EXPERIMENTAL STUDY OF ERRORS IN GEARS BEFORE AND AFTER HEAT TREATMENT PROCESSES

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ABSTRACT: This paper involves studying errors produced in the gear before and after heat treatment processes while manufacturing a spur gear. High torque load demands, low running noises and compact designs are basically the characteristics of modern gearboxes. In order to fulfill these requirements, profile specifications have to be controlled tightly. Heat treatment processes, hobbing, shaving, etc. leads to distortion in the profile, while manufacturing high accuracy gears. In this analysis two different blanks were taken to manufacture a spur gear of module 1.75mm , which went through a series of inspection at different stages of its manufacturing to get the gear within desired permissible limits. The present paper also deals with the finding of profile, lead and pitch errors before and after the heat treatment processes using Gear Testing Machine- TTi-300 N.

Keywords: Hobbing, Profile, lead, pitch error, gear testing machine.

[I]INTRODUCTION:

Gears are widely used in various mechanisms and devices to transmit power and motion positively (without slip) between parallel, intersecting (axis) or non-intersecting non parallel shafts. According to the requirements special attention needs to be paid while manufacturing of gears. The gear tooth flanks have a complex and precise shape demanding requirements of high surface finish. The starting product in gear manufacturing is called a gear blank. Machine, work fixture, cutter, arbor, machined blanks, and also the cutting parameters add some amount of errors to different gear elements. Heat treatment processes involved during formation of gears enhances its mechanical properties. But due to phase transformation as well as thermal stresses occurring during heat treatment processes, uncontrolled distortion of gears takes place causing deviation from required gear accuracy.

In this paper two blanks of the composition 16MnCr5H have been taken for experimental purpose. It went through the following processes to get the desired shape.

Blank -> Quality assurance ->hobbing -> Heat treatment -> tempering -> shot blasting -> honing ->washing -> Rolling-> Final inspection.

[II]LITERATURE REVIEW:

Nitin Haridas Mulay [4] presented a paper reviewing the current aspects of inspection metrology. He checked gear parameter errors by using different methods of inspection tester/instruments for getting good quality transmission gears. Isaich Paul Jenzen presented a thesis on modeling of heat treating processes for transmission gears in Dec.2009 to the faculty of Worcester Polytechnic Institute for the degree of Master in Science in Material Science and Technology. It provided a detailed review of the mass transfer, heat transfer and stress that occur during heat treatment. Raveen John, Dr. Y.S. Varadarjan & Paul Pereira[7] arrived at a solution for profile distortion problem encountered during heat treatment process of gear manufacturing using root cause analysis.

[III]DIFFERENT PROCESSES INVOLVED DURING MANUFACTURING OF GEARS:

1)Hobbing:- gear hobbing is a machining process. It is used for cutting teeth of a workpiece using a cutting tool called hob. It is inexpensive yet accurate maching process compared to other gear forming process.

2) Heat treatment process:-for transmission gears it is required that the surface of the tooth should be hard enough to resist wear while the core of the tooth should be soft for impact absorption without breakage during actual running.

Processes involved in surface hardening are as follows:-

a) Carburizing:- used to attain desired depth in the workpiece with carbon.

b) Quenching:- to induce hardness at the surface but not the core.

c) Tempering:- process relieves the structure of high residual stress to achieve improved toughness.

3) Shot blasting:- Shot blasting is a process in which the material is cleaned by removing the carbon content which remains after heat treatment process by bombarding round steel balls over the workpiece.

4) Honing:-it is a super finishing operation done on gears with bore. It is used to give super finish to the internal diameter of the gears, producing a precision surface by scrubbing an abrasive stone against it along a controlled path.

[IV]TERMINOLOGIES RELATED TO ERRORS IN GEARS:-

1) Profile inspection:- profile is the shape of the gear tooth curve measured from the root to the tip of the gear. Due to momentary disturbances of the rotational velocity ,profile errors results in the non- uniform motion transmission of the gears.

a) Profile form variation:-it is defined as the difference between the nominal involute form to the actual involute form.

b) Profile angle variation:-it is the distance between two nominal profiles that intersect the average profile at start and end points of the profile range.

c) Total profile variation:- it is the sum of the profile form variation and the profile angle deviation.

