to develop. The system can be with differential or without differential; the said limitation should be eliminated. This paper emphasis on the differential-less drive systems which have capabilities of eliminating said problems. New practical concepts shown in the paper will help researchers to develop physical models to run the vehicle.

***Keywords*— Differential, Automobile, Wheels, Drive system, AWD, 4WD.**

1. INTRODUCTION

The automobile sector changed much more in its 130 years life [1]. Some basic parts and their application remain unchanged during revolution of the automobile [2]. The vehicles used today are not limited only for earth; no they have application in the universe. Recently China has launched their robotic probe on the Moon which has electronic control over wheels. Unfortunately the probe does not worked in environment of moon. A sensitive and reliable system is needed to work in extreme environment conditions. Also in case of our Earth, the advanced differentials have some limitation so we are needed to define some new alternative methods for differential [3].

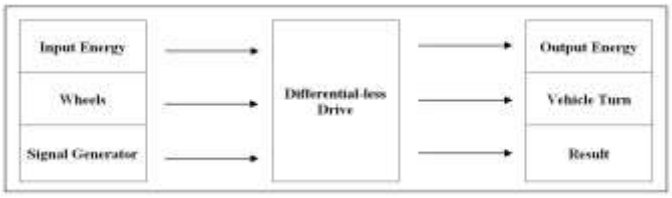

Figure 1: Function Diagram with black box

Now we need to generate some visual models that can satisfy customer requirements. A product concept is preliminary step towards good design. These concept generations should have a start point and the point begins with a function diagram. The differential-less drive system acts like black box in the airplane. The results are known but causes we have to find out. Similarly in the function diagram inputs and outputs are known and an effective way to convert inputs into outputs is to find out. The function diagram shows it in the following way.

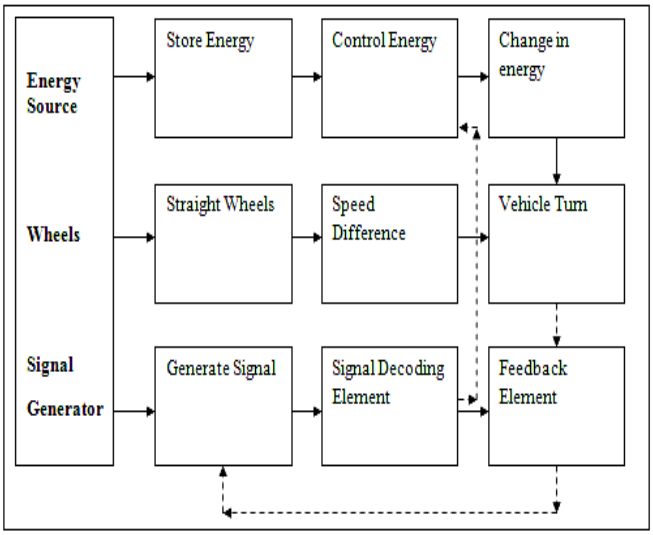

Figure 2: Function Diagram with Sub functions

2. CONCEPT COMBINATIONS

The function diagram is consisting of input, output and black box. The black box is divided into sub-functions using simple compartments that will simplify the problem. Here the problem is divided into three elements named as energy controller, wheel speed, and signal transmission. These three elements are useful causes to turn the system. The feedback element controls turn of the vehicle. The elements are subdivided into subfunctions as shown in the function diagram with subfunctions.

Table 1: Concept combination table for the Differential-less Drive System

Type of Energy	Energy Utilization	Energy Control	Type of Drive	Input Signal
Mechanical	Rotary	Incremental	RWD	Program
Chemical	Linear	Distributing	FWD	Sensor
Pneumatic		Braking	4WD	Steering angle
Hydraulic		Disconnection	AWD	Road Friction
Electric				

The concept combination table provides a way to consider combination of solution fragments systematically. Five columns with type of energy, energy utilization, energy control, Type of drive and input signal are essential functions to generate various concepts. Using each element from all columns shows a different combination. (5 x 2 x 4 x 4 x 4) = 640 combinations are possible in the concept generation table. Some of the combinations are hard to achieve so they can be neglected. From the combination table some combinations are shown below.

