

Getting started



UM 软件入门系列教程

(07)

四川同算科技有限公司 译

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本教程介绍使用**UM Train**模块进行列车纵向动力学建模和仿真的基本方法 和流程。

请读者在学习本课程之前务必先学习《UM软件入门系列教程01:多体系统 动力学仿真》,并熟悉UM软件的基本操作:新建模型,创建几何图形、刚体、 较和力元。

本教程只是帮助用户快速熟悉UM Train模块的基本使用方法,更详细的理 论和方法介绍请查阅用户手册第十五章。此外,UM软件还支持在列车纵向动力 学模型中加入若干考虑轮轨接触作用的三维车辆模型(UM Train3D模块),详 见用户手册第十七章(要求同时具备UM Train和UM Loco建模和仿真基础)。

请先运行**UM Input**或**UM Simulation**程序,选择菜单**Help**|**About**,在弹出窗口查看**UM Train**一栏是否为 "+" 标记,若显示为 "-",则请重新申请试用或购买正版许可。



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联系方式

最新版的UM软件和相应的用户手册下载地址:

<u>http://www.universalmechanism.com/en/pages/index.php?id=3</u>. 若无法访问,请点击: <u>http://www.umlab.ru/en/pages/index.php?id=3</u>. 在使用过程中,读者如有任何报错、疑问和建议,请发送邮件至:

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1. 列车制动模拟

1.1 课程内容

本课程将通过模拟一个简单的列车制动工况介绍 UM Train 模块的功能和使用方法,主要包含以下内容:

- 定义铁路线形;
- 定义阻力模型;
- 设置牵引和制动参数;
- 显示仿真结果;

现在,我们来创建一个俄罗斯重载列车模型,它由2节机车和58节敞车组成。

1.2 创建列车模型

首先,请运行 UM Input 程序。

选择主菜单 Tools | Train wizard, 打开列车向导界面, 如图 1.1 所示。

🗿 Train wizard

- 🗆 🗙

-	🕒 Num	ber of vehicles 2]				
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	Locomotives	Cars Wagon connections
1							LTDB-Loco Type 1
2							LTDB-Loco Type 2
						1	Diesel locomotive TE10
							Diesel locomotive TE10 (turned)
						Sector Con-	Electric locomotive VL80s
							Electric locomotive VL80s (turned)
_							

图 1.1

用户需要先指定机车和车辆的总数,然后从右侧的机车和车辆库(支持自定 义)添加所需的模型以及相应的车钩缓冲器。





这里,我们设置车辆数为60,敲回车,主界面随即显示60行元素,每一行 对应一节机车或车辆,每一列为相应的参数,如图 1.2 所示。

ම	Train wiza	rd							-		\times
8	™ 3 N	umber of vehicles 60									
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	^	Locomotives	Cars W	agon conne	ctions	
44								LTDB-Loco T	ype 1		
45								LTDB-Loco T	ype 2		
46								Diesel locom	otive TE 10	0	
47								Electric locon	notive VI 80	(turnea) s	
48								Electric locor	notive VL80	s (turned)	
49											
50											
51											
52											
53											
54											
55											
56											
57											
58											
59											
60						-					
۲					>						
				反 1	2						

图 1.2 下一步,我们需要指定机车和车辆模型。依次双击机车模型库(Locomotives) 里的 Electric locomotive VL80s 和 Electric locomotive VL80s (Turned),这样就 添加了列车头部的两节机车。此时,二者并未编组连接。

୲ୄ	Train wizard								-		×
8	Num	ber of vehicles 60									
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	^	Locomotives	Cars	Wagon conn	ections	
1	and the second	Electric locomotive VL80s	Unknown coupler	96000	16.42			LTDB-Loo	to Type 1		
2		Electric locomotive VL80s	Unknown coupler	96000	16.42			LTDB-Loo	to Type 2		
3								Diesel lo	comotive TE10	(turned)	
4								Electric le	ocomotive VL8	Os	
5								Electric le	ocomotive VL8	Ds (turned))
6											- 1
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17						~					
<					>						

图 1.3





接下来,指定车辆模型,切换到车辆模型库(Cars)页面,选中敞车 Open wagon,然后点**右键**,选择 Assign to selected。



图 1.4

这一步操作缺省选择了 3-60 号车辆(已定义机车的 1-2 号除外),点击 OK。



图 1.5





这样就一键完成了所有车辆模型的添加,如图 1.6 所示。

0	Train wizard							_		\times
8	Num	ber of vehicles 60]							
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	Locomotives	; Cars	Wagon connectio	ns	
44		Open wagon	Unknown coupler	90000	14.73		Passeng	er car		
45		Open wagon	Unknown coupler	90000	14.73		 Flat car 			
46		Open wagon	Unknown coupler	90000	14.73	876 87	Hopper	agon Type 1		
47		Open wagon	Unknown coupler	90000	14.73	ana an	LTDB-W	agon Type 1 agon Type 2		
48		Open wagon	Unknown coupler	90000	14.73		Open wa	agon		
49		Open wagon	Unknown coupler	90000	14.73		Tank car			
50		Open wagon	Unknown coupler	90000	14.73		Tank car	with liquid		
51		Open wagon	Unknown coupler	90000	14.73					
52		Open wagon	Unknown coupler	90000	14.73					
53		Open wagon	Unknown coupler	90000	14.73					
54		Open wagon	Unknown coupler	90000	14.73					
55		Open wagon	Unknown coupler	90000	14.73					
56		Open wagon	Unknown coupler	90000	14.73					
57		Open wagon	Unknown coupler	90000	14.73					
58		Open wagon	Unknown coupler	90000	14.73					
59		Open wagon	Unknown coupler	90000	14.73					
60		Open wagon	Unknown coupler	90000	14.73					
۲					>					

图 1.6 最后一步,指定车钩缓冲器模型(非线性磁滞特性力元)。转到钩缓模型库 (Wagon connections)页面,选中 Sh-2-T,点右键,选择 Assign to all。

ම	Train wizard								-		×
8	Num	ber of vehicles 60]								
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	^	Locomotives	Cars	Wagon connect	ions	
44		Open wagon	Unknown coupler	90000	14.73		LTDB Dra	ft Gear	10 mm slacks		
45		Open wagon	Unknown coupler	90000	14.73		2.7 Sh-1-1				
46		Open wagon	Unknown coupler	90000	14.73		L2 Sh-2	Inser	t vehicle		
47		Open wagon	Unknown coupler	90000	14.73		L. Draf	Repla	ace current		
48		Open wagon	Unknown coupler	90000	14.73			Add	venicie		
49		Open wagon	Unknown coupler	90000	14.73			Assig	gn to all		
50		Open wagon	Unknown coupler	90000	14.73		_	Assig	gn to selected		
51		Open wagon	Unknown coupler	90000	14.73						
52		Open wagon	Unknown coupler	90000	14.73						
53		Open wagon	Unknown coupler	90000	14.73						
54		Open wagon	Unknown coupler	90000	14.73						
55		Open wagon	Unknown coupler	90000	14.73						
56		Open wagon	Unknown coupler	90000	14.73						
57		Open wagon	Unknown coupler	90000	14.73						
58		Open wagon	Unknown coupler	90000	14.73						
59		Open wagon	Unknown coupler	90000	14.73						
60	100 ALC:	Open wagon	Unknown coupler	90000	14.73	~					
<					1	>					

