AUTOMOTIVE ENGINEERING-II

MEEN 689 - Project:1

Simulation of Engine starting with seasonal temperature change

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Submitted by

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1 Abstract

A cold start is an attempt to start a vehicle's engine when it is cold, relative to its normal operating temperature, often due to normal cold weather. A cold start situation is commonplace, as weather conditions in most climates will naturally be at a lower temperature than the typical operating temperature of an engine. We notice that when we leave the lights out in a car, it isn't difficult to start it, but it needs to be jumped in winter. A Dymola model was analyzed using a cylinder, starter motor, one way clutch and damper. All the parts were taken to be as close to real life values. The temperature dependence on viscosity of lubricant (SAE 10W40) was consolidated into a damper system and the damping constant was calculated using valid references and suitable approximations. In summer conditions, the engine starts in 0.78 N-m-s/rad and stabilizes at 250 rad/s (2500 rpm), whereas in winter conditions, the engine fails to start. It oscillates between 15 to -20 rad/s and goes to zero. The suitable graphs were plotted and inferences were made in this report.

2 Introduction

Engine starting becomes a problem with seasonal temperature change. Starting problem becomes more significant in lower temperatures, mostly in winter season. While in summer with the same state of charge of battery, engine can be started without any hindrance. The following model makes an attempt to simulate the behaviour of engine with varying temperatures with equal SOC of battery. The starting problem can be blamed on the increase of damping parameters with decrease in temperature. Mostly this damping is a combination of engine oil, lubricant, coolant performance along with losses from friction. Dymola(Modelica) is used as the simulation ground for addressing the problem. The damping coefficients are calculated as a function of viscosity, which in turn is a function of temperature. This model also explains the change in behaviour for different input variables.

3 Simulation Setup

Our setup is divided into 2 parts, the electrical section and the engine section. First, a single cylinder is taken from the library and modified to not have combustion initially. A bearing is then modeled and connected to an inertia (the flywheel) and damper system. This damper encapsulates the temperature effect on starting the engine that we will be addressing in this report. The inertia is connected to an ideal gear train to get a suitable gear ratio and supply torque. This is then linked to a one way clutch which is then joined to a DC series excited motor which is then connected to a switch and cell stack (which condenses our electrical source).

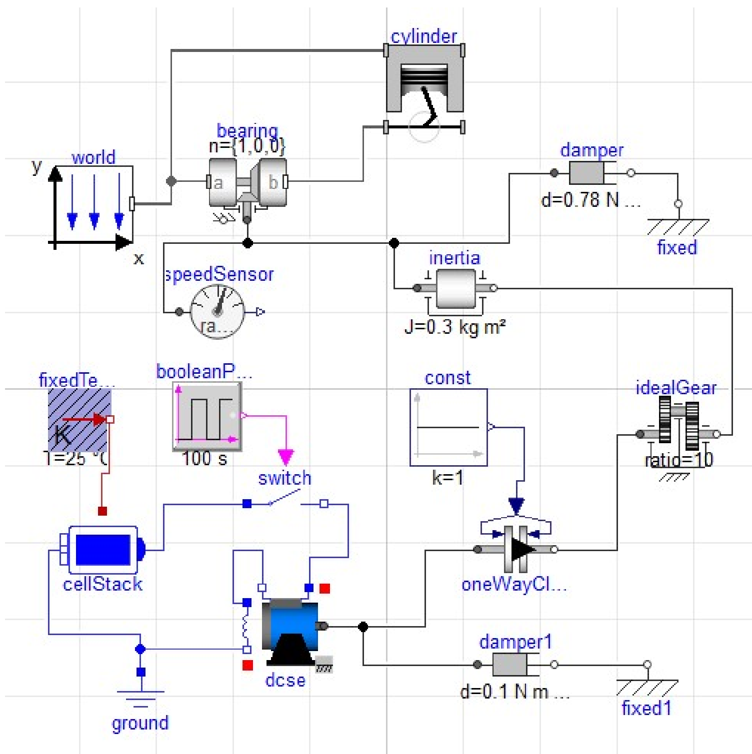

Figure 1: Block Diagram

3.1 Model Parameters

We have taken a single cylinder engine from the standard library having a stroke length of 0.2 m and a bore diameter of 0.1 m, thereby yielding a volume of 2.5 L. The engine is assumed to start from Bottom Dead Center (BDC). The flywheel inertia is taken as 0.3 $kg-m^2$. All the engine parameters are shown in Fig.2

