



To Generate an Estimation Rule for Prediction of the Changes in Dimension of Components Due to Heat Treatment

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ABSTRACT

Heat treatment changes the physical properties of materials. Components are generated with the part print dimensions before they are sent to heat treatment. After heat treatment this dimensions alter. These changes may cause rejection of component or extra machining at the final stage of component. Prediction of the dimensional changes due to heat treatment will help in reducing the number of rejections and reduces the final stage machining. So record the changes in dimensions of components and based on that establish the rule which help in prediction of the dimensional change for a component.

KEYWORDS: gear wheel, pinion, pinion shaft, crown gear, heat treatment distortion.

INTRODUCTION

A gear wheel, pinion, pinion shaft and the crown gear are the components of the gear box so accurate machining is the important consideration of the any organization where the manufacturing of the gear box is done.

Vulcan industrial Engineering Co. Ltd. manufacturing the all type of gear box and its components such as gear wheel, pinion, pinion shaft and the crown gear.

Thermal and residual stresses that develop during heat treatment and quenching can result in distortion. After Heat Treatment process, Distortion is generally come out on the MOT and BORE.

The life of the any Gears depends on Case depth So if the distortion is come out on the MOT, to remove this distortion grinding is required. If

the distortion is higher than final grinding required more depth to remove this distortion and also the life of the gears is decrease, so reduce this distortion finding the before and after measurement of MOT and BORE and get the distortion.

EXPERIMENTAL WORK:

The main purpose is take a 250 to 300 reading for MOT and BORE and from that predict the general rule for the component after heat treatment process which is useful to set machining allowances before heat treatment process.

In this paper, record the dimensions of particular components before and after heat treatment, compute the dimension change and establishing dimension change prediction rules for the components. This prediction is done with respect to the Module of gear for MOT of gear.

Experimental work (Reading) for the particular components are listed below in the table:

PINION SHAFT							
Sr. No	Batch No.	Parts No.	Module	No. of teeth	MOT (3-Teeth)		
					Before	After	Distortion
1	112	30304026-1	4.5	19 (67)	36.78-36.80	36.95	+ 0.15
2		30304026-2	4.5	19 (67)	36.75- 36.76	36.87	+ 0.11
3		30306897-1	6	15 (66)	47.55- 47.60	47.90	+ 0.30
4		30306897-2	6	15 (66)	47.55- 47.60	47.86	+ 0.26
5		30306898-1	6	15 (59)	47.65- 47.70	47.87	+ 0.17
6		30306898-2	6	15 (59)	47.65- 47.70	47.93	+ 0.23
7		30306877	7	15 (53)	56.65- 56.70	56.89	+ 0.19
8		30400140	8	18 (57)	64.53- 64.70	64.82	+ 0.12
9	113	30300573	12	16 (64)	97.19- 97.25	97.32	+ 0.07
10	114	30304597-1	3.5	21 (57)	27.93- 27.95	28.06	+ 0.11
11		30304597-2	3.5	21 (57)	27.90- 27.94	27.99	+ 0.05
12		30306639-1	2.75	18 (45)	22.05- 22.07	22.22	+ 0.15
13		30306639-2	2.75	18 (45)	22.05- 22.07	22.18	+ 0.11
14	115	30300406	4	21 (58)	31.85- 31.90	32.05	+ 0.15
15		30300408	5	18 (68)	40.20- 40.25	40.37	+ 0.12
16		30303393	5	19 (68)	39.77- 39.80	39.96	+ 0.16
17		30306763	3.75	15 (76)	30.67- 30.70	30.77	+ 0.07
18	118	30306583-1	4.5	18 (80)	35.45- 35.47	35.53	+ 0.06
19		30306583-2	4.5	18 (80)	35.45- 35.47	35.53	+ 0.06
20		30306880-1	4.5	15 (54)	35.76- 35.82	35.93	+ 0.11
21		30306880-2	4.5	15 (54)	35.77- 35.82	35.90	+ 0.08
22	119	30306881-1	6	21 (71)	47.35- 47.38	47.51	+ 0.14
23		30306768-1	2.5	17 (60)	20.05- 20.08	20.24	+ 0.16
24		30306768-2	2.5	17 (60)	20.05- 20.10	20.26	+ 0.16
25	120	30305018	2.5	18 (51)	20.10- 20.14	20.36	+ 0.22
26	122	061916- 1	11	15 (66)	86.90- 86.96	87.05	+ 0.09
27		061916- 2	11	15 (66)	86.92- 87.00	86.99	+ 0.01
28		061916- 3	11	15 (66)	86.92- 87.00	87.01	+ 0.01