图 1.7





至此,我们就完成了列车编组模型的创建,点击➡按钮保存当前模型,请

读者自行定义模型名称和路径,如: {UM Data}\My models\Trains\TestTrain。

0	Train wizard								_			\times
8	Num	ber of vehicles 60]									
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length '	^	Locomotives	Cars	Wagon co	nnec	tions	
44		Open wagon	Sh-2-T	90000	14.73			aft Gear	10 mm slacks	5		
45		Open wagon	Sh-2-T	90000	14.73		Sh-1-T					
46		Open wagon	Sh-2-T	90000	14.73		Sh-2-V					
47		Open wagon	Sh-2-T	90000	14.73		Draft ge	ar				
48		Open wagon	Sh-2-T	90000	14.73							
49		Open wagon	Sh-2-T	90000	14.73							
50		Open wagon	Sh-2-T	90000	14.73							
51		Open wagon	Sh-2-T	90000	14.73							
52		Open wagon	Sh-2-T	90000	14.73							
53		Open wagon	Sh-2-T	90000	14.73							
54		Open wagon	Sh-2-T	90000	14.73							
55		Open wagon	Sh-2-T	90000	14.73							
56		Open wagon	Sh-2-T	90000	14.73							
57		Open wagon	Sh-2-T	90000	14.73							
58		Open wagon	Sh-2-T	90000	14.73							
59		Open wagon	Sh-2-T	90000	14.73							
60		Open wagon	Sh-2-T	90000	14.73	-						
<					>							

图 1.8

保存后,请关闭 Train Wizard 和 UM Input 程序。

备注:

列车向导中的机车库、车辆库和钩缓库都支持用户自定义扩展,详见用户手 册第十五章。





1.3 列车动力学仿真

利用前面建立的列车模型,我们来模拟列车在一个曲线坡道上的制动工况,曲线半径为600m,坡度为-7‰,制动初速度为30m/s。

1.3.1 设置仿真工况参数

首先,请运行 UM Simulation 程序,并加载列车模型 TestTrain。

设置求解器

置为55s。

- 1. 选择主菜单 Analysis | Simulation 或按 F9 键, 打开仿真控制界面 Object simulation inspector。
- 2. 定位到 Solver 页面,选择 Park 求解器,勾选 Computation of Jacobian 选项。
- 3. 缺省的终止条件为运行距离,点击¹图标,切换**时间**为终止条件,并设

Info	rmation	Tools	Trair	ı
Solver	Identifiers	Initial conditions	Object variables	XVA
Simulation process pa Solver O BDF O ABM O Park O Gear 2 O Park Parallel Time Step size for animation Error tolerance	Type of solu Null space Range sp t Null space Range sp t Null space Range sp	tions Type of coordinates for bodie tion e method (NSM) ace method (RSM) 55 []] 0.02	s PP: Options	
□ Delay to real time : □ Keep system matri ☑ Computation of Ja □ Block-diagonal	simulation x decomposition cobian Jacobian			

图 1.9





创建铁路线形文件

缺省状态,列车位于平直线路。

1. 选择主菜单 **Tools** | **Macrogeometry Editor** | **Railway or monorail track** 或点击工具栏图标²,打开线形制作工具,如图 1.10 所示,系统缺省 创建了 100m 的直线段。



图 1.10

 窗口界面由上下两部分组成,其中上部用于描述铁路平面曲线,下部用 于描述纵断面。在上部窗口右侧点击+.按钮,选择 Add curve,添加一 段标准曲线(缓和曲线-圆曲线-缓和曲线),如图 1.11 所示。



图 1.11

Universal Mechanism 9





3. 曲线半径默认为 300m, 在图 1.11 中双击 Curve 一栏, 弹出曲线参数页 面。修改曲线半径为 600m,点击 Apply。

Horizontal macrogeometry	Curve parameters X
+, +€ @ /;	Type of curve Left Right
S Horizontal track profile	P1 50
0 Tangent; L=100.00	S 200
100 Curve (left): R=600; H=0.09;	P2 50
	R 600
	Н 0.09
	dY 0.01
	L 300
	Friction coefficients
Vertical macrogeometry	Outer rail 0.25
	Inner rail 0.25
+ + + + + + + + + + + + + + + + + + +	Flange 0.25
S Vertical track profile	Transient section
0 L=100.00; 0ppt; R=0	from 20 to 40 degrees
	10 40 degrees
	Apply Cancel
图 1.1.	2

4. 到下部窗口右侧双击直线段(由于仅仅是模拟一个下坡工况,因此无需 添加其他线形),在弹出界面修改长度为600m,坡度为-7‰(输入-7)。

Vertical ma	crogeometr	у		
╋ᢩ⊕		ŕ		
S	Vertical tr	ack profile		
0	L=100.00	; 0ppt; R=0		
Gradie	nt)	×
Length,	m	600		
Gradien	t, ppt	-7		
Nextra	dius, m	0.00		
		Apply	Cancel	
	Ś	1.13		

5. 点击 Apply, 最终得到如图 1.14 所示的铁路线形。







- 然后关闭线形工具。 月存为 Х « 9 > My models > Trains > TestTrain G ← $\mathbf{\Lambda}$ ~ 组织 ▼ 新建文件夹 2 ^ 名称 修改日期 类型 大小 没有与搜索条件匹配的项。 E 1 文件名(N): R600 \sim 保存类型(T): Railway track macrogeometry (*.mcg) \sim 保存(S) 取消 ∧ 隐藏文件夹
 - 图 1.15
 - 7. 回到仿真控制界面(Object simulation inspector),如果不慎关闭,请按
 F9 打开。定位到 Train | Option | Track 页面,点击 → 按钮加载刚才制作
 的线形文件 r600.mcg。





Solver	r Ider	ntifiers	Initial	conditions	Object variables	XVA	Information	Tools	Train
- 8	Br	raking: No		Tra	action: User				
Options	Traction	Braking	Tools I	Masses					
Track	Resistance	Vehicle	positions	Identification					
Macroge	eometry								
"C:\User	rs\Public\Do	cuments\	JM Softwa	are Lab\Univer	sal Mechanism\9\My mo	dels\Trains	\TestTrain\R600.m	icg"	ê X
Drav	v ballast bed ed sleepers	d 	1.	~	[
Maximal	length for s	implified t	rack imag	e	100000				
Maximal	length for t	he accura	te track in	nage	10000				
Current	track length	I			400				
Train re v= 10	sistance for	rce m/s	<u>N</u>						
	Integr	- Hon					1		

图 1.10

设置阻力模型

所有列车相关的参数设置选项都位于图 1.16 的 Train 页面。

定位到 Train | Options | Resistance | Propulsion 页面,这里显示了两个列表。

位于上部的是当前模型可用的阻力模型库,可以通过按钮+和 来添加和删除,软件缺省的四种俄罗斯标准的阻力模型不支持删除操作。在上部列表选中某个阻力模型,点右键,选择 Assign to all 可以一键分配给所有的机车和车辆。

位于下部的显示当前模型里每个机车和车辆已经分配的阻力模型。在下部列 表某车辆一栏对应的 Resistance model 单元格,通过双击操作可以切换阻力模型 (双击一次,变换一次,在上面的模型库里依次循环)。