Parameters

animation	true		= true, if animation shall be enabled
cylinderTopPosition	0.42	m	Length from crank shaft to end of cylinder.
pistonLength	0.1	m	Length of cylinder
rodLength	0.2	m	Length of rod
crankLength	0.2	m	Length of crank shaft in x direction
crankPinOffset	0.1	m	Offset of crank pin from center axis
crankPinLength	0.1	m	Offset of crank pin from center axis
cylinderInclinationAngle	0	°	Inclination of cylinder
crankAngleOffset	180	°	Offset for crank angle
cylinderLength	cylinderTopPosition - (pistonLength + rodLength - cr	m	Maximum length of cylinder volume

Figure 2: Engine Parameters

A standard DC series excited motor is taken from the Electrical library and assigned with an inertia of 0.07 $kg - m^2$. For the sake of simplicity, a single cell stack with one cell in series and parallel each is taken from the Electrical library and its parameters are initialized to be as close to real life as possible. The temperature co-efficient of resistance of the battery and the motor is taken to be 0.004 /K.

TaOperational	298.15	K
VaNominal	100	V
IaNominal	100	A
wNominal		rad/s
TaNominal	293.15	K
Ra	0.05	Ohm
TaRef	293.15	K
alpha20a	0.004	1/K
La	0.0015	H
Jr	0.07	kg.m2

Figure 3: Motor Parameters

The battery discharge was observed by discharging it for 2 hours, where the interior lights are described by a resistance. The State of Charge (SOC) after this simulation is taken to be the starting SOC for our overall model. The parameters for discharge are given in Fig.5. The simulation was done for both winter (-10 C) and summer (25 conditions by changing the temperature through the Heat Port.