3. CONCEPT NO.1

Table 2: Concept combination 2-2-2-2-3

Type of Energy	Energy Utilization	Energy Control	Type of Drive	Input Signal
Chemical	Linear	Distributing	FWD	
				Steering angle

In this concept, two engines are used to both of the front wheels rather than use a central engine. Each engine is using single cylinder with flywheel. This flywheel is connected to wheel through clutch and gearbox. A tee section manifold is connected to both engines; three connections are as fuel tank, right and left wheel suction manifold. The tee section controls charge to both engines assisted by inlet charge control valve. Steering rod operates the inlet charge control valve. If we turn steering to the left, valve reduces charge flow to left wheel engine and increases to right wheel engine. When steering returns to straight ahead position, valve distributes charge equally to both engines.

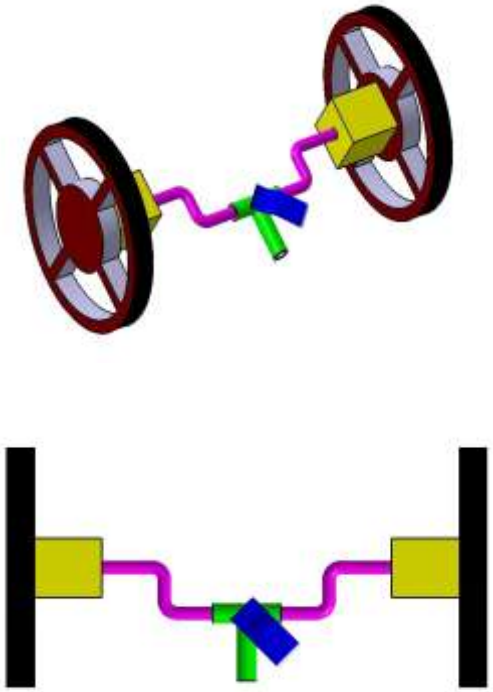

Figure 3: Concept no.1

4. CONCEPT NO. 2

Table 3: Concept combination 4-1-2-1-2

Type of Energy	Energy Utilization	Energy Control	Type of Drive	Input Signal
	Rotary		RWD	
		Distributing		Sensor
Hydraulic				

In this concept, two fluid systems are used to both of the rear wheels with hydraulic system. Each motor is directly connected to the wheels. The need of gearbox is eliminated by central flow control valve. A tee section hose is connected to both motors; three connections are as oil tank, right and left wheel input hoses. The tee section controls fluid flow to both motors assisted by flow control valve.

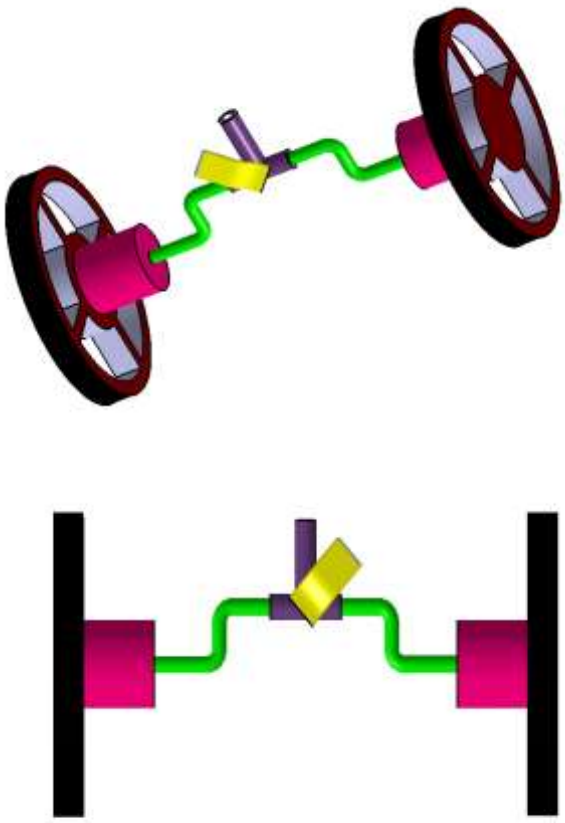

Figure 4: Concept no. 2

Steering rod operates the flow control valve indirectly through sensors. Steering system activates the sensor, when turn is to be taken. The sensor sends signal to actuator to change the flow. If we turn steering to the left, valve reduces fluid flow to left wheel motor and increases to right wheel motor. When steering returns to straight ahead position, valve distributes fluid flow equally to both motors.

