

Supplementary I Simulation data and range analysis table

(Physical parameters /F2→F3)

Table S1 Output shaft speed drop simulation data and range analysis table (Physical parameters /F2→F3)

	factor	A	B	C	D	minimum speed	time (s)	speed drop
	column number	1	2	3	4	(r/min)		
scheme	1	1 (1200)	1 (120)	1 (30)	1 (3)	289.24	20.70	1425.05
	2	1	2 (160)	2 (40)	2 (4)	285.34	20.57	1428.95
	3	1	3 (200)	3 (50)	3 (5)	285.64	20.56	1428.65
	4	2 (1600)	1	2	3	411.44	20.57	1874.27
	5	2	2	3	1	411.46	20.73	1874.25
	6	2	3	1	2	414.62	20.63	1871.09
	7	3 (2000)	1	3	2	538.41	20.65	2318.73
	8	3	2	1	3	546.25	20.57	2310.89
	9	3	3	2	1	545.81	20.73	2311.33
mean	\bar{K}_{1j}	1427.55	1872.68	1869.01	1870.21	$\bar{K}=1871.47$		
	\bar{K}_{2j}	1873.20	1871.36	1871.52	1872.92			
	\bar{K}_{3j}	2313.65	1870.36	1873.88	1871.27			
Range	\bar{R}_j	886.10	2.32	4.87	2.71			
optimization scheme	A ₁ C ₁ D ₁ B ₃		feasible scheme			A ₁		

Note: When the input speed is 1200/1600/2000(r/min), the stable rotating speed of mechanical gear is 1714.29/2285.71/2857.14(r/min).

Table S2 Output shaft acceleration torque ratio simulation data and range analysis table (Physical parameters /F2→F3)

	factor	A	B	C	D	acceleration torque	time	dynamic load
	column number	1	2	3	4	(Nm)	(s)	coefficient
scheme	1	1 (1200)	1 (120)	1 (30)	1 (3)	307.55	22.05	2.56
	2	1	2 (160)	2 (40)	2 (4)	329.18	21.82	2.06
	3	1	3 (200)	3 (50)	3 (5)	350.00	21.67	1.75
	4	2 (1600)	1	2	3	331.24	22.12	2.76
	5	2	2	3	1	354.92	22.39	2.22
	6	2	3	1	2	308.24	22.27	1.54
	7	3 (2000)	1	3	2	355.32	22.59	2.96
	8	3	2	1	3	308.56	22.68	1.93
	9	3	3	2	1	331.98	22.83	1.66
mean	\bar{K}_{1j}	2.12	2.76	2.01	2.15	$\bar{K}=2.16$		
	\bar{K}_{2j}	2.17	2.07	2.16	2.19			
	\bar{K}_{3j}	2.18	1.65	2.31	2.15			
range	\bar{R}_j	0.06	1.11	0.30	0.04			
optimization scheme	B ₃ C ₁ A ₁ D ₁		feasible scheme			B ₃		

Table S3 Output shaft maximum impact simulation data and range analysis table (Physical parameters /F2→F3)

	factor	A	B	C	D	maximum impact	time (s)
	column number	1	2	3	4		
scheme	1	1 (1200)	1 (120)	1 (30)	1 (3)	9.15	22.74
	2	1	2 (160)	2 (40)	2 (4)	7.51	22.51
	3	1	3 (200)	3 (50)	3 (5)	10.60	22.34
	4	2 (1600)	1	2	3	8.12	22.93
	5	2	2	3	1	8.62	23.09
	6	2	3	1	2	8.21	23.15
	7	3 (2000)	1	3	2	8.13	23.37
	8	3	2	1	3	8.91	23.58
	9	3	3	2	1	7.58	23.68
mean	\bar{K}_{1j}	9.09	8.47	8.76	8.45	$\bar{K}=8.54$	
	\bar{K}_{2j}	8.32	8.35	7.74	7.95		
	\bar{K}_{3j}	8.21	8.80	9.12	9.21		
range	\bar{R}_j	0.88	0.45	1.38	1.26		
optimization scheme	C ₂ D ₂ A ₃ B ₂		feasible scheme		C ₂ D ₂		

