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REDUCTION IN STRESS OF SPUR GEAR BY APPLYING STRESS RELIEVING FEATURES WITH VARIANT SHAPE, SIZE AND LOCATION

Chirag M. Pateliya[1] Prof. Amit Anakiya[2] Prof. Kapil Lakhani[3]

[1] P.G. Student - M.E. Machine Design (09) [Gujarat Technological University - GTU]
[2/3]Assistant Professor (M.Tech-CAD/CAM)
[Arham Veerayatan Institute of Engineering, Technology & Research, Mandvi – Kutch, INDIA]

ABSTRACT

Gear drive is used to transmit power between two shafts when distance between them is very small. It maintains the stable velocity ratio without slip. It is observed that gears are the most effective by means of transmitting power due to their high degree of reliability and compactness. The cost of replacement of gear is very high and also the system down time is one of the effective factors. Failure of gear due to high stresses developed which leads to breakdown of system.

To avoid failure stresses should be minimized at maximum stress concentrated area. Stress occurs during its actual working. These stresses can be minimized by introducing stress relief features at stress zone.

In this direction of research work, various stress relieving features were studied. Single or more circular and oval shape. Also combination of circular and elliptical shape was used to study the effect of these features in stress reduction. Here effect of 'Single Aero-fin shape and in combination with other geometrical shapes' will studied.

INTRODUCTION

As per our mythological stories Indian history is more than 12,000 years old. Since then people living here have been striving to improve the living conditions. We also know that earlier people were living in the caves and the doors of the caves were made of granite. How were these heavy doors opened and closed? They were opened and closed by none other than a system with gear mechanism, wheel, lever and rope drives. However, the documented evidence has been lost due to destruction by the invaders and improper storing of palm leaf literature. But, the knowledge of gears has gone from India to east through some of the globe trotters from China as back as 2600 years BC. They have used the gears then ingeniously in chariots for measuring the speed and other mechanisms.

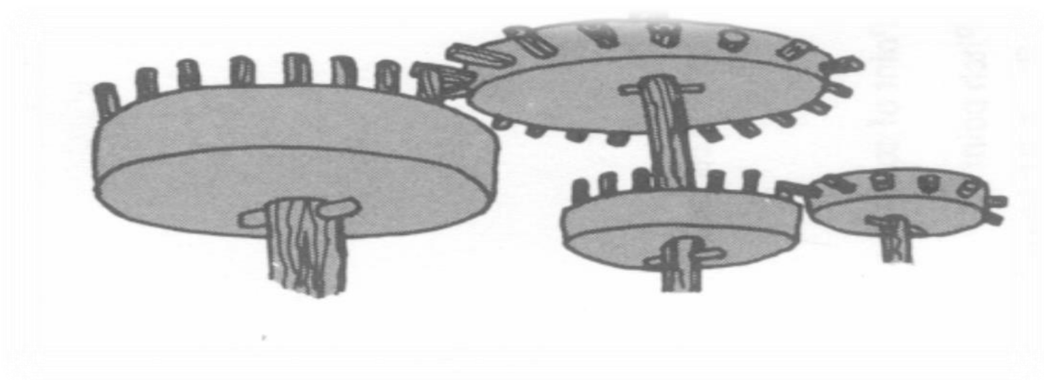


Fig. - 1 Gear concept (1)

Primitive gears made of wood Archimedes 287-212 B.C.

Primitive gears shown in Fig. 1 were first used in door drive mechanism in temples and caves, and water lifting mechanisms 2600 B.C. in India and elsewhere. Gears are toothed members which transmit power or motion between two shafts by meshing without any slip. Hence, gear drives are also called positive drives. Gear was invented in 3rd century BC. In Greek, people used gear as water wheels. Around the time wheel it was found in Leonardo da Vinci's notebook.

