Dynamic Analysis of the Electric Locomotive SS7CG with ADAMS/Rail

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Abstract The dynamic performance of the modified electric locomotive SS7CG, which is new designed by Datong Locomotive Works together with Zhuzhou Institute of Electric Locomotive, is analyzed and simulated using ADAMS/Rail. The critical speed for non-linear stability on curved track, dynamic performance negotiation on various curved tracks, comfort study and axle load transference are calculated. The results show that the dynamic performance of the modified Locomotive SS7CG can completely meet the requirement of running speed of 160km/h on China main tracks.

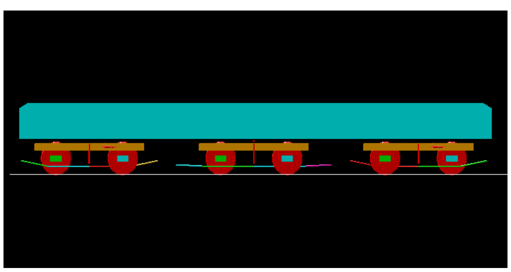
Key words: Electric Locomotive; Dynamics; ADAMS/Rail

1. Introduction

The electric locomotive is designed for increasing running speed on China main tracks by Datong Locomotive Works together with Zhuzhou Institute of Electric Locomotive, which is belongs to the type of B0-B0-B0, based on the old type of SS7C but the suspension means of the traction motors are changed. The modified one uses complete suspension and the old one accepted axle fixed. The more important is that the main parameters of the modified SS7CG are different to the old SS7C. So that in order to know whether its dynamic performance meet the requirement of realistic running with the speed of 160km/h, it is necessary to simulate the motion with virtual prototyping technology. This paper presents a dynamic model with the same parameters provided by the designers and results of the simulation of the motion using ADAMS/Rail are also provided, which include stable critical speed , dynamic performance negotiating on curved track, comfort study and the traction analysis.

2. The model for dynamic analysis

With ADAMS/Rail a three dimension model of a locomotive or a vehicle can be built quickly and easily. Considering the analysis aim and the characteristics of the modified locomotive SS7CG, the virtual prototyping model of the modified



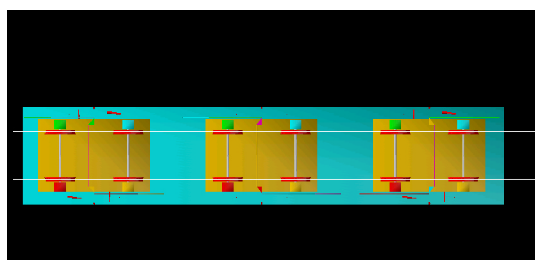


Fig.1 The dynamic model of the locomotive SS7CG

locomotive SS7CG is built and shown in Fig. 1. During creating the model, more attention is focus on the non-linear characteristics of suspensions such as the lateral hinders, dry friction pairs, spring-dampers are added and the tract equipment is also considered. All the suspension locations take the actual design ones and the inertial parameters are determined from the calculation of the software I-DEAS. So that the virtual prototyping model has complete same dynamic characteristics as physical one.

3. Stability evaluation---- calculation of critical speed

From the beginning design of the modified locomotive SS7CG , Engineers of MDI, Beijing Office jointed the preliminary plan studies and suggested that traction motors should connect to bogies by suspension way replacing axle fixed to meet the requirement of running speed of 160km/h. Starting from this point Datong locomotive works cooperated with Zhuzhou Institute of Electric Locomotive undergo the detail design and provide the complete parameters. With these parameters the stable critical speeds are calculated under different parameter cases.