Table S4 Shift time simulation data and range analysis table (Physical parameters /F2→F3)

	factor	A	B	C	D	timing of gear shift (s)	time (s)
	column number	1	2	3	4		
scheme	1	1 (1200)	1 (120)	1 (30)	1 (3)	2.69	22.69
	2	1	2 (160)	2 (40)	2 (4)	2.47	22.47
	3	1	3 (200)	3 (50)	3 (5)	2.30	22.30
	4	2 (1600)	1	2	3	2.87	22.87
	5	2	2	3	1	3.04	23.04
	6	2	3	1	2	3.09	23.09
	7	3 (2000)	1	3	2	3.32	23.32
	8	3	2	1	3	3.52	23.52
	9	3	3	2	1	3.62	23.62
mean	\bar{K}_{1j}	2.49	2.96	3.10	3.12	$\bar{K}=2.99$	
	\bar{K}_{2j}	3.00	3.01	2.99	2.96		
	\bar{K}_{3j}	3.49	3.00	2.89	2.90		
range	\bar{R}_j	1.00	0.05	0.21	0.22		
optimization scheme	A ₁ D ₃ C ₃ B ₁		feasible scheme		A ₁ D ₃ C ₃		

Supplementary II Simulation data and range analysis table (Gear shift timing /F1→F2)

Table S5 Output shaft speed drop simulation data and range analysis table (Gear shift timing /F1→F2)

	factor	A	B	C	D	minimum speed	time	speed
	column number	1	2	3	4	(r/min)	(s)	drop
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	121.14	10.65	335.46
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	149.42	11.12	307.18
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	149.51	11.62	307.09
	4	2 (10.0)	1	2	3	73.94	11.04	382.66
	5	2	2	3	1	245.30	11.37	211.30
	6	2	3	1	2	54.00	11.11	402.60
	7	3 (10.5)	1	3	2	143.05	11.36	313.55
	8	3	2	1	3	72.22	10.89	384.38
	9	3	3	2	1	68.81	11.30	387.79
mean	\bar{K}_{1j}	316.58	343.89	374.15	311.52	$\bar{K}=336.89$		
	\bar{K}_{2j}	332.19	300.95	359.21	341.11			
	\bar{K}_{3j}	361.91	365.83	277.31	358.04			
range	\bar{R}_j	45.33	64.88	96.84	46.52			
optimization scheme	C ₃ B ₂ D ₁ A ₁		feasible scheme			C ₃ B ₂		

Note: When the input speed is 1600(r/min), The stable rotating speed of hydraulic mechanical gear is 456.60(r/min)

Table S6 Output shaft acceleration torque ratio simulation data and range analysis table (Gear shift timing /F1→F2)

	factor	A	B	C	D	acceleration torque	time	dynamic load
	column number	1	2	3	4	(Nm)	(s)	coefficient
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	262.36	10.64	1.64
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	253.47	11.12	1.58
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	253.44	11.62	1.58
	4	2 (10.0)	1	2	3	255.59	11.03	1.60
	5	2	2	3	1	208.06	11.37	1.30
	6	2	3	1	2	219.55	11.11	1.37
	7	3 (10.5)	1	3	2	216.93	11.35	1.36
	8	3	2	1	3	265.80	10.88	1.66
	9	3	3	2	1	247.50	11.30	1.55
mean	\bar{K}_{1j}	1.60	1.53	1.56	1.50	$\bar{K}=1.52$		
	\bar{K}_{2j}	1.42	1.51	1.58	1.44			
	\bar{K}_{3j}	1.52	1.50	1.41	1.61			
range	\bar{R}_j	0.18	0.03	0.17	0.17			
optimization	A ₂ D ₂ C ₃ B ₃		feasible scheme			A ₂ D ₂ C ₃		

scheme

Table S7 Output shaft maximum impact simulation data and range analysis table (Gear shift timing /F1→F2)

	factor	A	B	C	D	maximum impact	time (s)
	column number	1	2	3	4		
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	15.73	10.66
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	13.85	11.13
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	16.03	11.63
	4	2 (10.0)	1	2	3	7.56	11.04
	5	2	2	3	1	16.03	11.38
	6	2	3	1	2	11.05	11.12
	7	3 (10.5)	1	3	2	10.66	11.37
	8	3	2	1	3	8.16	10.89
	9	3	3	2	1	10.11	11.31
mean	\bar{K}_{1j}	15.20	11.32	11.65	13.96	$\bar{K}=12.13$	
	\bar{K}_{2j}	11.55	12.68	10.51	11.85		
	\bar{K}_{3j}	9.64	12.40	14.24	10.58		
range	\bar{R}_j	5.56	1.36	3.73	3.38		
optimization scheme		A ₃ C ₂ D ₃ B ₁		feasible scheme		A ₃ C ₂ D ₃	

