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OBTAINING OPTIMAL CONTROL PARAMETERS-ACCELERATION BASED WHEEL TRACTION CONTROL

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Abstract

This project deals with a detailed dynamic model of a two independent wheel drives and a traction control system. By applying external force it is possible to have a path plan in each wheel drive that enables the implementation of a traction control algorithm. This control level improves the stability and the safety of the vehicle. Analysis, design and simulation results of this system will be presented. The wheel traction control method for path tracking of the two independent wheel drives is the function of velocity and acceleration of the mobile robots. The traction control algorithm which can be independently implemented to each wheel without extra sensors and devices compared with standard speed control. Simulations are performed to verify the validity of the algorithm. The proposed traction control algorithm to improve the tracking control efficiency. This project work aims to analyze the fixed acceleration path for two independent wheel drives system by using analyzing software (Adams 12.0) and also this project work is mainly focused on the increase stability and the safety of the two independent wheel drives by planning the fixed acceleration path.

Keywords: Traction control algorithm, Optimization, Adams

1. INTRODUCTION

Mobile robots have been developed in various application fields, including building inspection and security, military reconnaissance, and planetary exploration. The application of wheeled mobile robots (WMR) has been rapidly increasing in recent years, while the overall capabilities of the WMRs have improved significantly over the years. The ability of the WMR is to operate autonomously at a high speed on unstructured environment. Mobile robots developed in the NASA Jet Propulsion Laboratory (JPL) are successful examples for planetary missions. Other examples of traversing rough terrain can be found in the mining industries and hazardous material handling applications as well as in building inspection. The common requirements of these mobile robots are long-term operation and high mobility in rough terrain to perform difficult tasks. For rough terrain, it is important for mobile robots to maintain adequate wheel traction. Excessive wheel slip could cause an increase in the amount of dissipated energy at the contact point between the wheel and ground or, even more seriously, the robot could lose all mobility and become trapped. Traction control algorithm that have been developed for the car industry was applied to flat surfaces to improve the mobility and energy efficiency of vehicles.

However, it is not appropriate for rough terrain mobile robots as the required wheel velocity to maintain the rolling state of each wheel is different.

1.2 ADAMS 12.0

Adams is a motion simulation solution for analyzing the complex behaviour of mechanical assemblies. Adams is a family of interactive motion simulation software modules. Once the virtual prototype is complete, Adams checks the model and then runs simultaneous equations for kinematics simulations.
Results are viewable as graph, data plots, reports, or colourful animations that you can easily share with others. Work in a secure virtual environment. Improve product quality by exploring numerous design variations in order to optimize full-system performance.

- Offer a pre-processor (ADAMS/View) for people to be able to generate models
- Offer a solution engine (ADAMS/Solver) for people to be able to find the time evolution of their models
- Offer a post-processor (ADAMS/PPT) for people to be able to animate and plot results

2. LITERATURE SURVEY

(a) A. Roque J. Esteves J. Maia P. Verdelho [1], they have developed detailed dynamic model of an electric vehicle with two independent wheel drives and a traction control system.
If the road conditions changes, a simple torque motor control is not sufficient. In this situation it is necessary, to implement a traction control algorithm, without any substantial extra hardware incorporation. With the information about the real speed of the vehicle, on left and right sides, the control algorithm changes the generated torques in each wheel drive, in order to produce the same traction force applied to the road surface

(b) Choi. Hyun Do, Woo. Chun Kyu, Yoon. Sukjune, Kim. Soohyun, and Kwak. Yoon Keun,[2], They have developed the traction control algorithm; this is independently implemented to each wheel without extra sensors and devices compared with standard speed control. The Simulations are performed to verify the validity of the algorithm. The proposed traction control algorithm obtained 40.5% reduction of total slip distance and 48.4% reduction of dissipated work on the contact point compared with standard speed control.

(c) Kevin J Worrall and Euan W McGookino. [3], They are built a mathematical model of a differential drive robot from Lego Mindstorms. The dynamics and kinematics of the mathematical model are described. With a complete mathematical model and a multi-rate simulation validation has been carried out using analogue matching and integral least square. The results from the validation show the model is a suitable representation of the physical robot. Using two PID controllers and a LOS Autopilot the simulation shows that the robot can be controlled easily. The model provides a basis for the development of control methodologies and navigation heuristics that can be applied to a mobile robot of this type.

