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APPENDIX A

The industrial data of the production of T41Ti steel grade in Dillinger Huette GTS, Germany

Heat No.2762258												Steel quality T41Ti																			
operation	time	temp.	addition									steel analysis										slag analysis									
			CaO	Al-dp.	Al-wire	C	Ti	MgO	ElMn	Ar	st wt.	%C	%Si	%Mn	%P	ppmS	%Al	ppmN	ppmO	%Ti	slag wt.	%CaO	%SiO2	%Al2O3	%S	%Fe	%MgO	%P2O5	SAT.	BAC
Tapping	13.58	1694									177.9	0.02	0.006	0.116	0.011	69	#	18	759	#	#	56.12	10.17	0.604	0.051	18.78	1.38	1.56	1.116	5.52
begin	14.02																														
finish	14.08					15		150	60																						
Homoginizing																															
begin										1200 l.																					
finish	14.28	1633																													
Vacuum	14.30	1627									178.2	0.014	0.006	0.101	0.007	98	0.005	31	519	#											
begin	14.32																														
	14.42		400	150																				typical slag composition							
finish	14.57																														
	15.02	1611																	231			56	3	28	#	2	8	#	1.095	18.667
	15.05		340	85	166																										
												0.003	0.006	0.123	0.009	89	0.042	35		#											
Alloy strand	15.19				26																										
	15.24						254																								
	15.29	1597										0.004	0.01	0.133	0.009	64	0.032	39	#	0.084											
	15.35				45																										
Casting-begin	15.55																														
tundish	16.04	1567																													
	16.30											0.004	0.016	0.131	0.010	56	0.041	37	21	0.076											
	16.51											0.004	0.015	0.131	0.010	55	0.040	36	#	0.075											
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.08											
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08											
T-liquidus	1533																														
T-casing	1573																														
Vacuum period	20 min.																														

table A1

Heat No.2762259											Steel quality T41TI																				
operation	time	temp.	addition								steel analysis										slag analysis										
			CaO	Al-dp.	Al-wire	C	Ti	MgO	ElMn	st wt.	%C	%Si	%Mn	%P	ppmS	%Al	ppmN	ppmO	%Ti	%CaO	%SiO2	%Al2O3	%S	%Fe	%MgO	%P2O5	SAT.	BAC		
Tapping	15.03	1681								179.5	0.019	0.006	0.110	0.010	69	#	16	816	#	57.63	11.21	0.855	0.052	13.32	1.30	1.61	1.148	5.142		
begin	15.06																													
finish	15.12					20		150	70																					
Homoginizing																														
finish	15.16	1644																												
Vacuum	15.22	1630								180.1	0.018	0.005	0.104	0.006	68	0.005	#	533	#											
begin	15.25																													
	15.29		399	166																										
finish	15.49																													
	15.56	1613	350	48	100													53												
											0.003	0.009	0.124	0.007	53	0.055	33		#											
Alloy strand	16.12						269																							
	16.23	1590									0.003	0.012	0.121	0.007	53	0.045	33	3	0.091											
	16.29				23																									
Casting-begin	16.56																													
	16.59	1546																												
	17.36										0.004	0.017	0.123	0.007	36	0.041	37	15	0.078											
	17.59										0.004	0.002	0.123	0.007	33	0.040	34	15	0.078											
Steel quality	T41TI									min	0.000	0.000	0.090	0.000	0	0.02	0		0.06											
composition										max	0.004	0.030	0.180	0.012	120	0.05	50		0.08											
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A2

Heat No.2762263												Steel quality T41TI																
operation	time	temp.	addition									steel analysis								slag analysis								
			CaO	Al-dp.	Al-wire	C	Ti	MgO	FeMn	Ar	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.	BAC
Tapping	18.03	1711									180.3	0.021	0.001	0.105	0.012	66	#	27	901	#	59.67	10.3	0.73	0.049	15.7	1.50	1.59	1.17	5.79
begin	18.06										t	%	%	%	%	ppm	%	ppm	ppm	%	%	%	%	%	%	%	%	%	%
finish	18.13					30		160																					
	18.14	1675																											
Vacuum	18.53	1633									181	0.019	0.007	0.116	0.010	70	#	33	522	#									
begin	18.55																												
	18.56			158																									
	18.58		400																										
finish	19.19																												
	19.25	1617		40															42										
	19.26		299																										
	19.28		48		100																								
	19.31											0.002	0.009	0.124	0.011	62	0.056	31		#									
Alloy strand	19.43						258																						
	20.10						23																						
end	20.11											0.003	0.012	0.129	0.011	51	0.043	41	#	0.088									
ladle	20.15	1593																											
Casting-begin	20.30																												
	20.37	1564																											
	20.57											0.004	0.016	0.129	0.011	40	0.038	39	19	0.082									
	21.12											0.003	0.016	0.128	0.011	37	0.041	37	16	0.083									
Steel quality	T41TI										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06									
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08									
T-liquidus	1533																												
T-casing	1573																												
Vacuum period	20 min.																												