2) Helix or lead angle:-for parallel axis spur and helical gears, uniform loading across the full width of the teeth is required for this the pair of the meshing gears must have identical helix angles. The inadequate face width contact between the mating gears is caused due to lead error resulting in wear and noise of the gears.

a) Lead form variation:- it is defined as the difference between the nominal lead form line to the actual form line.

b) Lead angle variation:- it is defined as the result between the nominal and actual helix angle.

c) Total lead variation:- distance between two nominal leads enclosed within the lead inspection range.

3) Pitch error and run out :- due to these errors gears tends to make noise and also the motion transmission is non-uniform.

a) Run out variation (F_r):- it is defined as the maximum difference of the nominal radial position of all the teeth to the actual measured position.

b) Total pitch variation (F_p):- it is defined as the maximum difference between nominal angular position of each right and left flank to the actual measured position.

c) Single pitch variation (f_p) :- it is defined as the difference between the nominal angular position of each flank to the previous flank at the same side.

d) Difference between adjacent pitches (f_u):- difference between the actual dimensions of two successive right or left flank transverse position.

[V]METHODOLOGIES AND EXPERIMENTATIONS:

2 blanks of the composition 16 MnCr5H were taken. Its chemical composition was:-

% C-0.16/0.19

% Si- 0.25 max

% Mn- 1.0/1.3

% Cr- 0.8/1.1

% Mo- absent

% S- 0.015-0.035

% P- 0.035

% Cu- 0.30 max

% Al- 0.015/0.035

% Ti- 30 ppm max

% Ca- 10/20 ppm

The gear of the following specification was to be obtained:-

- No. of teeth -23
- Module- 1.75 mm
- Outside Ø- 45.60 /45.70
- MOT (between teeth)- 4 teeth
- MOT (soft)- 19.336/19.366
- MOT (hard)- 19.336/19.392

1) Inspection:- the bore size, parallelism and face run out of the blanks were measured using Air Unit, Height Gauge and Tapered Mandrel respectively.
These blanks were numbered 1 and 2 and the following observation was recorded:-

S.no.	Bore Size(mm)	Parallelism(microns)	Face run out(micron)
1.	16.990	20	20
2.	16.991	10	10

Where, Standard for bore size is: 16.990- 17.008 and maximum permissible error for parallelism and Face Run Out is 20 microns.

2) Hobbing:-

Now, these blanks were taken to the hobbing cell for cutting of tooth.

MACHINE DESCRIPTION:- Hobbing
MAKE :- LEIBHERR

S.NO.	PARAMETER	SPECIFICATION	MEAS. METHOD
1.	Material	16MnCr5H	Third party insp.
2.	Hardness	170 to 210 BHN	Harness tester
3.	OD	Φ45.6~45.7mm	Snap gauge
4.	Bore Size	Φ16.990~17.008	APG
5.	Dim	12.3~12.4mm	Snap gauge

6.	Dim	9.1~9.3mm	Snap gauge
7.	Surface Roughness	0.8Ra	Surface finish tester
8.	OD Runout	0.1mm	Mandrel & Dial
9.	perpendicularity	.020 mm	Between center mandrel and dial

MODEL :- LC150

INPUT MATERIAL CONDITIONS

PROCESS PARAMETERS:-
CUTTING SPEED:- 130~180m/min. (750~800 rpm)
FEED :- 1.3~1.8 mm/tr.
SHIFTING AMOUNT PER GEAR:- 5.515 mm