3. CONCEPTUAL DESIGN

The Two Dimensional Model of the two independent wheels is done by using AUTOCAD 2007 Software as shown in figure 1

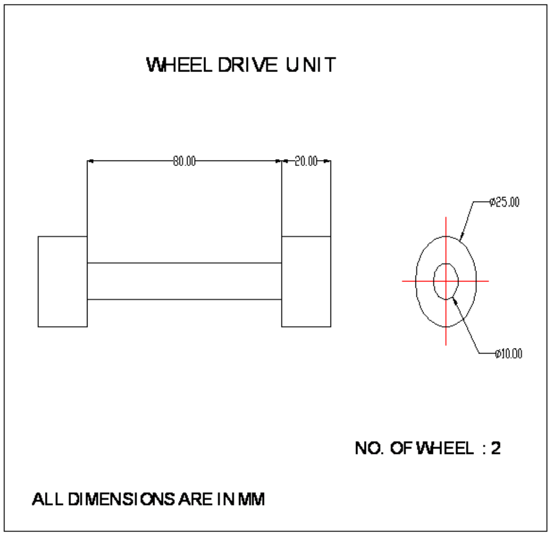


Figure: 1 Two Dimensional Model

3.1 Specifications

Wheel Right

Wheel right dimension- 20mm (length), 30mm (radius)

Material- steel
Density- 7.801 X 10^{-6} kg/mm^3,
Young's modulus - 2.07 X 10^{11} N/m^2,
Poisson's ratio - 0.29,
Calculated mass-0.44kg
Cylinder Angle- 360.0 deg
Coordinate axis- Global XY Axes,
Global Location- 0.0, 0.0, 0.0 (mm)
Global Orientation- 0.0, 0.0, 0.0 (deg)
Calculated Mass Inertia Tensor
I_{XX} : 198.511 kg-mm^2
I_{YY} : 113.960 kg-mm^2
I_{ZZ} : 113.960 kg-mm^2
I_{XY} : 0.0 kg-mm^2
I_{ZX} : 0.0 kg-mm^{2s}
I_{YZ} : 0.0 kg-mm^2

Wheel Left

Wheel left dimension- 20mm (length), 30mm (radius)
Material- steel
Density- 7.801 X 10^{-6} kg/mm^3,
Young's modulus- 2.07 X 10^{11} N/m^2,
Poisson's ratio- 0.29,
Calculated mass-0.44kg
Cylinder Angle - 360.0 deg
Coordinate axis- Global XY Axes,
Global Location - 0.0, 0.0, 0.0 (mm)
Global Orientation- 0.0, 0.0, 0.0 (deg)
Calculated Mass Inertia Tensor
I_{XX} : 198.511 kg-mm^2
I_{YY} : 113.960 kg-mm^2
I_{ZZ} : 113.960 kg-mm^2
I_{XY} : 0.0 kg-mm^2
I_{ZX} : 0.0 kg-mm^2
I_{YZ} : 0.0 kg-mm^2

Shaft

Wheel shaft dimension- 20mm (length), 30mm (radius)

Material - steel
Density - 7.801 X 10^{-6} kg/mm^3,
Young's modulus- 2.07 X 10^{11} N/m^2,
Poisson's ratio- 0.29,
Calculated Wheel shaft mass-0.44kg
Cylinder Angle - 360.0 deg
Coordinate axis - Global XY Axes,
Global Location - 0.0, 0.0, 0.0 (mm)
Global Orientation - 0.0, 0.0, 0.0 (deg)
Calculated Mass Inertia Tensor
I_{XX} : 4.015 kg-mm^2
I_{YY} : 68.930 kg-mm^2
I_{ZZ} : 68.930 kg-mm^2
I_{XY} : 0.0 kg-mm^2
I_{ZX} : 0.0 kg-mm^2
I_{YZ} : 0.0 kg-mm^2

4. MODELING OF TWO INDEPENDENT WHEEL DRIVE

The modeling procedure the three dimensional model is developed in as ADAMS/View 12.0.0 shown in figures.