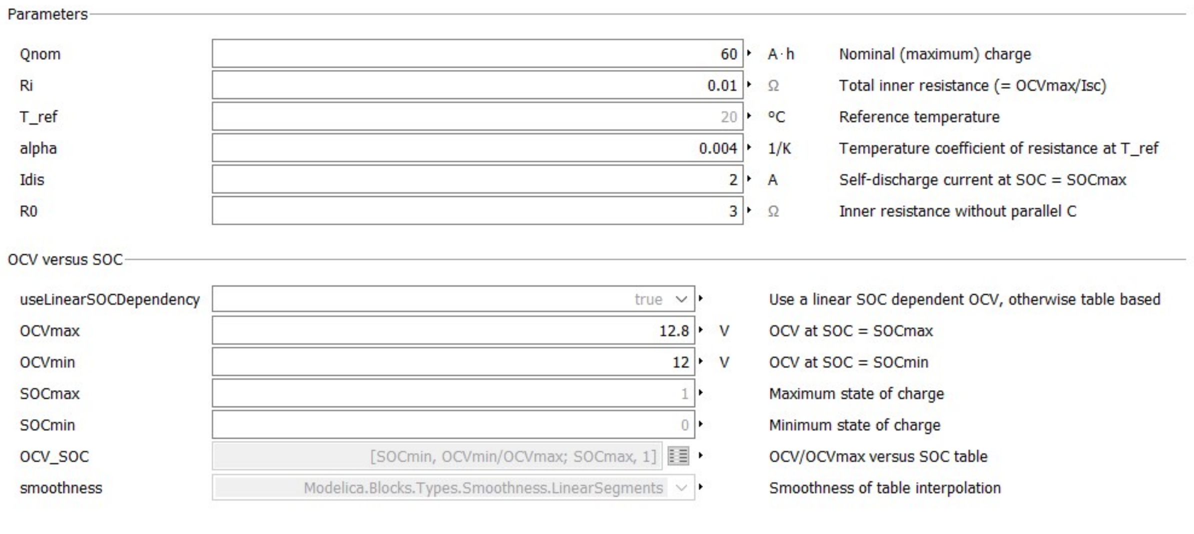

Figure 4: Cell Parameters

The Ideal Gear Ratio was between the flywheel and starter motor is assigned a value of 10. The damper is given a damping coefficient of 0.78 for summer and 4.5 for winter conditions. These values were taken using the formula given in [1] assuming a viscous fluid journal bearing whose viscosity varies as a function of temperature. The viscosity in winter is taken as 1085 mPa s and summer as 165 mPa s.

The switch is actuated using a pulse which is ON for 2 s and OFF for the remaining time. This pulse is given with the help of a Boolean pulse connected to an Ideal Closing Switch.

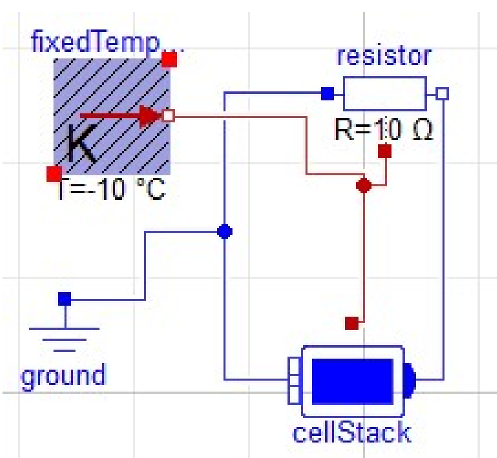

Figure 5: Block diagram for battery discharge

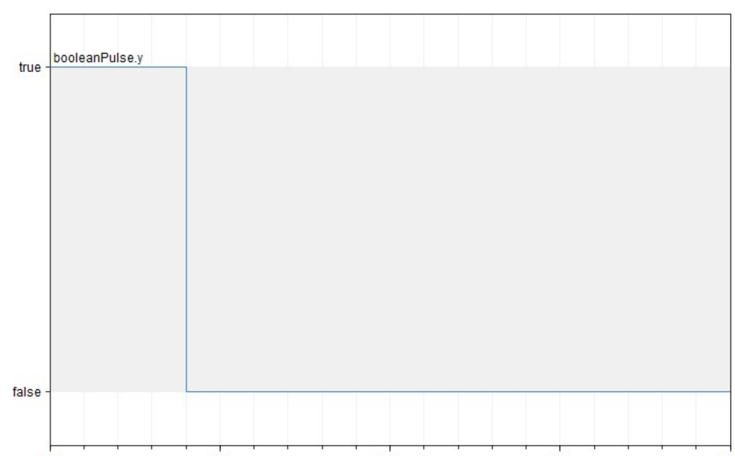

Figure 6: Boolean Pulse

4 Results and Discussion

The battery discharge was initially simulated by discharging it for 2 hours, where the interior lights are given as a resistance. The SOC after this simulation is taken to be the starting SOC for our model. The discharge of battery with time for summer and winter conditions is given in Fig.7 and Fig.8.

