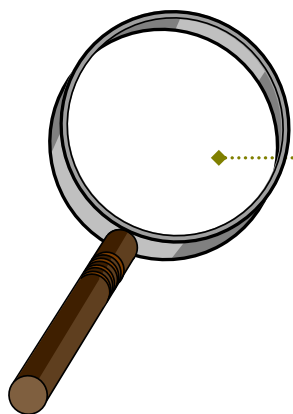
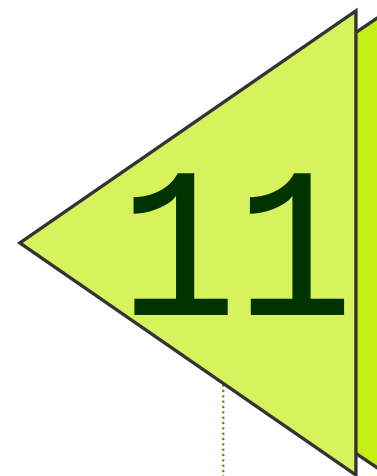
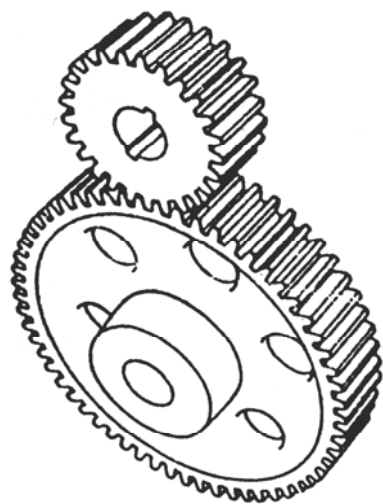


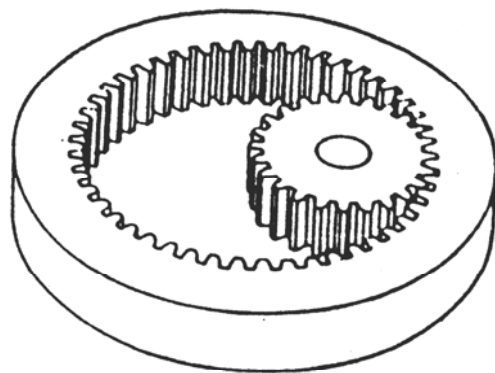
精密量測

齒輪量測

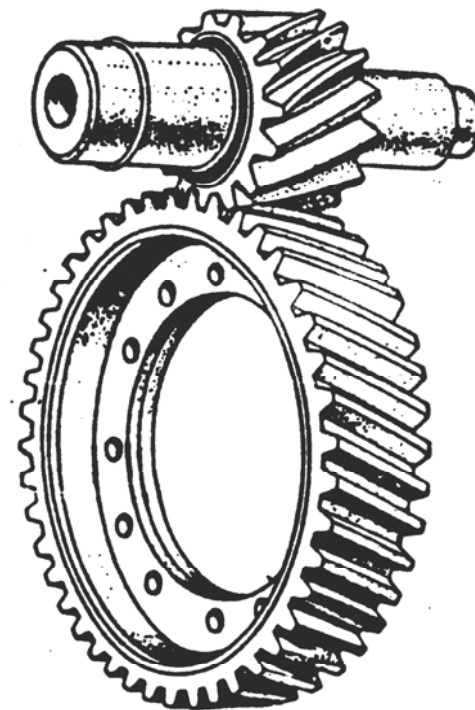




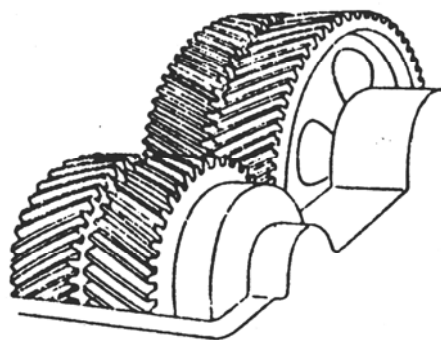
(a) 正齒輪



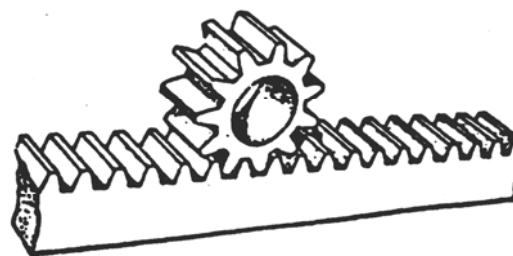
(b) 內正齒輪



(c) 螺旋齒輪

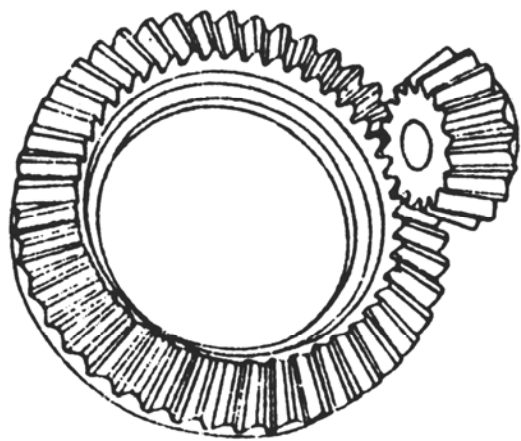


(d) 人字齒輪

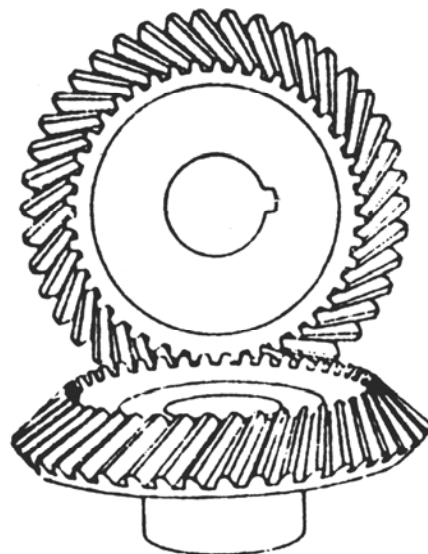


(e) 齒 條

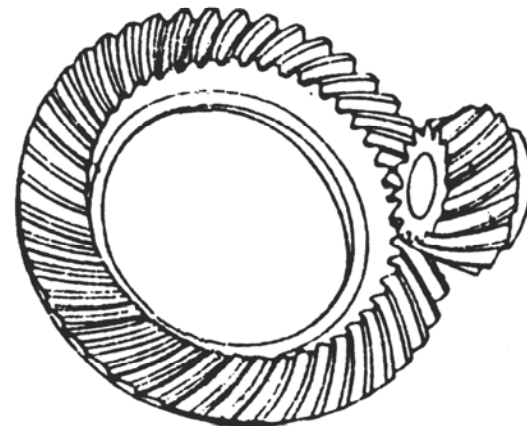
圖 11-1-1 兩軸同在一平面且平行之齒輪 ([18], P.460)



(a) 直齒斜齒輪

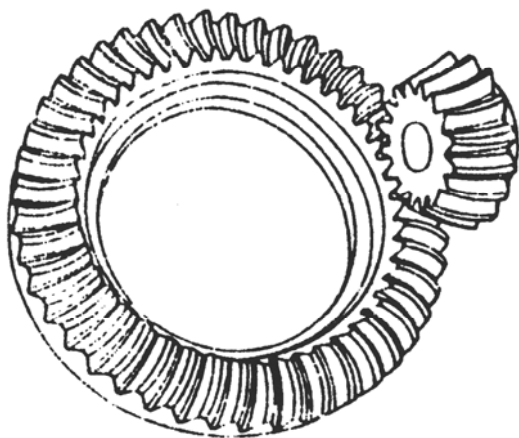


(b) 螺旋斜齒輪

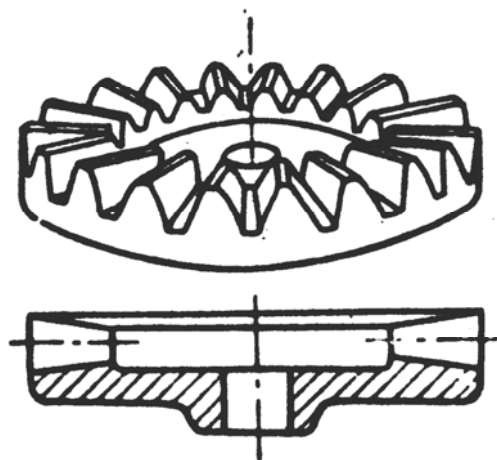


(c) 螺線斜齒輪

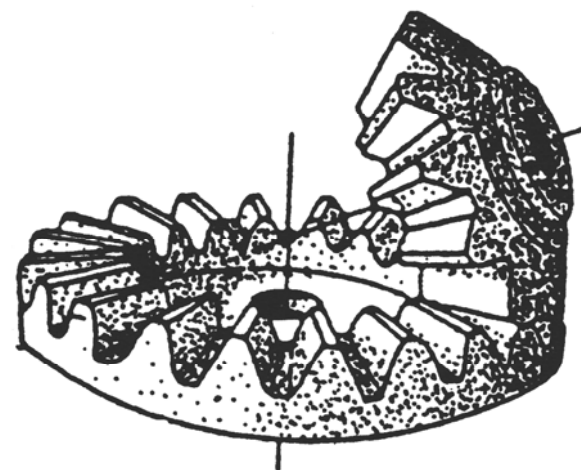
圖 11-1-2 兩軸相交之齒輪 ([18], P.461)



(d) 零角螺線斜齒輪



(e) 冠狀齒輪

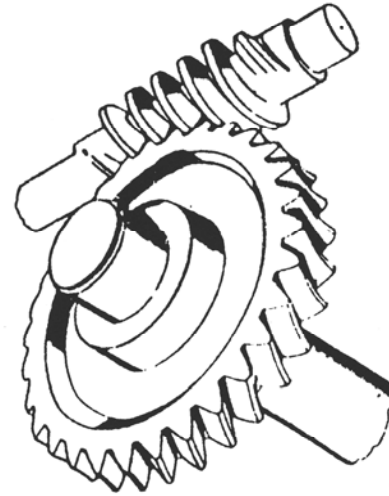


(f) 斜交斜齒輪

圖 11-1-2 兩軸相交之齒輪 (續) ([18], P.461)



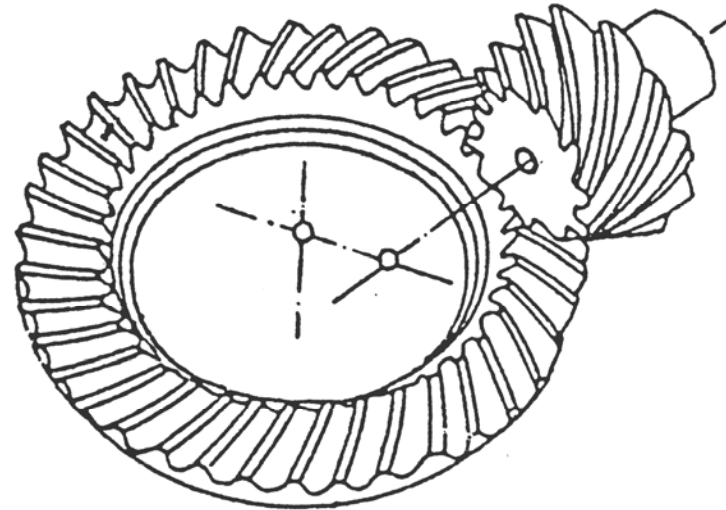
(a) 交叉螺旋齒輪



(b) 圓柱蝸輪蝸桿



(c) 細腰型蝸桿



(d) 戟齒輪

圖 11-1-3 不相交又不平行之齒輪 ([18], P.462)