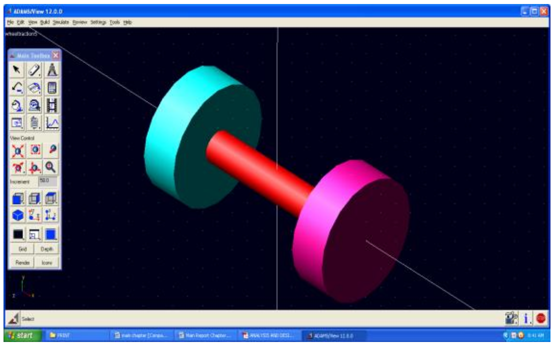


Figure: 2 Three Dimensional Model in ADAMS/View 12.0.0

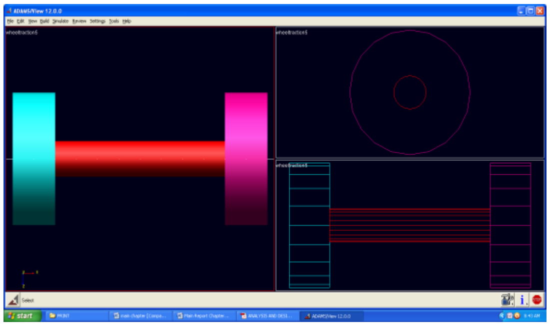


Figure: 3 Various Three Dimensional view of the model in ADAMS/View 12.0.0

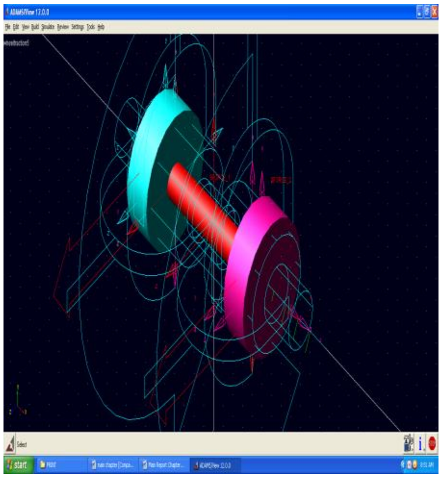


Figure: 4 Joints and models in Three Dimensional model in ADAMS/View 12.0.0

5. ANALYSIS

5.1 *Different forces and speed applying the wheels*

The displacements of the wheels with respect to the Global X-Y axes in the Z direction are shown in figure 5

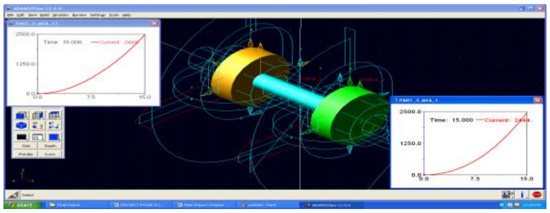


Figure: 5 Displacements result of ADAMS/View 12.0.0

5.2 wheel velocities

The velocities of the wheels with respect to the Global X-Y axes in the Z direction are shown in figure 6

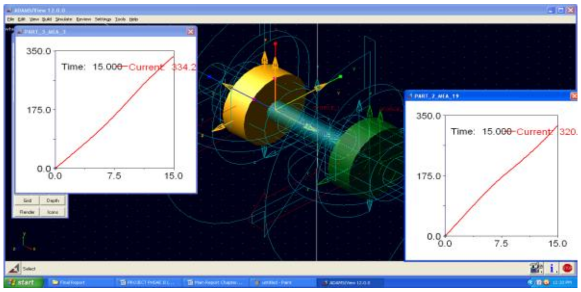


Figure: 6 Velocities result of Adams view

5.3 Wheel accelerations

The accelerations of the wheels with respect to the Global X-Y axes in the Z direction are shown in figure 7

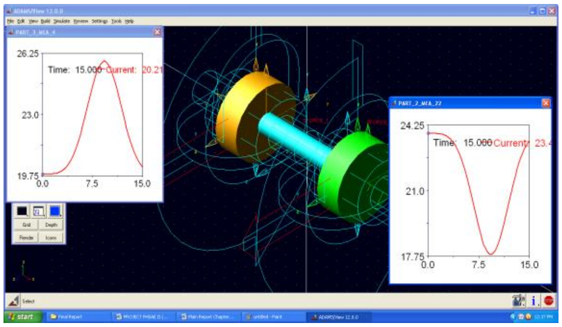


Figure: 7 Accelerations result of Adams view

5.4 Wheel angular velocities

The angular velocities of the wheels with respect to the Global X-Y axes in the Z direction are shown in figure 8

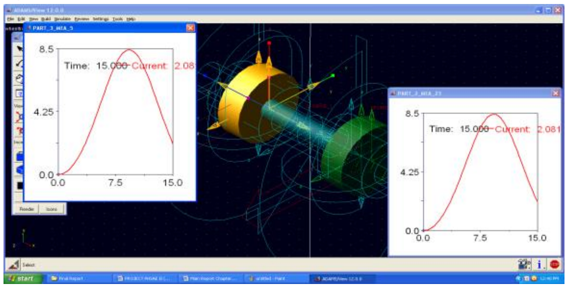


Figure: 8 Angular velocities result of Adams view

5.5 Wheel angular accelerations

The angular accelerations of the wheels with respect to the Global X-Y axes in the Z direction are shown in figure 9