29	126	30306881-2	6	20 (71)	36.20- 36.25	36.41	+ 0.16
31		30403382	4.5	20 (40)	47.35- 47.40	47.52	+ 0.12
32	128	30306683-1	2	16 (81)	15.99- 16.00	16.05	+ 0.05
33		30404008-1	3	17 (34)	23.91- 23.93	24.48	+ 0.55
34	131	30306994	5	17 (69)	40.27- 40.32	40.43	+ 0.11
MOT (2 teeth)							
1	128	30403555	2	14 (72)	10.00	10.09	+ 0.09
MOT (4 teeth)							
1	114	30303392	3.5	21 (67)	38.54- 38.56	38.70	+ 0.14
2	119	30304780-1	2	24 (53)	22.15- 22.18	22.30	+ 0.12
3		30304780-2	2	24 (53)	22.14- 22.16	22.26	+ 0.10
4	131	61912- 1	7	26 (74)	77.28- 77.32	77.34	+ 0.02
5		61912- 2	7	26 (74)	77.28- 77.32	77.09	- 0.23
6		65878- 1	5	28 (82)	55.42- 55.45	55.54	+ 0.09
7		65880- 1	5	28 (82)	55.42- 55.45	55.56	+ 0.11

GEAR WHEEL										
Sr. No	Batch No.	Parts No.	Module	No. of teeth	MOT			Bore		
					Before	After	Distortion	Before	After	Distortion
1	112	40300409	5	68	148.92-149.05 (10 teeth)	149.64	+ 0.59	111.05	111.00	- 0.05
2		40421384	5	77	162.80- 162.85 (11 teeth)	163.01	+ 0.16	124.08	123.90	- 0.18
3		40421394	7	53	163.92- 163.95 (8 teeth)	163.99	+ 0.04	179.05	178.97	- 0.08
4	114	40300407	4	58	79.40- 79.535 (7 teeth)	79.58	+ 0.045	---	---	---
5		40407243	3.5	67	92.40- 92.35 (9 teeth)	92.88	+ 0.48	64.08- 64.60	64.18	- 0.42
6		40421264	2	81	59.10- 59.25 (10 teeth)	59.45	+ 0.20	49.60- 49.63	49.92	+ 0.29
7	118	40421415-1	4.5	54	90.18- 90.22 (7 teeth)	90.23	+ 0.01	84.05- 84.07	84.37	+ 0.30
8		40421415-2	4.5	54	90.15- 90.20 (7 teeth)	90.24	+ 0.04	84.06- 84.07	84.38	+ 0.31
9	119	40421413-1	3.5	21	27.95- 28.05 (3 teeth)	28.14	+ 0.09	49.55	49.63	+ 0.08
10		40421413-2	3.5	21	28.00- 29.05 (3 teeth)	29.13	+ 0.08	49.55	49.59	+ 0.04
11		40421414-1	3.5	41	37.49- 37.75 (4 teeth)	37.76	+ 0.01	49.57	49.51	- 0.06
12		40421414-2	3.5	41	37.47- 37.49 (4 teeth)	37.61	+ 0.12	49.57	49.50	- 0.07
13	122	40421358	9	66	207.60- 207.62 (8 teeth)	207.92	+ 0.30	187.05	187.82	+ 0.77
14	124	061915- 2	11	66	254.31- 254.32 (8 teeth)	254.63	+ 0.31	187.10	187.80	+ 0.70
15	124	061915- 3	11	66	254.34- 254.35 (8 teeth)	254.70	+ 0.35	187.08- 187.09	187.80	+ 0.71
16	125	061915- 1	11	66	254.31- 254.32 (8 teeth)	254.63	+ 0.31	187.10	187.74	+ 0.64
17		065018- 1	10	101	20.40- 20.50 (chordal thickness)	20.86	+ 0.36	272.05	273.04	+ 0.99
18		065018- 2	10	101	20.65- 20.67 (chordal thickness)	21.06	+ 0.39	272.10	273.12	+ 1.02
19	126	40302271	6	64	158.50- 158.54 (9 teeth)	158.70	+ 0.16	129.05	129.43	+ 0.38
20		40403383	4.5	40	76.76- 76.79 (6 teeth)	76.86	+ 0.07	64.60	64.92	+ 0.32
21		40421416- 1	6	71	156.75- 156.80 (9 teeth)	156.93	+ 0.13	139.10	139.63	+ 0.53
22		40421416- 2	6	71	156.78- 156.82 (9 teeth)	156.93	+ 0.11	139.09	138.94	- 0.15
23		40420991	5	69	147.67- 147.72 (10 teeth)	147.84	+ 0.12	109.05- 109.06	109.30	+ 0.24
24		061913- 1	5	82	145.97- 146.03 (10 teeth)	146.33	+ 0.30	109.10	109.66	+ 0.56
25		40407367- 2	7	68	184.27- 184.28 (9 teeth)	184.75	+ 0.47	140.05	140.18	+ 0.13
26	127	40407367- 1	7	68	184.26- 184.27 (9 teeth)	184.55	+ 0.28	140.05	140.18	+ 0.13
27		061917- 1	7	74	184.76- 184.77 (9 teeth)	185.00	+ 0.23	117.05- 117.06	177.23	+ 0.17
28		061917- 2	7	74	184.76- 184.77 (9 teeth)	184.98	+ 0.21	117.05- 117.06	177.21	+ 1.15
29		061917- 3	7	74	184.78- 184.80 (9 teeth)	185.00	+ 0.20	117.05- 117.06	177.20	+ 0.14