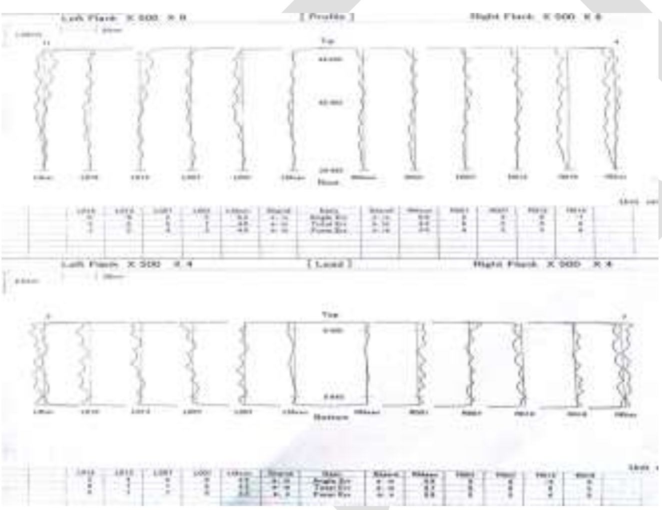
After Hobbing, these gears went to roll tester machine to find TCE and Micrometer to measure MOT :-

SAMPLE No.	TCE(microns)	MOT (mm)
1.	20	19.351
2.	20	19.357

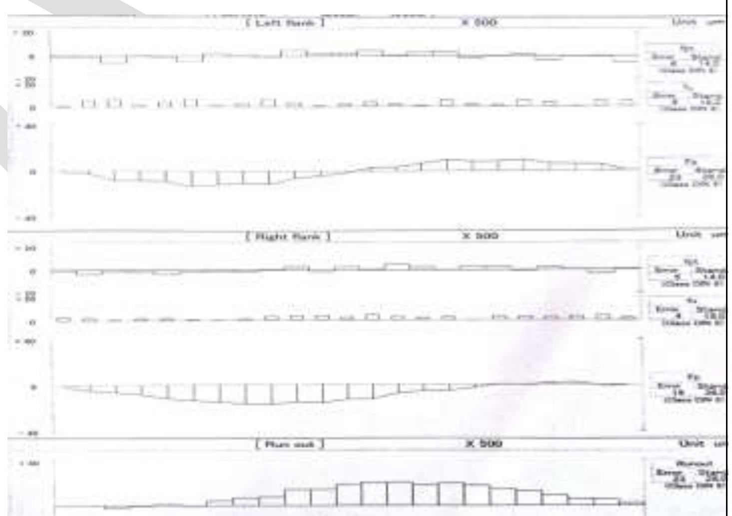
3) Standard Room:-

After hobbing ,these samples went to the standard room to measure the pitch error , lead error and profile error using Gear Testing Machine- TTi-300 N.

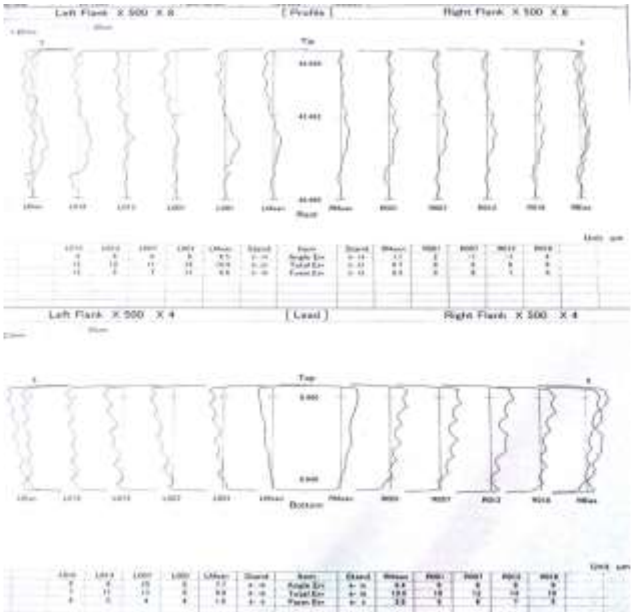
Gear quality grades are standardized for different normal module/DP ranges and different ranges of reference diameters in AGMA, DIN, JIS and other standards. AGMA provides 8 grades from 15 to 8, where the higher grade number indicates the better gear accuracy. In DIN and JIS, a lower grade number means better gear accuracy. We have followed DIN 3962 standards.