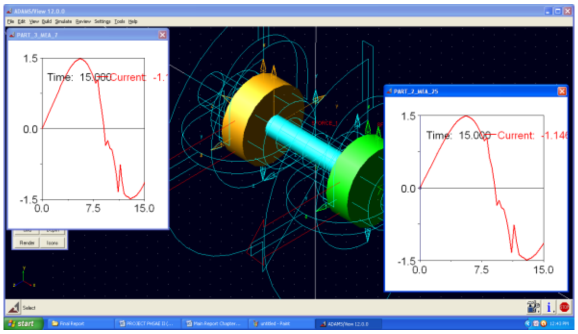


Figure: 9 Angular accelerations result of Adams

Adams view of all result of two independent wheels drives are shown figure 10

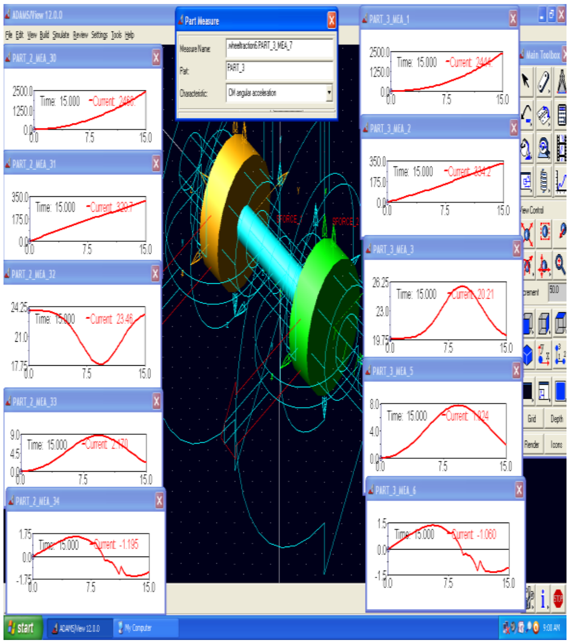


Figure: 10 All result of Adams view

5.6 Same forces and speeds applying the wheels

Result of two wheel parameters are same value because here applied same forces and speeds on the wheels. Adams view of all result of two independent wheels drives are shown figure11

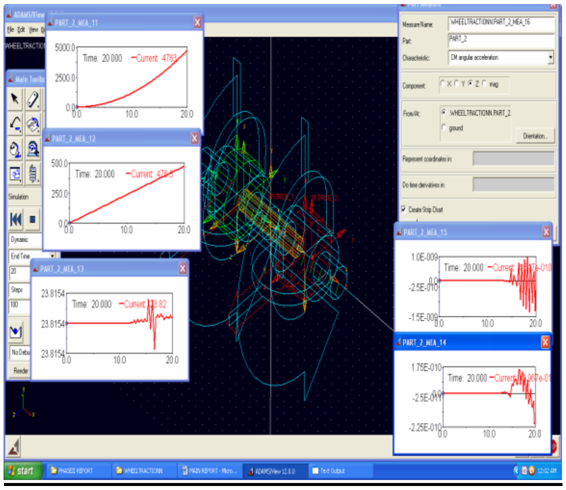


Figure: 11 Same forces applied wheel all result

5.7 *Orientation measure of pitch value*

Measuring Orientation Characteristics Orientation measures capture the orientation characteristics of one part or marker relative to another coordinate system in a specified convention. For example, you could use orientation measures to determine the:Yaw angle associated with a yaw, pitch, roll or body-fixed 321 rotations sequence.

5.8 First Euler parameter

Second rotation associated with a body-fixed 360 rotation sequence. All such orientation characteristics are simply transformed from the direction cosine matrix.