a) **without anti-hunting dampers** b) **with anti-hunting dampers**

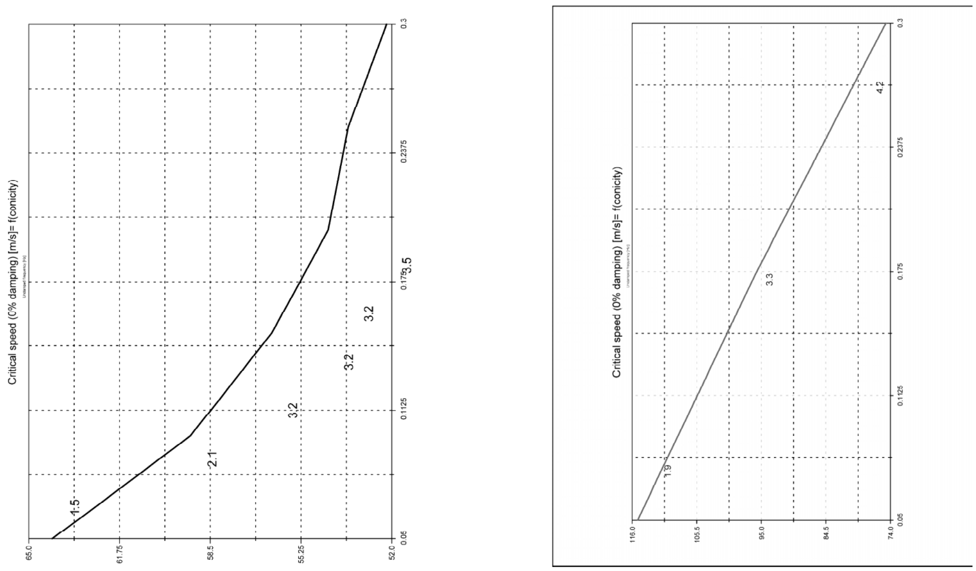


Fig. 2 Curve of the stable critical speed

Table 1 represents the values of stable critical speed under different stiffness of the primary suspension, with profiles of equal conicity 0.3.

Table 1 Critical speed for different primary suspension cases

Stiffness Case	longitudinal □N/m□	lateral □N/m□	vertical□N/m □	equal conicity	critical speed (km/h)
1	1.6e7	0.8e7	3.00e5	0.3	148
2	3.2e7	1.6e7	3.75e5	0.3	157
3	4.8e7	2.4e7	4.00e5	0.3	186

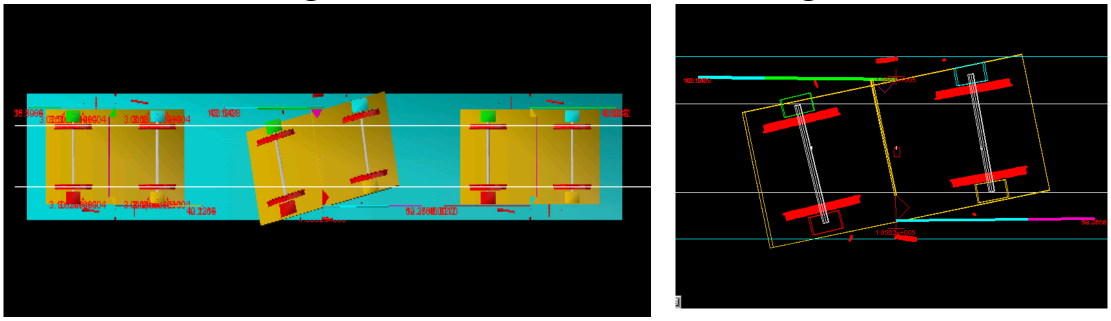
From table one we find that the case 3 shows a higher stable critical speed. Fig.2a is the result of the stable critical speed as function of the equal conicity, which is the further design studies on case 3. It tells that the stable critical speed can reach up to 228km/h with theoritical profiles of wheel and rail. Considering certain time running we take the equal conicity as 0.15(it is realistic in railway engineering), the stable critical speed is still about 200km/h . So that we can say it meet the requirement of running speed of 160km/h.

Fig.3 represents the unstable mode in case 3 with equal conicity 0.3. From the figure it shows that the unstability happens due to middle bogie, the unstable motion is mainly yaw with the frequency being 3.595HZ.

Fig. 2 b)is also the stable critical speed of case 3, but anti-hunting dampers on middle bogie are added. We can easily find that the critical speed increase sharply.

According to the results above a conclusion can be obtained: the modified electric locomotive SS7CG can meet the requirement of running speed of 160km/h; if anti-hunting dampers added on middle bogie the stable critical speed can reach up to 180km/h.

Fig. 3 Unstable mode of the middle bogie



4. Curve negotiation of the locomotive SS7CG

We use some typical tracks which their curve radii and cants being taken according to the standard of China Ministry of Railway are shown in table 2. These parameters can be used to create different tracks. In this section investigation is focus on the vehicle curve negotiation . The tracks which selected consist of straight line—transition curve—cycle curve-- transition curve-- straight line, so it combine a complete track.