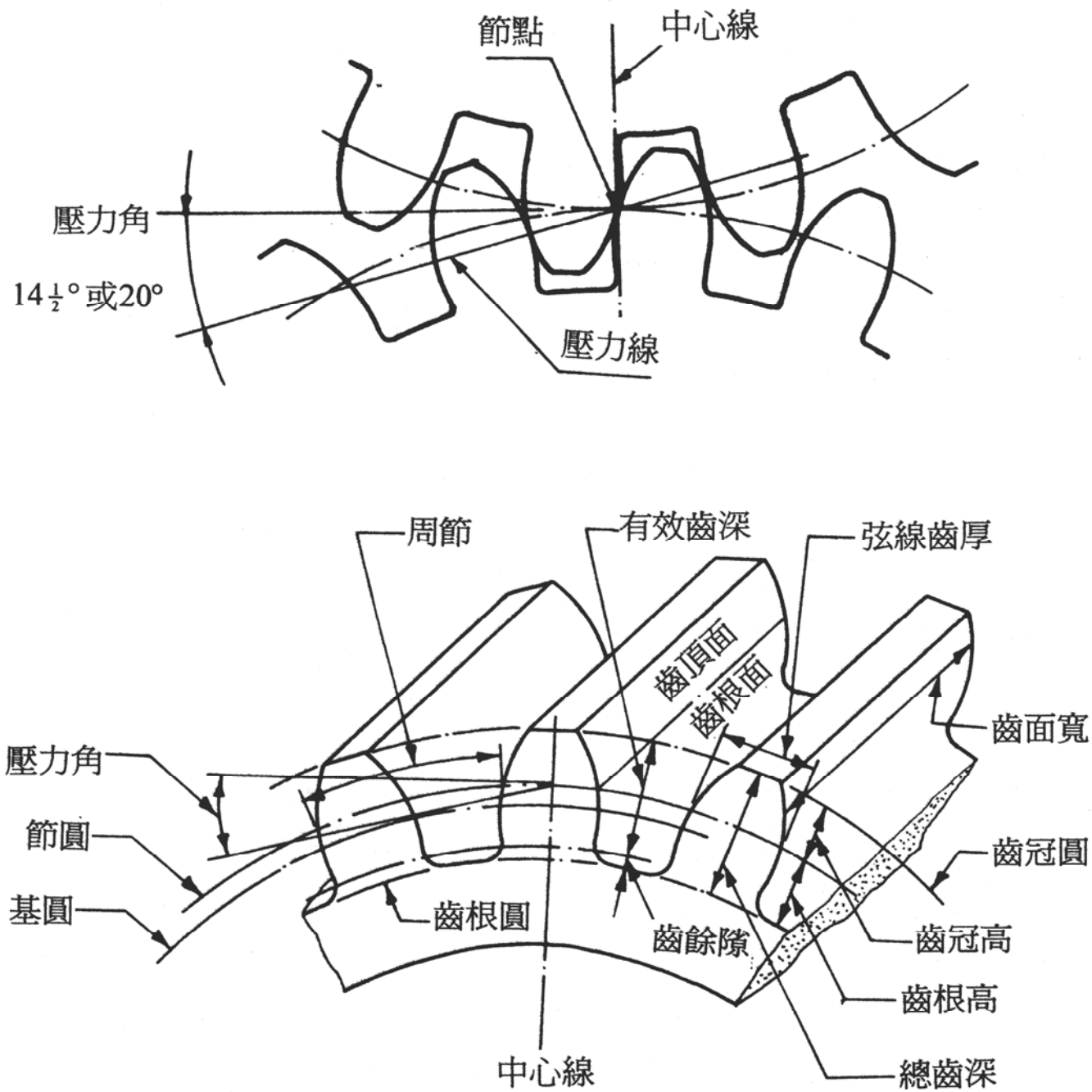


圖 11-1-4 正齒輪之各部位名稱

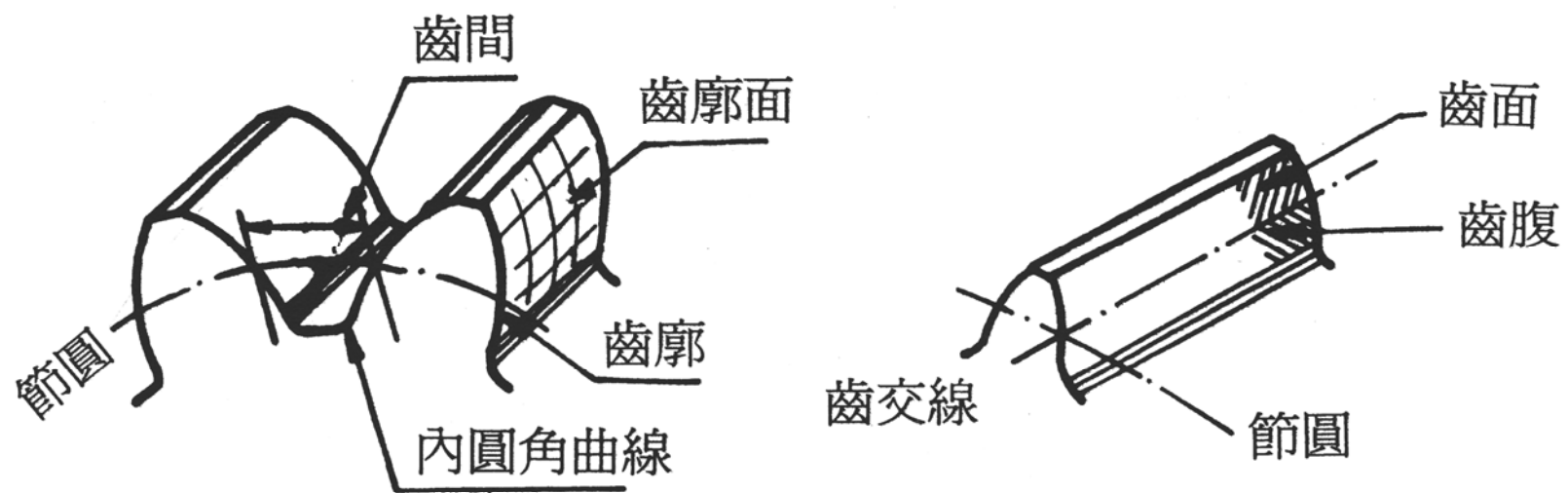


圖 11-1-5 齒輪局部名稱

表 11-1-1 標準正齒輪之計算公式

號碼	項 目	小 齒 輪 ①	大 齒 輪 ②
01	齒輪齒形	標 準	
02	模 數	m	
03	壓 力 角	$\alpha_0 = \alpha_c$	
04	齒 數	z_1	z_2
05	有效齒深	$h_e = 2m$	
06	全 齒 深	$h = 2m + c$	
07	齒 項 隙	c	
08	基 準 節 圓 直 徑	$d_{01} = z_1 m$	$d_{02} = z_2 m$
9	外 徑	$d_{k1} = (z_1 + 2)m$	$d_{k2} = (z_2 + 2)m$
10	齒 底 圓 直 徑	$d_{r1} = (z_1 - 2)m - 2c$	$d_{r2} = (z_2 - 2)m - 2c$
11	基 礎 圓 直 徑	$d_{s1} = z_1 m \cos \alpha_0$	$d_{s2} = z_2 m \cos \alpha_0$
12	周 節	$t_0 = \pi m$	
13	法線節距	$t_e = \pi m \cos \alpha_0$	
14	圓弧齒厚	$s_0 = \pi m / 2$	
15	弦 齒 厚	$s_{j1} = z_1 m \sin \frac{\pi}{2z_1}$	$s_{j2} = z_2 m \sin \frac{\pi}{2z_2}$
16	齒輪游標 尺 齒 高	$h_{j1} = \frac{z_1 m}{2} \left(1 - \cos \frac{\pi}{2z_1} \right) + m$	$h_{j2} = \frac{z_2 m}{2} \left(1 - \cos \frac{\pi}{2z_2} \right) + m$
17	跨 齒 數	$z_{m1} = \frac{\alpha_0 z_1}{180} + 0.5$	$z_{m2} = \frac{\alpha_0 z_2}{180} + 0.5$
18	跨 齒 厚	$s_{m1} = m \cos \alpha_0 \{ \pi(z_{m1} - 0.5) + z_1 \operatorname{inv} \alpha_0 \}$	$s_{m2} = m \cos \alpha_0 \{ \pi(z_{m2} - 0.5) + z_2 \operatorname{inv} \alpha_0 \}$
19	銷 (鋼珠) 子 直 徑	$d = 1.728 m$	
20	圓柱量測 尺 寸	$d_{m1} = \frac{z_1 m \cos \alpha_0}{\cos \phi 1} + d \text{ (偶齒數)}$ $d_{m1} = \frac{z_1 m \cos \alpha_0}{\cos \phi 1} \cos \frac{90^\circ}{z_1} + d \text{ (奇齒齒)}$ 其中 $\operatorname{inv} \phi 1 \frac{1}{z_1} \left\{ \frac{d}{m \cos \alpha_0} - \frac{\pi}{2} \right\} + \operatorname{inv} \alpha_0$	$d_{m2} = \frac{z_2 m \cos \alpha_0}{\cos \phi 2} + d \text{ (偶齒數)}$ $d_{m2} = \frac{z_2 m \cos \alpha_0}{\cos \phi 2} \cos \frac{90^\circ}{z_2} + d \text{ (奇齒齒)}$ 其中 $\operatorname{inv} \phi 2 \frac{1}{z_2} \left\{ \frac{d}{m \cos \alpha_0} - \frac{\pi}{2} \right\} + \operatorname{inv} \alpha_0$
21	齒 隙	f	

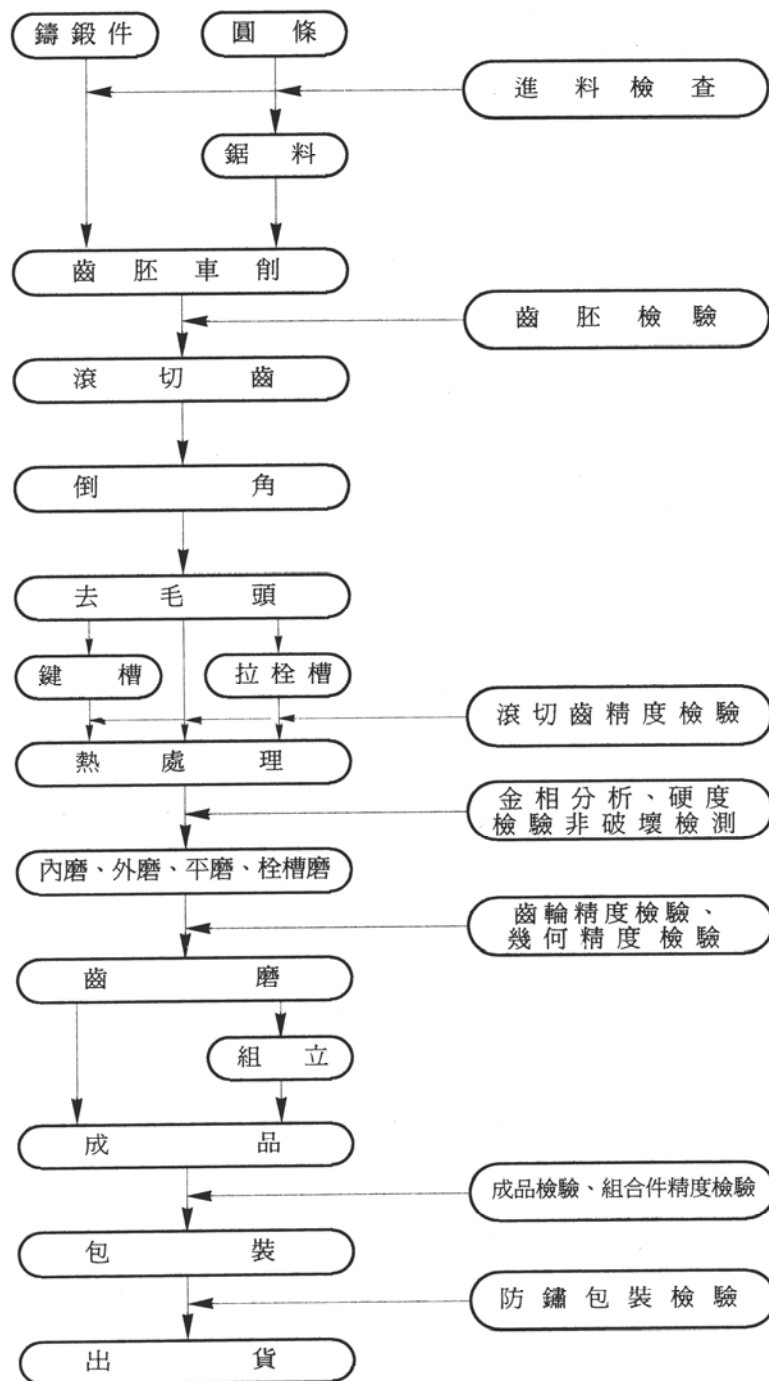


圖 11-2-1 製造過程與檢驗點 ([18], P.471)

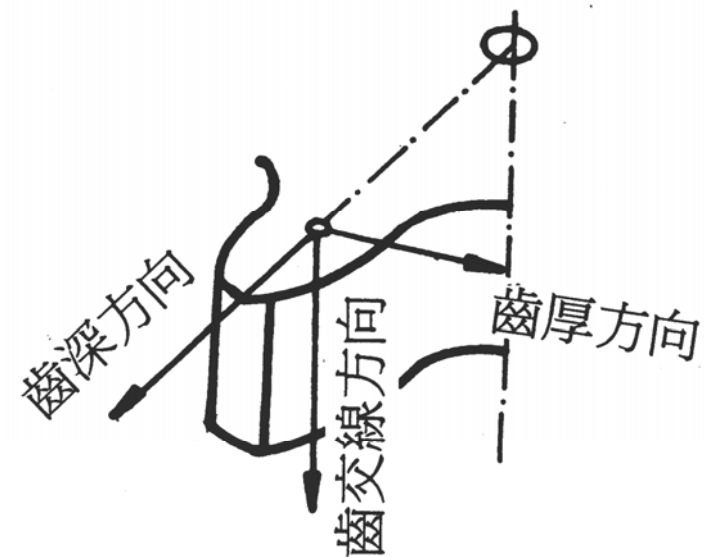


圖 11-2-2 齒輪量測方向

表 11-2-1 ISO 1328 齒輪毛胚之公差表

等級 檢驗項目	1	2	3	4	5	6	7	8	9	10	11	12
尺寸誤差 孔	IT 4	IT 4	IT 4	IT 4	IT 5	IT 6	IT 7	IT 8	IT 8	IT 8	IT 8	IT 8
形狀誤差	IT 1	IT 2	IT 3									
尺寸誤差 軸	IT 4	IT 4	IT 4	IT 4	IT 5		IT 6	IT 7	IT 7	IT 8	IT 8	IT 8
形狀誤差	IT 1	IT 2	IT 3									
齒冠圓直徑	IT 6		IT 7			IT 8			IT 9	IT 11		
基準面徑向 之偏差 ※	0.1 a_o		0.25 a_o		0.40 a_o		0.63 a_o		1 a_o			
基準面軸向 之偏差	0.1 a_o		0.25 a_o		0.40 a_o		0.63 a_o		1 a_o			

註：※ 基準面若為齒頂圓柱時，為其徑向之偏差。

表 11-2-2 ISO 之齒輪基準公差 (IT) 值

單位：μm

直徑或 中心距離 (d) (mm)	IT 1	IT 2	IT 3	IT 4	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11
6 ~ 0010	1	01.5	02.5	04	6	9	15	22	36	58	90
10 ~ 0018	1.2	02	03	05	8	11	18	27	43	70	110
18 ~ 0030	1.5	02.5	04	06	9	13	21	33	52	84	130
30 ~ 0050	1.5	02.5	04	07	11	16	25	39	62	100	160
50 ~ 0080	2	03	05	08	13	19	30	46	74	120	190
80 ~ 0120	2.5	04	06	10	15	22	35	54	87	140	220
120 ~ 0180	2.5	05	08	12	18	25	40	63	100	160	250
180 ~ 0250	4.5	07	10	14	20	29	46	72	115	185	290
250 ~ 0315	6	08	12	16	23	32	52	81	130	210	320
315 ~ 0400	7	09	13	18	25	36	57	89	140	230	360
400 ~ 0500	8	10	15	20	27	40	63	97	155	250	400
500 ~ 0630				22	32	44	70	110	175	280	440
630 ~ 0800				25	36	50	80	125	200	320	500
800 ~ 1000				28	40	56	90	140	230	360	560
1000 ~ 1250				33	47	66	105	165	260	420	660
1250 ~ 1600				39	55	78	125	195	310	500	780
1600 ~ 2000				46	65	92	150	230	370	600	920
2000 ~ 2500				55	73	110	175	280	440	700	1100
2500 ~ 3150				68	96	135	210	330	540	860	1350
3150 ~ 4000				82	115	165	260	410	660	1050	1650