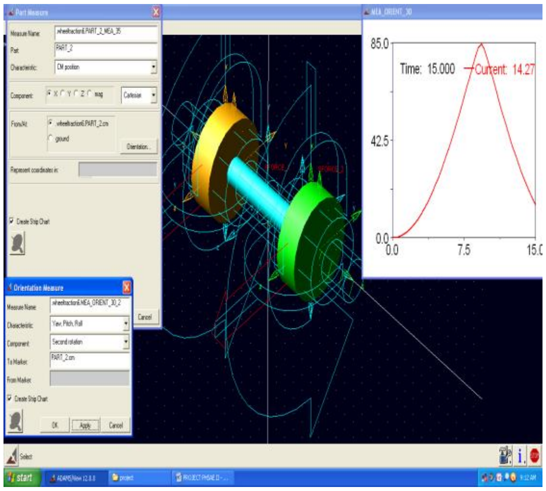


Figure: 12 Wheel Orientation angle of Adams view

5.9 Plotting the results

A full size plot in the ADAMS/Postprocessor is shown in figure 13

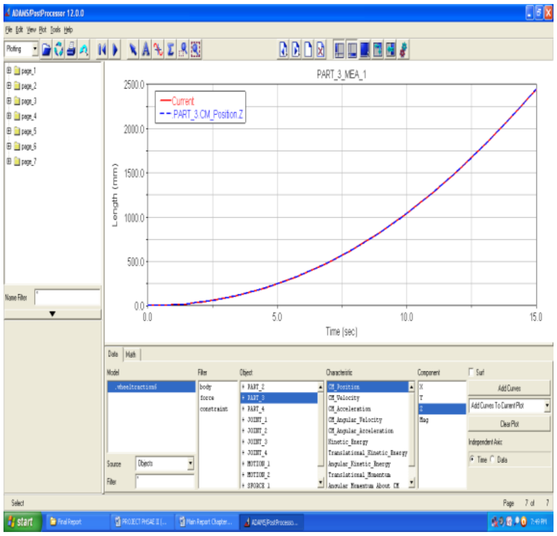


Figure: 13 Analysis of Displacement of point in z - axis using ADAMS/PPT

Finally we get the resulting plot for the Displacement of the point in z- Component as shown in figure 14

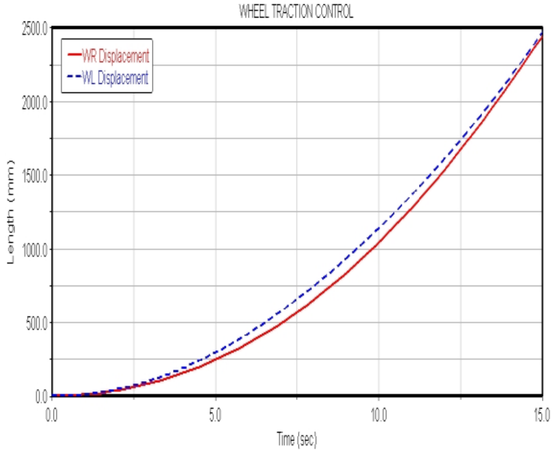
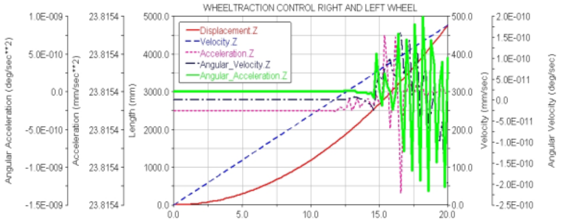


Figure: 14 Plot of the Displacement of the point in Z- Component

6. RESULTS

6.1 Same forces and speeds are applied to wheel and Overall result of Wheel Displacement, Velocity, Acceleration, Angular Velocity and Angular Acceleration in The Z-Component

From the figure 15 shows the overall values of the wheels parameters at the every second. From the following table 8.8 t he Wheel will move from its initial displacement, velocity, acceleration, angular velocity and angular acceleration to final stages