Table 2.Types of curve tracks

Cases terms	1	2	3	4	5
Speed (km/h)	60	120	140	160	180
curve radii (m)	300	1400	1400	2000	2000

Fig. 4 is the part results of the vehicle curve negotiation under case 1. From figures we can find that the characteristics of the vehicle negotiation with the speed of 60km/h, which the curve radius is smaller than 300m, look like quit fine.

Table 3 represents the values of transient relative translation of the primary and the second suspension, in which the x, y, z stand for longitudinal, lateral and vertical movements respectively.

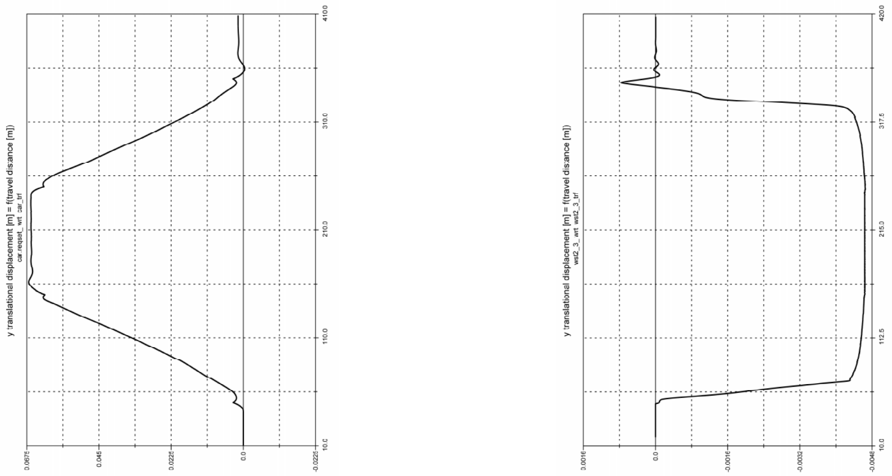


Table 3. The relative translations of the primary and the second suspension of the front bogie (mm)

Cases / Locations		1	2	3	4	5
Wheelset 1 (Left)	x	0.84	0.39	0.55	0.27	1.57
	y	0.46	0.58	1.10	0.87	0.82
	z	3.33	1.55	3.78	3.14	4.25
Front Bogie (Left)	x	26.00	6.50	6.70	4.80	4.74
	y	17.40	7.12	16.00	14.50	13.00
	z	6.20	6.85	6.50	4.60	6.61

a)Carbody lateral disp. (m) b) Wheelset 1 lateral disp. (m)

c) Net lateral force of wheelset 1 d) wheelset 1 L/V

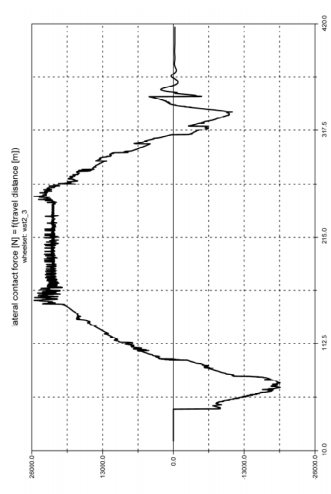
Fig 4

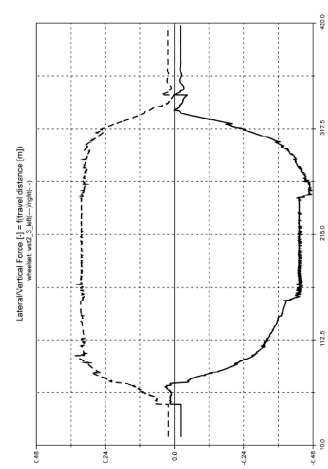
From the table 3 we can find that the transient translation of the primary and the second suspension of the front bogie are all in the range of standard values according to the five calculation cases.

Table 4 represents the lateral forces and the net lateral forces of the wheelsets. In table 6 one can find the values of the derailment coefficients.