这里我们保持缺省即可,不做任何修改。





Solv	/er	Ide	entifiers	Init	tial condition	ns Object	t variables	XVA	Informa	tion Tools	Train		
≥ E	9	E	Braking: N	lo		Traction: Us	er						
ptions	Tr	action	Braking	Tools	Masses								
Track	Re	sistance	e Vehicle	e positior	ns Identif	ication							
Propu	lsion	Curve	e										
т	Na	ame				Resistance	e model			Comment		Path	
т	Lo	comotiv	/e			9.81*(2.4	4+0.009*v*3	.6+0.0003	5*(v*3.6)*	Standard Russian	resistance		
iii	Lo	aded fr	eight car,	long-we	lded rails	9.81*(0.3	7*M/1000+(3	+0.09*v*3	3.6+0.002*	Standard Russian	resistance		
	En	npty fre	ight car, l	ong-wel	ded rails	9.81*(1+	0.042*v*3.6	+0.00016*	*(v*3.6)*(v	Standard Russian	resistance		
	Pa	issenge	r car, long	g-welded	rails	9.81*(0.3	7*M/1000+ (8	+0.16*v*3	3.6+0.0023	Standard Russian	resistance		
	<												>
N	Veh	ide					Resistance	model					^
1	Elec	tric loco	omotive V	L80s			Locomotive						
2	Elec	tric loc	omotive V	L80s (tu	rned)		Locomotive						
3	Оре	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			
4	Ope	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			
5	Ope	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			
6	Ope	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			
7	Ope	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			
8	Ope	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			
9	Оре	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			
10	Open wagon						Loaded freight car, long-welded rails						
11	Ope	en wago	n				Loaded freig	ght car, lon	g-welded ra	ils			۷
<	_											>	
		Inte	oration				Message			Clo			

图 1.17

设置制动系统

下面来设置列车制动系统参数,选项位于 Train | Braking | Brake equipment 页面。

制动系统主要包括车轮与闸瓦/制动盘的摩擦系数、制动模式、制动倍率和 空气波速等参数。

其中,制动力定义为摩擦系数与闸瓦力(正压力合力)的乘积。

$$F_B = f \cdot F_N$$

因此需要定义每个车辆的摩擦系数和闸瓦力模型。

在 Train | Braking | Brake equipment 页面,我们可以先定义常用制动的空 气波速为 280m/s,如图 1.18 所示。





	Identifiers	Initial con	ditions C	bject variables	XVA	Information	Tools	Train
	Braking: N	Tools Mass	Tractio	n: User				
rake mode Braking	3rake equipme	ent						
✓ Speed of s	ervice brake i	wave, m/s:		280				
✓ Speed of e ✓ Speed of re	mergency bra elease wave,	ake wave, m/s: m/s:		300 100				
Pneum. brake	Auxiliary b	rake Rigging	Brake ID Re	lease ID Friction of	oefficient			
e ^t e								
Name		Comment			Path			
(none)		No brake equi	pment					
(interpolation)	Force is calcul	ated by interpo	olation				
٢								>

在 Train | Braking | Brake equipment | Rigging 页面,可以选择制动装置类型。点击 P*按钮,从本地库添加适用于机车的 VL80, grey iron.pf,适用于货车

的 Freight car, grey iron.pf。

选中列表中的 Freight car, iron shoes, 点右键, 选择 Assign to all, 分配给 所有车辆。

Pneum. brake	Auxiliary brake	Rigging	Brake ID	Release ID	Friction coef	ficient
Name		Comment				Path
(none)		No brake e	quipment			-
VL80, iron shoe	es	VL80, brake	e rigging fo	r grey iron bra	ake shoes	C: \Users \Public \Documents \UM Software Lab \Universal
Freight car, iro	n shoes	Assign to Delete	all	for grey i	ron brake sho	C: \Users\Public\Documents\UM Software Lab\Universal



转到 Train | Braking | Brake equipment | Pneum.brake 页面,你会发现包括 机车在内的所有车辆都设置成了 Freight car, iron shoes。请分别双击两个机车 对应的制动装置 Freight car, iron shoes 两次,使之切换为 VL80, iron shoes。





Pneu	m. brake Auxiliary brake	Rigging Brake	ID Releas	e ID Friction coeffic	ient			
Ν	Vehicle	Rigging system	m	Service braking	Emergency braking	Release	Friction coef.	^
1	Electric locomotive VL80s	VL80, iron sho	bes	(none)	(none)	(none)	(none)	
2	Electric locomotive VL80s	VL80, iron sho	es	(none)	(none)	(none)	(none)	
3	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
4	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
5	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
6	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
7	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
8	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
9	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
10	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	
11	Open wagon	Freight car, in	on shoes	(none)	(none)	(none)	(none)	~
<							>	*
	Integration			Message		(Close	

图 1.20

转到 Train | Braking | Brake equipment | Brake ID 页面,点击 萨按钮,从本 地库添加一个空气压力时程曲线, service_braking_25s_example.id。在列表中选 中,点右键,选择 Assign as service braking to all,将其分配给所有机车和车辆。

Pneum. brake Auxiliary	brake Rigging Brake ID Release ID Friction co	pefficient
Name	Comment	Path
(none)	No brake equipment	
(interpolation)	Force is calculated by interpolation	
Service braking, 25 s	Service braking, 35 seconds, example Assign as service braking to all	C+1U3ers\Public\Documents\UM Software Lab\Universal
	Assign as emergency braking to all Delete	

图 1.21

转到 Train | Braking | Brake equipment | Friction coefficient 页面,点击 掌按 钮,从本地库添加一个摩擦系数模型 Composite.cf。在列表中选中,点右键,选择 Assign to all,将其分配给所有机车和车辆。





Column Identificate	Tailial and liana Object us is here	VVA Information Table Train
Solver Identifiers	Initial conditions Object variables	XVA Information Tools Iffain
Braking: N	lo Traction: User	
ptions Traction Braking	Tools Masses	
rake mode Brake equipme	ent	
Braking	1200 m/m	
Speed of service brake v	vave, m/s: 200	
Speed of release wave.	m/s: 100	
Poeum brake Auviliary br	ake Pigging Brake ID Pelease ID Friction (efficient
	ake Rigging brake to Release to Theorem	
8		
Name	Comment	Path
(none)	Friction coefficient is not defined	-
Composite	Composite brake chaos	C:\Users\Public\Documents\UM Software Lab\Universa
	Assign to all	
	Delete	
<		>
Integration	Message	Close
THICHAUOH	Picaduc	

转到 Train | Braking | Brake mode 页面,点击 + 按钮,添加一个制动工况, 缺省设置开始时间为 0s,制动类型为 Brake pipe,制动模式为 Service braking, 制动机车为 1.Electric locomotive VL80s。

请注意,在Braking处有个选项,只有勾选上才开启制动模式,否则无效。

Object simulatio	n inspect	or								
Solver I	dentifiers	Initial conditions	Object variables	XVA	Information	Tools	Train			
൙ 🖪 🗌	Braking: Y	es	Traction: User							
Options Traction	Braking	Tools Masses								
Brake mode Bra	Brake mode Brake equipment									
Braking + 💽 🛍 💿 Time, s 🔿 Distance, m										
Time, s							0 🕅			
Type of brake: Options	Brake pi	pe					~			
Mode:	Service b	oraking					\sim			
Vehicle:	1. Electri	ic locomotive VL80s					\sim			
Final pressure	in BC, Pa:	0								

14

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在 Identifiers 页面设置初始速度为 30m/s,请在工具栏检查速度单位是否为 m/s。

·	Speed unit	0 m /n	
	} O km/h	⊙ m/s	

Solver	Identifiers	Initial conditions	Object variables	XVA	Information	Tools	Train
st of identifier	s Identifier co	ntrol					
≃ ₿	1 testtra	in					
Whole list							
	Everagier	n Value	Comment				
Name	Expression						