5. CONCEPT NO. 3

Table 4: Concept combination 5-1-1-4-1

Type of Energy	Energy Utilization	Energy Control	Type of Drive	Input Signal
	Rotary	Incremental		Program
			AWD	
Electric				

For a predefined path such as automatic guided vehicles we can use a program controlled drive system [4].If a predifined path is given within two defined places such as Pune to mumbai then this concept can be used on road too. in this concept, all four wheels are having independant speeds with help of DC motors. In the concept sketch a path is shown and to achieve curved turn, variable speed is essential as there is no steering wheel. The inner wheels are shown by orange colour i.e. normal speed and outer wheels are shown by red colour i.e. higher speed than the inner wheels. When vehicle moves straight then all wheels will be in orange colour. When the vehicle has to take U turn,the right side wheels will move in reverse direction and left side wheels will move in forward direction.

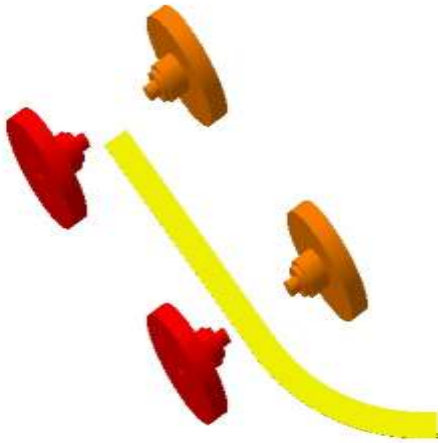

Figure 5: Concept no. 3

6. CONCEPT NO. 4

Table 5: Concept combination 1-1-4-1-4

Type of Energy	Energy Utilization	Energy Control	Type of Drive	Input Signal
Mechanical	Rotary		RWD	
		Disconnection		Road Friction

This mechanical system has ability to transfer torque equally in straight travel of vehicle and the system is able to turn by means of disengaging outer wheel. When we apply force to steering wheel to turn, the outer wheel increases displacement as co-efficient of friction is same for both the wheels but distance to travel is more for outer wheel. Mechanical system is used to disengage one wheel, which do not need any sensor or any program to turn vehicle. The disengagement function works automatically and more reliable.

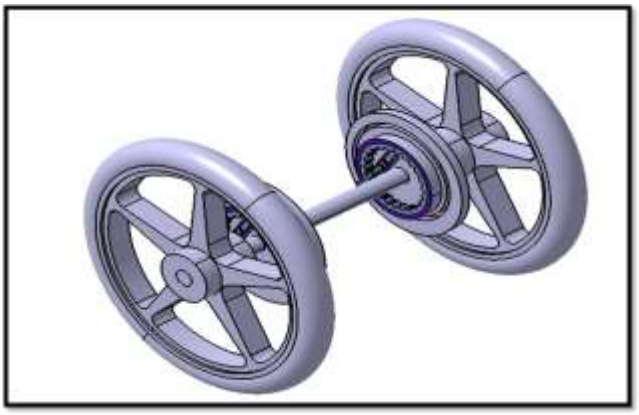

Figure 6: Concept no. 4

7. CONCEPT SELECTION

The concepts generated in this section are need to screen-out i.e. all concepts are not applicable at a time. We have to study the concepts in different criteria. If two concepts can be combined or not that is to be determined, a comparative rating among all concepts will clear confusion [16].

Table 6: Concept selection table

Sr. No.	Criteria	Concept 1	Concept 2	Concept 3	Concept 4
1	Reliability	-	0	0	+
2	Speed range	-	0	+	+
3	Verity of use	0	+	0	+
4	Actuation automation	0	0	0	+
5	Cost	+	0	-	0
6	Sensitivity	-	0	+	0
7	Life of system	0	0	-	0
-	Sum +'s	1	1	2	4
-	Sum 0's	0	6	3	3
-	Sum –'s	3	0	2	0
-	Net score	-2	+1	0	+4
-	Rank	4	2	3	1

In above concept screening method mechanical system gets first rank in all concepts generated. The mechanical differential-less drive system will reliable in working with higher and lower speeds. This system will compatible with verity of vehicles in different operations. A mechanical system does not require sensors, program or any control valve as it actuates automatically with the road friction. Cost of this system will be economical compared to other concepts. The mechanical system is sensitive after electronic control system. Life of the electronic system is less; hence a mechanical system will be forwarded to further progress as a differential-less drive system.

CONCLUSION

In above generated concepts; direct engine powered, Hydraulic powered, electronic powered and mechanical differential are studied with mentioned criteria. All concepts are compared to each other for reliability, speed range, cost, verity of use and sensitivity. A concept combination table is prepared in which combination of subsystem provides 640 alternative solutions for differential-less drive system. This study of various concepts can solve mysteries of universe for astronomers in sense of vehicle differentials in astro-environmental conditions. Also research students can take one of the concepts for his thesis work to make concept practically working and can generate experiments.

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