Table S8 Shift time simulation data and range analysis table (Gear shift timing /F1→F2)

	factor	A	B	C	D	timing of gear shift (s)	time (s)
	column number	1	2	3	4		
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	1.97	11.47
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	2.36	11.86
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	2.86	12.36
	4	2 (10.0)	1	2	3	2.76	12.26
	5	2	2	3	1	2.30	11.80
	6	2	3	1	2	2.75	12.25
	7	3 (10.5)	1	3	2	2.62	12.12
	8	3	2	1	3	2.94	12.44
	9	3	3	2	1	2.87	12.37
mean	\bar{K}_{1j}	2.40	2.45	2.55	2.38	$\bar{K}=2.60$	
	\bar{K}_{2j}	2.60	2.53	2.66	2.58		
	\bar{K}_{3j}	2.81	2.83	2.59	2.85		
range	\bar{R}_j	0.41	0.38	0.11	0.47		
optimization scheme		D ₁ A ₁ B ₁ C ₁		feasible scheme		D ₁ A ₁ B ₁	

Supplementary III Simulation data and range analysis table (Gear shift timing /F2→F3)

Table S9 Output shaft speed drop simulation data and range analysis table (Gear shift timing /F2→F3)

	factor	A	B	C	D	minimum speed	time	speed drop
	column number	1	2	3	4	(r/min)	(s)	
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	411.18	20.14	1874.53
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	410.81	20.64	1874.90
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	383.02	21.14	1902.69
	4	2 (10.0)	1	2	3	526.61	20.42	1759.10
	5	2	2	3	1	380.96	20.29	1904.75
	6	2	3	1	2	427.86	20.71	1857.85
	7	3 (10.5)	1	3	2	379.72	20.48	1905.99
	8	3	2	1	3	531.08	20.41	1754.63
	9	3	3	2	1	379.87	20.10	1905.84
mean	\bar{K}_{1j}	1884.04	1846.54	1829.00	1895.04	$\bar{K}=1860.03$		
	\bar{K}_{2j}	1840.57	1844.76	1846.61	1879.58			
	\bar{K}_{3j}	1855.49	1888.79	1904.48	1805.47			
range	\bar{R}_j	43.47	44.03	75.48	89.57			
optimization scheme	D ₃ C ₁ B ₂ A ₂		feasible scheme			D ₃ C ₁		

Note: When the input speed is 1600(r/min), the stable rotating speed of mechanical gear is 2285.71(r/min).

Table S10 Output shaft acceleration torque ratio simulation data and range analysis table (Gear shift timing /F2→F3)

	factor	A	B	C	D	acceleration	time	dynamic load
	column number	1	2	3	4	torque (Nm)	(s)	coefficient
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	331.50	21.71	2.07
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	331.38	22.21	2.07
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	331.54	22.74	2.07
	4	2 (10.0)	1	2	3	330.06	21.90	2.06
	5	2	2	3	1	330.94	22.54	2.07
	6	2	3	1	2	331.99	22.43	2.07
	7	3 (10.5)	1	3	2	330.37	22.45	2.06
	8	3	2	1	3	331.82	21.94	2.07
	9	3	3	2	1	331.66	22.56	2.07
mean	\bar{K}_{1j}	2.07	2.06	2.07	2.07	$\bar{K}=2.07$		
	\bar{K}_{2j}	2.07	2.07	2.07	2.07			
	\bar{K}_{3j}	2.07	2.07	2.07	2.07			
range	\bar{R}_j	0	0.01	0	0			
optimization scheme	-		feasible scheme			-		

Table S11 Output shaft maximum impact simulation data and range analysis table (Gear shift timing /F2→F3)

	factor	A	B	C	D	maximum impact	time (s)
	column number	1	2	3	4		
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	6.97	22.52
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	6.66	23.03
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	7.37	23.55
	4	2 (10.0)	1	2	3	7.43	22.69
	5	2	2	3	1	6.36	23.35
	6	2	3	1	2	7.14	23.19
	7	3 (10.5)	1	3	2	7.27	23.24
	8	3	2	1	3	7.23	22.70
	9	3	3	2	1	7.40	23.36
mean	\bar{K}_{1j}	7.00	7.22	7.11	6.91	$\bar{K}=7.09$	
	\bar{K}_{2j}	6.98	6.75	7.16	7.02		
	\bar{K}_{3j}	7.30	7.30	7.00	7.34		
range	\bar{R}_j	0.32	0.55	0.16	0.43		
optimization scheme		B ₂ D ₁ A ₂ C ₃		feasible scheme		B ₂ D ₁	