图 1.24

下面,我们来创建一些变量,用于分析列车的动力学行为。

选择菜单 Tools | Wizard of variables, 打开变量向导。

定位到 Train 页面,在左侧全选机车和车辆,在右侧选择标准变量 FBrake,

然后点击 必按钮,生成每个车的制动力变量并显示在同一个绘图窗口。

🔄 Wizard of variables					×
Variables for group of bodies	A Joint forces	Bipolar forces	Angular variable	les 🛃 Lii	near variables
Vehice 1, Electric locor Vehice 2, Electric locor Vehice 3, Open wagor Vehice 4, Open wagor Vehice 5, Open wagor Vehice 5, Open wagor Vehice 6, Open wagor Vehice 7, Open wagor Vehice 8, Open wagor Vehice 9, Open wagor Vehice 10, Open wagor Vehice 11, Open wagor Vehice 12, Open wagor Vehice 13, Open wagor Vehice 14, Open wagor Vehice 15, Open wagor Vehice 16, Open wagor Vehice 17, Open wagor Vehice 18, Open wagor Vehice 19, Open wagor	Selected (total 60) Electric locomotive VL Name Forces ECoupling FBrake LoadForce PropulsionResist GradeResistance CurveResistance CurveResistance CurveResistance RealizedTractio Pressures BCPressure General variable ThrottlePosition Distance Speed history m ControlForce <	80s, Electric locomotive V Comment Eorce in wanon connectio Braking force Load force "brake pad-wi Propulsion resistance Grade resistance Curve resistance Realized traction or brake Brake cylinder pressure es Throttle position Vehicle distance from the mode Control force (traction or	L80s (turned), Open w L80s (turned), Open w neel" e force in consideration simulation start braking force)	vagon, Open wa	it
FBrake(Electric locomotive VL80s, . Bra	king force (Electric loco	omotive VL80s,)			F

图 1.25

用同样的方法,创建车钩力 FCoupling 和距离 Distance 变量,分别显示在 不同窗口。

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切换到 Linear variables 页面,定义头部机车的纵向速度变量,并显示在一个独立的绘图窗口,如图 1.26 所示。

Image: Selected Image: Selected	Identifiers
a+b Expression Train User variables ** Reactions Coordinates Solver variables * All forces id id id id Solver variables * Angular variables * Linear id id id Solver variables * Intervention Solver variables * Linear id id Solver variables Solver variables * Linear id id Solver variables Solver variables * Linear id id Solver variables Solver variables * Linear id Solver variables Solver variables * Linear id id Solver variables * Linear id Solver variables Solver variables * Linear id id Solver variables * Linear i	Identifiers
Image: Warables for group of bodies Image: Warables for group	a second and a second sec
Image: Selected Vehicle Vehicle Coordinates of point in the body-fixed frame of reference Image: Optimized frame of the selected 0 Image: Optimized frame of the selected 0	variables
Vehicle Coordinates of point in the body-fixed frame of reference	
Coordinates of point in the body-fixed frame of reference	
	0
Grupe Type	
Vehicle O Coordinate O Bipolar vector	
4. Open wagon OBipolar velocity	
Vehicle O Acceleration O Bipolar acceleration	
S. Open wagon	
P 7. Open wagon	
Base0	
Relative to body	
Base0	-
Sopen wagon	
v:x(1. Electric locomotive VL80s.Ve Velocity of point (0,0,0) of body 1. Electric locomotive VL80s.Vehicle relative to Base0, SC Bas	ʻ 🖗 🔂
图 1.26 最后,仿真程序界面布置如图 1.27所示。	
Variational Constraints of the second state of	Tran
Contraction of the second seco	
Image: Control of Con	Ope





1.3.2 列车动力学仿真

在仿真控制界面点击 Integration 或按 F9 开始仿真。

由于钩缓力元位于每节车辆尾部,而最后一个车钩后面没有连接其他车辆,因此会出现如下提示。勾选 **Do not show this window anymore**,点击 **Continue** 即可。



仿真完毕后,得到制动力时程曲线如图 1.29 所示,很明显,有两种特征波形,分别对应机车和车辆。



图 1.29





车钩力如图 1.30 所示,最大值约为 362kN,发生在第 44 节车辆。



图 1.31





其实,对于车钩力,采用柱状图(Tools | Histogram)显示更为直观,效果 如图 1.32 所示。可通过工具栏上的 · · · 按钮进行曲线动画的播放、暂停和 停止操作。







2. 列车纵向动力学国际考题测试

2.1 课程内容

2016 年,UM 软件参与了由澳大利亚中央昆士兰大学铁路工程中心组织的 列车纵向动力学仿真软件考题测试。来自澳大利亚、中国、意大利、荷兰和法国 的共计9个仿真软件参与了这个测试,详细报告请见文献[1-3]。

本次考题测试主要有以下目的:

- 通过不同软件计算结果的对比,让开发者对各自软件有进一步的认识;
- 体现不同软件计算结果的差异,为后续研究提出新的问题;
- 为现有的和开发中的计算软件提供评估参考;

考题测试对象为四个不同工况配置的重载列车模型,其中机车轴重有 22 吨、33 吨和 32.5 吨三种,货车轴重有 32 吨和 40 吨两种。

工况设置包括:机车和车辆参数、编组配置、钩缓特性、铁路线形、初始速 度、牵引和制动特性。

计算后输出结果:头部机车的位移和速度、指定车辆的车钩力和钩缓变形量, 以及每个车钩的最大压钩力和拉钩力。

从结果对比看,UM 软件和其他软件总体上都很吻合,因此使用 UM Train 模块进行纵向动力学分析是可靠可信的。

本课程选取考题测试的第一个工况配置进行建模和仿真的演示。列车编组形式为两节机车牵引五十节货车。

读者可以从本地目录 {UM Data}/SAMPLES/Trains/LTDB-Train Configuration 1 找到该模型。





2.2 创建列车模型

运行 UM Input 程序,按以下步骤创建列车编组动力学模型。

1. 选择菜单 Tools | Train wizard, 打开变量向导, 如图 1.21 所示。



图 2.2





- 3. 从机车模型库 Locomotives 双击 LTDB-Loco Type1 两次, 添加两个机车 模型。
- 4. 转到车辆模型库 Cars,选中 LTDB-Wagon Type 1, 点右键,选择 Assign to selected,点击 OK,自动设置为剩下的 50 节车辆。

୭	Train wizard								-		×
8	Num	ber of vehicles 52									
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	^	Locomotives	Cars	Wagon co	onnections	;
1	A	LTDB-Loco Type 1	Unknown coupler	133980	22.95			assenge	er car		
2	A	LTDB-Loco Type 1	Unknown coupler	133980	22.95			=lat car			
3								Hopper	-		
4							418 618	7	Insert ve	hicle	
5								 Di	Replace	current	
6								Γa	Add veh	icle	
7							ا يَتْسَعْ	Ta _	Assign to	o all	
8									Assign to	o selecte	d
9								_			

图 2.3

5. 转到钩缓模型库 Wagon connections,选中 LTDB Draft Gear 10mm slacks,点右键,选择 Assign to all,将这种钩缓模型赋给所有机车和车辆,其力学特性如图 2.5 所示(可以在 UM Input 里进入子系统查看)。