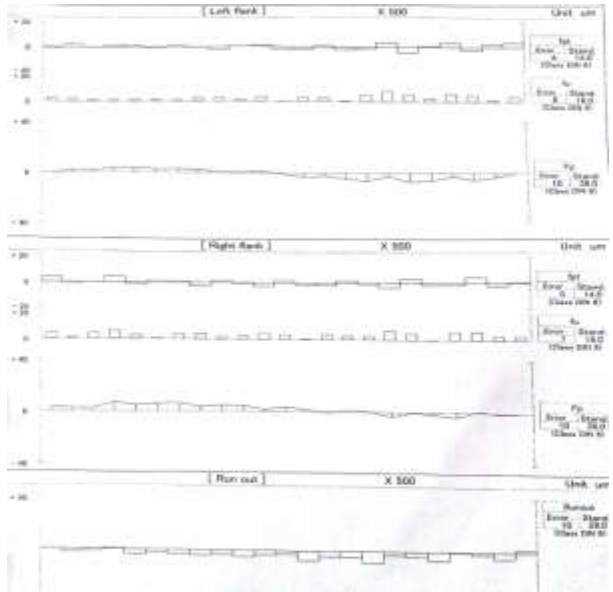
i)Profile and lead error of 1st piece



ii) pitch error of 1st piece



iii) profile and lead error of 2nd piece



iv) pitch error of 2nd piece

4) HEAT TREATMENT:-

PROCESS PARAMETERS:

Parameters	temperature	CP/MV	Time(min)	Endo gas flow	Enrichment LPG flow
Pre wash(spraying)	70±5°C	--	15±5	--	--
Pre wash(drying)	70±10°C		15±5		
Pre heating	500±15°C	--	60±5		
Heating	850±15°C	0.7±.05%	15±5	8~10Nm^3/hr	50~250LPH
Carburizing	900±5°C	1±0.05%	90±5	8~10Nm^3/hr	50~250LPH
Diffusion	900±5°C	0.8±0.05%	30±5	8~10Nm^3/hr	50~250LPH
Hardening	840±5°C	0.7±0.05%	30±5	8~10Nm^3/hr	50~250LPH
Quenching	120±5°C	--	15	--	--
Post wash(Dunking)	70±5°C	--	15±5	--	--
Post wash(Spraying)	70±5°C	--	15±5	--	--
Post wash(Drying)	70±5°C	--	15±5	--	--
Tempering	160±10°C	--	120±10	--	--

PROCESS CONDITION:

Check item	Specification	Meas. method
Endo gas flow rate	8~10Nm^3/hr	Flow meter
Carbon potential(cp/mv)	As per cycle	Mv/Cp controller
Temp	As per cycle	Flow meter
Quench oil level	Pokayoke-no quenching happens if oil level is low or high	Level indicator
Quench media temperature	120±10°C	Temp controller
Roof fan	Zero speed switch or RPM monitoring	Alarm if fail
Air pressure & flow monitoring	5~7 kg/cm^2	Pressure switch
Pre wash & Post wash water	1.free of sludge 2.free of oil 3.PH- 8~12 4.cleaning media conc.- 3~5%	1.cleaning of water tank, every year 2.oil skimmer 3.PH test paper

	5.water pressure- 1.0 to 3 kg/cm^2	4.Refractories 5.pressure gauges

5)Testing lab:-

After heat treatment processes of these samples, they were taken to the testing lab to find the Surface and core hardness of the gears.

Rockwell hardness Tester(HRA)