table A3

Heat No.2762264												Steel quality T41Ti																		
operation	time	temp.	addition									steel analysis									slag analysis									
			CaO	Al-dp.	Al-wire	C	Ti	MgO	FeMn	Ar	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.	BAC
Tapping	18.58	1698									187.5	0.027	0.007	0.144	0.009	47	#	18	738	#	58.06	11.49	0.714	0.039	15.83	1.23	1.583	1.123	5.053
begin	19																													
finish	19.06					15		160																						
Vacrum	19.38																													
	19.40	1629																												
	19.43	1622									188.1	0.026	0.008	#	0.007	53	#	#	485	#										
begin	19.45																													
	19.46			151																										
	19.48		401																											
finish	20.10																													
	20.16	1605		49															116											
	20.18		349																											
	20.21				110																									
												0.003	0.01	0.123	0.01	63	0.042	20		#										
Alloy strand	20.32				26																									
	20.35						268																							
	20.42	1596										0.003	0.01	0.127	0.01	49	0.038	28	4	0.088										
	20.50				34																									
end	20.58																													
Casting-begin	21.20																													
	21.25	1569																												
	22.10											0.004	0.015	0.130	0.010	33	0.038	27	18	0.079										
	22.13											0.004	0.017	0.129	0.011	34	0.037	28	18	0.075										
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06										
composition											max	0.004	0.030	0.160	0.012	120	0.05	50		0.08										
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A4

Heat No.2762265												Steel quality T41Ti																		
operation	time	temp.	addition									steel analysis									slag analysis									
			CaO	Al-dp.	Al-wire	C	Ti	MgO	ElMn	Ar	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.	BAC
Tapping	20.31	1694									185.6	0.025	0.001	0.144	0.009	49	#	30	703	#			no slag analysis						
begin	20.34																													
finish	20.40					10		145																						
Vacuum	20.47																													
	20.48	1643									186.2	0.020	0.006	0.121	0.009	53	0.001	23	541	#									
begin	20.50																													
	20.51			163																										
	20.53		401																											
finish	21.15																													
	21.21	1619																	173											
	21.23		351	49																										
	21.24			120																										
	21.28											0.003	0.010	0.131	0.010	54	0.035	31		#										
Alloy strand	21.37				40																									
	21.39						20																							
	21.42						246																							
	21.46	1607										0.004	0.011	0.136	0.011	40	0.037	38	6	0.086										
	21.55				36																									
end	22.03																													
Casting-begin	22.17																													
	22.22	1568																												
	22.58											0.003	0.017	0.140	0.011	25	0.038	35	#	0.076										
	23.18											0.003	0.018	0.142	0.011	24	0.039	34	18	0.076										
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06										
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08										
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A5

Heat No.2762262												Steel quality T41Ti																
operation	time	temp.	addition									steel analysis									slag analysis							
			CaO	Al-dp.	Al-wire	C	Ti	MgO	FeMn	Mnaf	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.	BAC
Tapping	10.03	1698									183.7	0.03	0.005	0.164	0.012	77	#	18	660	#	59.06	11.27	0.78	0.058	14.9	1.99	1.76	1.14	5.24
begin	10.06																												
finish	10.11							150																					
Homoginizing																													
begin																													
finish																													
Vacuum	10.25	1649									184	0.020	0.005	0.127	0.010	89	0.004	22	591	#									
begin	10.27																												
	10.36		401	180																									
finish	10.51																												Mn
	10.55	1628																	28		57.69	2.64	29.28	0.199	1.29	9.39	0.04	1.11	0.34
	10.56			49																									
	10.57		348									0.003	0.006	0.14	0.011	90	0.01	27		#									
	10.58			27	72																								
Alloy strand	11.12				89																								
	11.15						259																						
	11.23	1619										0.004	0.014	0.145	0.011	67	0.091	35	3	0.068									
	11.36	1609										0.004	0.02	0.147	0.012	55	0.087	36	3	0.066									
end	11.50																												
ladle	11.53	1602																											
Casting-begin	12.04																												
	12.10	1575																											
	12.33											0.004	0.039	0.146	0.012	19	0.047	36	19	0.066									
	12.50											0.004	0.040	0.149	0.012	18	0.048	35	#	0.068									
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06									
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08									
T-liquidus	1533																												