ම	Train wizard		_					-		\times
8	Num	ber of vehicles 52								
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	^	Locomotives Cars	Wagon co	onnection	3
34		LTDB-Wagon Type 1	Unknown coupler	128000	15		LTDB Draf	insert vel	nicle	
35		LTDB-Wagon Type 1	Unknown coupler	128000	15		2 Sh-1-1	Replace o	urrent	
36		LTDB-Wagon Type 1	Unknown coupler	128000	15		Sh-2-V	Add vehic	cle	
37		LTDB-Wagon Type 1	Unknown coupler	128000	15		2_J Draft gear	Assign to	all	
38		LTDB-Wagon Type 1	Unknown coupler	128000	15			Assign to	selecte	d
39		LTDB-Wagon Type 1	Unknown coupler	128000	15					
40		LTDB-Wagon Type 1	Unknown coupler	128000	15					
41		LTDB-Wagon Type 1	Unknown coupler	128000	15					
42		LTDB-Wagon Type 1	Unknown coupler	128000	15					
43		LTDB-Wagon Type 1	Unknown coupler	128000	15					
44		LTDB-Wagon Type 1	Unknown coupler	128000	15					
45		LTDB-Wagon Type 1	Unknown coupler	128000	15					
46		LTDB-Wagon Type 1	Unknown coupler	128000	15					
47		LTDB-Wagon Type 1	Unknown coupler	128000	15					
48		LTDB-Wagon Type 1	Unknown coupler	128000	15					
49		LTDB-Wagon Type 1	Unknown coupler	128000	15					
50		LTDB-Wagon Type 1	Unknown coupler	128000	15					
51		LTDB-Wagon Type 1	Unknown coupler	128000	15					
52		LTDB-Wagon Type 1	Unknown coupler	128000	15					
						*				

图 2.4



8 Nr

1 2 3

4 5

6

7 8

9

10

11

12

13

14

15

16

17

18

19

LTDB-Wagon Type 1



		2500 2000 1500 1500 500 0	0 15 30) 45 Deflection() 图 2.5	60 7 mm)	5 90
ම	6. 至	此,完成列车	三编组模型, 女	口图 2.6 户	所示。	
8	De Num	her of vehicles 52				
Nr	Icon	Vehicle	Wagon connections	Vehicle mass	Vehicle length	Locomotives Cars Wagon connections
1	100H	LTDB-Loco Type 1	LTDB Draft Gear 10 mm slacks	133980	22.95	LTDB Draft Gear 10 mm slacks
2		LTDB-Loco Type 1	LTDB Draft Gear 10 mm slacks	133980	22.95	2 Sh-1-T
3		LTDB-Wagon Type 1	LTDB Draft Gear 10 mm slacks	128000	15	レビン Sh-2-T レン Sh-2-V
4		LTDB-Wagon Type 1	LTDB Draft Gear 10 mm slacks	128000	15	Draft gear
5	115 215	LTDB-Wagon Type 1	LTDB Draft Gear 10 mm slacks	128000	15	
6		LTDB-Wagon Type 1	LTDB Draft Gear 10 mm slacks	128000	15	
7		LTDB-Wagon Type 1	LTDB Draft Gear 10 mm slacks	128000	15	
8		LTDB-Wagon Type 1	LTDB Draft Gear 10 mm slacks	128000	15	

15

15

15

15

15

15

LTDB Draft Gear 10 mm slacks	128000	15
LTDB Draft Gear 10 mm slacks	128000	15
LTDB Draft Gear 10 mm slacks	128000	15
LTDB Draft Gear 10 mm slacks	128000	15
LTDB Draft Gear 10 mm slacks	128000	15
[图 2.6	

LTDB Draft Gear 10 mm slacks 128000

7.

Models\Trains\LTDBTrain。

8. 关闭列车向导界面,关闭 UM Input 程序。





2.3 设置仿真工况参数

运行 UM Simulation 仿真程序,加载 LTDBTrain 模型。

设置求解器参数

打开仿真控制界面,在 Simulation process parameters 页面选择 Park 求解器, Type of Solution 为 Range space method (RSM),勾选 Computation of Jacobian 和 Block-diagonal Jacobian,仿真距离为 50 000m,如图 2.7 所示。

Solver Identifiers	Initial conditions	Object variables	XVA	Information	Tools	Train
Simulation process paramet	ters Solver options Type	of coordinates for bodie	s PP: Op	otions		
Solver	Type of solution					
○ ABM	O Null space method (NS	SM)				
Park						
🔾 Gear 2	Range space method	(RSM)				
O Park Parallel						
Distance - Vehicle distance	t >= ~ 50 000					
Step size for animation and	data storage 0.02					
Frror tolerance	1E-6	=				
Delay to real time simula	tion					
Keep system matrix dec	omposition					
Computation of Jacobia	n					
Block-diagonal Jacob	ian					
Integration		Message			Close	
		困っっ				
		호 Z./				





设置制动模式

机车的制动特性如图 2.8 所示。制动力与制动把位对应,而制动把位又随时间变化。我们需要一些特别的操作来定义这种复杂的特性曲线。



- 在仿真控制界面, 定位到 Identifiers | Identifier control , 点击 按钮, 添加一个控制符。
- 10. 在弹出窗口点击 brake_position。



图 2.9





11. 在 **Assign value to identifiers with the same name** 下选择 **All**,表示将所 有机车都设置为同一制动把位。

 Identifier control Enabled Compute after kinematics Refresh dependent elements Identifier 		×	
1. LTDB-Loco Type 1.dynamic_brake_	position		
Assign value to identifiers with the sa	ame name O In subsystems		
Comments			
Ordinate Curve editing No data	Type of description Points Variable		
Abscissa Variable Time	Type Time Variable		
Accept Cancel	2 10		

12. 点击 Curve editing 下的按钮…,弹出曲线编辑器窗口,通过点击按钮,

加载位于本地目录的制动把位时程曲线 **{UM Data}\Samples\Trains \LTD-Train Configuration 1\Dynamic brake position.crv**,如图 2.11 所示。