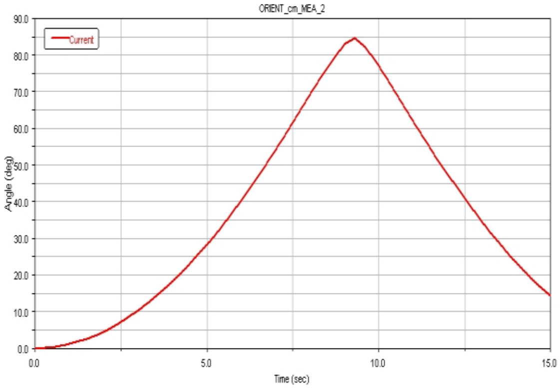


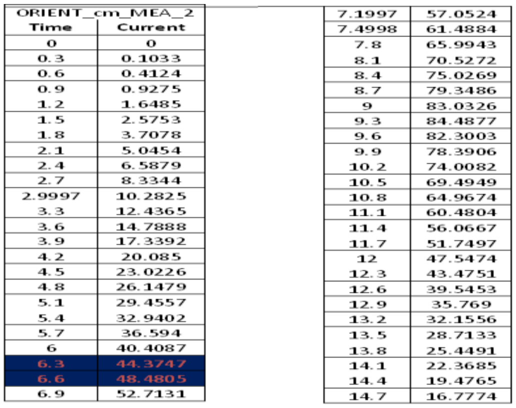
WHEELTRACTION CONTROL RIGHT AND LEFT WHEEL					
Time(sec)	Displacement.Z(mm)	Velocity.Z(mm/sec)	Acceleration.Z(mm/sec2)	Angular_Velocity.Z(rad/sec)	Angular_Acceleration.Z (rad/sec)
0	0.00	0.00	23.8154	6.12E-16	0
1	11.9104	23.8154	23.8154	6.12E-16	0
2	47.6335	47.6308	23.8154	6.12E-16	0
3	107.172	71.4462	23.8154	6.12E-16	0
4	190.526	95.2616	23.8154	6.12E-16	0
5	297.6953	119.077	23.8154	6.12E-16	0
6	428.68	142.8924	23.8154	6.12E-16	0
7	583.4801	166.7078	23.8154	6.12E-16	0
8	762.0957	190.5232	23.8154	6.12E-16	0
9	964.5266	214.3386	23.8154	6.12E-16	0
10	1190.773	238.154	23.8154	6.12E-16	0
11	1440.8347	261.9695	23.8154	6.12E-16	0
12	1714.7119	285.7849	23.8154	9.17E-14	6.67E-13
13	2012.4044	309.6003	23.8154	4.63E-12	1.00E-11
14	2333.9124	333.4157	23.8154	-2.23E-12	-8.37E-12
15	2679.2357	357.2311	23.8154	6.34E-11	2.32E-11
16	3048.3745	381.0465	23.8154	6.70E-11	-2.40E-10
17	3441.3287	404.8619	23.8154	1.16E-10	6.90E-10
18	3858.0983	428.6773	23.8154	-3.90E-11	-1.18E-09
19	4298.6833	452.4927	23.8154	2.97E-11	3.73E-10
20	4763.0836	476.3081	23.8154	-1.97E-10	4.52E-10

Figure: 15 Result of Same forces and speeds are applied on wheel Displacement, velocity, acceleration, angular velocity and angular acceleration

6.2 Wheel Orientation angle

From the figure 8.9 shows result of orientation angle of the wheels with respect to time and orientation angle ,at 6.3seconds the corresponding orientation angle is 45 degree.





ORIENT_cm_MEA_2	
Time	Current
0	0
0.3	0.1033
0.6	0.4124
0.9	0.9275
1.2	1.6485
1.5	2.5753
1.8	3.7078
2.1	5.0454
2.4	6.5879
2.7	8.3344
2.9997	10.2825
3.3	12.4365
3.6	14.7888
3.9	17.3392
4.2	20.085
4.5	23.0226
4.8	26.1479
5.1	29.4557
5.4	32.9402
5.7	36.594
6	40.4087
6.3	44.3747
6.6	48.4805
6.9	52.7131
7.1997	57.0524
7.4998	61.4884
7.8	65.9943
8.1	70.5272
8.4	75.0269
8.7	79.3486
9	83.0326
9.3	84.4877
9.6	82.3003
9.9	78.3906
10.2	74.0082
10.5	69.4949
10.8	64.9674
11.1	60.4804
11.4	56.0667
11.7	51.7497
12	47.5474
12.3	43.4751
12.6	39.5453
12.9	35.769
13.2	32.1556
13.5	28.7133
13.8	25.4491
14.1	22.3685
14.4	19.4765
14.7	16.7774

Figure: 16 Result of wheel orientation angle with respect to time

7. CONCLUSION

In this project, a mathematical model of a differential drive wheeled robot and acceleration based traction control algorithm has been studied and implemented. The differential drive mechanism was developed and applied forces and speeds of wheel in different conditions along the straight line and circular curvature path for tracking the desired trajectory. Acceleration was kept constant for dynamic analysis. The project aim is to avoid the instability of the independent wheel drives by analyzing the acceleration based path planning. It is done for various wheel parameter displacements, velocities, accelerations, angular accelerations and angular velocities are analyzed by dynamic analysis software (ADAMS 12.0) and simulations were done. The result of the project is to give better performance for two independent wheel drives.

Future works is to analyzing friction and slip range of the two independent wheel drives.

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