30	128	40300407-2	4	58	76.36- 76.40 (7 teeth)	76.42	+ 0.02	71.55- 71.56	71.60	+ 0.04
31	129	40404009-1	3	34	42.55- 42.60 (5 teeth)	42.73	+ 0.13	35.55- 35.58	35.52	- 0.06
32						MOT (4 teeth)		Bore		
33		065948- 2	1.75	26	19.71- 19.75	19.93	+ 0.18	19.20- 21.82	21.58	- 0.24
34		065948- 3	1.75	26	19.69- 19.75	19.82	+ 0.07	19.22- 21.82	21.54	- 0.28
35		065948- 4	1.75	26	19.70- 19.73	19.88	+ 0.15	19.25- 21.82	21.60	- 0.22
36		065948- 5	1.75	26	19.70- 19.75	19.81	+ 0.06	19.23- 21.82	21.36	- 0.46
37		065948- 7	1.75	26	19.70- 19.75	19.84	+ 0.09	19.22- 21.82	21.36	- 0.46
38		065948- 8	1.75	26	19.75- 19.76	19.77	+ 0.01	19.20- 21.82	21.50	- 0.32
39		065948- 9	1.75	26	19.75- 19.76	19.78	+ 0.02	19.22- 21.82	21.52	- 0.30
40		065948- 10	1.75	26	19.78- 19.82	19.78	- 0.04	19.10- 19.73	21.58	- 0.15
41		065948- 11	1.75	26	19.75- 19.78	19.85	+ 0.07	19.18- 21.77	21.60	- 0.17
42						MOT (7 teeth)		Bore		
43		065949- 1	1.75	50	36.35- 36.38	36.45	+ 0.07	29.84	29.64	- 0.20
44		065949- 3	1.75	50	36.33- 36.35	36.48	+ 0.13	29.85- 29.87	29.72	- 0.15
45		065949- 4	1.75	50	36.33- 36.35	36.44	+ 0.09	29.82- 29.87	29.70	- 0.17
46		065949- 5	1.75	50	36.33- 36.35	36.44	+ 0.09	29.85- 29.87	29.62	- 0.25
47		065949- 6	1.75	50	36.33- 36.35	36.43	+ 0.08	29.82- 29.87	29.64	- 0.23
48		065949- 7	1.75	50	36.31- 36.35	36.42	+ 0.07	29.82- 29.87	29.64	- 0.23
49		065949- 8	1.75	50	36.33- 36.36	36.47	+ 0.11	29.82- 29.87	29.62	- 0.25
50		065949- 9	1.75	50	36.33- 36.36	36.46	+ 0.10	29.85- 29.87	29.64	- 0.23
51		065949- 10	1.75	50	36.31- 36.35	36.45	+ 0.10	29.85- 29.87	29.70	- 0.17
52		065949- 11	1.75	50	36.33- 36.35	36.42	+ 0.07	29.85- 29.87	29.62	- 0.15
53	130	40303556-1	2	72	66.19- 66.23 (11 teeth)	66.36	+ 0.13	41.55	41.78	+ 0.23
54	131	065948- 1	1.75	26	19.70- 19.75 (4 teeth)	19.83	+ 0.08	19.22- 21.82	21.64	- 0.18
55	131	061913- 1	5	82	146.02- 146.05 (9 teeth)	146.31	+ 0.26	109.05	109.56	+ 0.51
56		061913- 2	5	82	146.03- 146.08 (9 teeth)	146.38	+ 0.30	109.10	109.63	+ 0.53