table A6

Heat No.2762283											Steel quality T41Ti																			
operation	time	temp.	addition								steel analysis									slag analysis										
			CaO	Al-dp.	Al-wire	C	Ti	MgO	ElMn	Mnsf	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.	BAC
Tapping	10.46	1686									186.8	0.028	0.006	0.121	0.009	66	#	15	574	#	61.36	10.87	0.85	0.044	14.2	1.91	1.54	1.17	5.64
begin	10.52																													
finish	10.57							150																						
Vacuum	11.15	1620									188.1	0.017	0.009	0.099	0.007	93	0.005	26	429	#										
begin	11.17																													
	11.35		403	145																										
finish	11.41																													
	11.49	1595																			50.53	10.68	4.76	0.084	#	3.35	1.1	1.07	4.732
	11.52		351	52																					Mn				
	11.55				130																				3.81				
	11.58	1596																												
Alloy strund	12.26						259																							
	12.30											0.004	0.007	0.112	0.011	92	0.009	27	4	0.079										
	12.36				87																									
end	12.37																													
ladle	12.54	1658																												
Casting-begin	12.55																													
	13.31											0.004	0.012	0.120	0.012	67	0.034	27	#	0.062										
	13.56											0.005	0.013	0.118	0.012	65	0.036	28	#	0.063										
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06										
compositon											max	0.004	0.030	0.160	0.012	120	0.05	50		0.08										
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A7

Heat No.2762284												Steel quality T41Ti																		
operation	time	temp.	addition									steel analysis									slag analysis									
			CaO	Al-dp.	Al-wire	C	Ti	MgO	ElMn	Mnaf	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.	BAC
Tapping	12.08	1695									178.9	0.021	0.005	0.132	0.012	40	#	18	700	#	63.71	9.65	0.61	0.029	14.1	1.67	1.23	1.22	6.6
begin	12.10																													
finish	12.15							150																						
Vacuum	12.24	1651									179.3	0.010	0.005	0.102	0.007	90	0.004	26	565	#										
begin	12.27																													
	12.33		398	192																										
finish	12.50																													
	12.54		351																											
	12.55	1613		50															222											
	12 57											0.002	0.014	0.111	0.007	114	0.008	20		#										
	12.58				140																									
Alloy strand	13.08						43																							
	13.12						38																							
	13.29						63																							
	13.32						87																							
	13.37	1598										0.002	0.014	0.129	0.012	58	0.016	35	4	0.064										
	13.41						29																							
	13.44				77																									
end	13.55																													
Casting-begin	14.02																													
	14.10	1568																												
	14.44											0.004	0.020	0.130	0.011	38	0.039	35	20	0.064										
	15.03											0.003	0.023	0.129	0.012	34	0.036	34	20	0.058										
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.08										
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08										
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A8

Heat No.2762268												Steel quality T41Ti																		
operation	time	temp.	addition									steel analysis									slag analysis									
			CaO	Al-dp.	Al-wire	C	Ti	MgO	FeMn	Mnaf	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.	BAC
Tapping	1516	1715									183.3	0.022	0.006	0.126	0.011	39	#	21	853	#	61.05	11.6	1.08	0.04	15.1	1.54	1.58	1.15	5.26
begin	15.17																													
finish	15.22																													
	15.23					25		150																						
Vacuum	15.53	1641									183.8								531	#									
	15.54		399	167																										
begin	15.55																													
finish	16.19		349	42																										
	16.25	1625																												
	16.27	1621																	191											
	16.30				135																									
	16.33											0.003	0.009	0.106	0.009	54	0.048	31		#										
Alloy strand	16.46				14																									
	16.53						261																							
	16.58	1612										0.004	0.01	0.110	0.01	47	0.040	33	#	0.091										
	17.04				29																									
end	17.05																													
ladle	17.06	1605																												
Casting-begin	17.19																													
	17.28	1577																												
	17.46											0.004	0.016	0.108	0.009	36	0.040	34	23	0.060										
	18.03											0.004	0.017	0.108	0.010	35	0.040	35	19	0.062										
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06										
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08										
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A9