 ◆ ● ◆ ◆ ▲ SAMPLES → Trains → LTDB-Train Configuration 1 ◆ ○ P 提案'LTDB-Train Configur #説 ◆ 新建文件共 ● ● ◆ ● ● ● ● ● ● ● ● ● ● ●	Read data						×
超訳 新建文件共 IEI <	\leftarrow \rightarrow \checkmark \bigstar SAMPLES \Rightarrow Trains \Rightarrow LTDB-Train Cor	nfiguration 1	~	5		B-Train Co	nfigur
日文: ↑ 日文: ↑ 日(日): ↑ 日): ↑ 日(日): ↑ 日(组织 ▼ 新建文件夹				ł	= •	
● 外 ● り ● か ● か ● か <td< th=""><th></th><th>修改日期</th><th></th><th>类型</th><th>大</th><th>N</th><th></th></td<>		修改日期		类型	大	N	
9 %	📰 🖉 🖈 🔄 🗍 Dynamic brake position.crv	2016/6/23 1	4:47	CRV 文件		1 KB	
文件名(N): Dynamic brake position.crv UM curve files (*.crv) 丁田(0) 取消 Curve editor - Identifier control	9 🖈 🧻 Throttle position.crv	2016/6/27 1	0:30	CRV 文件		48 KB	
文件名(N): Dynamic brake position.crv UM curve files (*.crv) 打开(O) 取満 Curve editor - Identifier control	, x€ x						
\dot{X} (K): Dynamic brake position.crv UM curve files (*.crv) \dot{T} (T): \dot{T} (W):	, U 🖈						
文件名(N): Dynamic brake position.crv 文件名(N): Dynamic brake position.crv UM curve files (*.crv) 打开(O) 取消 Curve editor - Identifier control Curve editor - Identifier control	, U 🖈						
文件名(N): Dynamic brake position.crv 可用(O) 取消 で Curve editor - Identifier control ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・	_ U 🖈 🗸						
打开(の) 取消 で Curve editor - Identifier control ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・	文件名(N): Dynamic brake position.crv			~	UM curve files	; (*.crv)	\sim
Curve editor - Identifier control Curve editor - I					打开(O)	取	消
Curve editor - Identifier control							
8 Image: Cur 0 V	Curve editor - Identifier control					- 0	×
0 N X Y Type Smoothing □ -1 0 0 Line Yes □ -2 640 0 Line Yes □ -3 641 1 Line Yes □ -4 653 1 Line Yes □ -5 654 2 Line Yes □ -6 666 2 Line Yes □ -7 667 3 Line Yes □ 9 680 4 Line Yes □ 10 692 4 Line Yes □ 11 693 3 Line Yes		+ +	🗍 Line		× 🖻 🗄	Ē \$	V.
□ 2000 4000 0 2000 4000 • 1 0 0 Line Yes • 1 0 0 Line Yes • 3 641 1 Line Yes • 5 654 2 Line Yes • 6 666 2 Line Yes • 9 680 4 Line Yes • 1 693 3 Line Yes	° I	N	x	Y I	ype Smo	othing	
- 1 0 0 Line Yes - 2 640 0 Line Yes - 3 641 1 Line Yes - 3 641 1 Line Yes - 5 654 2 Line Yes - 6 666 2 Line Yes - 7 667 3 Line Yes - 9 680 4 Line Yes - 10 692 4 Line Yes - 11 693 3 Line Yes							^
1 2 0+0 0 Line Tes -3 641 1 Line Yes -4 653 1 Line Yes -5 654 2 Line Yes -6 666 2 Line Yes -8 679 3 Line Yes -9 680 4 Line Yes -10 692 4 Line Yes -11 693 3 Line Yes		- 1	0	0 1	line Yes		
- 4 653 1 Line Yes - 5 654 2 Line Yes - 6 666 2 Line Yes - 7 667 3 Line Yes - 8 679 3 Line Yes - 9 680 4 Line Yes - 10 692 4 Line Yes - 11 693 3 Line Yes - 11 693 3 Line Yes - 0 OK Cancel		- 3	641	1	line Yes		
- 5 654 2 Line Yes - 6 666 2 Line Yes - 7 667 3 Line Yes - 8 679 3 Line Yes - 9 680 4 Line Yes - 10 692 4 Line Yes - 11 693 3 Line Yes - 0 OK Cancel		- 4	653	1	ine Yes		
- 6 666 2 Line Yes - 7 667 3 Line Yes - 8 679 3 Line Yes - 9 680 4 Line Yes - 10 692 4 Line Yes - 11 693 3 Line Yes - 11 693 3 Line Yes - 0 OK Cancel	4+	5	654	2 I	line Yes		
- 7 667 3 Line Yes - 8 679 3 Line Yes - 9 680 4 Line Yes - 10 692 4 Line Yes - 11 693 3 Line Yes - 11 693 3 Line Yes - 0 OK Cancel		- 6	666	2 !	Line Yes		
- - 8 679 3 Line Yes - 9 680 4 Line Yes - 10 692 4 Line Yes - 11 693 3 Line Yes		7	667	3 I	line Yes		
9 680 4 Line Yes 10 692 4 Line Yes 11 693 3 Line Yes		8	679	3	Line Yes		
10 692 4 Line Yes		- 9	680	4 1	Line Yes		
Lo 2000 4000 OK Cancel		10	692	4 I 2 I	ine Yes		
0OK Cancel			093	3	Line Yes		~
	2000 4000				OK	(Cancel

图 2.11

- 13. 点击 OK,关闭曲线编辑器。
- 14. 点击 Accept, 完成对控制符 dynamic_brake_position 的定义。





设置牵引模式

机车牵引力与车辆速度的关系如图 2.12 所示。前面已经定义了制动把位的 时程曲线,下面来定义牵引力特性曲线。



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 再打开曲线编辑器,读入位于本地目录{UM Data}\Samples\Trains
 \LTDB-Train Configuration 1\Throttle position.crv 的牵引级位时程曲 线文件。



图 2.14

3. 点击 OK 和 Accept。

设置铁路线形文件

给定的铁路纵断面(高程)和曲率(平面)原始数据分别如图 2.15 和图 2.16 所示。



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Getting Started





经转换格式导入UM后,如图 2.17 所示。



定位到 Train | Options | Track 页面,从本地目录读入已准备好的线形文件 {UM Data}\rw\MacroGeometry\LTDB-MacroGeometry.mcg,如图 2.18 所示。

Object simulat	tion inspecto	or						
Solver	Identifiers	Initial conditions	Object variables	XVA	Information	Tools	Train	
🖻 🖻	Braking: No	0	Traction: User					
Options Tract	ion Braking	Tools Masses						
Track Resist	ance Vehicle	positions Identifica	tion					
Macrogeomet	ry							_
"C:\Users\Pub	lic\Documents\	UM Software Lab\Uni	iversal Mechanism\9\rw\	lacroGeomet	ry\LTDB-MacroGeo	metry.mcg"	1	ĕ ∡
Show track								
Show railw	ay track							
Draw balla	st bed							
Simplified slee	epers	~						
Maximal length	for simplified t	track image	100000]				
Maximal length	for the accura	ate track image	10000	Ī				
Current track le	ength		52000					
-Train resistan	ce force							
v= 10	m/s							
	Integration		Message			d	ose	

图 2.18





阻力模型

运行阻力模型按以下公式定义:

$$F_{rr} = m_w \left(2.943 + \frac{89.2}{m_a} + 0.0306v + \frac{0.122v^2}{m_w} \right)$$

其中, *m*_w是车辆质量, 单位为吨; *m*_a是轴重(32吨), *v*是车辆速度。 曲线阻力模型定义为:

$$F_{cr} = m_w \frac{6116}{R},$$

其中, R 表示曲线半径。

定位到 Train | Options | Resistance | Propulsion 页面,点击+按钮,添加机 车和车辆运行阻力模型,这里需要一共需要添加三个阻力模型: LTDB-Leading Locomotive.rf, LTDB-All Other Locomotive.rf, LTDB-All Wagons.rf。

添加完成后,选中 LTDB-All Wagons.rf,点右键,选择 Assign to all,分配 给所有机车和车辆。

bject	simulation inspector						
Solv	ver Identifiers Initial conditions	Object variables	XVA	Informa	ation 1	Tools Train	
Options	Braking: No Traction Braking Tools Masses	Traction: User					
Track	Resistance Vehide positions Identific	ation					
Propu	Ision Curve	30011					
ope	Name	Pesistance model			Comment		Path
+		0.91*/2.4+0.000*	9.81*(2.4+0.009*v*3.6+0.00035*(v*3.6)* Standard Russian resistance 9.81*(0.7*M/1000+(3+0.09*v*3.6+0.002* Standard Russian resistance 9.81*(1+0.047*v*3.6+0.00016*(v*3.6)*(. Standard Russian resistance				
龠	Locdod freight car, long wolded rails	0.81*/0.7*M/1000					
	Evolution register and sold and sold	9.81 (0.7 14/1000					
	Passenger car, long-weided rails	9.81*(1+0.042***	1/01016	2 6 10 0025	Stanuaru R	ussian resistance	
	LTDR - Loading Locomptive	3.01 (0.7 %) 1000	0*4*20 2/M	10 0206*2	Stanuaru K	ussian resistance	Cult leare\Dub
		5.2 M (2.945+100	3.21M*(2.943+1000*6*89.2/M+0.0306*3.)				
		M*(2.945+1000*6	09.2/M+0.0	206*2.6*			C: JUsers (Pub
	LTDB - All Wagons Ass	gn to all	'89.2/M+0.0	300~3.0~VH			C: Users (Pub
-							>
N	- Vehicle	Resistan	ce model				^
1	LTDB-Loco Type 1	LTDB - A	Wagons				
2	LTDB-Loco Type 1	LTDB - All Wagons					
3	LTDB-Wagon Type 1	LTDB - A	LTDB - All Wagons LTDB - All Wagons LTDB - All Wagons				
4	LTDB-Wagon Type 1	LTDB - A					
5	LTDB-Wagon Type 1	LTDB - A					
6	LTDB-Wagon Type 1	LTDB - A	ll Wagons				
7	LTDB-Wagon Type 1	LTDB - A	- Il Wagons				
8	LTDB-Wagon Type 1	LTDB - A	l Wagons				
9	LTDB-Wagon Type 1	LTDB - A	ll Wagons				
10	LTDB-Wagon Type 1	LTDB - A	ll Wagons				
11	LTDB-Wagon Type 1	LTDB - A	l Wagons				
<			-				>
-							
	Integration	Messa	ge			Close	