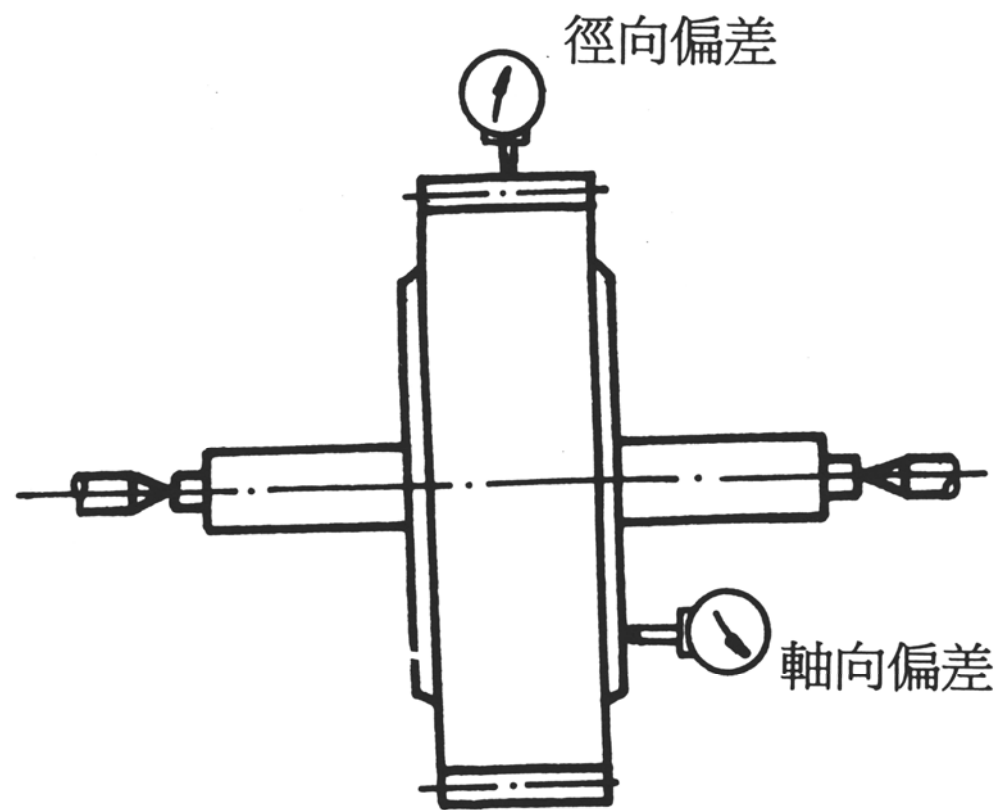
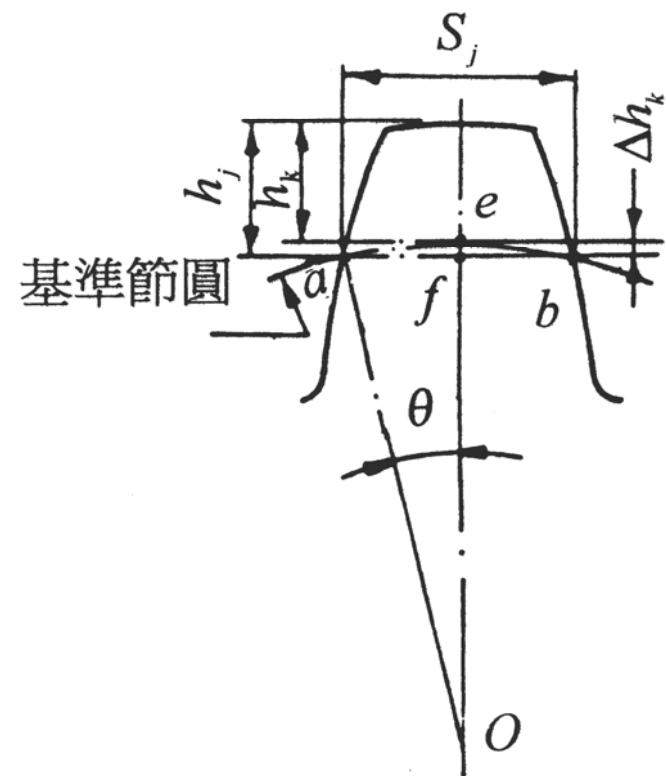
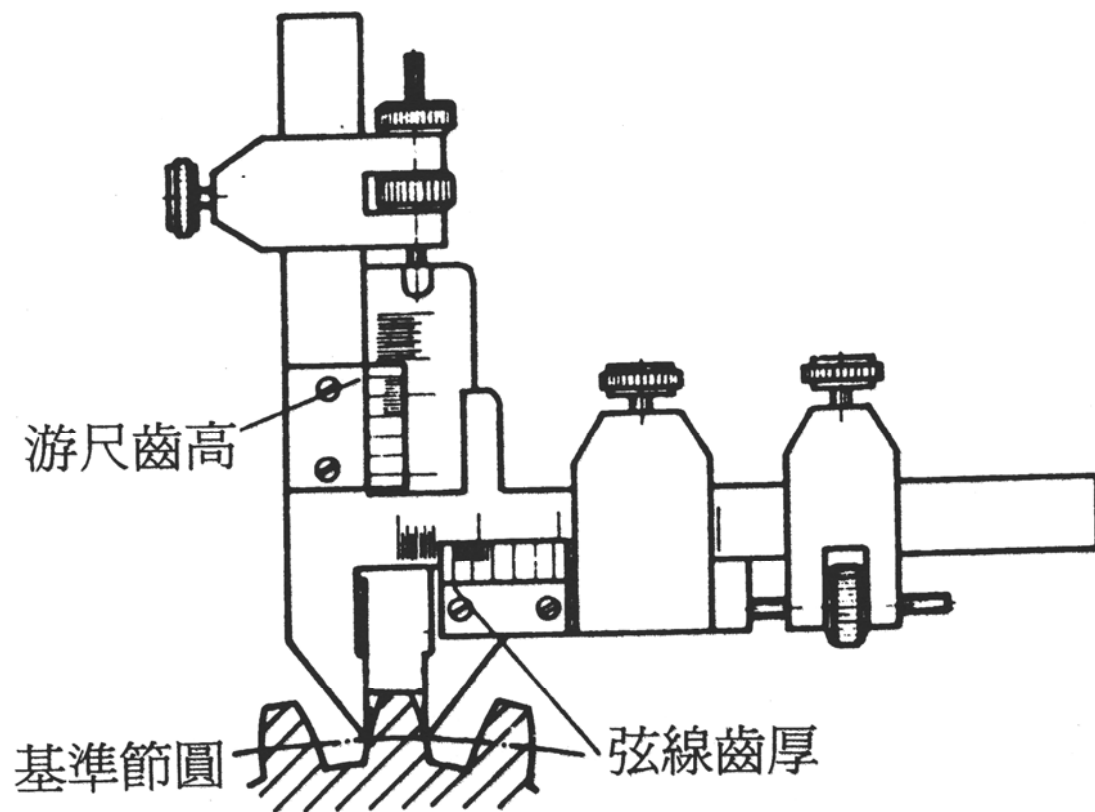


圖 11-2-3 齒輪徑向及軸向偏差之檢驗



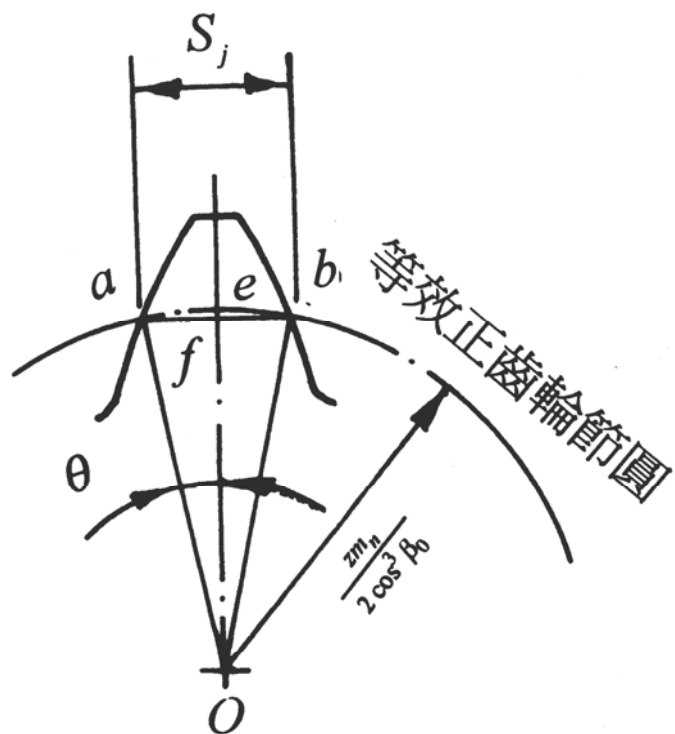
細部分析圖

圖 11-2-4 弦線齒厚量測

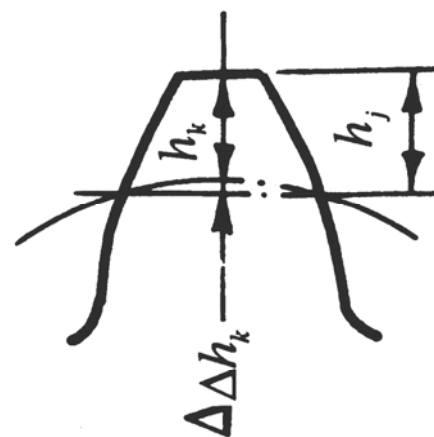
表 11-2-3 弦線齒厚及游標尺齒深表 ($m = 1$)

單位：mm

z	s_j	h_j	z	s_j	h_j	z	s_j	h_j
06	1.5529	1.1022	50	1.5705	1.0123	095	1.5707	1.0065
07	1.5568	1.0873	51	1.5706	1.0121	096	1.5707	1.0064
08	1.5607	1.0769	52	1.5706	1.0119	097	1.5707	1.0064
09	1.5628	1.0684	53	1.5706	1.0117	098	1.5707	1.0063
			54	1.5706	1.0114	099	1.5707	1.0062
10	1.5643	0.0616	55	1.5706	1.0112	100	1.5707	1.0061
11	1.5654	1.0559	56	1.5706	1.0110	101	1.5707	1.0061
12	1.5663	1.0514	57	1.5706	1.0108	102	1.5707	1.0060
13	1.5670	1.0474	58	1.5706	0.0106	103	1.5707	1.0060
14	1.5675	1.0440	59	1.5706	0.0105	104	1.5707	1.0059
			60	1.5706	1.0102	105	1.5707	1.0059
15	1.5678	1.0411	61	1.5706	1.0101	106	1.5707	1.0058
16	1.5683	1.0385	62	1.5706	1.0100	107	1.5707	1.0058
17	1.5686	1.0362	63	1.5706	1.0098	108	1.5707	1.0057
18	1.5688	1.0342	64	1.5706	1.0097	109	1.5707	1.0057
19	1.5690	1.0324						
20	1.5692	1.0308	65	1.5706	1.0095	110	1.5707	1.0056
21	1.5694	1.0294	66	1.5706	1.0094	111	1.5707	1.0056
22	1.5695	1.0281	67	1.5706	1.0092	112	1.5707	1.0055
23	1.5696	1.0268	68	1.5706	1.0090	113	1.5707	1.0055
24	1.5697	1.0257	69	1.5707	1.0088	114	1.5707	1.0054
			70	1.5707	1.0087	115	1.5707	1.0054
25	1.5698	1.0247	71	1.5707	1.0086	116	1.5707	1.0053
26	1.5698	1.0237	72	1.5707	1.0085	117	1.5707	1.0053
27	1.5699	1.0228	73	1.5707	1.0084	118	1.5707	1.0052
28	1.5700	1.0220	74	1.5707	1.0083	119	1.5707	1.0052
29	1.5700	1.0213						
30	1.5701	1.0208	75	1.5707	1.0081	120	1.5707	1.0052
31	1.5701	1.0199	76	1.5707	1.0080	121	1.5707	1.0051
32	1.5702	1.0193	77	1.5707	1.0079	122	1.5707	1.0051
33	1.5702	1.0187	78	1.5707	1.0079	123	1.5707	1.0050
34	1.5702	1.0181	79	1.5707	1.0077	124	1.5707	1.0050
			80	1.5707	1.0076	125	1.5707	1.0049
35	1.5702	1.0176	81	1.5707	1.0075	126	1.5707	1.0049
36	1.5703	1.0171	82	1.5707	1.0074	127	1.5707	1.0049
37	1.5703	1.0167	83	1.5707	1.0074	128	1.5707	1.0048
38	1.5703	1.0162	84	1.5707	1.0073	129	1.5707	1.0048
39	1.5704	1.0158						
40	1.5704	1.0154	85	1.5707	1.0072	130	1.5707	1.0047
41	1.5704	1.0150	86	1.5707	1.0071			
42	1.5704	1.0147	87	1.5707	1.0070	135	1.5708	1.0046
43	1.5705	1.0143	88	1.5707	1.0069			
44	1.5705	1.0140	89	1.5707	1.0068	150	1.5708	1.0045
			90	1.5707	1.0068			
45	1.5705	1.0137	91	1.5707	1.0067	250	1.5708	1.0025
46	1.5705	1.0134	92	1.5707	1.0067			
47	1.5705	1.0131	93	1.5707	1.0067	∞	1.5708	1.0000
48	1.5705	1.0129	94	1.5707	1.0066			
49	1.5705	1.0126						

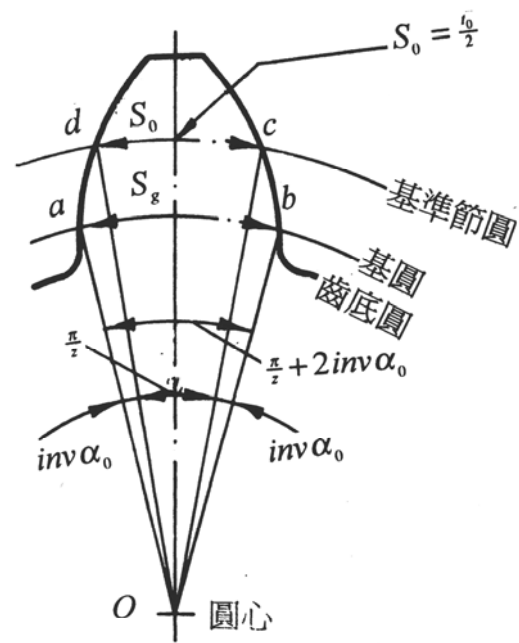
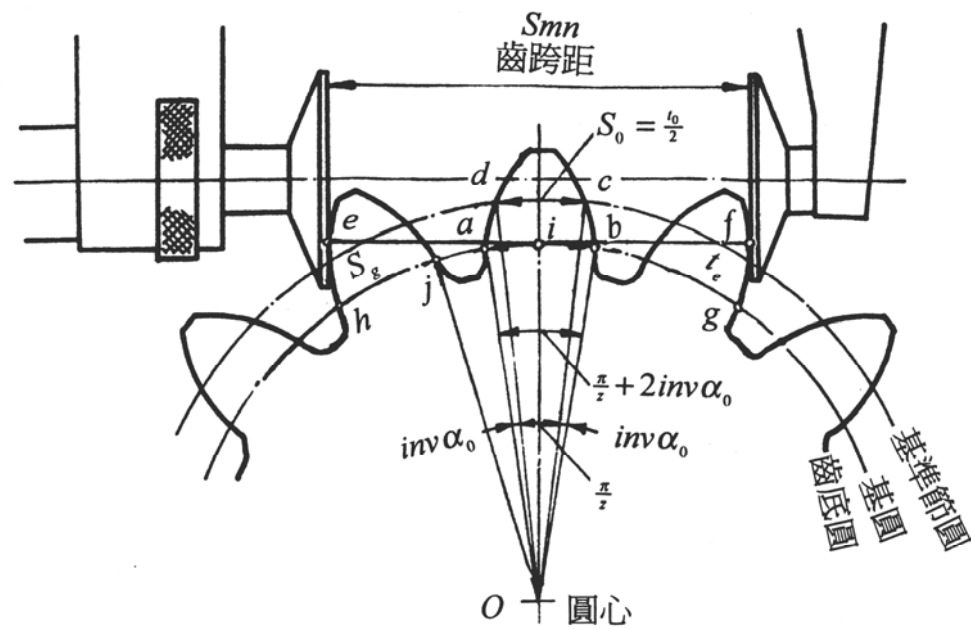