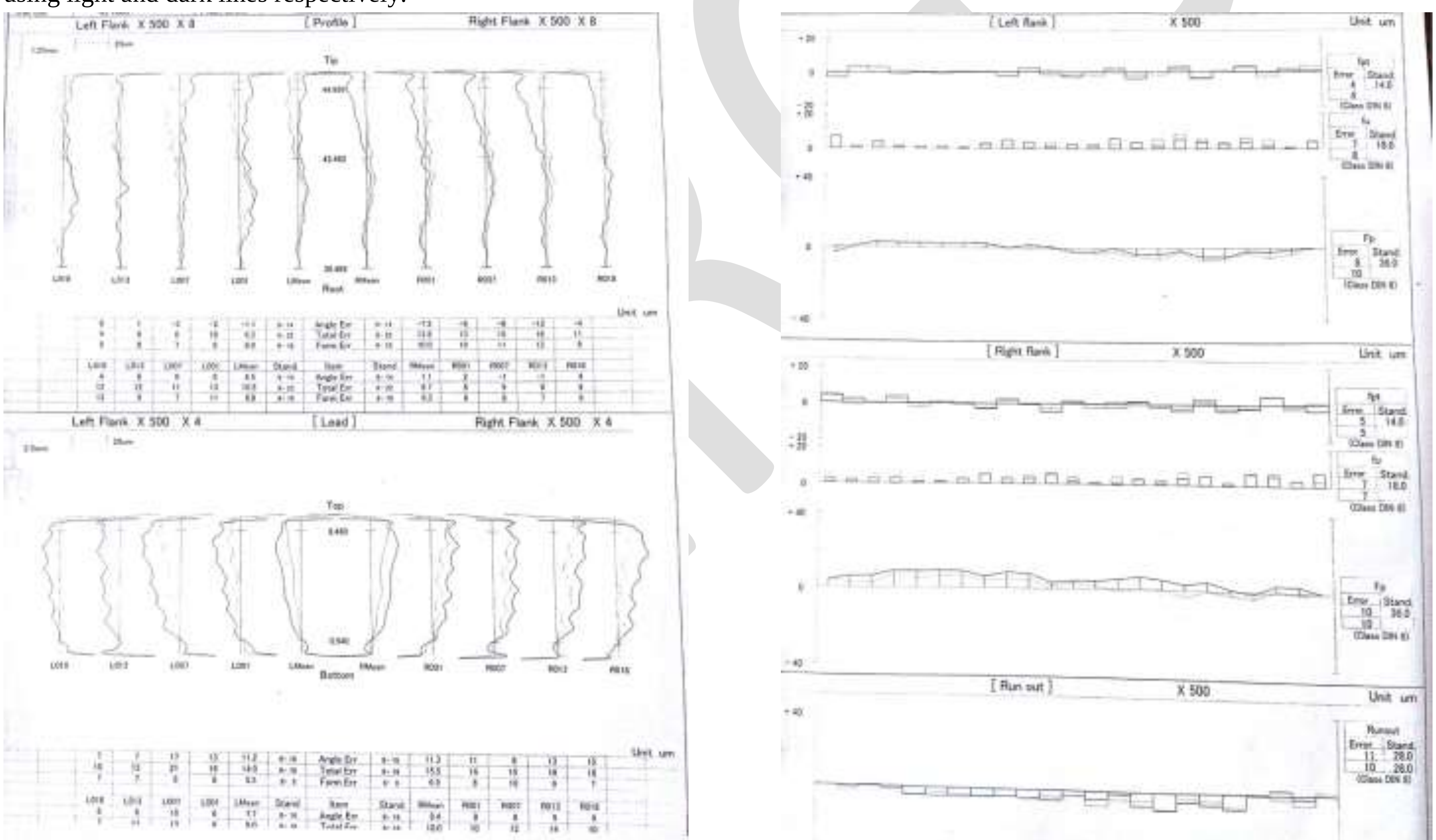
Sample no.	Surface hardness
1.	81
2.	81

Core Hardness:- 38 HRC (Bainite + LCM)