REAR SATELLITE OF REDUCTION (Pinion)							
BATCH NO. : 117							
Sr. No.	Part No.	MOT (3 Teeth)			Bore		
		Before	After	Distortion	Before	After	Distortion
1	060988-01	31.92-31.90	31.98	+ 0.06	35.15-35.20	35.06	- 0.14
2	060988-02	31.92-31.90	32.02	+ 0.10	35.15-35.20	35.30	+ 0.10
3	060988-03	31.92-31.90	31.98	+ 0.06	35.15-35.20	35.00	- 0.20
4	060988-04	31.92-31.90	31.97	+ 0.05	35.15-35.20	35.26	+ 0.06
5	060988-05	31.92-31.90	31.93	+ 0.01	35.15-35.20	35.12	- 0.08
6	060988-06	31.92-31.90	31.98	+ 0.06	35.15-35.20	35.14	- 0.06
7	060988-07	31.92-31.90	31.96	+ 0.04	35.15-35.20	35.20	0.00
8	060988-08	31.92-31.90	31.98	+ 0.06	35.15-35.20	35.20	0.00
9	060988-09	31.92-31.90	31.93	+ 0.01	35.15-35.20	35.04	- 0.16
10	060988-10	31.92-31.90	31.97	+ 0.05	35.15-35.20	35.00	- 0.20
11	060988-11	31.92-31.90	31.99	+ 0.07	35.15-35.20	34.94	- 0.26
12	060988-12	31.92-31.90	31.96	+ 0.04	35.15-35.20	35.14	- 0.06
13	060988-13	31.92-31.90	32.00	+ 0.08	35.15-35.20	35.14	- 0.06
14	060988-14	31.92-31.90	31.95	+ 0.03	35.15-35.20	35.04	- 0.16
15	060988-15	31.92-31.90	31.97	+ 0.05	35.15-35.20	35.10	- 0.10
16	060988-16	31.92-31.90	31.95	+ 0.03	35.15-35.20	35.20	0.00
17	060988-17	31.92-31.90	31.96	+ 0.04	35.15-35.20	35.12	- 0.08
18	060988-18	31.92-31.90	31.94	+ 0.02	35.15-35.20	35.10	- 0.10
19	060988-19	31.92-31.90	31.94	+ 0.02	35.15-35.20	35.20	0.00
20	060988-20	31.92-31.90	31.91	- 0.01	35.15-35.20	35.08	- 0.12
21	060988-21	31.92-31.90	31.99	+ 0.07	35.15-35.20	35.00	- 0.20

22	060988-22	31.92-31.90	31.92	0.00	35.15-35.20	35.14	- 0.06
23	060988-23	31.92-31.90	31.91	- 0.01	35.15-35.20	35.10	- 0.10
24	060988-24	31.92-31.90	31.87	- 0.05	35.15-35.20	35.12	- 0.08
25	060988-25	31.92-31.90	31.87	- 0.05	35.15-35.20	35.00	- 0.20
26	060988-26	31.92-31.90	31.95	+ 0.03	35.15-35.20	35.10	- 0.10
27	060988-27	31.92-31.90	31.89	- 0.03	35.15-35.20	35.10	- 0.10
28	060988-28	31.92-31.90	31.87	- 0.05	35.15-35.20	35.18	- 0.02
29	060988-29	31.92-31.90	31.88	- 0.04	35.15-35.20	35.20	0.00
30	060988-30	31.92-31.90	31.88	- 0.04	35.15-35.20	35.14	- 0.06
31	060988-31	31.92-31.90	31.86	- 0.06	35.15-35.20	35.06	- 0.14
32	060988-32	31.92-31.90	31.85	- 0.07	35.15-35.20	35.20	0.00
33	060988-33	31.92-31.90	31.82	- 0.10	35.15-35.20	35.10	- 0.10
34	060988-34	31.92-31.90	31.95	+ 0.03	35.15-35.20	35.20	0.00
35	060988-35	31.92-31.90	31.90	- 0.02	35.15-35.20	35.18	- 0.02
36	060988-36	31.92-31.90	31.89	- 0.03	35.15-35.20	35.14	- 0.06
37	060988-37	31.92-31.90	31.91	- 0.01	35.15-35.20	35.10	- 0.10
38	060988-38	31.92-31.90	31.91	- 0.01	35.15-35.20	35.14	- 0.06
39	060988-39	31.92-31.90	31.91	- 0.01	35.15-35.20	35.10	- 0.10
40	060988-40	31.92-31.90	31.94	+ 0.02	35.15-35.20	35.06	- 0.14
REAR SATELLITE OF REDUCTION (Pinion)							
BATCH NO. : 119							
Sr. No.	Part No.	MOT (3 Teeth)			Bore		
		Before	After	Distortion	Before	After	Distortion
41	060988-41	31.94-31.90	31.98	+ 0.04	35.15-35.20	35.06	- 0.14
42	060988-42	31.94-31.90	31.94	+ 0.00	35.15-35.20	35.32	+ 0.12