Gears are used for a wide range of industrial applications. They are the most common by means of transmitting power. Gears are the optimal medium for low energy loss and high accuracy. Their function is to convert input provided by prime mover into an output with variant speed range and corresponding torque. (1)

GEAR MANUFACTURING PROCESSES

Hobbing is a practical method for cutting teeth in spur gears, helical gears, worms, worm gears, and many special forms. Conventional hobbing machines are not applicable to cutting bevel and internal gears. Tooling costs for hobbing are lower than those for broaching or shear cutting. Therefore, hobbing is used in low quantity production or even for a few pieces. On the other hand, hobbing is a fast and accurate method (compared to other) and is therefore suitable for medium and high production quantities. (2)

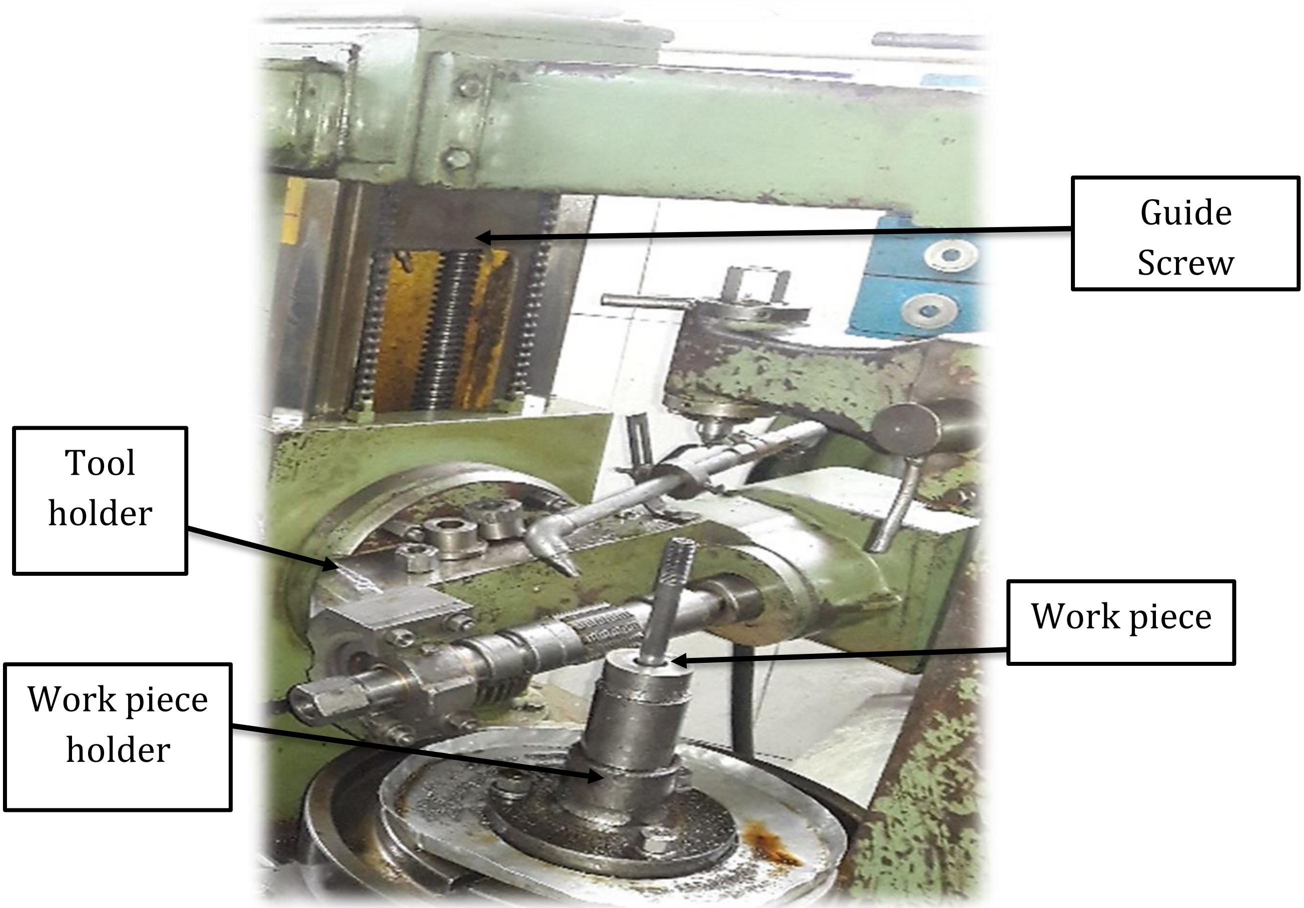


Fig. 2 - Hobbing Machine (Courtesy to Subham Gears – Rajkot) (3)