Table S12 Shift time simulation data and range analysis table (Gear shift timing /F2→F3)

	factor	A	B	C	D	timing of gear shift (s)	time (s)
	column number	1	2	3	4		
scheme	1	1 (9.5)	1 (9.5)	1 (9.5)	1 (9.5)	2.97	22.47
	2	1	2 (10.0)	2 (10.0)	2 (10.0)	3.47	22.97
	3	1	3 (10.5)	3 (10.5)	3 (10.5)	4.01	23.51
	4	2 (10.0)	1	2	3	3.14	22.64
	5	2	2	3	1	3.79	23.29
	6	2	3	1	2	3.64	23.14
	7	3 (10.5)	1	3	2	3.69	23.19
	8	3	2	1	3	3.15	22.65
	9	3	3	2	1	3.81	23.31
mean	\bar{K}_{1j}	3.47	3.27	3.25	3.52	$\bar{K}=3.52$	
	\bar{K}_{2j}	3.52	3.47	3.47	3.60		
	\bar{K}_{3j}	3.55	3.82	3.83	3.43		
range	\bar{R}_j	0.08	0.55	0.58	0.17		
optimization scheme		C ₁ B ₁ D ₃ A ₁		feasible scheme		C ₁ B ₁	

Supplementary IV Test data and analysis of variance table (Gear shift timing /F1→F2)

Table S13 Output shaft speed drop test data and range analysis table (Gear shift timing /F1→F2)

factor	A	B	C	D	test result Y_{ij}									
column number	1	2	3	4	1	2	3	4	$X=$	$Z=$				
test value	1	1	1	1	287.86	301.21	366.86	317.18	1273.11	408780.26				
	2	1	2	2	325.18	260.49	320.67	275.17	1181.51	352144.85				
	3	1	3	3	256.05	337.28	335.99	247.48	1176.80	353455.03				
	4	2	1	2	378.95	362.95	323.04	308.46	1373.40	474838.22				
	5	2	2	3	221.19	232.16	231.27	221.10	905.72	205194.30				
	6	2	3	1	361.17	341.77	420.60	360.97	1484.51	554454.20				
	7	3	1	3	359.70	281.91	343.31	359.55	1344.47	455995.30				
	8	3	2	1	344.94	326.45	363.28	383.23	1417.90	504390.80				
	9	3	3	2	313.22	365.84	312.29	368.94	1360.29	465587.44				
statistical value	K_{1j}	3631.42	3990.98	4175.52	3539.12	$\bar{Y}=$ 319.94	$O=$ 132657643.64	$P=$ 14980388.29	$Q=$ 3774840.40					
	K_{2j}	3763.63	3505.13	3915.20	4010.49									
	K_{3j}	4122.66	4021.60	3426.99	3968.10									
	R_j	491.24	516.47	748.53	471.37	$C_3B_2A_1D_1$								
	S	10769.4	13992.5	24067.0	11333.6	$S_C > S_B > S_D > S_A$								

Table S14 Output shaft speed drop test data and variance analysis table (Gear shift timing /F1→F2)

source		S	f	F	P	conclusion
factor	A	10769.41	2	4.89	< 0.05	※ ※
	B	13992.47	2	6.35	< 0.01	※ ※ ※
	C	24067.02	2	10.92	< 0.01	※ ※ ※ ※
	D	11333.62	2	5.14	< 0.05	※ ※
error	e	29743.33	27			