43	060988-43	31.94-31.90	31.91	-0.03	35.15-35.20	35.10	-0.10
44	060988-44	31.90-31.88	31.86	-0.04	35.15-35.20	35.22	+0.02
45	060988-45	31.94-31.90	31.92	-0.02	35.15-35.20	35.26	+0.06
46	060988-46	31.94-31.90	31.92	-0.02	35.15-35.20	35.18	-0.02
47	060988-47	31.94-31.90	31.95	+0.01	35.15-35.20	35.10	-0.10
48	060988-48	31.94-31.90	31.93	-0.01	35.15-35.20	35.18	-0.02
49	060988-49	31.94-31.90	31.95	+0.01	35.15-35.20	35.02	-0.18
50	060988-50	31.94-31.90	31.93	-0.01	35.15-35.20	35.08	-0.12
51	060988-51	31.94-31.90	31.94	0.00	35.15-35.20	35.20	0.00
52	060988-52	31.94-31.90	31.92	-0.02	35.15-35.20	35.04	-0.16
53	060988-53	31.94-31.90	31.98	+0.04	35.15-35.20	35.10	-0.10
54	060988-54	31.94-31.90	31.93	-0.01	35.15-35.20	35.28	+0.08
55	060988-55	31.94-31.90	31.92	-0.02	35.15-35.20	35.18	-0.02
56	060988-56	31.94-31.90	31.92	-0.02	35.15-35.20	35.02	-0.18
57	060988-57	31.94-31.90	31.90	-0.04	35.15-35.20	35.22	+0.02
58	060988-58	31.94-31.90	31.95	+0.01	35.15-35.20	35.28	+0.08
59	060988-59	31.94-31.90	31.90	-0.04	35.15-35.20	35.14	-0.06
60	060988-60	31.94-31.90	31.90	-0.04	35.15-35.20	35.08	-0.12
61	060988-61	31.94-31.90	31.92	-0.02	35.15-35.20	35.08	-0.12
62	060988-62	31.94-31.90	31.95	+0.01	35.15-35.20	35.10	-0.10
63	060988-63	31.94-31.90	31.95	+0.01	35.15-35.20	35.24	+0.04
64	060988-64	31.94-31.90	31.96	+0.02	35.15-35.20	35.26	+0.06
65	060988-65	31.90-31.88	31.89	-0.01	35.15-35.20	35.20	0.00
66	060988-66	31.94-31.90	31.96	+0.02	35.15-35.20	35.22	+0.02
67	060988-67	31.90-31.88	31.89	-0.01	35.15-35.20	35.10	-0.10
68	060988-68	31.94-31.90	31.91	-0.03	35.15-35.20	35.32	+0.12
69	060988-69	31.94-31.90	32.08	+0.14	35.15-35.20	35.16	-0.04
70	060988-70	31.94-31.90	32.03	+0.10	35.15-35.20	35.16	-0.04
71	060988-71	31.94-31.90	32.07	+0.13	35.15-35.20	35.20	0.00
72	060988-72	31.94-31.90	32.05	+0.11	35.15-35.20	35.10	-0.10
73	060988-73	31.94-31.90	31.96	+0.02	35.15-35.20	35.12	-0.08
74	060988-74	31.94-31.90	31.97	+0.03	35.15-35.20	35.16	-0.04
75	060988-75	31.94-31.90	31.95	+0.01	35.15-35.20	35.16	-0.04
76	060988-76	31.94-31.90	31.98	+0.04	35.15-35.20	35.30	+0.10
77	060988-77	31.94-31.90	31.92	-0.02	35.15-35.20	35.14	-0.06
78	060988-78	31.94-31.90	31.92	-0.02	35.15-35.20	35.18	-0.02
79	060988-79	31.94-31.90	31.96	+0.02	35.15-35.20	35.20	0.00
80	060988-80	31.94-31.90	31.92	-0.02	35.15-35.20	35.18	-0.02
81	060988-81	31.94-31.90	31.95	+0.01	35.15-35.20	35.20	0.00
82	060988-82	31.94-31.90	31.96	+0.02	35.15-35.20	35.12	-0.08
83	060988-83	31.94-31.90	31.94	+0.00	35.15-35.20	35.16	-0.04
84	060988-84	31.94-31.90	31.94	0.00	35.15-35.20	35.20	0.00