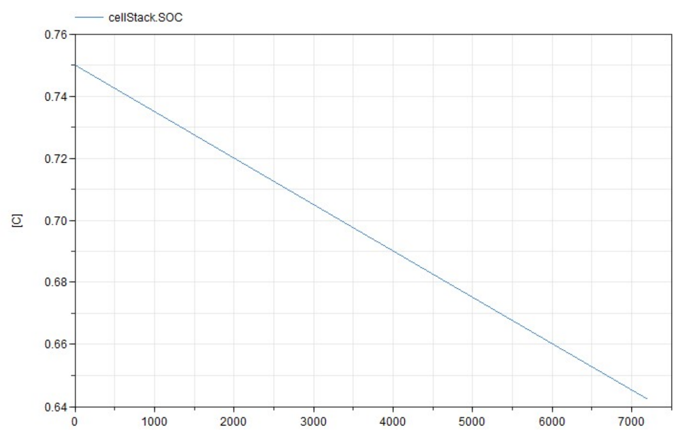

Figure 7: SoC vs Time in Summer

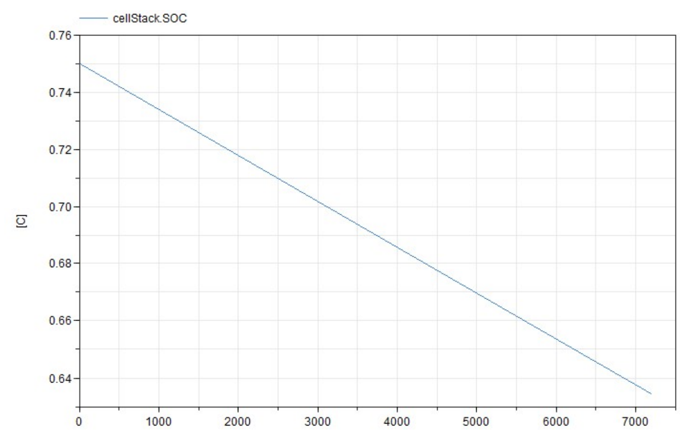

Figure 8: SoC vs Time in Winter

4.1 Summer

The motor and engine speeds in rad/s is given in Fig.9. At 1.32 s, there is slip in the one way clutch (OWC) while the engine gains speed. At 2 s, the power to the motor is cut off as the switch becomes open.

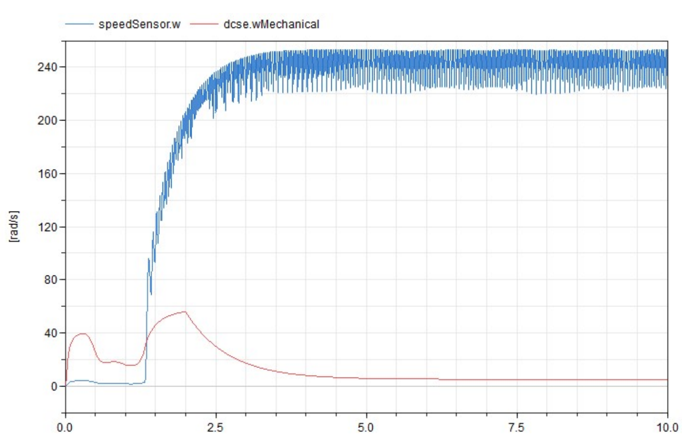

Figure 9: Engine and Motor speed vs Time

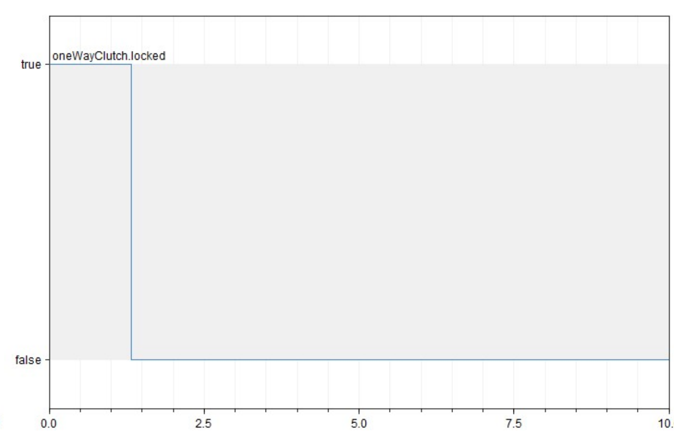

Figure 10: OWC locked condition vs Time

As for motor torque, it reaches a peak of about 36 N m, and as the pulse input is removed, it goes down to zero. In motor current vs time graph, the current is at its peak at about 85 A, and after the switch becomes open, it depletes to zero.