From the results of curve negotiation with five typical tracks, we can conclude that the vehicle negotiation performance of the modified electric locomotive SS7CG completely meet the aim of design. The values of the acceleration of car, the contact forces between wheel and rail, the derailment coefficient and the reduction rate of wheel load are all in the range of technical requirement, so that we can say that the vehicle negotiation performance of SS7CG is better fine.

Table 4. Leteral contact forces (KN)





Cases / Wheelsets		1	2	3	4	5
1	Left	-54.33	-12.26	-9.13	-5.59	-7.60
	Right	33.88	23.57	17.86	11.506	13.72
2	Left	-24.75	-24.49	-12.77	-24.48	-24.77
	Right	20.33	-12.16	-27.13	-11.27	-11.97

Table 5. Net Leteral contact forces (KN)

cases / wheelsets	1	2	3	4	5
1	25.49	23.59	-17.15	13.34	9.81
2	37.46	36.57	40.74	35.46	36.27

Table 6. Derailment (L/V)

cases / wheelsets		1	2	3	4	5
1	left	-0.468	-0.18	-0.081	-0.05	-0.069
	right	0.340	0.215	0.171	0.11	0.132
2	left	-0.20	-0.198	-0.21	-0.19	-0.136
	right	0.193	0.133	-0.153	-0.129	-0.198

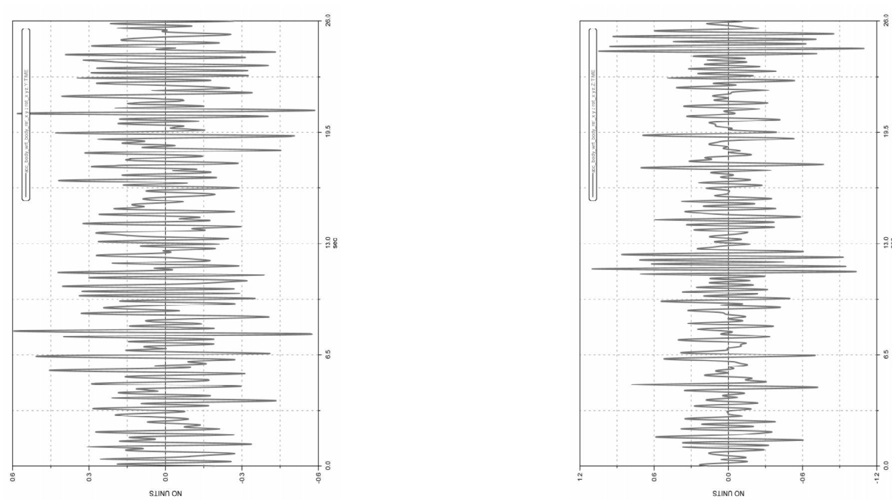
5. Comfort analysis

With the speeds of 110km/h, 140km/h, 160km/h and 180km/h along the straight track with irregularities which input by PSD method, the acceleration and ride comfort index of the carbody are calculated. Fig. 5 gives the part results due to the speed of 180km/h. The values of the lateral, vertical acceleration and the ride comfort index of the carbody can be found in table 7.

Table 7. The acceleration and ride comfort index of the car body

Speed / Results		110	140	160	180
Lateral	Acc.	0.32	0.35	0.47	0.58
	Index	2.11	2.20	2.33	2.57
Vertical	Acc.	0.43	0.74	0.58	0.84
	Index	2.21	2.56	2.40	2.70

From the results we know that the ride comfort indexes of the modified locomotive SS7CG are complete meet the design requirements.



a) Lateral Acc. B) Vertical Acc.

Fig. 5

6. Calculation of the axle-load transference

Considering the maximum traction force(282KN) acting on the locomotive, we analyze the axle-load transference and the results are shown in table 10.

Table 10 The results of the axle-load transference with traction force of 228KN

Wheelsets	1	2	3	4	5	6
Values	-8.08	1.59	-4.79	4.88	-1.58	8.12

By some calculations we can get the adhesion utilization is about 91.2% and can meet the requirement of traction.

7. Conclusions

From above simulation with ADAMS/Rail, we can obtain that the performances of the stability, curve negotiation, ride comfort and so on are all meet the design requirements and the technical requirement of increasing running speed. It is important that if anti-hunting dampers are added on middle bogie the critical speed will increase largely; this will be suitable to the running speed of 180km/h in near future.