85	060988-85	31.94-31.90	31.96	+0.02	35.15-35.20	35.10	-0.10
86	060988-86	31.94-31.90	31.97	+0.03	35.15-35.20	35.18	-0.02
87	060988-87	31.94-31.90	32.07	+0.13	35.15-35.20	35.14	-0.06
88	060988-88	31.94-31.90	31.96	+0.02	35.15-35.20	35.20	0.00
89	060988-89	31.94-31.90	31.98	+0.04	35.15-35.20	35.20	0.00
90	060988-90	31.94-31.90	31.99	+0.05	35.15-35.20	35.20	0.00
91	060988-91	31.94-31.90	31.96	+0.02	35.15-35.20	35.10	-0.10
92	060988-92	31.94-31.90	32.00	+0.06	35.15-35.20	35.20	0.00
93	060988-93	31.94-31.90	32.00	+0.06	35.15-35.20	35.14	-0.06
94	060988-94	31.94-31.90	32.00	+0.06	35.15-35.20	35.10	-0.10
95	060988-95	31.94-31.90	31.95	+0.01	35.15-35.20	35.14	-0.06
96	060988-96	31.94-31.90	31.95	+0.01	35.15-35.20	35.20	0.00
97	060988-97	31.94-31.90	31.97	+0.03	35.15-35.20	35.16	-0.04
98	060988-98	31.94-31.90	31.91	-0.03	35.15-35.20	35.20	0.00
99	060988-99	31.94-31.90	31.92	-0.02	35.15-35.20	35.14	-0.06
100	060988-100	31.94-31.90	31.94	0.00	35.15-35.20	35.26	+0.06
101	060988-101	31.90-31.88	31.89	-0.01	35.15-35.20	35.12	-0.08
102	060988-102	31.94-31.90	31.92	-0.02	35.15-35.20	35.14	-0.06
103	060988-103	31.94-31.90	31.96	+0.02	35.15-35.20	35.18	-0.02
104	060988-104	31.94-31.90	31.93	-0.01	35.15-35.20	35.10	-0.10
105	060988-105	31.90-31.88	31.87	-0.03	35.15-35.20	35.20	0.00
106	060988-106	31.90-31.88	31.86	-0.04	35.15-35.20	35.26	+0.06
107	060988-107	31.94-31.90	31.90	-0.04	35.15-35.20	35.18	-0.02
108	060988-108	31.90-31.88	31.88	-0.02	35.15-35.20	35.12	-0.08
109	060988-109	31.90-31.88	31.85	-0.05	35.15-35.20	35.20	0.00
110	060988-110	31.90-31.88	31.86	-0.04	35.15-35.20	35.14	-0.06
111	060988-111	31.90-31.88	31.86	-0.04	35.15-35.20	35.06	-0.14
112	060988-112	31.90-31.88	31.89	-0.01	35.15-35.20	35.16	-0.04
113	060988-113	31.94-31.90	31.91	-0.03	35.15-35.20	35.22	+0.02
114	060988-114	31.94-31.90	31.93	-0.01	35.15-35.20	35.18	-0.02
115	060988-115	31.94-31.90	31.93	-0.01	35.15-35.20	35.18	-0.02
116	060988-116	31.94-31.90	31.93	-0.01	35.15-35.20	35.18	-0.02
117	060988-117	31.94-31.90	31.99	+0.05	35.15-35.20	35.18	-0.02
118	060988-118	31.94-31.90	31.92	-0.02	35.15-35.20	35.06	-0.14
119	060988-119	31.94-31.90	31.95	+0.01	35.15-35.20	35.18	-0.02
120	060988-120	31.94-31.90	31.94	0.00	35.15-35.20	35.06	-0.14
121	060988-121	31.94-31.90	31.98	+0.04	35.15-35.20	35.28	+0.08
122	060988-122	31.94-31.90	31.94	0.00	35.15-35.20	35.30	+0.10
123	060988-123	31.94-31.90	31.94	0.00	35.15-35.20	35.04	-0.16
124	060988-124	31.94-31.90	31.90	-0.04	35.15-35.20	35.10	-0.10
125	060988-125	31.94-31.90	31.94	0.00	35.15-35.20	35.16	-0.04
126	060988-126	31.94-31.90	31.95	+0.01	35.15-35.20	35.26	+0.06