Heat No.2762289												Steel quality T41Ti																		
operation	time	temp.	addition									steel analysis									slag analysis									
			CaO	Al-dp.	Al-wire	C	Ti	MgO	FeMn	scrap	st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.	BAC
Tapping	16.15	1693									173.5	0.032	0.006	0.122	0.01	75	#	22	700	#	56.45	12.67	1.7	0.052	14.9	2.22	1.87	1.09	4.46
begin	16.19																													
finish	16.23					20		150	50																					
Vacuum	16.39	1637									173	0.032	0.006	0.126	0.009	90	0.001	#	433	#									
	16.43									570																				
begin	16.45		399																											
	16.47			116																										
	16.49		348	55																										
finish	17.11																					/								
	17.16	1593																	93											
	17.19				105																									
	17.23											0.002	0.010	0.143	0.011	94	0.069	25		#										
Alloy strand	17.34						247																							
	17.42	1567										0.003	0.014	0.145	0.011	83	0.059	33	3	0.095										
end	17.49																													
Casting-begin	16.09																													
	16.10	1570																												
	16.43											0.004	0.022	0.143	0.011	59	0.043	34	21	0.089										
	19.02											0.004	0.019	0.146	0.011	57	0.043	34	23	0.090										
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06										
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08										
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A10

Heat No 2762290												Steel quality T41Ti																		
operation	time	temp.	addition									steel analysis									slag analysis									
			CaO	Al-dp.	Al-wire	C	Ti	MgO	ElMn		st wt.	C	Si	Mn	P	S	Al	N	O	Ti	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.	BAC
Tapping	17.26	1702									181.9	0.021	0.006	0.146	0.01	46	#	22	#	#	58.56	11.4	1.25	0.044	14.8	1.66	1.65	1.14	5.13
begin	17.30																													
finish	17.36					20		150																						
			CaO	Al-dp.	Al-wire	C	Ti	MgO	ElMn																					
Vacuum	17.44	1648									183								627										
begin	17.45		400	197																										
	17.47			44																										
	17.49		349																											
finish	18.11																													
	18.16	1614																	97											
	18.19				105																									
	18.22											0.003	0.015	0.136	0.011	59	0.047	30		#										
Alloy strand	13.32				15																									
	18.36						259																							
	18.43	1602										0.004	0.016	0.137	0.011	58	0.043	32	6											
	18.47				27																									
end	18.48																													
Casting-begin	19.06																													
	19.12	1566																												
	19.47											0.004	0.021	0.139	0.012	46	0.046	31	23	0.087										
	20.06											0.004	0.023	0.137	0.011	41	0.046	33	18	0.087										
Steel quality	T41Ti										min	0.000	0.000	0.090	0.000	0	0.02	0		0.06										
composition											max	0.004	0.030	0.180	0.012	120	0.05	50		0.08										
T-liquidus	1533																													
T-casing	1573																													
Vacuum period	20 min.																													

table A11

APPENDIX B

The industrial data of the production of F56NBV steel grade in Dillinger Huette GTS, Germany

Heat No.1763548													Steel quality F56NBV																
operation	time	temp.	addition										steel analysis										slag analysis							
			CaO	Al-dp.	Al-wire	C	MnAf	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.
Tapping	15.20	1716											186.9	0.025	0.001	0.167	0.011	0.0156	#	#	0.002	3E-04	53.15	15.34	0.79	0.11	13	2.35	1.7	1.03
begin	15.22																													
	15.23		1340				296		786																					
	15.24									2268	79	82																		
	15.25			279																										
finish	15.28							75																						
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT
Vacuum	15.49	1635											187.2	0.062	0.209	1.448	0.012	0.0113	0.048	0.0045	0.037	0.028	58.59	8.66	19	0.388	1.23	10.3	0.01	1.05
	15.51						1510																							
begin	15.53							58																						
	15.55																													
	15.57			99																										
	16.00					18				141																				
	16.01								157																					
finish	16.06																													
	16.10	1602																												
	16.11												2	0.079	0.276	1.517	0.012	0.0010	0.02	0.0033	0.037	0.028								
					Al-wire	Nb			MnAf	FeSi	CaSi																			
Alloy strand	16.29				60																									
	16.31										50																			
	16.33					18			60	50																				
end	16.34																													
ladle	16.37	1589																												
Casting-begin	16.51																													
	17.01	1558																												
	17.14												1	0.087	0.309	1.549	0.014	0.0011	0.034	0.0046	0.037	0.036								
	17.28												3	0.086	0.311	1.543	0.013	0.0010	0.038	0.0037	0.037	0.036								
Steel quality	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032								
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038								
T-liquidus	1519																													
T-casing	1574																													
Vacuum period	10																													