弦線齒厚 (齒法線剖面)



游標尺齒高

圖 11-2-5 螺旋齒輪



細部分析圖

圖 11-2-6 跨齒厚量測

表 11-2-4 模數 = 1 之標準正齒輪的跨齒厚速見表

單位: mm

z	a. _o = 20°		a. _o = 14.5°		z	a. _o = 20°		a. _o = 14.5°		z	a. _o = 20°		a. _o = 14.5°		z	a. _o = 20°		a. _o = 14.5°	
	z _m	S _m	z _m	S _m		z _m	S _m	z _m	S _m		z _m	S _m	z _m	S _m		z _m	S _m	z _m	S _m
6	2	4.5122	2	4.5945	42	5	13.8728	4	10.8708	78	9	26.1855	8	20.1887	114	13	38.4983	10	29.5065
7	2	4.5262	2	4.5999	43	5	13.8868	4	10.8762	79	9	26.1996	8	20.1940	115	13	38.5123	10	29.5119
8	2	4.5402	2	4.6052	44	5	13.9008	4	10.8816	80	9	26.2136	8	20.1994	116	13	38.5263	10	29.5172
9	2	4.5542	2	4.6106	45	6	16.8670	4	10.8869	81	10	29.1797	8	20.2048	117	14	41.4924	10	29.5226
10	2	4.5683	2	4.6160	46	6	16.8810	4	10.8923	82	10	29.1937	8	20.2101	118	14	41.5064	10	29.5280
11	2	4.5823	2	4.6213	47	6	16.8950	4	10.8977	83	10	29.2077	8	20.2155	119	14	41.5204	10	29.5333
12	2	4.5963	2	4.6267	48	6	16.9090	4	10.9030	84	10	29.2217	8	20.2209	120	14	41.5344	10	29.5387
13	2	4.6103	2	4.6321	49	6	16.9230	4	10.9084	85	10	29.2357	8	20.2262	121	14	41.5484	10	29.5441
14	2	4.6243	2	4.6374	50	6	16.9370	5	13.9553	86	10	29.2497	8	20.2316	122	14	41.5624	10	29.5494
15	2	4.6383	2	4.6428	51	6	16.9510	5	13.9607	87	10	29.2637	8	23.2785	123	14	41.5765	10	29.5548
16	2	4.6523	2	4.6482	52	6	16.9650	5	13.9660	88	10	29.2777	8	23.2839	124	14	41.5905	11	32.6017
17	2	4.6663	2	4.6536	53	6	16.9790	5	13.9714	89	10	29.2917	8	23.2892	125	14	41.6045	11	32.6071
18	3	7.6324	2	4.6589	54	7	19.9452	5	13.9768	90	11	32.2579	8	23.2946	126	15	44.5706	11	32.6124
19	3	7.6464	2	4.6643	55	7	19.9592	5	13.9821	91	11	32.2719	8	23.3000	127	15	44.5846	11	32.6178
20	3	7.6604	2	4.6697	56	7	19.9732	5	13.9875	92	11	32.2859	8	23.3053	128	15	44.5986	11	32.6232
21	3	7.6744	2	4.6750	57	7	19.9872	5	13.9929	93	11	32.2999	8	23.3107	129	15	44.6126	11	32.6285
22	3	7.6884	2	4.6804	58	7	20.0012	5	13.9982	94	11	32.3139	8	23.3161	130	15	44.6266	11	32.6339
23	3	7.7025	2	4.6858	59	7	20.0152	5	14.0036	95	11	32.3279	8	23.3214	131	15	44.6406	11	32.6393
24	3	7.7165	2	4.6911	60	7	20.0292	5	14.0090	96	11	32.3419	8	23.3268	132	15	44.6546	11	32.6447
25	3	7.7305	3	7.7380	61	7	20.0432	5	14.0143	97	11	32.3559	8	23.3322	133	15	44.6686	11	32.6500
26	3	7.7445	3	7.7434	62	7	20.0572	6	17.0612	98	11	32.3699	8	23.3375	134	15	44.6826	11	32.6554
27	4	10.7106	3	7.7488	63	8	23.0233	6	17.0666	99	12	35.3361	9	26.3844	135	16	47.6488	11	32.6608
28	4	10.7246	3	7.7541	64	8	23.0373	6	17.0720	100	12	35.3501	9	26.3898	136	16	47.6628	12	35.7077
29	4	10.7386	3	7.7595	65	8	23.0513	6	17.0773	101	12	35.3641	9	26.3952	137	16	47.6768	12	35.7130
30	4	10.7526	3	7.7649	66	8	23.0653	6	17.0827	102	12	35.3781	9	26.4005	138	16	47.6908	12	35.7184
31	4	10.7666	3	7.7702	67	8	23.0794	6	17.0881	103	12	35.3921	9	26.4059	139	16	47.7048	12	35.7238
32	4	10.7806	3	7.7756	68	8	23.0934	6	17.0934	104	12	35.4061	9	26.4113	140	16	47.7188	12	35.7291
33	4	10.7946	3	7.7810	69	8	23.1074	6	17.0988	105	12	35.4201	9	26.4167	141	16	47.7328	12	35.7345
34	4	10.8086	3	7.7863	70	8	23.1214	6	17.1042	106	12	35.4341	9	26.4220	142	16	47.7468	12	35.7399
35	4	10.8227	3	7.7917	71	8	23.1354	6	17.1095	107	12	35.4481	9	26.4274	143	16	47.7608	12	35.7452
36	5	13.7888	3	7.7971	72	9	26.1015	6	17.1149	108	13	38.4142	9	26.4328	144	17	50.7270	12	35.7506
37	5	13.8028	4	10.8440	73	9	26.1155	6	17.1203	109	13	38.4282	9	26.4381	145	17	50.7410	12	35.7560
38	5	13.8168	4	10.8493	74	9	26.1295	7	20.1672	110	13	38.4422	9	26.4435	146	17	50.7550	12	35.7613
39	5	13.8308	4	10.8547	75	9	26.1435	7	20.1725	111	13	38.4563	9	26.4489	147	17	50.7690	12	35.7667
40	5	13.8448	4	10.8601	76	9	26.1575	7	20.1779	112	13	38.4703	10	29.4958	148	17	50.7830	12	35.7721
41	5	13.8588	4	10.8654	77	9	26.1715	7	20.1833	113	13	38.4843	10	29.5011	149	17	50.7970	13	38.8190
															150	17	50.8110	13	38.8243

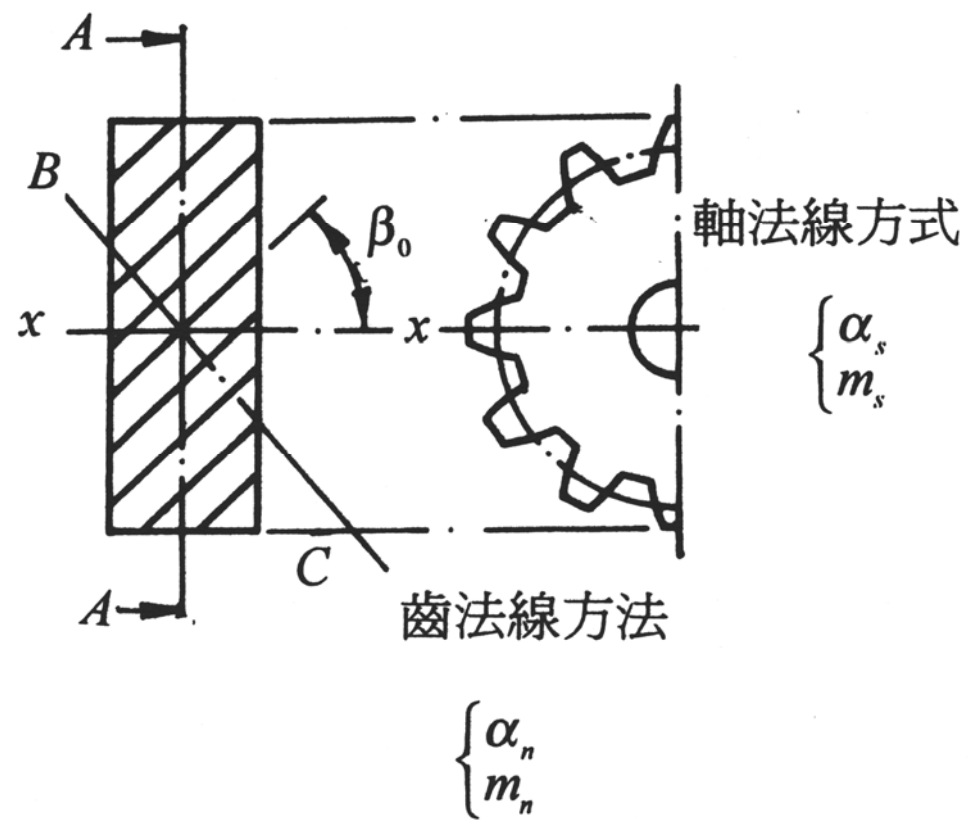


圖 11-2-7 螺旋齒輪

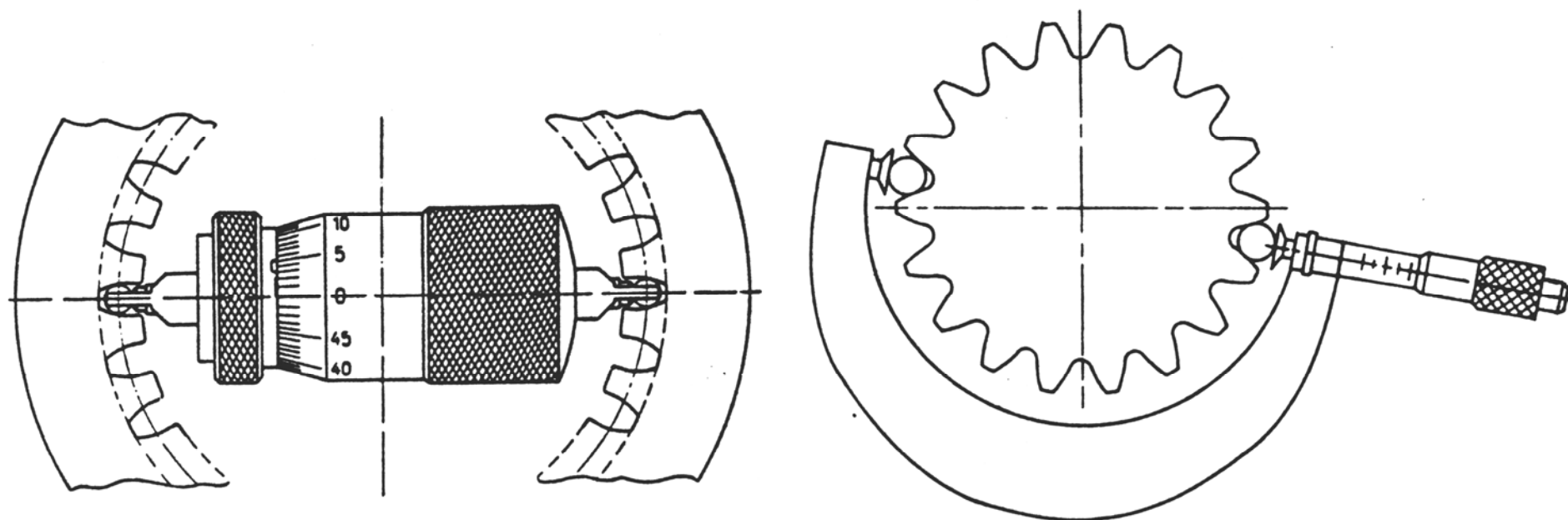
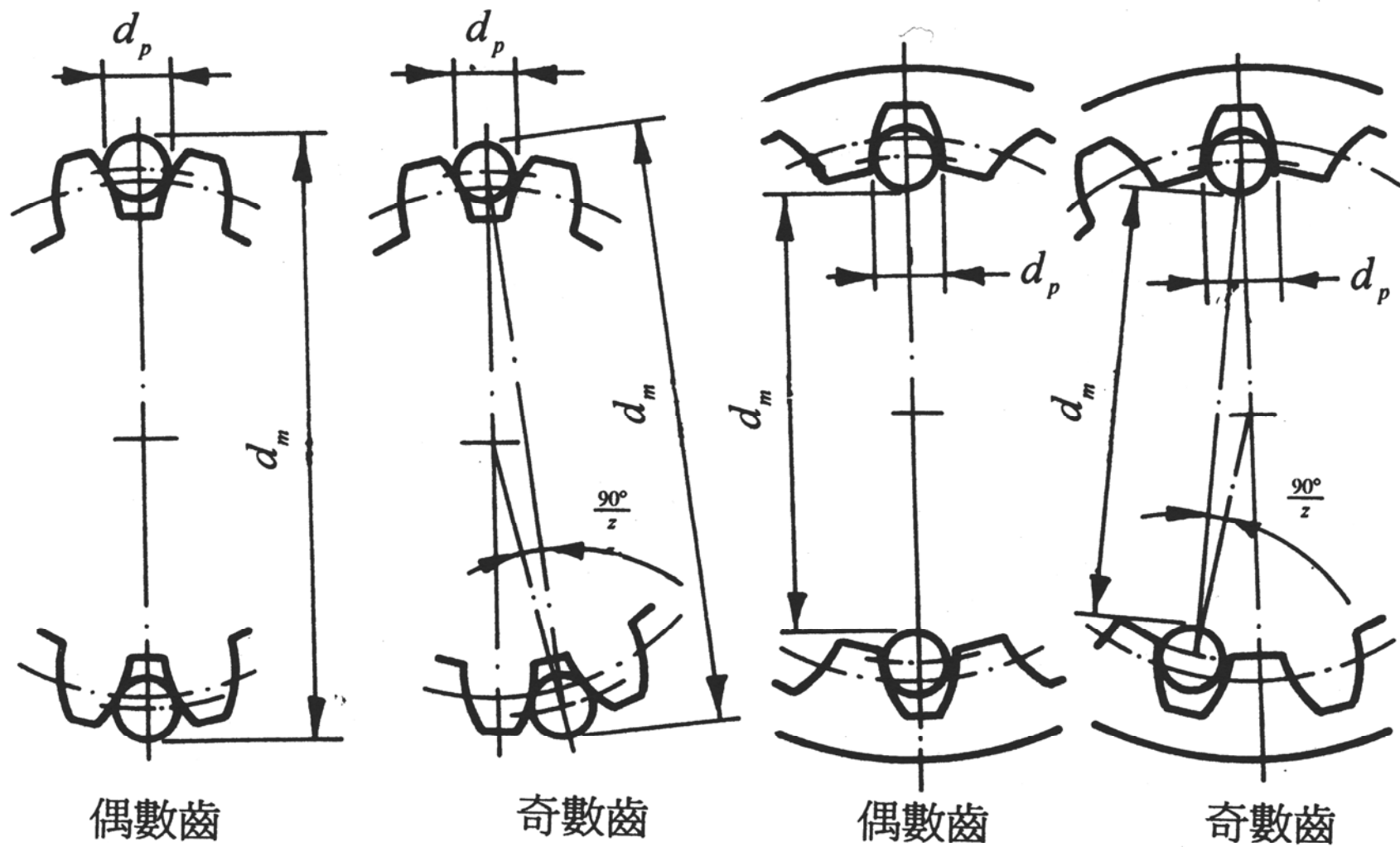