127	060988-127	31.94-31.90	31.91	-0.03	35.15-35.20	35.28	+0.08
128	060988-128	31.94-31.90	31.92	-0.02	35.15-35.20	35.20	0.00
129	060988-129	31.94-31.90	32.00	+0.06	35.15-35.20	35.20	0.00
130	060988-130	31.94-31.90	31.99	+0.05	35.15-35.20	35.06	-0.14
131	060988-131	31.94-31.90	31.98	+0.04	35.15-35.20	35.20	0.00
132	060988-132	31.94-31.90	31.98	+0.04	35.15-35.20	35.04	-0.16
133	060988-133	31.94-31.90	31.90	-0.04	35.15-35.20	35.10	-0.10
134	060988-134	31.94-31.90	31.94	0.00	35.15-35.20	35.10	-0.10
135	060988-135	31.94-31.90	31.93	-0.01	35.15-35.20	35.10	-0.10
136	060988-136	31.94-31.90	31.99	+0.05	35.15-35.20	35.16	-0.04
137	060988-137	31.94-31.90	31.93	-0.01	35.15-35.20	35.02	-0.18
138	060988-138	31.94-31.90	31.95	+0.01	35.15-35.20	35.20	0.00
139	060988-139	31.94-31.90	31.93	-0.01	35.15-35.20	35.12	-0.18
140	060988-140	31.94-31.90	31.95	+0.01	35.15-35.20	35.18	-0.02
141	060988-141	31.94-31.90	31.96	+0.02	35.15-35.20	35.14	-0.06
142	060988-142	31.94-31.90	31.98	+0.04	35.15-35.20	35.10	-0.10
143	060988-143	31.94-31.90	31.96	+0.02	35.15-35.20	35.12	-0.08
144	060988-144	31.94-31.90	31.95	+0.01	35.15-35.20	35.20	0.00
145	060988-145	31.94-31.90	31.97	+0.03	35.15-35.20	35.10	-0.10
146	060988-146	31.94-31.90	32.02	+0.08	35.15-35.20	35.18	-0.02
147	060988-147	31.94-31.90	32.00	+0.06	35.15-35.20	35.08	-0.12
148	060988-148	31.94-31.90	32.02	+0.08	35.15-35.20	35.12	-0.08
149	060988-149	31.94-31.90	32.02	+0.08	35.15-35.20	35.14	-0.06
150	060988-150	31.94-31.90	31.95	+0.01	35.15-35.20	35.18	-0.02
151	060988-151	31.94-31.90	31.99	+0.05	35.15-35.20	35.20	0.00
152	060988-152	31.94-31.90	32.00	+0.06	35.15-35.20	35.20	0.00
153	060988-153	31.94-31.90	31.95	+0.01	35.15-35.20	35.18	-0.02
154	060988-154	31.94-31.90	31.95	+0.01	35.15-35.20	35.18	-0.02
155	060988-155	31.94-31.90	31.93	-0.01	35.15-35.20	35.18	-0.02
156	060988-156	31.94-31.90	31.94	0.00	35.15-35.20	35.18	-0.02
157	060988-157	31.94-31.90	31.93	-0.01	35.15-35.20	35.10	-0.10
158	060988-158	31.94-31.90	32.02	+0.08	35.15-35.20	35.16	-0.04
159	060988-159	31.90-31.88	31.87	-0.03	35.15-35.20	35.10	-0.10
160	060988-160	31.94-31.90	32.01	+0.07	35.15-35.20	35.16	-0.04
161	060988-161	31.94-31.90	31.96	+0.02	35.15-35.20	35.10	-0.10
162	060988-162	31.94-31.90	32.02	+0.06	35.15-35.20	35.30	+0.10
163	060988-163	31.94-31.90	31.94	0.00	35.15-35.20	35.10	-0.10
164	060988-164	31.94-31.90	31.94	0.00	35.15-35.20	35.18	-0.02
165	060988-165	31.94-31.90	31.92	-0.02	35.15-35.20	35.20	0.00
166	060988-166	31.94-31.90	31.95	+0.01	35.15-35.20	35.18	-0.02
167	060988-167	31.90-31.88	31.86	-0.04	35.15-35.20	35.08	-0.12
168	060988-168	31.94-31.90	31.94	0.00	35.15-35.20	35.30	+0.10

169	060988-169	31.94-31.90	32.04	+0.10	35.15-35.20	35.16	-0.04
170	060988-170	31.94-31.90	32.05	+0.11	35.15-35.20	35.10	-0.10
171	060988-171	31.94-31.90	32.00	+0.06	35.15-35.20	35.30	+0.10
172	060988-172	31.94-31.90	31.99	+0.05	35.15-35.20	35.18	-0.02

CROWN GEAR				
Batch No. 117				
Sr. No.	Part No.	MOP (14 teeth)		
		Before	After	Distortion
1	60982-01	211.63- 211.08	211.49	- 0.14
2	60982-12	211.63- 211.08	211.65	+ 0.02
3	60982-36	211.63- 211.08	211.66	+ 0.03
4	60982-37	211.63- 211.08	211.48	- 0.15
5	60982-38	211.63- 211.08	211.55	- 0.18
6	60982-39	211.63- 211.08	211.64	+ 0.01
7	60982-40	211.63- 211.08	211.75	+ 0.12
8	60982-41	211.63- 211.08	211.64	+ 0.01
9	60982-42	211.63- 211.08	211.70	+ 0.07
10	60982-43	211.63- 211.08	211.81	+ 0.18
11	60982-44	211.63- 211.08	211.73	+ 0.10
12	60982-45	211.63- 211.08	211.43	- 0.20
13	60982-46	211.63- 211.08	211.64	+ 0.01
14	60982-47	211.63- 211.08	211.64	+ 0.01
15	60982-48	211.63- 211.08	211.79	+ 0.16
16	60982-49	211.63- 211.08	211.54	- 0.09
17	60982-50	211.63- 211.08	211.54	- 0.09
18	60982-51	211.63- 211.08	211.77	+ 0.14
19	60982-52	211.63- 211.08	211.69	+ 0.06
20	60982-53	211.63- 211.08	211.64	+ 0.01
21	60982-54	211.63- 211.08	211.59	- 0.04
22	60982-55	211.63- 211.08	211.59	- 0.04
23	60982-56	211.63- 211.08	211.48	- 0.25
24	60982-57	211.63- 211.08	211.50	- 0.13
25	60982-58	211.63- 211.08	211.43	- 0.20
26	60982-59	211.63- 211.08	211.70	+ 0.07
27	60982-60	211.63- 211.08	211.89	+ 0.26
28	60982-61	211.63- 211.08	211.64	+ 0.01
29	60982-62	211.63- 211.08	211.40	- 0.23
30	60982-63	211.63- 211.08	211.43	- 0.20
31	60982-64	211.63- 211.08	211.93	+ 0.30
32	60982-65	211.63- 211.08	212.07	+ 0.44