图 2.19

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在下部列表,通过双击单元格操作分别将两个机车的阻力模型设置为 LTDB-Leading Locomotive.rf 和 LTDB-All Other Locomotive.rf, 如图 2.20 所示。

rack	Resistance	Vehicle positi	tions Identi	ification	
Propuls	sion Curve				
+	Name			Resistance model Comment	Path
-	Locomotive			9.81*(2.4+0.009*v*3.6+0.00035*(v*3.6)* Standard Russian resistance	æ
Ī	Loaded freight car, long-welded rails			9.81*(0.7*M/1000+(3+0.09*v*3.6+0.002* Standard Russian resistance	e
	Empty freight car, long-welded rails			9.81*(1+0.042*v*3.6+0.00016*(v*3.6)*(v Standard Russian resistance	e
	Passenger of	ar, long-weld	ded rails	9.81*(0.7*M/1000+(8+0.16*v*3.6+0.0023 Standard Russian resistance	e
	LTDB - Lead	ing Locomotiv	ve	3.2*M*(2.943+1000*6*89.2/M+0.0306*3.0	C:\Users\Pub
	LTDB - All Other Locomotives			M*(2.943+1000*6*89.2/M+0.0306*3.6*v+	C:\Users\Pub
	LTDB - All W	agons		M*(2.943+1000*4*89.2/M+0.0306*3.6*v+	C:\Users\Pub
	1				
Vehicle	<			Resistance model	>
Vehick	e Loco Type 1			Resistance model	>
Vehick LTDB-I LTDB-I	e Loco Type 1 Loco Type 1			Resistance model LTDB - Leading Locomotive LTDB - All Other Locomotives	、
Vehick LTDB-I LTDB-I LTDB-I	e Loco Type 1 Loco Type 1 Wagon Type	1		Resistance model LTDB - Leading Locomotive LTDB - All Other Locomotives LTDB - All Wagons	<u>)</u> 〕换
Vehide LTDB-I LTDB-I LTDB-I	e Loco Type 1 Loco Type 1 Wagon Type Wagon Type	1		Resistance model LTDB - Leading Locomotive LTDB - All Other Locomotives LTDB - All Wagons LTDB - All Wagons	<u>)</u> 换
Vehick LTDB-I LTDB-I LTDB-I LTDB-I	e Loco Type 1 Loco Type 1 Wagon Type Wagon Type Wagon Type	1 1 1		Resistance model LTDB - Leading Locomotive LTDB - All Other Locomotives LTDB - All Wagons LTDB - All Wagons LTDB - All Wagons LTDB - All Wagons	<u>)</u> 〕换
Vehick LTDB-I LTDB-I LTDB-I LTDB-I LTDB-I	e Loco Type 1 Loco Type 1 Wagon Type Wagon Type Wagon Type Wagon Type	1 1 1 1 1 1		Resistance model LTDB - Leading Locomotive LTDB - All Other Locomotives LTDB - All Wagons	<u>)</u> 〕换

图 2.20

转到 Train | Options | Resistance | Curve 页面,选择曲线阻力模型 F=a/(R-b), 设置系数 a=6116, b=0。

Object simu	lation inspecto	or					
Solver	Identifiers	Initial conditions	Object variables	XVA	Information	Tools	Train
🖻 🖻	Braking: No	o Tr	raction: User				
Options Tra	action Braking	Tools Masses					
Track Res	sistance Vehicle	positions Identificatio	n				
Propulsion	Curve						
Resistance	e in curve						
Force m	nodel: a/(R-b)						
Coefficie	ents						
a: 611	16 b: 0						
			图 221				

图 2.21

设置车辆位置

定位到 Train | Options | Vehicle positions 页面,设置头车的初始位置为 **3011.475m** °





Solver	Identifiers	Initial cond	tions	Object variables	XVA	Information	Tools	Train
≥ 8	Braking: N	lo	Trac	tion: User				
Options Tra	action Braking	Tools Masse	s					
Track Res	sistance Vehicle	e positions Ider	tification					
Position of t	he first car, m:	3011.4	75					

图 2.22

创建变量列表

选择主菜单 Tools | List of variables, 出现一个列表, 用于储存变量, 可以分 组管理, 如图 2.23 所示。

list of varial	les	
🖻 🖻 📑) 🏝 📇 🗐	
No name		
Name	Comment	
]

图 2.23

点击 一按钮,修改列表缺省变量组名称为 Locomotives,点击 OK,如图 2.24 所示。

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List of variab	oles <mark>, [ĂII], <mark>=</mark>ĬII], ≣</mark>	*			
comotives					
lame	Comment				
Rename pag	e			×	
Rename page			O	к	
Locomotives			Can	icel	
		図 2	21.		Х в

选择菜单 Tools | Wizard of variables,打开变量向导,在 Linear variables 页面依次定义两节机车的位移(Coordinate)、速度(Velocity)和加速度(Acceleration)变量,如图 2.25 所示。

🔄 Wizard of variables							x		
a+b Expression Train	User variables	🕀 Reactions	Coordinates	🕑 Solver v	variables 📑 Al	forces id Identifi	iers		
🥩 Variables for group of	bodies 🙎	Joint forces	🚀 Bipolar forces	s 🛆 An	gular variables	💒 Linear variable	25		
 Itdbtrain Vehide Vehide Vehide Vehide Vehide StDB-Loco Type: Vehide StDB-Wagon Typ Vehide Vehide Vehide Vehide Vehide Vehide Vehide Vehide 		ielected (total 2) /ehide, Vehide Coordinates of point in the body-fixed frame of reference 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0							
 Vehide October Vehide October Vehide October Vehide October Vehide Vehide Vehide Vehide Vehide Vehide Vehide October Vehide Octob	on Typ	mponent) X (isolved in SC of bo se0 lative to body se0	Or (ody)z	0111	Ov			
a:x(Vehicle,) r:x(1. LTDB-Loc r:x(2. LTDB-Loc v:x(1. LTDB-Loc v:x(2. LTDB-Loc a:x(1. LTDB-Loc a:x(2. LTDB-Loc	Accelera	tion of point (0,0,	0) of body (Vehicle,) relative to	Base0, SC Base0,	projection X			

图 2.25

将这些变量全部框选,并拖入变量列表 Locomotives 变量组,如图 2.26 所示。

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图 2.26

在变量列表窗口,点击按钮[+,添加一个变量组,命名为 Coupler forces。

list of vari	ables	- • ×
🗁 🖪 E	± × = + =>	
Locomotives	Coupler forces	
Name	Comment	
	图 2.27	