Table S15 Output shaft acceleration torque ratio test data and range analysis table (Gear shift timing /F1→F2)

factor	A	B	C	D	test result Y_{ij}					
column number	1	2	3	4	1	2	3	4	$\bar{X} =$	$\bar{Z} =$
test value	1	1	1	1	1.57	1.80	1.63	1.71	6.71	11.29
	2	1	2	2	1.67	1.50	1.65	1.73	6.55	10.75
	3	1	3	3	1.48	1.74	1.73	1.49	6.44	10.43
	4	2	1	2	1.74	1.68	1.51	1.59	6.52	10.66
	5	2	2	3	1.36	1.43	1.42	1.36	5.57	7.76
	6	2	3	1	1.23	1.44	1.43	1.37	5.47	7.51
	7	3	1	3	1.29	1.36	1.49	1.42	5.56	7.75
	8	3	2	1	1.66	1.74	1.57	1.66	6.63	11.00
	9	3	3	2	1.31	1.62	1.70	1.63	6.26	9.89
statistical value	K_{1j}	19.70	18.79	18.81	18.54	$\bar{Y} =$	$O =$	$P =$	$Q =$	
	K_{2j}	17.56	18.75	19.33	17.58					
	K_{3j}	18.45	18.17	17.57	19.59	1.55	3103.60	346.91	87.04	
	R_j	2.14	0.62	1.76	2.01	$A_2D_2C_3B_3$				
	S	0.193	0.020	0.136	0.168	$S_A > S_D > S_C > S_B$				

Table S16 Output shaft acceleration torque ratio test data and analysis of variance table (Gear shift timing /F1→F2)

source		S	f	F	P	conclusion
factor	A	0.193	2	8.365	< 0.05	※※※
	B	0.020	2	0.871		
	C	0.136	2	5.917	< 0.01	※※※
	D	0.168	2	7.315	< 0.05	※※※
error		e	27			

Table S17 Output Shaft Maximum Impact Test Data and Range Analysis Table (Gear shift timing /F1→F2)

factor	A	B	C	D	test result Y_{ij}					
column number	1	2	3	4	1	2	3	4	$X=$	$Z=$
test value	1	1	1	1	15.07	12.71	12.64	13.30	53.72	725.31
	2	1	2	2	16.05	11.74	11.13	11.16	50.08	643.85
	3	1	3	3	12.88	16.00	12.89	12.92	54.69	754.97
	4	2	1	2	8.24	6.41	6.08	6.09	26.82	183.04
	5	2	2	3	13.57	17.61	15.94	12.93	60.05	915.53
	6	2	3	1	8.92	8.94	11.54	11.01	40.41	413.88
	7	3	1	3	11.16	11.72	9.54	9.03	41.45	434.46
	8	3	2	1	8.14	7.75	8.53	6.59	31.01	242.51
	9	3	3	2	8.17	8.12	11.07	9.62	36.98	347.77
statistical value	K_{1j}	158.49	121.99	125.14	150.75	$\bar{Y}=$		$O=$	$P=$	$Q=$
	K_{2j}	109.44	141.14	113.88	131.94	10.98		156190.90	18390.37	4661.32
	K_{3j}	109.44	132.08	156.19	112.52					
	R_j	49.05	19.15	42.31	38.23	$A_3C_2D_3B_1$				
	S	102.73	15.29	80.03	60.90	$S_A > S_C > S_D > S_B$				

Table S18 Output Shaft Maximum Impact Test Data and Analysis of Variance Table (Gear shift timing /F1→F2)

source		S	f	F	P	conclusion
factor	A	102.73	2	21.76	< 0.01	※※※
	B	15.29	2	3.24	< 0.10	※
	C	80.03	2	16.95	< 0.01	※※※
	D	60.90	2	12.90	< 0.01	※※※
error	e	63.73	27			

Table S19 Shift Time Test Data and Range Analysis Table (Gear shift timing /F1→F2)

factor	A	B	C	D	test result Y_{ij}					
column number	1	2	3	4	1	2	3	4	$\bar{X} =$	$Z =$
test value	1	1	1	1	1.89	2.16	1.96	2.06	8.07	16.32
	2	1	2	2	2.50	2.24	2.46	2.59	9.79	24.03
	3	1	3	3	2.67	2.57	3.13	2.71	11.08	30.87
	4	2	1	2	2.73	2.89	2.61	2.75	10.98	30.18
	5	2	2	3	2.64	2.53	2.29	2.18	9.64	23.37
	6	2	3	1	3.02	2.88	2.60	2.22	10.72	29.10
	7	3	1	3	2.48	2.36	2.87	2.74	10.45	27.46
	8	3	2	1	3.23	3.08	2.37	2.37	11.05	31.15
	9	3	3	2	2.32	2.31	3.14	2.73	10.50	28.03
statistical value	K_{1j}	28.94	29.50	29.84	28.21	$\bar{Y} =$		$O =$	$P =$	$Q =$
	K_{2j}	31.34	30.48	31.27	30.96	2.56		8515.60	953.70	240.52
	K_{3j}	32.00	32.30	31.17	33.11					
	R_j	3.06	2.80	1.43	4.90	$D_1 A_1 B_1 C_1$				
	S	0.432	0.336	0.106	1.005	$S_D > S_A > S_B > S_C$				