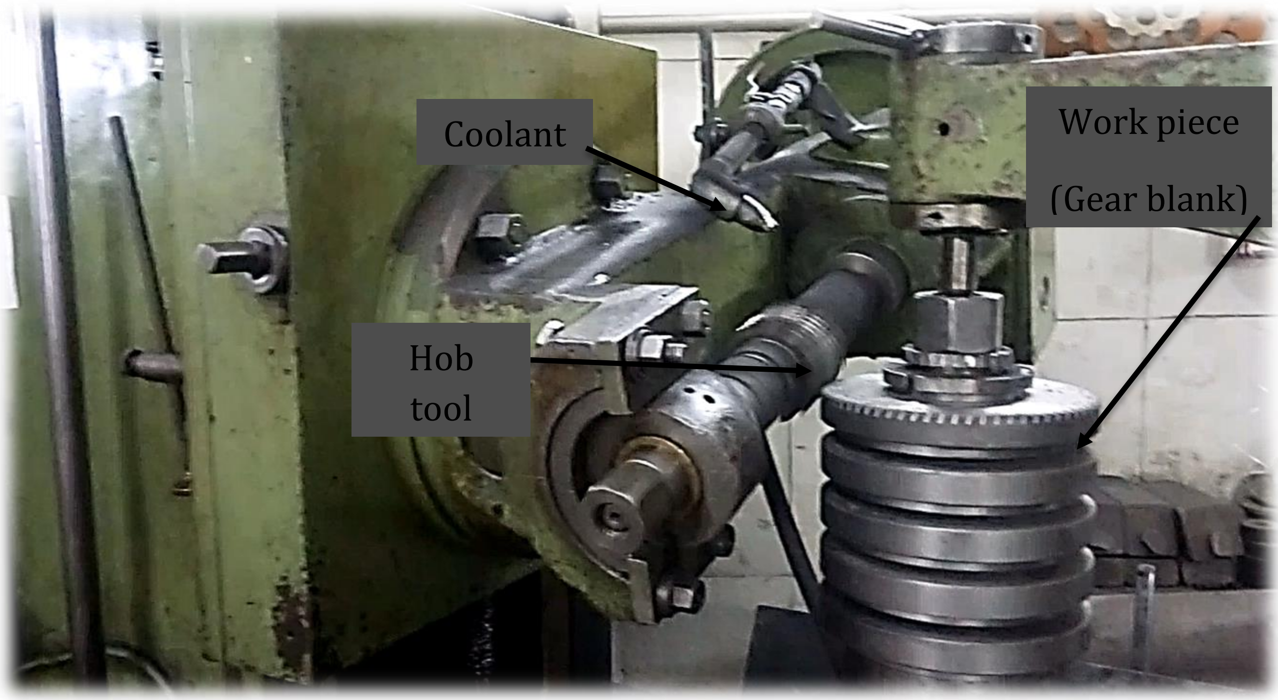


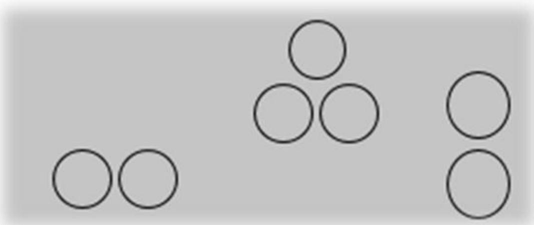
Fig. 3 - Hobbing Process (courtesy to Subham Gears – Rajkot) (3)

STRESS RELIEVE FEATURES - (SRF)

During transmission phase, gear pair encounter high stress at the point of contact. A pair of spur gear in action is generally subjected to two types of stresses.

- Bending stress
- Contact stress

Forces responsible for stress generation are Tangential Force (F_t) – in horizontal (x) direction and Radial Force (F_r) – in vertical (y) direction respectively.



Circular Pattern

Aero foil

Fig. 4 - Concept of Stress Relieve features

Stress Relief Features (SRF) is kind of different geometrical shapes cut, applied between the area below the root-fillet and above the shaft hole. In case of gear, possibility of maximum value of stress is generated near root fillet and then near shaft hole. When various shapes cuts there with appropriate size, combination of shapes and at an appropriate location will be more effective to reduce stress.