GENERAL ESTIMATION:

- From the above readings we concluded the heat treatment distortion for different component are as below:

Gear Wheel HT- Distortion Analysis				
Normal module	MOT		Bore	
	Min.	Max.	Min.	Max.
1.75	+ 0.01	+ 0.18	- 0.46	- 0.15
2.00	+ 0.13	+ 0.20	+ 0.23	+ 0.29
3.00	+ 0.13	+ 0.13	- 0.06	- 0.06
3.50	+ 0.01	+ 0.48	- 0.42	+ 0.08
4.00	+ 0.02	+ 0.045	+ 0.04	+ 0.04
4.50	+ 0.01	+ 0.07	+ 0.30	+ 0.32
5.00	+ 0.12	+ 0.59	- 0.18	+ 0.56
6.00	+ 0.11	+ 0.16	- 0.15	+ 0.53
7.00	+ 0.04	+ 0.47	- 0.08	+ 1.15
8.00	- 0.02	- 0.01	+ 0.32	+ 0.34

9.00	+ 0.30	+ 0.30	+ 0.77	+ 0.77
10.00	+ 0.36	+ 0.39	+ 0.99	+ 1.02
11.00	+ 0.31	+ 0.35	+ 0.64	+ 0.71

From the above heat treatment distortion analysis of gear wheel, we can find that 92.30% MOT of Gear wheel are increase after the heat treatment process. So to reduce the distortion set the machine allowances respected to the normal module which we have generated above.

We can also find that 69.23% BORE of the gear wheel are increase after the heat treatment process but we can not predicted the rule for Bore because the bore size is always changes which depends on the size of the gear wheel so reduce the distortion of the bore set the machine allowances as per the gear wheel heat treatment distortion analysis.

Pinion Shaft HT-Distortion Analysis		
Normal module	Min.	Max.
2.00	+ 0.05	+ 0.12
2.50	+ 0.16	+ 0.22
2.75	+ 0.11	+ 0.15
3.50	+ 0.05	+ 0.14
3.75	+ 0.07	+ 0.07
4.00	+ 0.15	+ 0.15
4.50	+ 0.06	+ 0.15
5.00	+ 0.09	+ 0.09
6.00	+ 0.14	+ 0.30
7.00	- 0.23	+ 0.19
8.00	+ 0.12	+ 0.12
11.0	+ 0.01	+ 0.09
12.0	+ 0.07	+ 0.07

Normal module.....Heat treatment distortion

2.00 to 2.75		+0.05 to +0.22
3.50 to 3.75		+0.05 to +0.14
4.00 to 4.50		+0.06 to +0.16
6.00 to 8.00		-0.23 to +0.19
11.0 to 12.0		+0.01 to +0.09

From the above heat treatment distortion analysis of pinion shaft, we can concluded that the 96.15% MOT of pinion shaft are increase after the heat treatment distortion analysis & to reduce this distortion we can generated the rule above with respected to the normal module are set on the machine allowances.

Crown Gear HT- Distortion Analysis

We take readings of the crown gear and from that we will analyzed that if the crown gear has normal module four then the heat treatment distortion is generally from -0.25 to +0.44

From our analysis we can concluded that 59.37% are increase after heat treatment process. To reduce this distortion set the machine allowances as per the crown gear analysis.

Rear Satellite of Reduction (Pinion) HT- Distortion Analysis

From the reading we analyzed the heat treatment distortion on rear satellite of reduction (pinion) for MOT and BORE.

Normal module	Heat Treatment Distortion analysis			
	MOT		Bore	
	Min.	Max.	Min.	Max.
4	-0.10	+0.14	-0.26	+0.12

From our analysis we concluded that 62.20% MOT are increase after heat treatment process and only 13.38% BORE is increase.

CONCLUSION:

We have established the general prediction rule for changes in dimensions by heat treatment following table shows that for particular module what should be the predicted dimension change for MOT and Bore of the gearwheel, Pinions and Pinion shafts.

Heat Treatment Distortion analysis				
Normal module	MOT		Bore	
	Min.	Max.	Min.	Max.
1.75	+ 0.01	+ 0.18	- 0.46	- 0.15
2.00 to 2.75	+ 0.05	+ 0.22	+ 0.29	+ 0.29
3.50 to 3.75	+0.01	+ 0.48	- 0.42	+ 0.14
4.00 to 4.50	- 0.23	+ 0.44	+ 0.04	+ 0.31
5.00 to 8.00	+ 0.04	+ 0.59	- 0.18	+ 0.34
9.00 to 12.0	+ 0.01	+ 0.36	+ 0.64	+ 1.02

This prediction will help in determining the pre heat treatment dimensions of particular components if we set allowance for heat treatment changes we find two benefits

- 1) Reduced machining after heat treatment leads to reduction in cost.
- 2) The case depth achieved can be maintained which increases the life of component.

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