圖 11-2-8 跨銷量測情形



(a) 外接正齒輪

(b) 內接正齒輪

圖 11-2-9 跨銷法量測外、內正齒輪尺寸

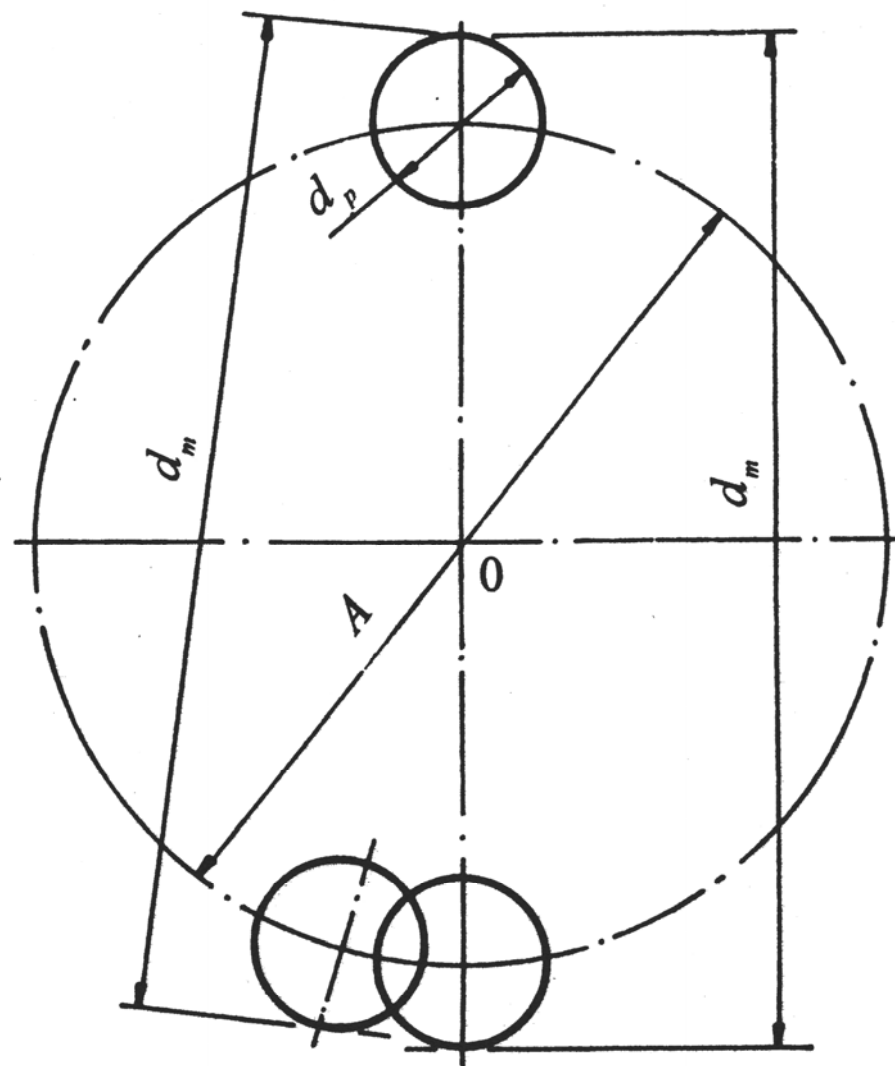
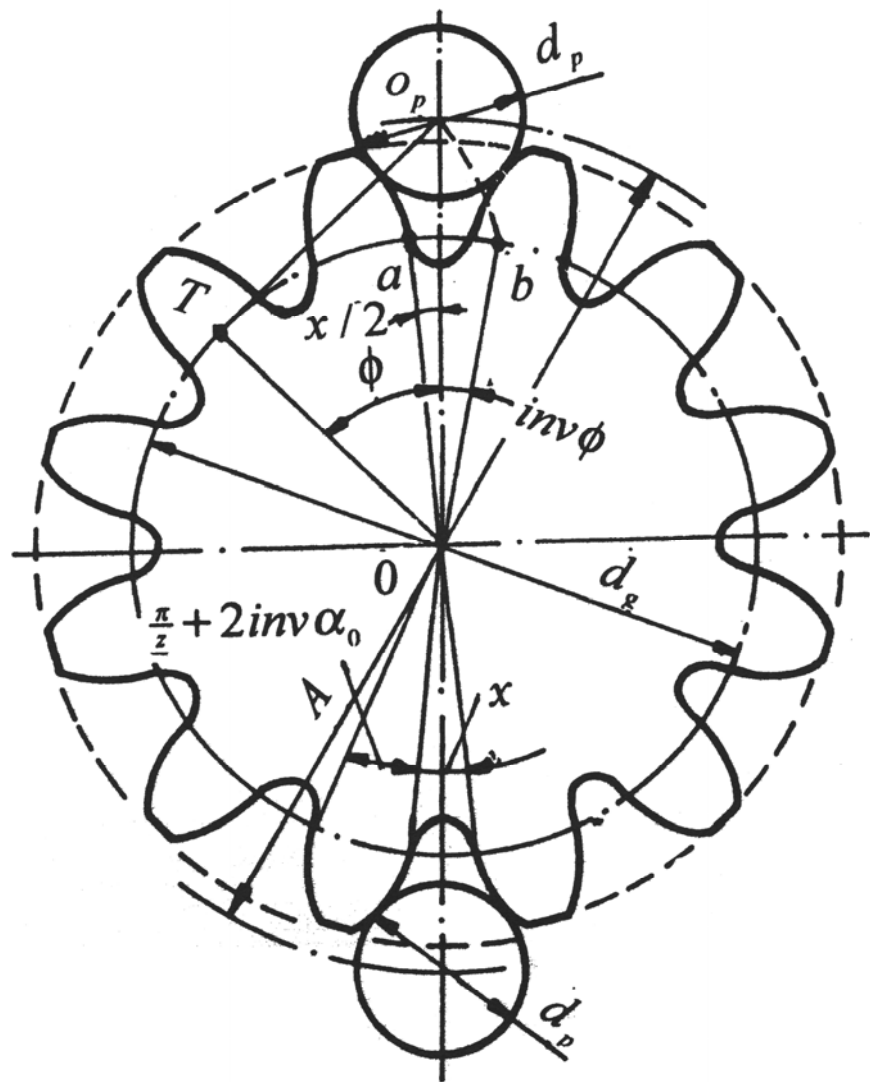


圖 11-2-10 跨銷量測原理

表 11-2-5 標準正齒輪 ($m = 1$ $d = 1.725m$) 標準銷量測值

單位：mm

偶 數 齒						奇 數 齒					
z	d_m		z	d_m		z	d_m		z	d_m	
	$\alpha_0 = 14.5^\circ$	$\alpha_0 = 20^\circ$		$\alpha_0 = 14.5^\circ$	$\alpha_0 = 20^\circ$		$\alpha_0 = 14.5^\circ$	$\alpha_0 = 20^\circ$		$\alpha_0 = 14.5^\circ$	$\alpha_0 = 20^\circ$
06	08.2864	08.3032	060	062.4884	062.4344	05	06.9936	07.0153	061	063.4689	063.4144
			062	064.4902	064.4352				063	065.4712	065.4159
			064	066.4918	066.4361				065	067.4734	067.4173
			066	068.4933	068.4369				067	069.4755	069.4186
08	10.3160	10.3271	068	070.4948	070.4376	09	11.1829	11.1905	069	071.4775	071.4198
10	12.3445	12.3445	070	072.4963	072.4383	11	13.2317	13.2332	071	073.4795	073.4210
12	14.3590	14.3578	072	074.4977	074.4390	13	15.2677	15.2639	073	075.4813	075.4221
14	16.3745	16.3683	074	076.4990	076.4396	15	17.2957	17.2871	075	077.4830	077.4232
16	18.3877	18.3768	076	078.5002	078.4402	17	19.3082	19.3053	077	079.4847	079.4242
18	20.3989	20.3840	078	080.5014	080.4408	19	21.3368	21.3200	079	081.4863	081.4252
20	22.4087	22.3900	080	082.5026	082.4413	21	23.3524	23.3321	081	083.4877	083.4262
22	24.4172	24.3953	082	084.5037	084.4418	23	25.3658	25.3423	083	085.4892	085.4271
24	26.4247	26.3997	084	086.5047	086.4423	25	27.3774	27.3511	085	087.4906	087.4271
26	28.4314	28.4036	086	088.5057	088.4428	27	29.3876	29.3586	087	089.4919	089.4287
28	30.4374	30.4071	088	090.5067	090.4433	29	31.3966	31.3652	089	091.4932	091.4295
30	32.4429	32.4102	090	092.5076	092.4437	31	33.4047	33.3710	091	093.4944	093.4303
32	34.4478	34.4130	092	094.5085	094.4441	33	35.4119	35.3761	093	095.4956	095.4310
34	36.4523	36.4155	094	096.5094	096.4445	35	37.4185	37.3807	095	097.4967	097.4317
36	38.4565	38.4178	096	098.5102	098.4449	37	39.4245	39.3849	097	099.4978	099.4323
37	40.4603	40.4198	098	100.5110	100.4453	39	41.4299	41.3886	099	101.4988	101.4329
40	42.4638	42.4217	100	102.5118	102.4456	41	43.4348	43.3920	101	103.4998	103.4335
42	44.4671	44.4234	102	104.5125	104.4460	43	45.4394	45.3951	103	105.5008	105.4341
44	46.4701	46.4250	104	106.5132	106.4463	45	47.4437	47.3980	105	107.5017	107.4346
46	48.4729	48.4265	106	108.5139	108.4466	47	49.4477	49.4007	107	109.5026	109.4352
48	50.4756	50.4279	108	110.5146	110.4469	49	51.4514	51.4031	109	111.5035	111.4357
50	52.4787	52.4292	110	112.5152	112.4472	51	53.4547	53.4053	111	113.5044	113.4362
52	54.4804	54.4304	112	114.5159	114.4475	53	55.4579	55.4074	113	113.5044	113.4367
54	56.4826	56.4315	114	116.5165	116.4478	55	57.4609	57.4093	115	117.5060	117.4372
56	58.4847	58.4325	116	118.5171	118.4481	57	59.4637	59.4111	117	119.5068	119.4376
58	60.4866	60.4335	118	120.5177	120.4484	59	61.4664	61.4128	119	121.5075	121.4380

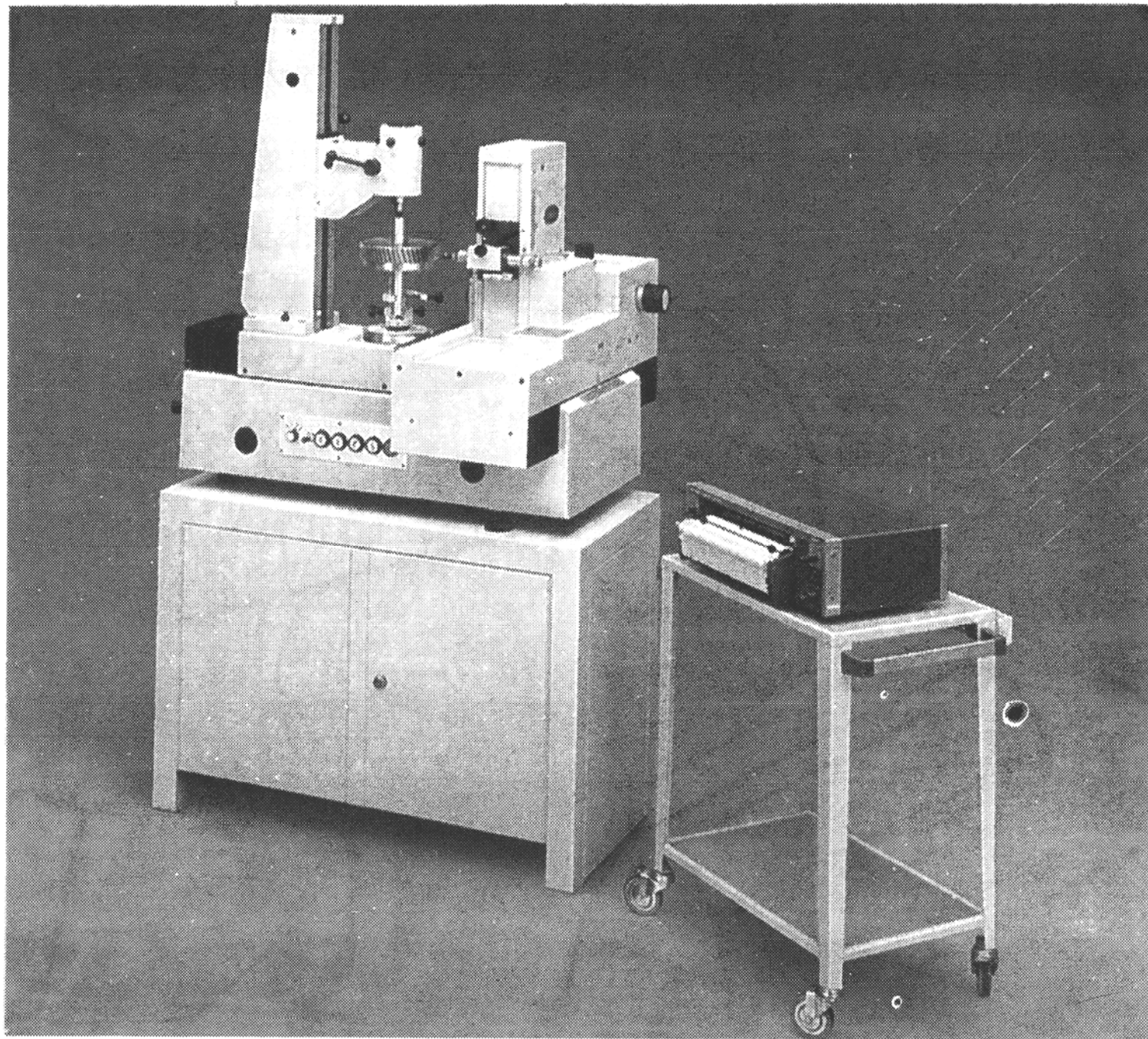


圖 11-2-11 齒形量測儀 ([31])