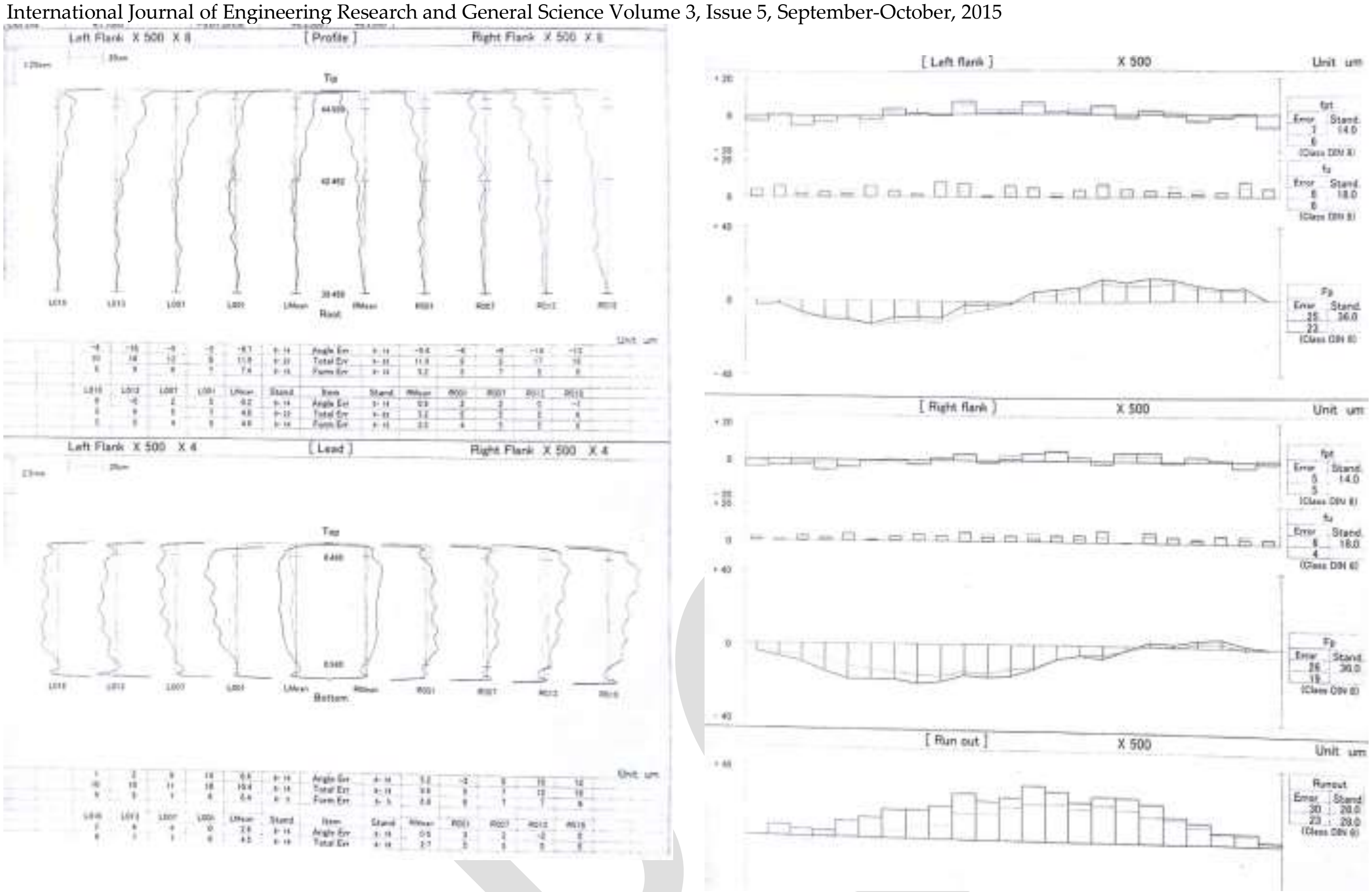
Case Depth:- 0.47mm (micro Vickers hardness tester) (Tempered Martensite with R.A. ≤5%)

5) Standard Room:-

After heat treatment, these samples again went to the standard room to measure the pitch error ,lead error and profile error using Gear Testing Machine- TTi-300 N. The graphs of the following are shown below. These graphs shows the errors in the gears before and after heat treatment using light and dark lines respectively.



v) comparsion of profile, lead and pitch error of 2nd gear before and after heat treatment process



vi) comparison of profile, lead and pitch error of 1st gear before and after heat treatment process

6)FID:-

Finally after shot blasting and honing, TCC, TCE and MOT were measured:

Sample no.	TCC(microns)	TTE(microns)	MOT(mm)
1.	30	10	19.372
2.	30	10	19.379

[VI] CONCLUSION:-

Predictable and controlled dimensional and distortional changes can be achieved during the development work of heat treatment processes. Allowances can be provided at soft finishing stages, by establishing changes in the heat treatment processes and hence final dimensional tolerances can be achieved which are required for transmission gears.

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