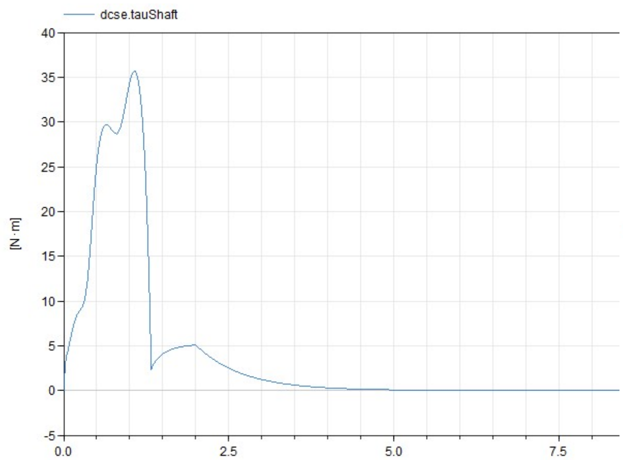

Figure 11: Motor Torque vs Time

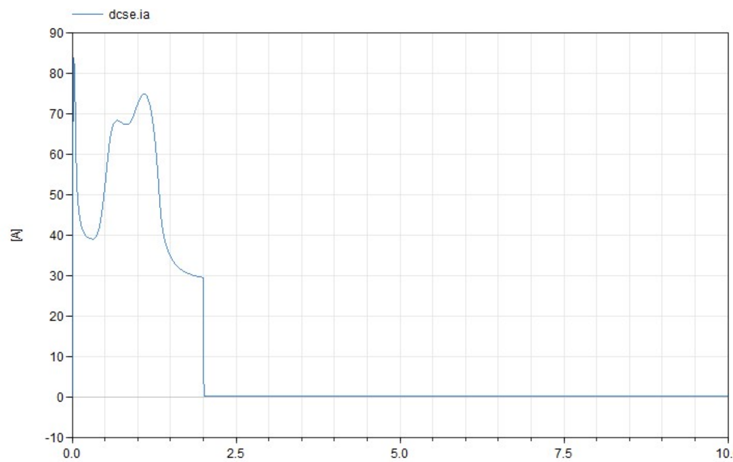

Figure 12: Motor current vs Time

4.2 Winter

In winter, we give a higher damping coefficient value so as to account for lower winter temperatures. The speeds of the engine and the motor are given in Fig. In the first 2 seconds when the motor is given an input pulse, they engine goes to a peak of 78 rad/s for a short period of time when driven by the motor, but the engine cannot sustain this due to high damping in winter, and thus falls back to zero.