table B1

Heat No.1763550														Steel quality F56NBV															
operation	time	temp.	addition											steel analysis										slag analysis						
			CaO	Al-dp.	Al-wire	C	MnAl	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5
Tapping	16.43	1678											191.1	0.027	0.001	0.128	0.008	0.0207	#	0.0027	0.002	3E-04	51.75	12.62	0.97	0.153	18.0	2.37	1.58
begin	16.45								862																				
	16.46		1290				318			2276	82	87																	
	16.47			297																									
finish	16.50							75																					
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5
Vacuum	17.10	1607											191.9	0.069	0.200	1.424	0.011	0.0147	0.053	0.0046	0.037	0.029	58.93	9.04	19.35	0.571	1.12	7.3	0.02
	17.11							46																					
begin	17.12																												
	17.16			89																									
	17.18								250	211																			
finish	17.25																												
	17.29	1586											2	0.072	0.296	1.559	0.011	0.0019	0.017	0.0037	0.038	0.030							
					Al-wire	Nb			MnAl	FeSi	CaSi																		
Alloy strand	17.39										9																		
	17.40				3						1																		
	17.56				60																								
	18.00					10					149																		
end	18.01																												
Casting-begin	18.20																												
	18.27	1540																											
	18.50												1	0.075	0.3420	1.556	0.0120	0.0016	0.037	0.0040	0.038	0.034							
	19.05												3	0.075	0.3460	1.547	0.0120	0.0016	0.037	0.0460	0.038	0.034							
Steel quality	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032							
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038							
T-liquidus	1519																												
T-casing	1559																												
Vacuum period	10																												

table B2

Heat No.1763551													Steel quality F56NBV															
operation	time	temp.	addition										steel analysis									slag analysis						
			CaO	Al-dp.	Al-wire	C	MnAf	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5
Tapping	17.21	1731											183.2	0.025	0.0010	0.150	0.0130	0.0211	#	0.0024	0.002	0.0003	49.12	12.94	1.03	0.131	19.3	2.17	1.64
begin	17.23		1390				328		858	2254																			
	17.24										82	82																	
	17.25			299																									
finish	17.28							75																					
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5
Vacuum	17.42	1654											183.5	0.068	0.1690	1.485	0.0140	0.008	0.029	0.0060	0.040	0.029	57.54	14.89	20.18	0.622	0.54	6.01	0
begin	17.44																												
	17.46			204																									
	17.51								180	224																			
finish	17.57																												
	18.01	1625											2	0.075	0.2980	1.534	0.0160	0.002	0.018	0.0038	0.040	0.031							
				Al-dp.	Al-wire	Nb			MnAf	FeSi	CaSi																			
Alloy strand	18.19					10																							
	18.35				35																								
	18.42										5																		
	18.45			40																									
	18.47										149																		
end	18.48																												
Casting-begin	19.06																												
	19.13	1552																											
	19.36												1	0.078	0.3610	1.553	0.0160	0.0014	0.040	0.0049	0.040	0.035							
	19.52												3	0.077	0.3570	1.548	0.0160	0.0016	0.040	0.0047	0.040	0.034							
Steel quality	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032							
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038							
T-liquidus	1519																												
T-casing	1559																												
Vacuum period	10																												

table B3

Heat No.1763553														Steel quality F56NBV																		
operation	time	temp.	addition											steel analysis											slag analysis								
			CaO	Al-dp.	Al-wire	C	MnAf	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.		
Tapping	18.30	1701											185.1	0.022	0.001	0.130	0.01	0.0213	#	0.0025	0.002	3E-04	52.67	12.87	0.98	0.147	17.2	1.97	1.73	1.04		
begin	18.33		1300						878																							
	18.34						264			2258	84	86																				
	18.35			264																												
finish	18.38							75																								
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi	CaSi		st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.		
Vacuum	19.07	1612											185.9	0.067	0.193	1.468	0.013	0.0089	0.040	0.0045	0.040	0.03	58.5	11.46	19.47	0.667	0.9	6.73	0.01	0.98		
	19.08						1590																									
begin	19.11		89																													
	19.14			139																												
	19.16								181	206																						
finish	19.24																															
	19.27	1578											2	0.076	0.300	1.529	0.013	0.0009	0.018	0.0034	0.04	0.03										
	19.34				54																											
	19.35										49																					
	19.36								47																							
Casting-begin	19.54																															
	19.59	1556																														
	20.22												1	0.062	0.328	1.576	0.014	0.0013	0.042	0.0035	0.04	0.034										
	20.39												3	0.075	0.326	1.583	0.014	0.0011	0.042	0.0038	0.04	0.034										
Steel quality	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032										
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038										
T-liqiudus	1519																															
T-casing	1559																															
Vacuum period	10																															