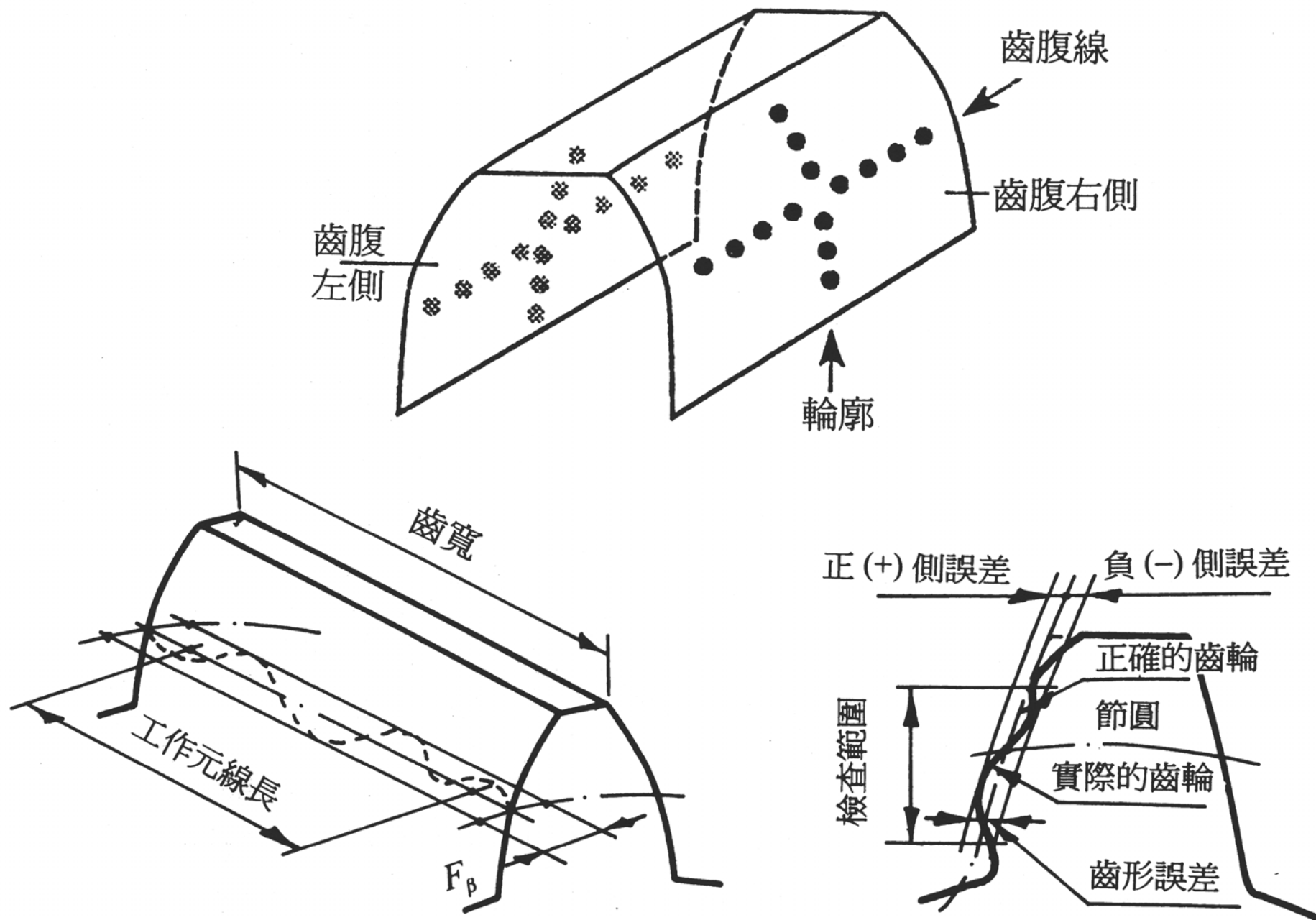
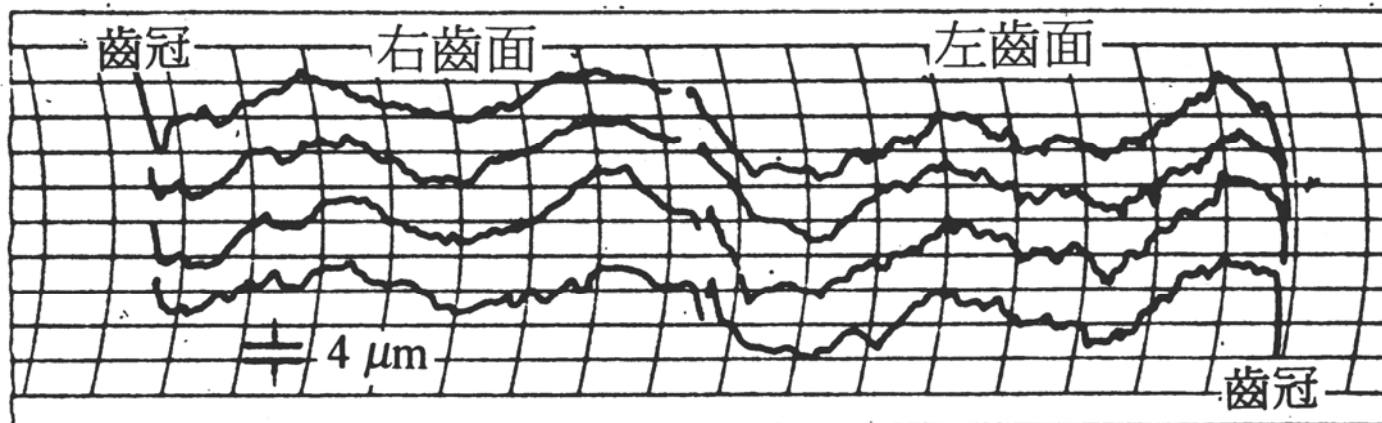
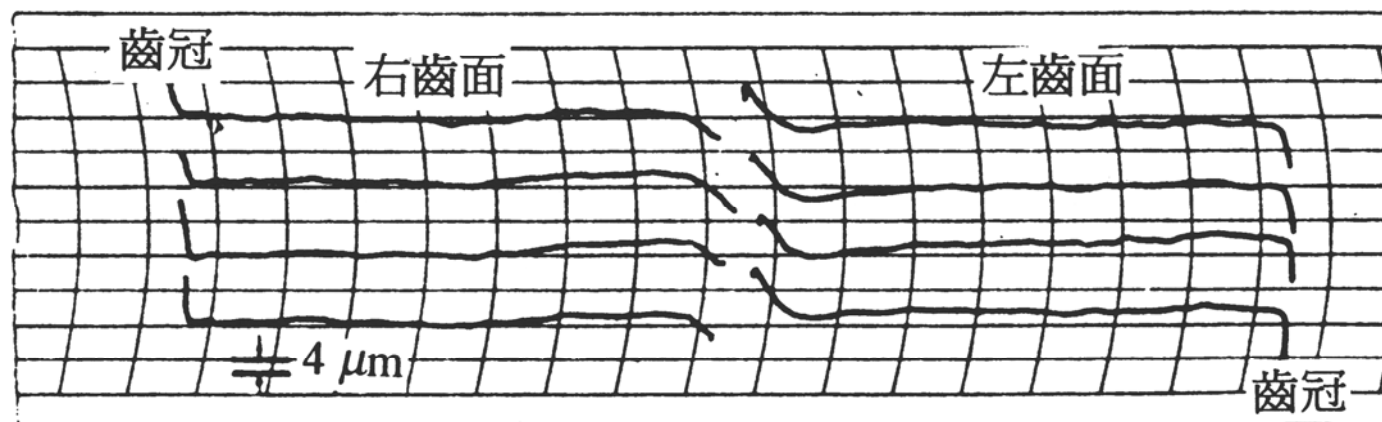


圖 11-2-12 齒形的誤差



(a) 滾齒齒輪 ($m = 3.5, z = 33, a = 20^\circ, b = 32$)



(b) 輪磨齒輪 ($m = 3, z = 30, a = 20^\circ, b = 32$)