回到变量向导窗口,切换到 Train 页面,定义第 2、25 和 51 三个车的车钩力(FCoupling),并拖入变量列表中的 Coupler forces 变量组。



图 2.28





接下来我们还要创建 Traction force, Resistance 和 Throttle position 三组变量。

请按上面介绍的方法在变量列表添加三个变量组,分别命名为 Traction

force, Resistance 和 Throttle position。

然后,从变量向导定义两个机车的相应变量,如图 2.29-图 2.31 所示,分别 拖入所属的变量组。

Variables for group of	fbodies	🔍 Joint forces	🔊 Bipolar forces	🛕 Angular variable	es 🛛 🛃 Linear variable
• Expression Train	User variat	oles 🎌 Reactions	Coordinates	🕑 Solver variables 🛛 🗏	Call forces id Identifi
🗉 🔳 Itdbtrain	^	Selected (total 2)			
Vehicle 1, LTDB	-Loco T	LTDB-Loco Type 1, LT	DB-Loco Type 1		
Vehicle 2, LTDB	3-Loco T 3-Wagor 3-Wagor	Name Forces	Comment		
Vehicle 5, LTDB	-Wagor	FCoupling	Force in wagor	connections	
···· 📃 Vehicle 6, LTDB	-Wagor	FBrake	Braking force		
···· 📃 Vehicle 7, LTDB	8-Wagor	LoadForce	Load force "bra	ake pad-wheel"	
···· 📃 Vehicle 8, LTDB	3-Wagor	PropulsionResistance	Propulsion resi	stance	
Vehicle 9, LTDB	-Wagor	GradeResistance	Grade resistan	ce	
Vehicle 10, LTD	B-Wago	CurveResistance	Curve resistan	ce	
Vehicle 11, LTD	B-Wago	RealizedTractionForce	e Realized tractio	on or brake force in consi	ideration of adhesion limit
Vehicle 12, LTD	B-Wago	Pressures			
Vehicle 13, LTD	B-Wago	BCPressure	Brake cylinder	pressure	
Vehide 14, LTD	08-Wagc 08-Wagc	General variable	s		
Vehicle 16, LTD	B-Wago	InrottlePosition	Inrottle positio	n - Com the simulation ato	
Vehicle 17, LTD	B-Wago	Distance	venicie distanc	e from the simulation sta	n
Vehicle 18, LTD	B-Wago	Speed history m	ode		
Vehicle 19, LTD	B-Wage	ControlForce	Control force (traction or braking force))
	>	<			>
alizedTractionForce(LTDB-	-Loco 1 Rea	lized traction or brake f	force in consideration o	f adhesion limit	7
alizedTraction alizedTraction					





🛱 Wizard of variables										×	
🥩 Variables for group of bod	es	🔍 Joint forces 🛛 🔗		Bipolar forces		🛕 Angular variables		1	🛃 Linear vari		
a+b Expression Train Use	r variable:	s 🕀 Reactions	1 0	Coordinates	۲	Solver variables	1	All forces	id Ide	ntifiers	
🖃 🔳 Itdbtrain	∧ Se	elected (total 2)									
Vehicle 1, LTDB-Loco	т	TDB-Loco Type 1, LT	DB-Loco	o Type 1							
Vehicle 2, LTDB-Loco		lame		Comment						^	
Vehicle 3, LTDB-Wag	lor .	Eorgos		commerte							
Vehicle 4, LTDB-Wag	lor E	Forces									
Vehicle 5, LTDB-Wag	or F	Coupling		Porce in wag	jon c a	onnections					
Vehicle 7, LTDB-Wag	ior I	oadEorce	e nad-wheel"								
Vehicle 8, LTDB-Wag	or P	ropulsionResistance		Propulsion re	esista	ance					
Vehicle 9, LTDB-Wag	jor G	GradeResistance		Grade resist	ance	1					
Vehicle 10, LTDB-Wa	igc C	CurveResistance	Curve resistance								
Vehicle 11, LTDB-Wa	igc R	ealizedTractionForce	e	Realized trac	ction	or brake force in o	conside	ration of a	dhesion lim	nit	
Vehicle 12, LTDB-Wa	gc	Pressures								- 1	
Vehicle 13, LTDB-Wa	gc B	CPressure		Brake cylinde	er pro	essure					
Vehicle 14, LTDB-Wa	gc	General variable	s —							- 1	
Vehicle 15, LTDB-Wa	Vehicle 15, LTDB-Wage ThrottlePosition				Throttle position						
Vehicle 10, LTDB-Wa		Vehicle distance from the simulation start									
Vehicle 18, LTDB-Wa	igc i	Speed history m	ode –								
Vehicle 19, LTDB-Wa	gc	optrolEorce		Control force	e (tra	action or braking fr	arce)				
<	>			Control for Co	- (00	sedon of braking it	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			> [×]	
CurveResistance(LTDB-Loco Type	Curve	resistance							8	7	
PropulsionResist											
PropulsionResist CradeResistanc											
GradeResistanc											
CurveResistanc											
Curvekesistanc											
			_								

图 2.30





🛱 Wizard of variables							×
🦻 Variables for group of bodies 🛛 🔍	Join	t forces	🔊 Bipolar forces	🛆 Angul	ar variables	1	Linear variables
a+b Expression Train User variables	ᠿ	Reactions	Coordinates	Solver varia	ables 🛛 茸	All forces	id Identifiers
📄 🔳 2. LTDB-Loco Type 1	^	Selected ((total 4)				
CouplingBase		throttle_p	osition, dynamic_brał	e_position, thro	ttle_position,	dynamic_	brake_position
···· WheelRadius							
Mass							
AxleOver							
CouplingLength							
BODYZ							
BogieBase							
WheelDistance							
CouplingPoint							
CouplingHeight							
🗖 h							
···· 🗹 throttle_position							
n_throttle_positions							
···· 🗹 dynamic_brake_position							
throttle_x_factor							
throttle_y_factor							
braking_x_tactor							
	۷.						
throttle_position, throttle_p	ositio	on,					P
1. LTDB-Loco Ty							
1. LTDB-Loco Ty							
2. LTDB-Loco Ty 2. LTDB-Loco Ty							
•							
	_						

图 2.31

点击 [□]按钮,保存变量列表,缺省与模型同名(LTDBTrain.var)。

关闭变量列表和变量向导。

现在,请回到仿真控制界面,定位到 Object variables 页面,加载刚才定义的变量列表,并确认 Automatic saving of variables 选项为勾选,否则计算过程中不会保存任何数据。

为了在仿真过程中实时观察各个指标,可以添加五个绘图窗口,并将之前定 义的五组变量分别拖入,如图 2.32 所示。











2.4 列车动力学仿真

通过前面的一系列操作,就完成了列车模型仿真工况的配置,仿真界面如图 2.33 所示。



图 2.33

点击 Integration 或按 F9 键,开始仿真。

第一次计算会遇到图 2.34 所示的提示窗口,这是因为最后一节车辆尾部的 钩缓力元未其他连接物体,勾选 Do not show this window anymore,并点击 Continue。

Iurned of	f forces	_	×
52. LTDB-Wagon	Type 1.RearCou	pling	\sim
			\sim
Do not show	this window any	more	
Interrupt	Continue	1	
Interrupt	Continue	J	
	图 2.	34	





2.5 仿真结果

计算完毕后,机车速度、实际的牵引/制动力、阻力以及牵引级位和制动把 位如图 2.35-图 2.39 所示。



图 2.36







图 2.38

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3.4







参考文献

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