table B4

Heat No.1763554														Steel quality F56NBV																
operation	time	temp.	addition											steel analysis									slag analysis							
			CaO	Al-dp.	Al-wire	C	MnAf	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.
Tapping	19.06	1698											187.1	0.024	0.001	0.159	0.016	0.0235	#	0.0029	0.002	3E-04	49.19	10.76	1.35	0.161	20	2.39	1.74	1.03
begin	19.09																													
	19.10		1310				248		884	2278	78	88																		
	19.11			269																										
finish	19.14							75																						
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.
Vacuum	19.43	1612											187.6	0.069	0.201	1.435	0.013	0.0157	0.057	0.0052	0.037	0.031	60.6	8.18	18.58	0.273	1.39	5.33	0.02	1.09
	19.45						1060																							
	19.46							110																						
begin	19.47																													
	19.49			101																										
	19.52								246	204																				
finish	20.00																													
	20.03	1581											2	0.078	0.309	1.573	0.014	0.0009	0.02	0.0027	0.038	0.031								
				Al-dp.	Al-wire	Nb			MnAf	FeSi	CaSi																				
Alloy strand	20.24										49																			
end	20.27																													
Casting-begin	20.42																													
	20.47	1552																												
	21.10												1	0.078	0.343	1.595	0.015	0.0011	0.038	0.0039	0.038	0.036								
	21.27												3	0.076	0.345	1.601	0.015	0.0010	0.039	0.0040	0.037	0.037								
Steel quality	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032								
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038								
T-liqludus	1519																													
T-casing	1559																													
Vacuum period	10																													

table B5

Heat No.1763555													Steel quality FS6NBV																
operation	time	temp.	addition										steel analysis									slag analysis							
			CaO	Al-dp.	Al-wire	C	MnAf	MgCl	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.
Tapping	19.42	1696											185.7	0.025	0.001	0.147	0.011	0.0224	#	0.0032	2E-03	3E-03	51.89	9.33	1.18	0.171	21	2.05	1.59	1.06
begin	19.43																													
	19.44		1300				222		856	2232	81	81																		
	19.45			286				76																						
finish	19.46																													
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.
Vacuum	20.15	1603											186.3	0.072	0.187	1.438	0.013	0.0099	0.045	0.0061	0.039	0.029	59.04	11.65	18.36	0.573	0.89	6.85	0.01	0.99
	20.16		201	134																										
begin	20.17																													
	20.23								199	194																				
finish	20.30																													
	20.33	1582																												
	20.34												2	0.072	0.286	1.536	0.013	0.0012	0.015	0.0041	0.039	0.030								
				Al-dp.	Al-wire	Nb			MnAf	FeSi	CaSi																			
Alloy strand	20.46				60																									
	20.48					14																								
	20.49										79																			
end	21.02																													
Casting-begin	21.28																													
	21.33	1548																												
	21.56												1	0.076	0.315	1.539	0.013	0.0013	0.037	0.0043	0.039	0.035								
	22.12												3	0.076	0.314	1.553	0.014	0.0014	0.035	0.0044	0.039	0.036								
Steel quality	FS6NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032								
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038								
T-liquidus	1519																													
T-casing	1559																													
Vacuum period	10																													

table B6

Heat No.1763556													Steel quality F56NBV																
operation	time	temp.	addition										steel analysis									slag analysis							
			CaO	Al-dp.	Al-wire	C	MnAl	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.
Tapping	20.20	1698											182.3	0.026	0.001	0.139	0.014	0.0242	#	0.0039	0.002	3E-04	50.71	10.03	1.1	0.163	21.1	2.33	1.76	1.05
begin	20.22																													
	20.23		1290				462		786	2254																				
	20.24			291							80	85																		
finish	20.27							75																						
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.
Vacuum	20.46	1616											182.7	0.067	0.189	1.503	0.011	0.0061	0.038	0.0067	0.035	0.032	57.3	11.18	20.58	0.722	0.65	7.87	0.01	0.96
begin	20.48		156																											
	20.51			130																										
	20.53							48	85	194																				
finish	21.01																													
	21.04												2	0.069	0.283	1.526	0.012	0.0013	0.015	0.0043	0.036	0.032								
				Al-dp.	Al-wire	Nb	C		MnAl	FeSi	CaSi																			
Alloy strand	21.16					5	10		50																					
	21.41				69																									
	21.43										99																			
end	21.48																													
Casting-begin	22.16																													
	22.20	1540																												
	22.44												1	0.075	0.319	1.545	0.012	0.0014	0.041	0.0045	0.036	0.036								
	22.56												3	0.076	0.320	1.552	0.012	0.0013	0.041	0.0045	0.036	0.037								
Steel quality composition	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032								
													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038								
T-liquidus	1519																													
T-casing	1559																													
Vacuum period	10																													