圖 11-2-13 量測齒形誤差例

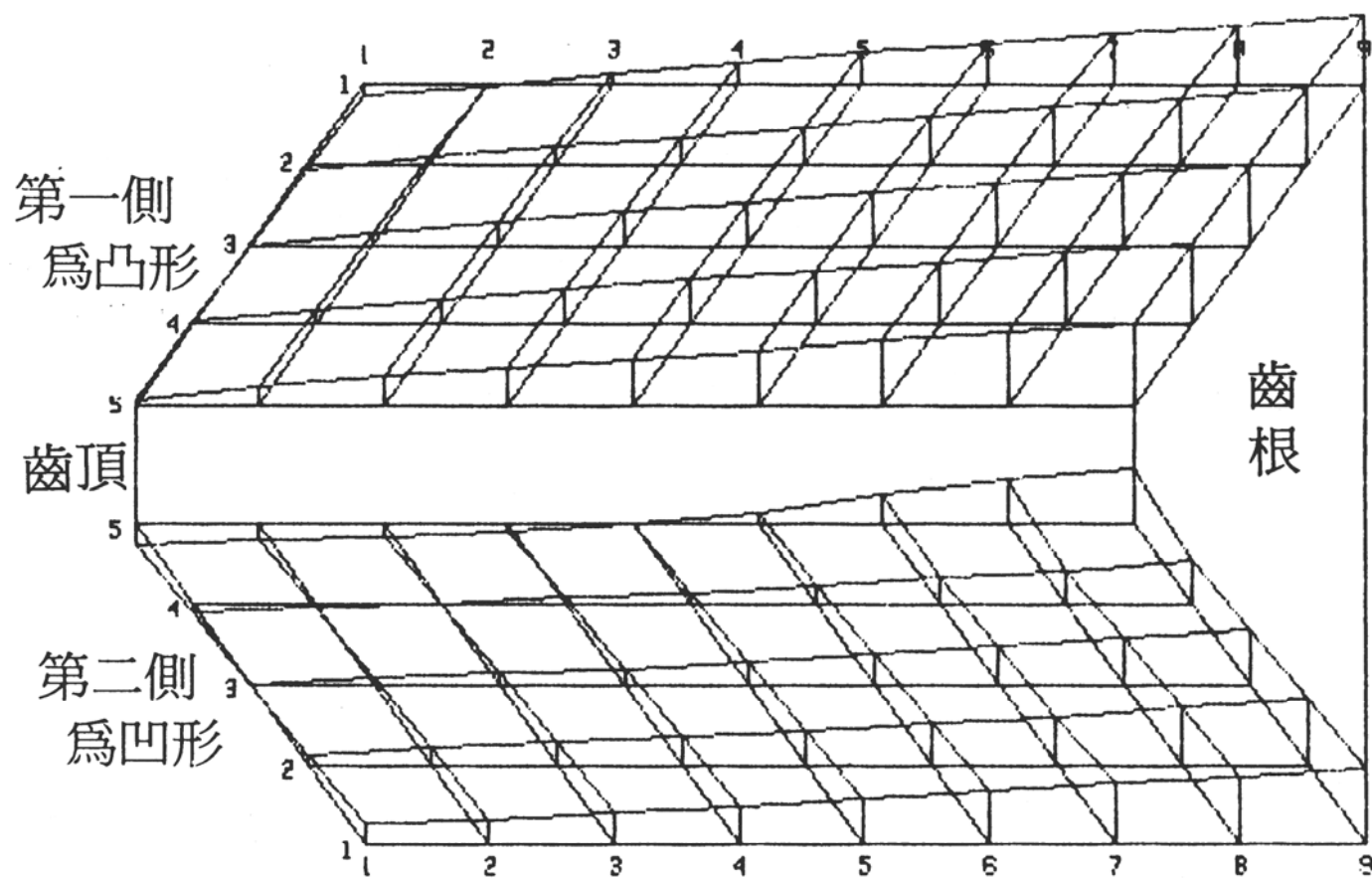


圖 11-2-14 齒形量測圖形

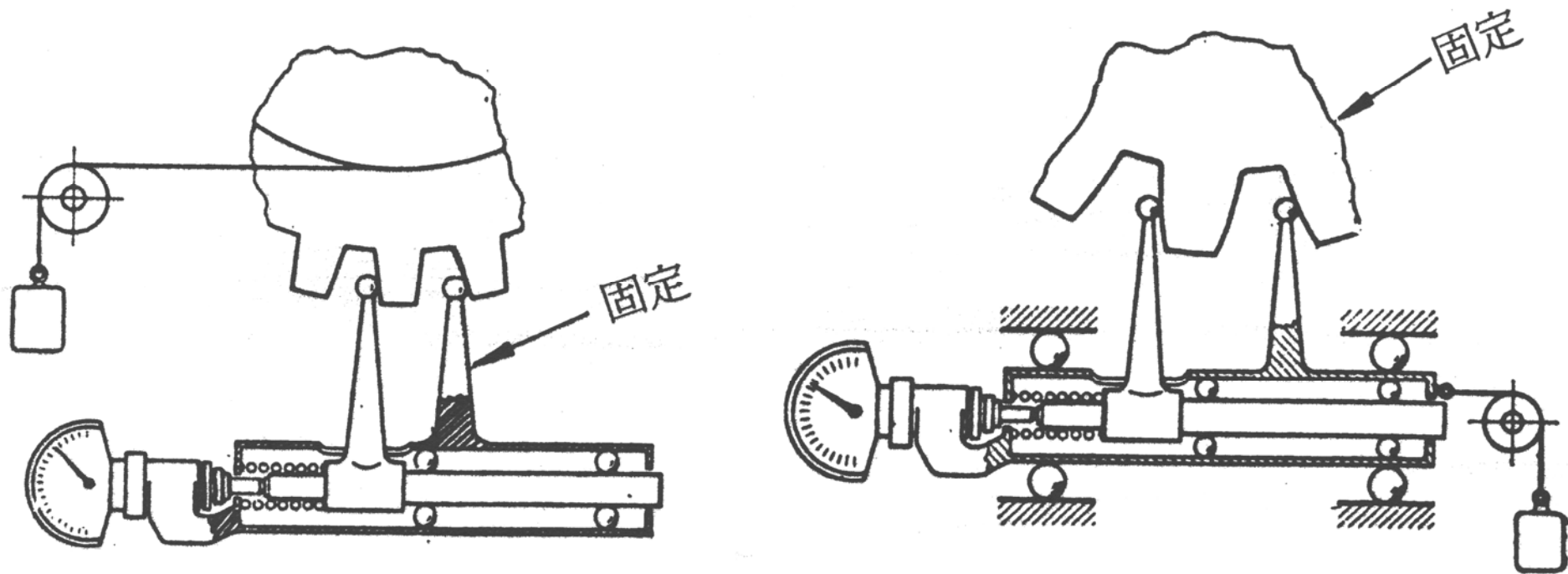


圖 11-2-15 齒輪量測儀之節距檢驗

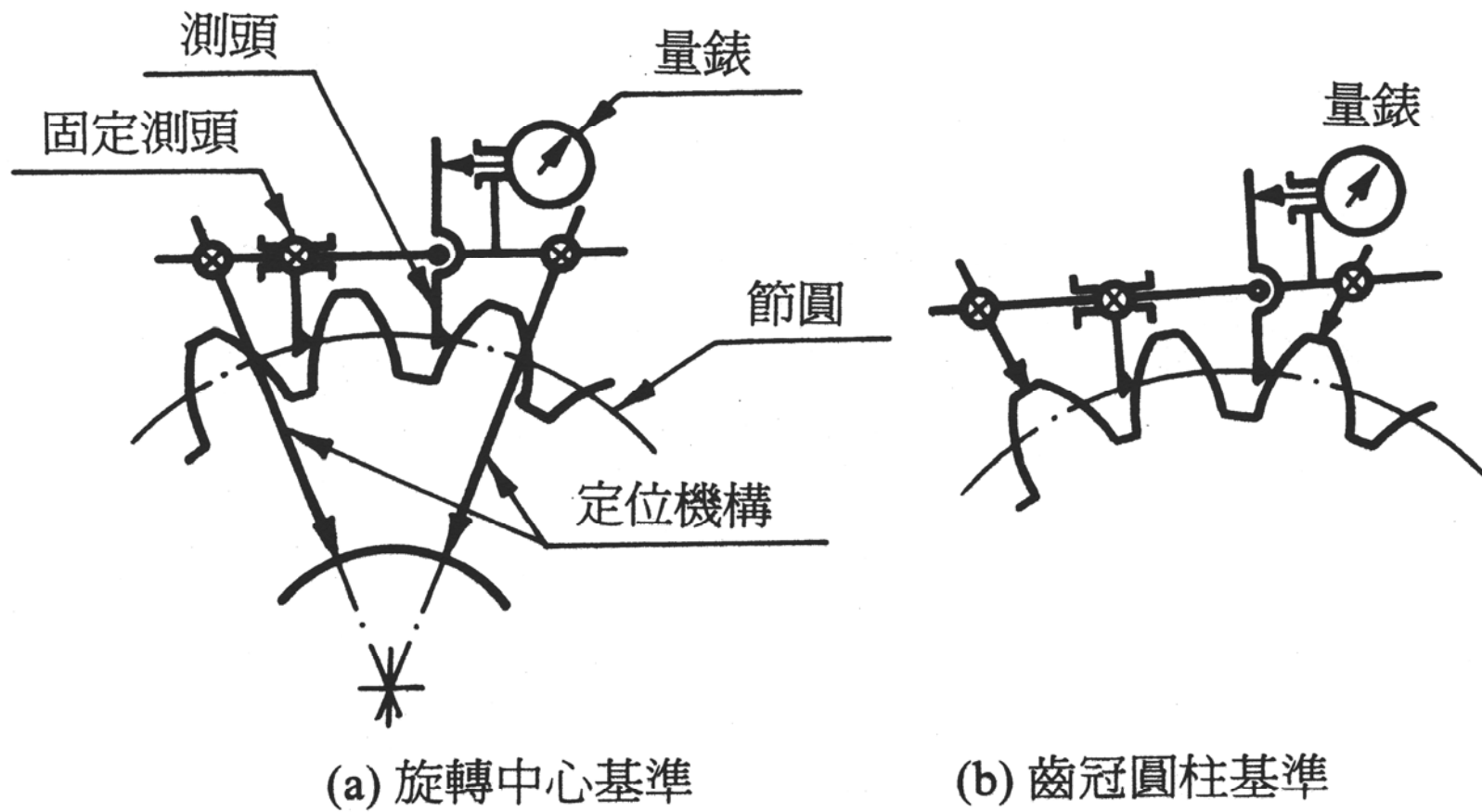


圖 11-2-16 周節量測方式

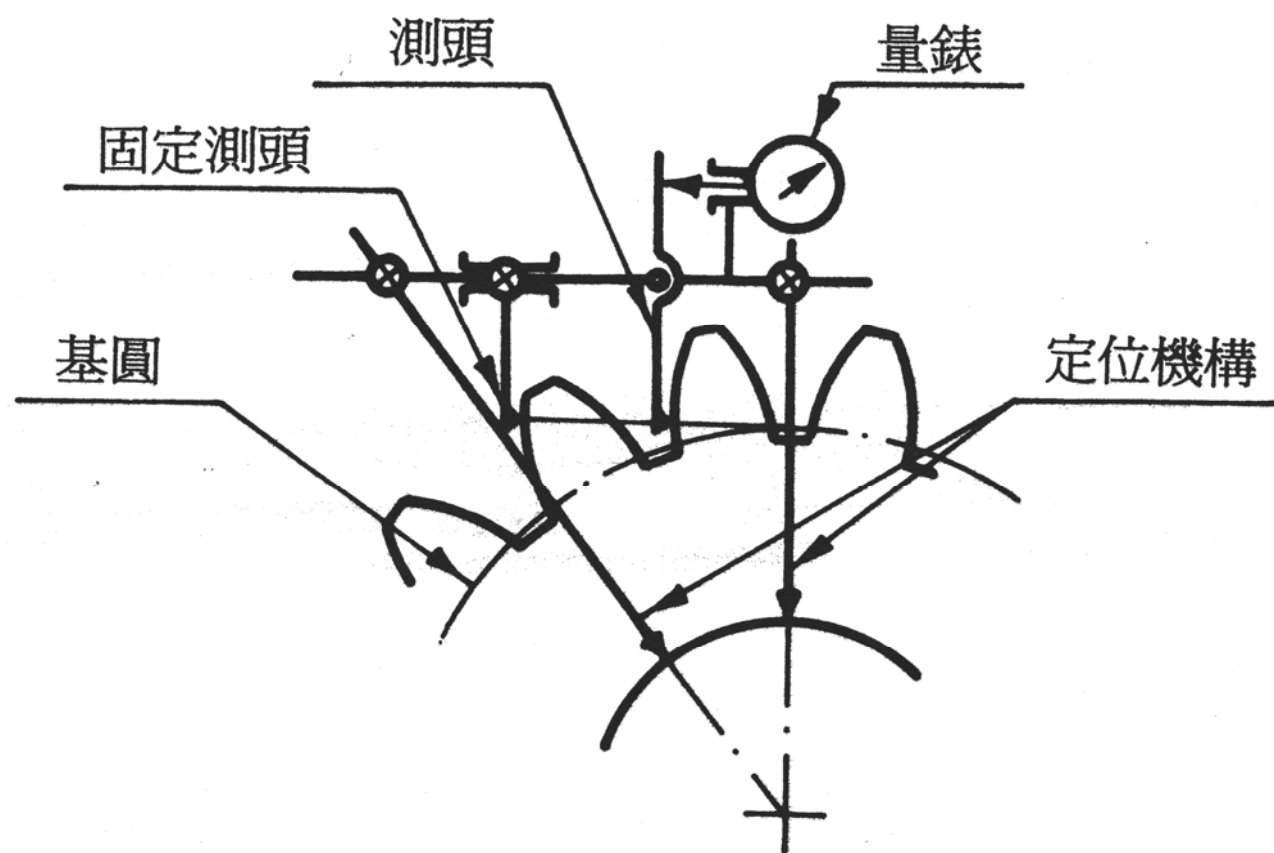


圖 11-2-17 法節量測方式

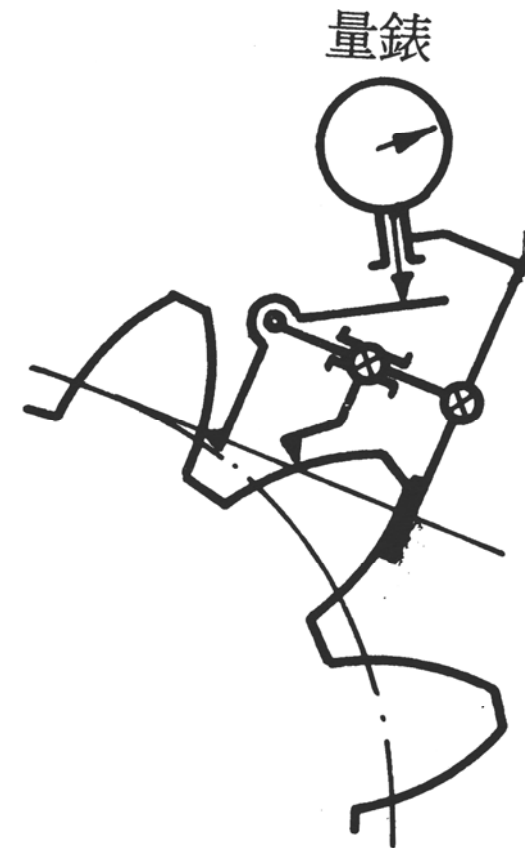
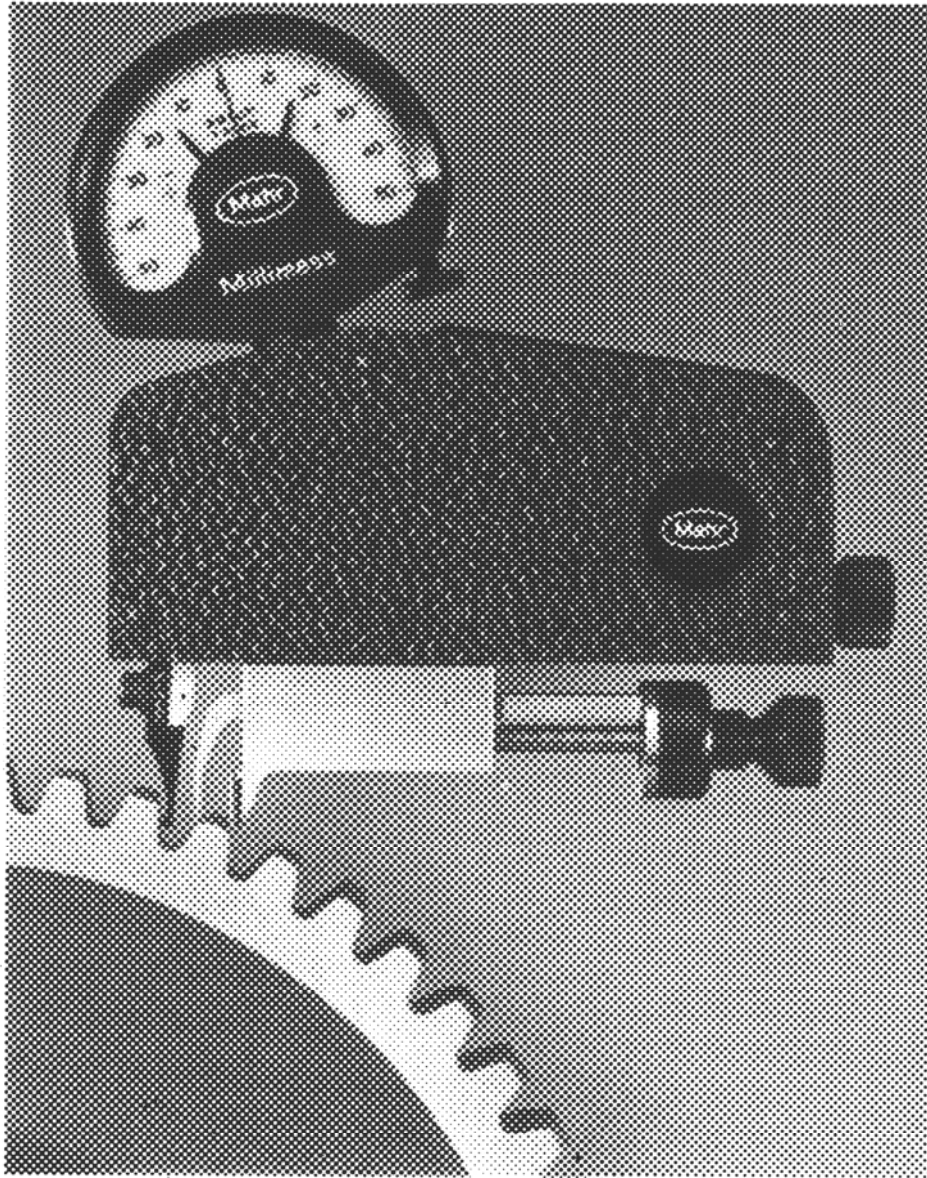
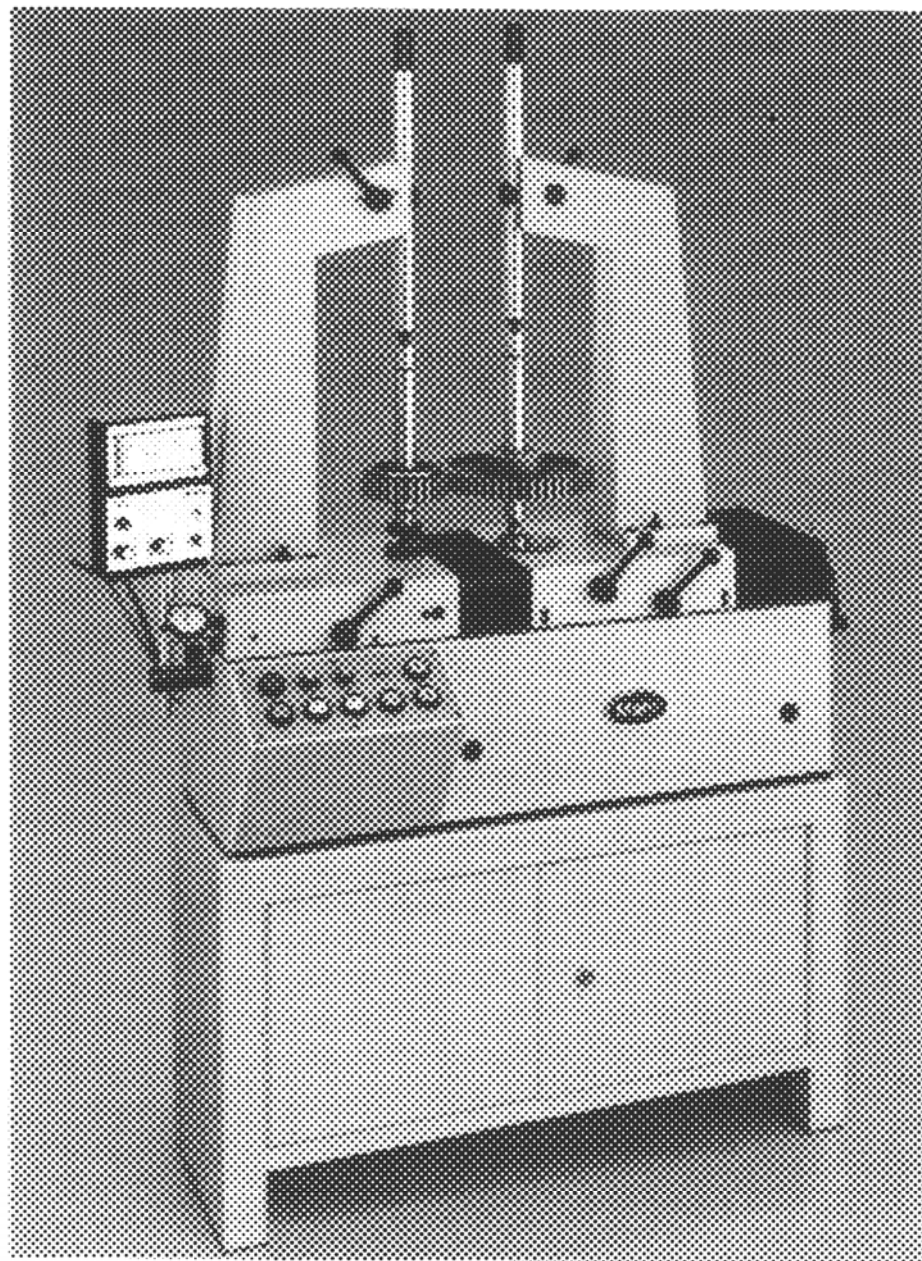
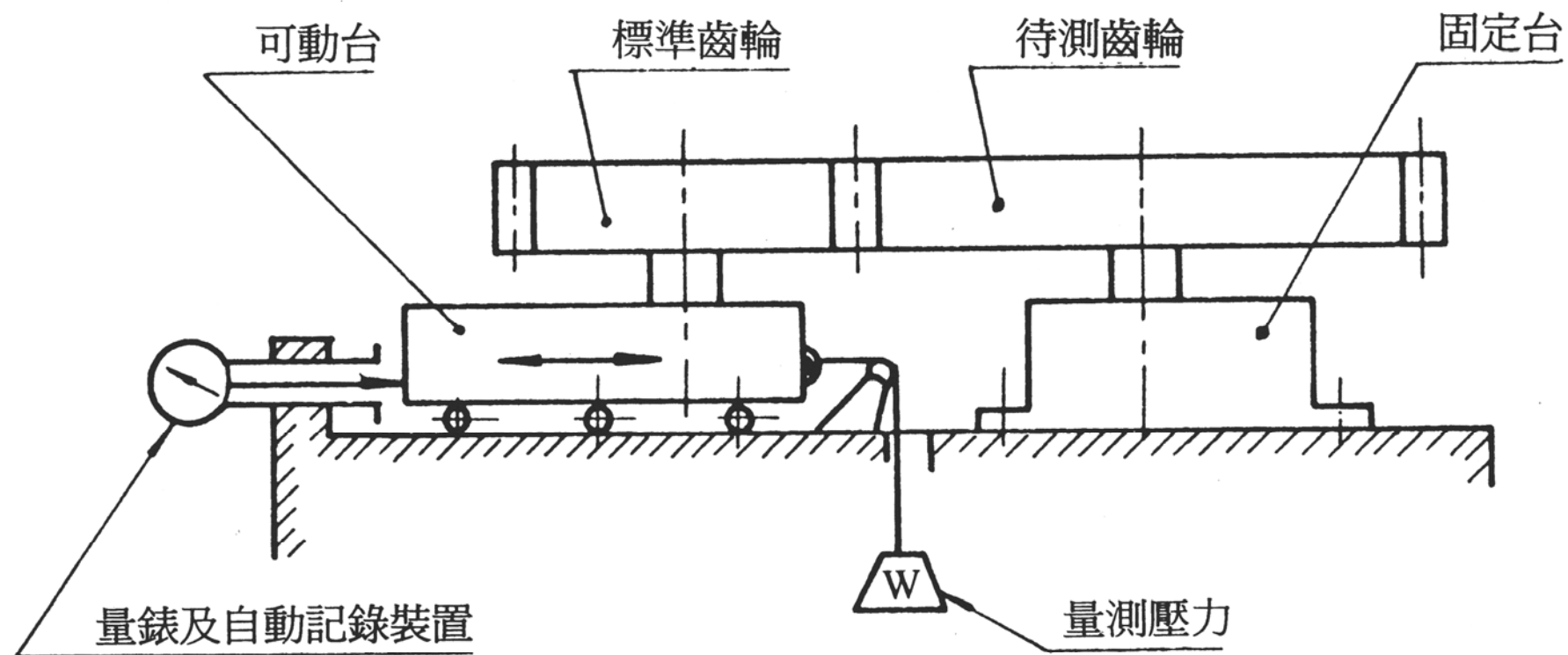