Table S20 Shift Time Test Data and Analysis of Variance Table (Gear shift timing /F1→F2)

source		S	f	F	P	conclusion
factor	A	0.432	2	2.78	< 0.10	*
	B	0.336	2	2.16		
	C	0.106	2	0.68		
	D	1.005	2	6.47	< 0.01	***
error	e	2.099	27			

Supplementary V Test data and analysis of variance table (Gear shift timing /F2→F3)

Table S21 Output Shaft Speed Drop Test Data and Range Analysis Table (Gear shift timing /F2→F3)															
factor		A	B	C	D	test result Y_{ij}				$\bar{X} =$	$\bar{Z} =$				
column number		1	2	3	4	1	2	3	4						
test value	1	1	1	1	1	1608.53	1870.59	1862.53	1772.37	7114.02	12696789.13				
	2	1	2	2	2	1984.77	1964.90	1957.21	2054.52	7961.40	15851867.38				
	3	1	3	3	3	1967.00	1937.51	1894.46	1799.75	7598.72	14451112.75				
	4	2	1	2	3	1917.95	1844.42	1660.94	1752.24	7175.55	12909484.04				
	5	2	2	3	1	1993.89	2092.75	1894.27	1993.13	7974.04	15916025.92				
	6	2	3	1	2	2038.25	1762.91	1940.90	2037.32	7779.38	15180080.32				
	7	3	1	3	2	1805.35	1904.27	2086.87	1804.40	7600.89	14496418.61				
	8	3	2	1	3	1750.07	1841.13	1658.30	1749.37	6998.87	12262758.97				
	9	3	3	2	1	1806.16	1797.97	1896.88	1813.22	7314.23	13380830.57				
statistical value	K_{1j}	22674	21890	21892	22402	$\bar{Y} =$ 1875.48		$O =$ 4558558792.41		$P =$ 507581971.63					
	K_{2j}	22928	22934	22451	23342										
	K_{3j}	21914	22692	23174	21773										
	R_j	1014	1044	1282	1569	$D_3A_1B_1C_3$									
	S	46471	49755	68786	103849	$S_D > S_C > S_B > S_A$									

Table S22 Output shaft deceleration amplitude test data and analysis of variance table (Gear shift timing /F2→F3)						
source		S	f	F	P	conclusion
factor	A	46471	2	2.51		
	B	46471	2	2.69	< 0.10	※
	C	68786	2	3.72	< 0.05	※※
	D	103849	2	5.61	< 0.01	※※※
error		e	249875	27		

Table S23 Output shaft acceleration torque ratio test data and range analysis table (Gear shift timing /F2→F3)

factor	A	B	C	D	test result Y_{ij}					
column number	1	2	3	4	1	2	3	4	$X=$	$Z=$
test value	1	1	1	1	1.98	2.27	2.06	2.16	8.47	17.98
	2	1	2	2	2.19	1.96	2.16	2.06	8.37	17.55
	3	1	3	3	1.93	2.27	2.06	1.96	8.22	16.96
	4	2	1	2	2.04	2.16	1.95	2.05	8.20	16.83
	5	2	2	3	2.17	2.27	2.06	2.05	8.67	18.81
	6	2	3	1	2.06	1.96	2.16	2.06	8.24	16.99
	7	3	1	3	1.95	2.06	2.26	2.06	8.22	16.96
	8	3	2	1	2.06	2.17	1.96	2.06	8.25	17.04
	9	3	3	2	2.17	1.95	2.06	1.97	8.15	16.64
statistical value	K_{1j}	25.06	24.89	24.96	25.29	$\bar{Y}=$ 2.08	$O=$ 5593.54		$P=$ 621.73	$Q=$ 155.76
	K_{2j}	25.11	25.29	24.72	24.83					
	K_{3j}	24.62	24.61	25.11	24.67					
	R_j	0.49	0.68	0.39	0.62	$D_3A_3B_3C_2$				
	S	0.012	0.019	0.006	0.017	$S_B > S_D > S_A > S_C$				