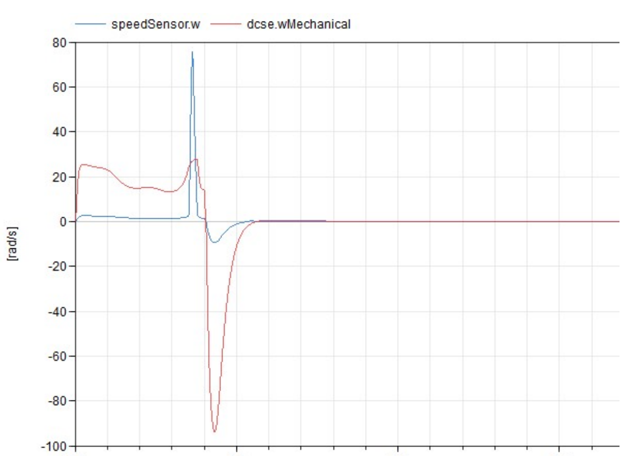

Figure 13: Engine and Motor speed vs Time

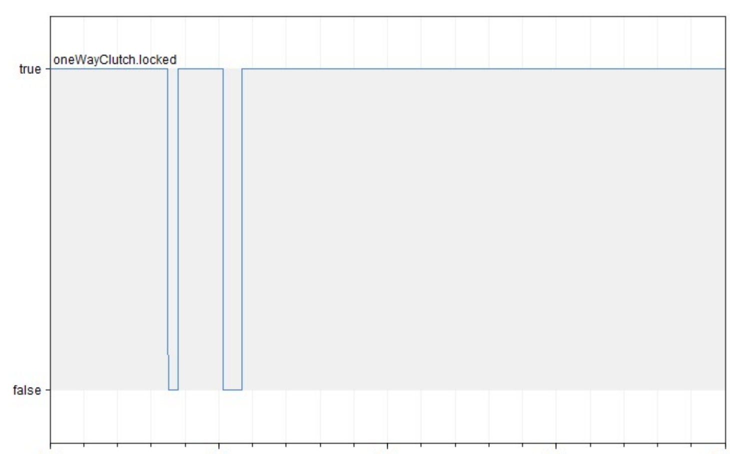

Figure 14: OWC locked condition vs Time

During the ascent of engine speed, it runs at a higher speed than motor, and after a short while, due to its inability to run in this condition, descends back to zero, running slower than the starter motor as a result. This effect can be observed in the OWC, as the clutch experiences oscillation. It initially gets disengaged as the engine speed crosses the motor speed in the upward direction, and gets engaged again as the engine does so in the downward direction. As the circuit is broken, motor cannot run the engine anymore and both of them eventually become stationary and the clutch is locked again.

Within the first 2 s, the motor reaches a peak of about 30 rad/s and then reaches zero. There is a negative spike observed in the motor speed value. The spike then dissipates and dies down to zero. This can be attributed to the switch having a voltage spike at 2 s(when the state changes). After this spike in the switch, the damper dissipates this energy and thus takes a little longer to saturate at zero. If a relay or a switch can be operated such that this spike is mitigated, it may prevent the motor from running at negative speed.

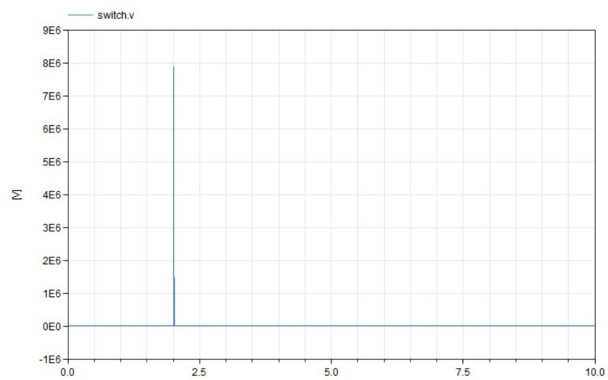

Figure 15: Switch voltage vs Time

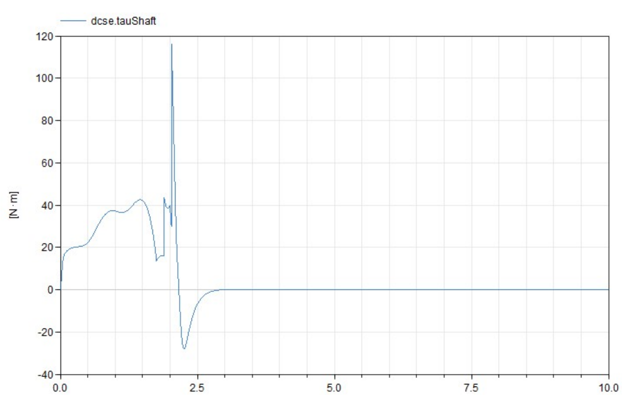

Figure 16: Motor Torque vs Time

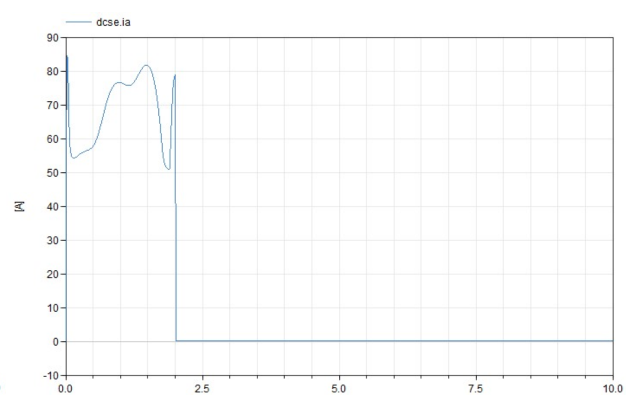

Figure 17: Motor current vs Time

The motor torque variation is given in Fig.16 A peak is observed of about 40 N-m at 1.5 s.