圖 11-2-18 手提式法節量錶 (德國 Mahr 公司出品, [31])



(a) 外形

圖 11-2-19 滾合試驗機



(b) 示意圖

圖 11-2-19 滾合試驗機

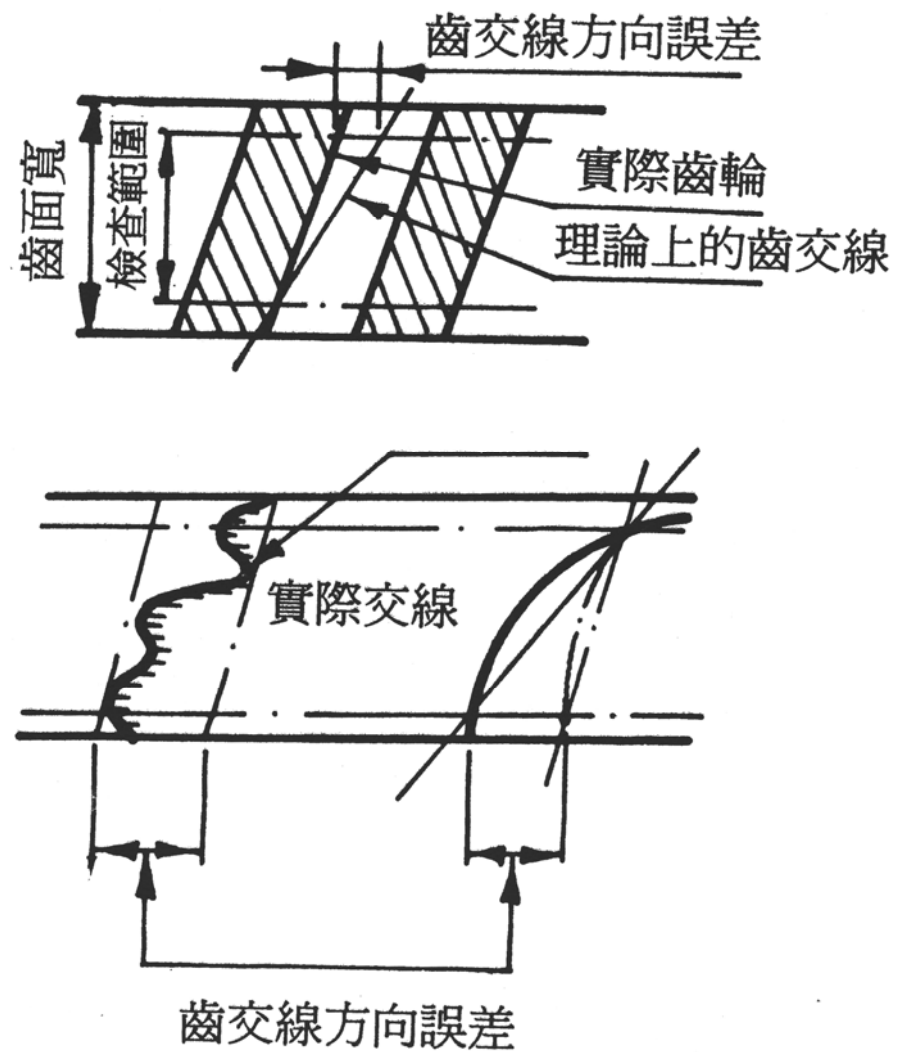


圖 11-2-20 齒交線方向誤差

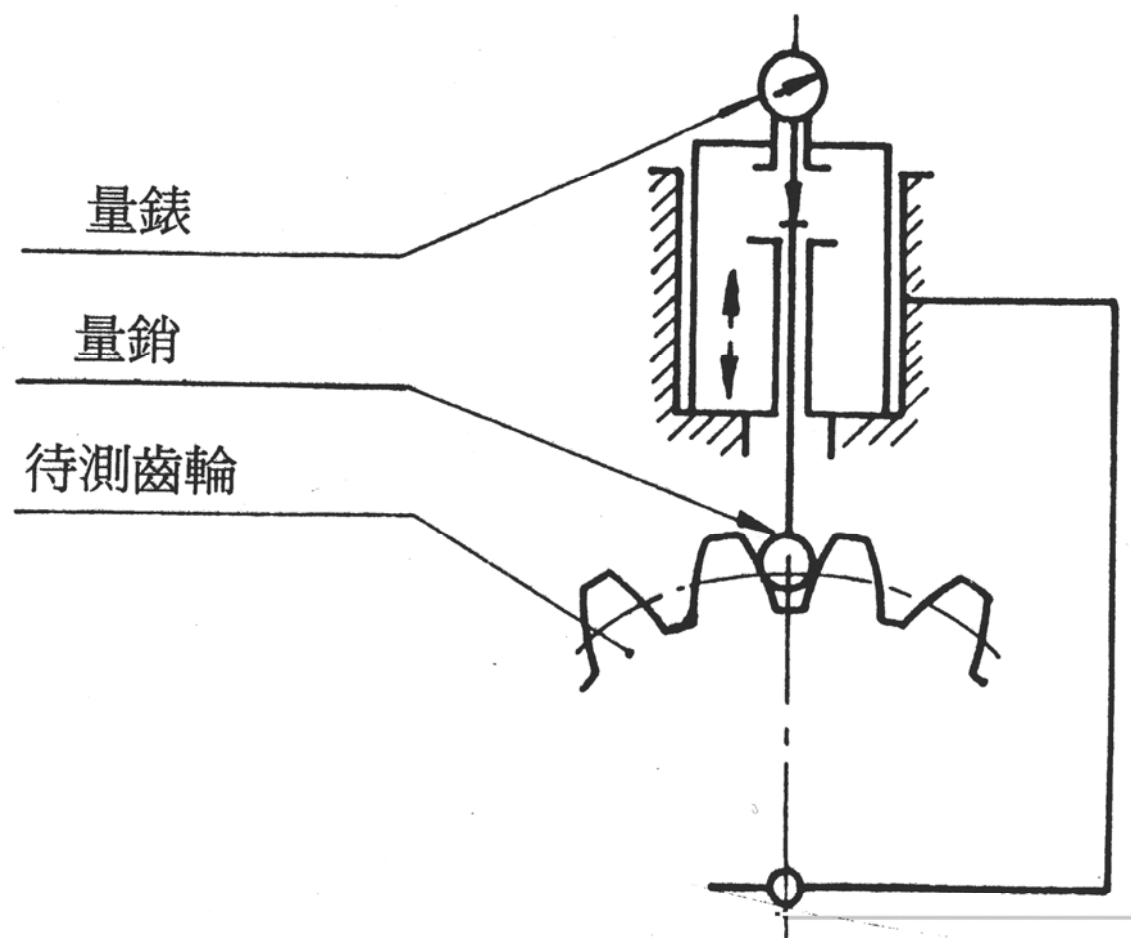


圖 11-2-21 徑向偏擺之檢驗

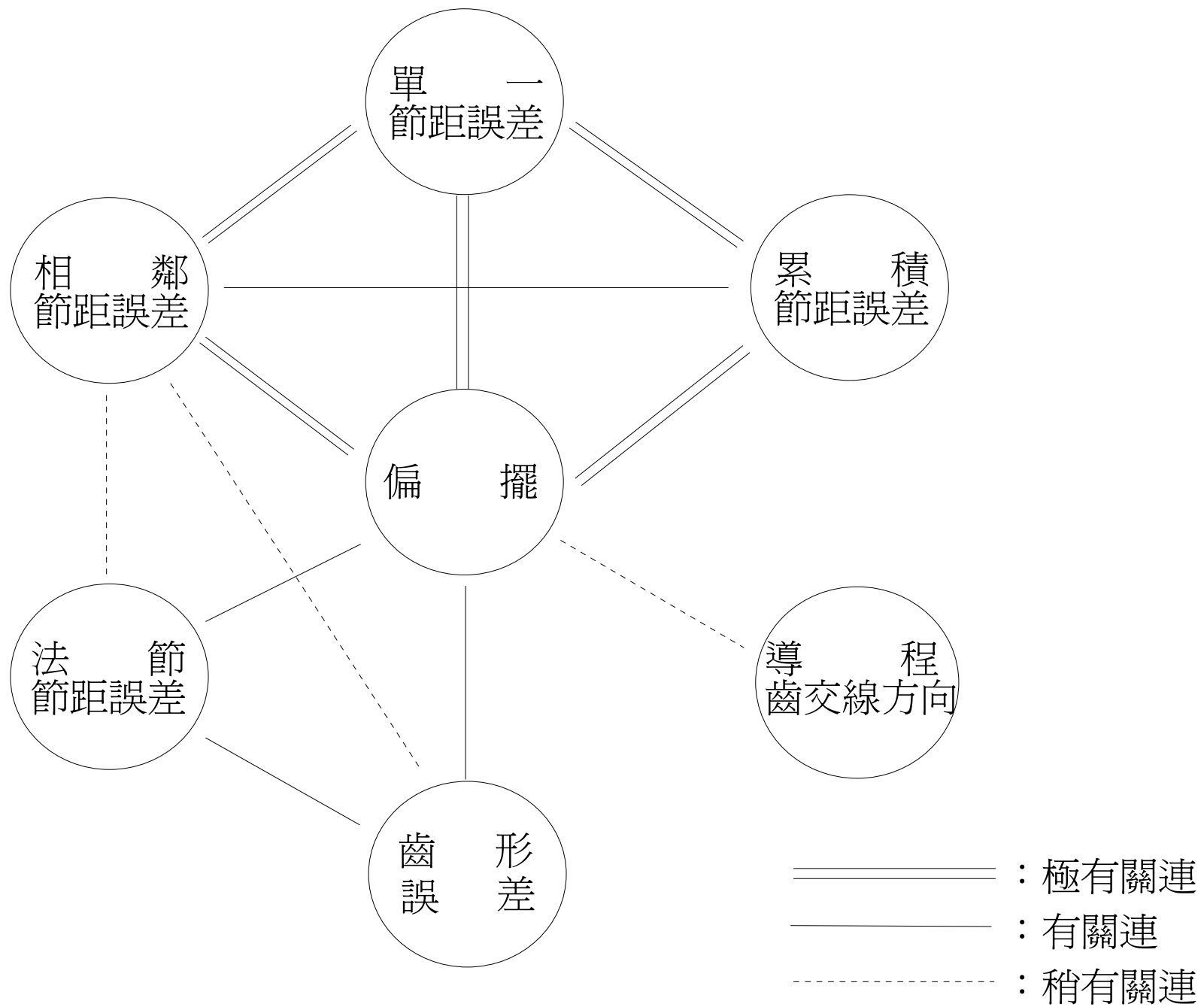


圖 11-2-22 個別誤差相關圖 ([17], P.277)