table B7

Heat No.1763558													Steel quality F56NBV																
operation	time	temp.	addition										steel analysis									slag analysis							
			CaO	Al-dp.	Al-wire	C	MnAl	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5
Tapping	21.29	1703											190.8	0.031	0.001	0.147	0.01	0.0239	#	0.0033	0.002	2E-04	48.73	10.21	1.22	0.187	20.2	2.34	1.79
begin	21.31																												
	21.32		1400				378		808	2252	83	81																	
	21.33			294																									
finish	21.36							75																					
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi	CaSi		st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5
Vacuum	21.52	1633											191	0.070	0.186	1.415	0.011	0.013	0.044	0.0063	0.038	0.028	60.27	10.3	18.76	0.508	0.77	5.57	0.01
	21.55						2190																						
begin	21.57							32																					
	21.59			111																									
	22.04								175	199																			
finish	22.10																												
	22.13	1592																											
	22.14												2	0.077	0.292	1.504	0.012	0.001	0.022	0.0043	0.039	0.028							
	22.22			46					159	39																			
	22.40	1580																											
	22.41										51																		
Casting-begin	23.01																												
	23.09	1550																											
	23.29												1	0.079	0.334	1.581	0.012	0.0010	0.044	0.0048	0.038	0.035							
	23.43												3	0.082	0.334	1.579	0.012	0.0010	0.044	0.0047	0.038	0.035							
Steel quality	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032							
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038							
T-liquidus	1519																												
T-casing	1559																												
Vacuum period	10																												

table B8

Heat No.1763559														Steel quality F56NBV																	
operation	time	temp.	addition											steel analysis										slag analysis							
			CaO	Al-dp.	Al-wire	C	MnAl	MgO	FeMn	SiMn	FeV	FeNb		st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.
Tapping	22.16	1695												188.6	0.027	0.001	0.146	0.012	0.0199	#	0.0028	0.002	2E-04	50.15	9.46	1.51	0.158	21.1	2.49	1.71	1.06
begin	22.18																														
	22.19		1250				312		880	2292	81	84																			
	22.20			295																											
finish	22.23							75																							
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi	CaSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO2	Al2O3	S	Fe	MgO	P2O5	SAT.
Vacuum	22.48	1614												188.9	0.075	0.191	1.469	0.014	0.0115	0.048	0.0049	0.037	0.029	58.86	10.77	19.5	0.517	0.91	7.04	0.01	1
	22.50						1040																								
begin	22.52			157					140	127																					
	22.59		52																												
finish	23.06																														
	23.10	1585												2	0.077	0.284	1.553	0.015	0.0008	0.026	0.0037	0.038	0.036								
	23.16				36																										
	23.17									38																					
	23.26	1577																													
	23.26										50																				
Casting-begin	23.51																														
	23.56	1557																													
	0.19													1	0.080	0.314	1.557	0.015	0.0008	0.040	0.0038	0.037	0.036								
	0.33													3	0.080	0.312	1.558	0.015	0.0009	0.040	0.0040	0.038	0.037								
Steel quality	F56NBV													min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032								
composition														max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038								
T-liquidus	1519																														
T-casing	1559																														
Vacuum period	10																														

table B9

Heat No.1763560														Steel quality F56NBV																			
operation	time	temp.	addition											steel analysis											slag analysis								
			CaO	Al-dp.	Al-wire	C	MnAf	MgO	FeMn	SiMn	FeV	FeNb		st wt.	C	Si	Mn	P	S.	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.
Tapping	23.04	1686												186.3	0.023	0.001	0.133	0.01	0.0223	#	0.0025	0.002	2E-04	48.7	12.4	1.13	0.148	18.8	2.02	1.84	1.00
begin	23.07		1290				408		802																							
	23.08									2282																						
	23.09			295							78	87																				
finish	23.12							75																								
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi	CaSi			st wt.	C	Si	Mn	P	S.	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.
Vacuum	23.35	1606												186.9	0.068	0.204	1.461	0.011	0.0159	0.062	0.0044	0.035	0.03	60.54	8.94	18.51	0.408	1.74	6.66	0.04	1.07
	23.37			145				113																								
begin	23.38								115	133																						
finish	23.54																															
	23.55	1585																														
	23.56																															
	0.02													2	0.07	0.296	1.53	0.012	0.0009	0.030	0.0033	0.039	0.034									
	0.03				30				36																							
	0.05	1578																														
	0.16	1573																														
	0.18										50																					
Casting-begin	0.38																															
	0.46	1565																														
	1.06																															
	1.26													1	0.076	0.307	1.571	0.012	0.0009	0.039	0.0033	0.039	0.034									
														3	0.078	0.309	1.568	0.012	0.0009	0.038	0.0037	0.039	0.034									
Steel quality	F56NBV																															
composition														min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032									
														max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038									
T-liquidus	1519																															
T-casing	1559																															
Vacuum period	10																															