There is also a tremendous spike in torque to 120 N m which can be attributed to the switch when the circuit is broken.

The motor current variation with time is given in Fig.17. It reaches a peak of about 85 A during the start and experiences a resurgence during the aforementioned spike. This can also be attributed to the uneven load experienced by a motor when the OWC experiences oscillation.

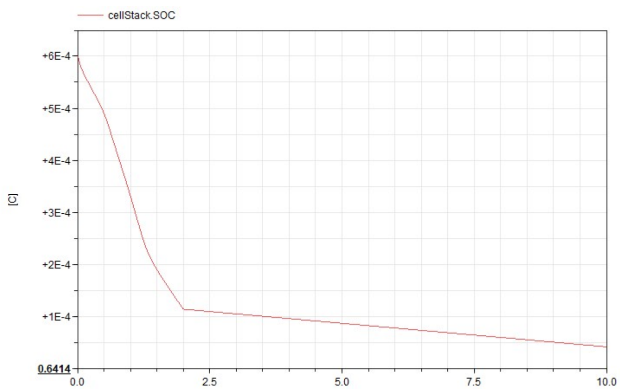

Figure 18: SoC vs Crank time in summer

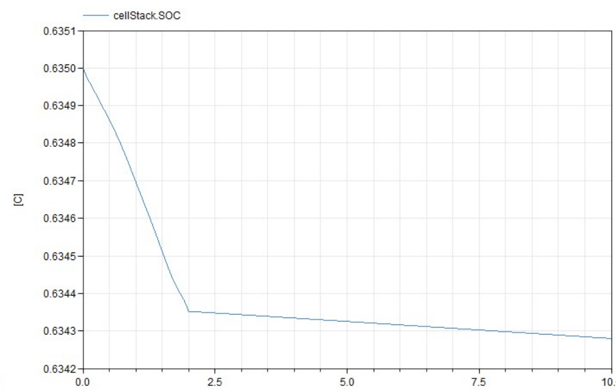

Figure 19: SoC vs Crank time in winter

The state of charge of the battery after starting during the summer and winter conditions is shown in Figs. respectively. In summer, as the resistance is higher and load due to the damping coefficient is lower, the motor draws less current. The final SOC is about 0.641.

In winter, the extra load due to the high damping coefficient and the temperature variation of resistance results in an SOC at 0.634.

5 Conclusion

As it can be seen with decrease in temperature the engine starting becomes a problem with same SOC of battery. The damping coefficient increases by 477% (0.78 to 4.5)when temperature decreases from 25°C to -10°C. The huge increase in damping coefficient causes the engine starting to halt for winter seasons.It should be noted that the data presented in this model are calculated using empirical formulae, actual engine parameters might change with a proper suitable damping value. However the result will be close to the result obtained. The performance shown is for one cylinder engine, the performance will improve with multiple cylinders.

References

[1] Myrna Cotran Sultan etal.,*"An Engine and Starting System Computer Simulation",SAE Transactions , 1990, Vol. 99, Section 3: JOURNAL OF ENGINES, Part 2(1990), pp. 1615-1623,* *Link*

[2] Emma Johansson,Sofia Wagnborg,Department of Applied Mechanics, Division of Combustion, CHALMERS UNIVERSITY OF TECHNOLOGY, *pg.18,"Analysis of Engine Cold Start Simulation in GT-Power",**Link***

[3] Wikipedia, *Cold start (automotive),Link*

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[5] Kalaikathir Achchagam,*Design Data: Data Book of Engineers, PSG College*