Table S24 Output shaft acceleration torque ratio test data and analysis of variance table (Gear shift timing /F2→F3)

source	S	f	F	P	conclusion
factor	A	0.012	2	0.493	
	B	0.019	2	0.793	
	C	0.006	2	0.263	
	D	0.017	2	0.703	
error	e	0.332	27		

Table S25 Output Shaft Maximum Impact Test Data and Range Analysis Table (Gear shift timing /F2→F3)

factor	A	B	C	D	test result Y_{ij}								
column number	1	2	3	4	1	2	3	4	$X=$	$Z=$			
test value	1	1	1	1	6.68	7.65	6.93	7.29	28.55	204.31			
	2	1	2	2	7.05	6.31	6.95	7.30	27.61	191.11			
	3	1	3	3	6.88	8.09	8.06	7.71	30.74	237.19			
	4	2	1	2	7.36	6.30	7.76	6.66	28.08	198.43			
	5	2	2	3	5.39	6.35	6.33	6.66	24.73	153.80			
	6	2	3	1	7.83	8.20	7.46	7.12	30.61	234.89			
	7	3	1	3	7.61	7.26	7.96	6.88	29.71	221.32			
	8	3	2	1	7.93	7.59	7.56	7.21	30.29	229.63			
	9	3	3	2	7.75	6.98	7.37	7.04	29.14	212.66			
statistical value	K_{1j}	86.90	86.34	89.45	82.42	$\bar{Y}=$ 7.21	$O=$ 67319.49	$P=$ 7508.70	$Q=$ 1883.35				
	K_{2j}	83.42	82.63	84.83	87.93								
	K_{3j}	89.14	90.49	85.18	89.11								
	R_j	5.72	7.86	4.62	6.69	$D_2A_1B_2C_2$							
	S	1.385	2.577	1.103	2.125	$S_B > S_D > S_A > S_C$							

Table S26 Output Shaft Maximum Impact Test Data and Analysis of Variance Table (Gear shift timing /F2→F3)

source		S	f	F	P	conclusion
factor	A	1.385	2	3.03	< 0.10	※
	B	2.577	2	5.63	< 0.01	※※※
	C	1.103	2	2.411		
	D	2.125	2	4.65	< 0.05	※※
error	e	6.174	27			

Table S27 Shift Time Test Data and Range Analysis Table (Gear shift timing /F2→F3)

factor	A	B	C	D	test result Y_{ij}									
column number	1	2	3	4	1	2	3	4	$X=$	$Z=$				
test value	1	1	1	1	2.85	3.26	2.95	3.11	12.17	37.12				
	2	1	2	2	3.67	3.29	3.62	3.80	14.38	51.84				
	3	1	3	3	3.74	4.00	4.39	3.79	15.92	63.62				
	4	2	1	2	3.11	3.29	2.96	3.13	12.49	39.05				
	5	2	2	3	3.97	4.16	3.77	3.97	15.87	63.04				
	6	2	3	1	3.99	3.45	3.80	3.99	15.23	58.18				
	7	3	1	3	3.50	3.69	4.04	3.49	14.72	54.37				
	8	3	2	1	3.14	3.31	2.98	3.14	12.57	39.56				
	9	3	3	2	3.08	3.06	4.17	3.62	13.93	49.34				
statistical value	K_{1j}	42.47	39.38	39.97	41.97	$\bar{Y}=$ 3.54	$O=$ 16200.20	$P=$ 1816.88	$Q=$ 456.13					
	K_{2j}	43.59	42.82	40.80	44.33									
	K_{3j}	41.22	45.08	46.51	40.98									
	R_j	2.37	5.70	6.54	3.35	$D_1A_1B_3C_3$								
	S	0.234	1.373	2.113	0.494	$S_C > S_B > S_D > S_A$								

Table S28 Shift Time Test Data and Analysis of Variance Table (Gear shift timing /F2→F3)

source		S	f	F	P	conclusion
factor	A	0.234	2	1.655		
	B	1.373	2	9.700	< 0.01	※※※
	C	2.113	2	14.927	< 0.01	※※※
	D	0.494	2	3.488	< 0.05	※※
error	e	1.911	27			