table B10

Heat No.1763566														Steel quality F56NBV																	
operation	time	temp.	addition											steel analysis									slag analysis								
			CaO	Al-dp.	Al-wire	C	MnAf	MgO	FeMn	SiMn	FeV	FeNb		st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.
Tapping	4.56	1731												186.9	0.029	0.001	0.136	0.009	0.0259	#	0.0027	0.002	2E-04	51.43	12.01	1.71	0.182	16.1	2.23	1.91	1.06
begin	4.59																														
	5.00		1550				510	75	746																						
	5.01									2552																					
	5.02										82	83																			
	5.03			298																											
funish	5.09																														
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi	CaSi			st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5	SAT.
Vacuum	5.25	1639												187.2	0.064	0.178	1.466	0.013	0.0102	0.021	0.0067	0.037	0.029	58.53	12.03	20.24	0.082	0.37	5.54	0.01	0.96
	5.26						2000																								
begin	5.30																														
	5.31								111	147																					
	5.33			207																											
	5.35		159	52																											
finish	5.43																														
	5.47	1582																													
	5.48													2	0.074	0.209	1.503	0.013	0.0010	0.026	0.0041	0.029									
	5.53				40																										
	5.54								100	28																					
	6.02	1583																													
	6.04										50																				
arrive	6.18	1580																													
Casting-begin	6.31																														
	6.35	1549																													
	6.56													1	0.077	0.32	1.561	0.013	0.0008	0.038	0.0045	0.039	0.033								
	7.03													3	0.074	0.327	1.579	0.014	0.0007	0.039	0.0039	0.040	0.035								
Steel quality	F56NBV													min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032								
composition														max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038								
T-liquidus	1519																														
T-casing	1559																														
Vacuum period	10																														

table B11

Heat No.1763567													Steel quality F56NBV																
operation	time	temp.	addition										steel analysis									slag analysis							
			CaO	Al-dp.	Al-wire	C	MnAl	MgO	FeMn	SiMn	FeV	FeNb	st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5
Tapping	5.41	1694											180.4	0.035	0.001	0.138	0.011	0.0257	#	0.0025	0.002	2E-04	48.11	12	2.27	0.163	19.2	2.35	1.84
begin	5.42																												
	5.43		1360				602		606	2268																			
	5.45										77	85																	
	5.46			292																									
	5.50							75																					
finish	5.51																												
			CaO	Al-dp.	Al-wire	C	scrap	sand	FeMn	FeSi	CaSi		st wt.	C	Si	Mn	P	S	Al	N	V	Nb	CaO	SiO_2	Al_2O_3	S	Fe	MgO	P_2O_5
Vacuum	6.14	1612											181.2	0.068	0.199	1.523	0.012	0.0078	0.038	0.0052	0.036	0.032	59.13	10.23	20.81	1.06	0.44	5.37	0.03
	6.16			203			810																						
begin	6.18																												
	6.20		59							123																			
finish	6.31																												
	6.35	1585											2	0.072	0.302	1.519	0.013	0.0010	0.036	0.0034	0.037	0.033							
	6.42				12				61																				
	6.45										50																		
Casting-begin	7.12																												
	7.14	1554																											
	7.40												1	0.073	0.328	1.565	0.013	0.0008	0.039	0.0038	0.037	0.033							
	7.54												3	0.074	0.326	1.571	0.013	0.0009	0.039	0.0035	0.037	0.033							
Steel quality	F56NBV												min	0.072	0.300	1.520	0.000	0.000	0.020	0.0000	0.035	0.032							
composition													max	0.085	0.350	1.600	0.015	0.0015	0.050	0.0090	0.045	0.038							
T-liquidus	1519																												
T-casing	1559																												
Vacuum period	10 min.																												

table B12

BIOGRAPHY

Mr. Kosee Nounle was born on March 28, 1973 in Songkhla, Thailand. He graduated a B.Eng. (Metallurgical Engineering) from Chulalongkorn University in 1994 and continued his study for a master degree in Metallurgical Engineering at Chulalongkorn University in that year.