To select circular and airfoil shape as a SRF due to its smooth flow line across stress field. To find one shape in pattern or Combination of a shape at most appropriate location for reducing maximum stress value is the main objective behind this work.

RESEARCH METHODOLOGY

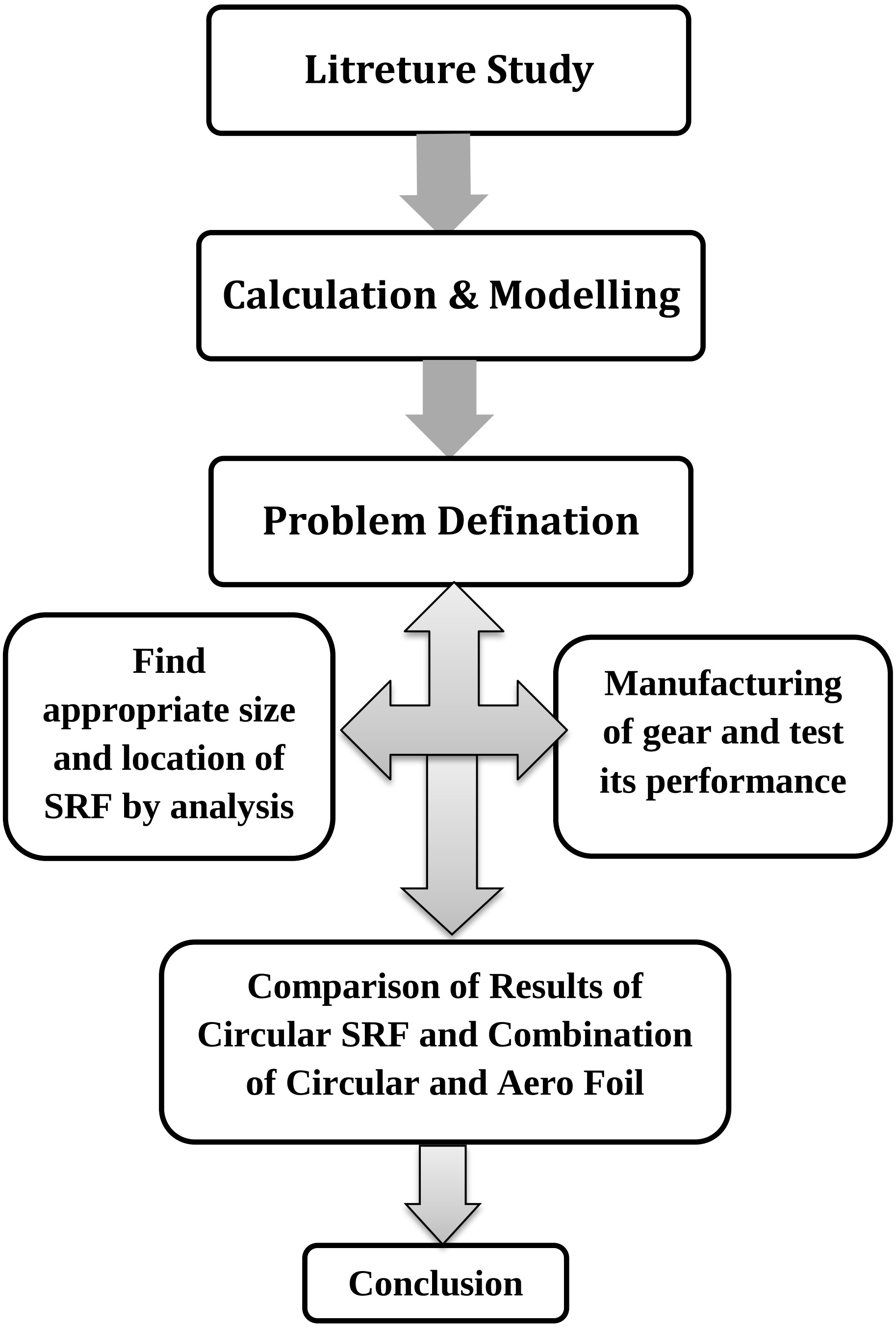


Fig. 5 – Flow Chart of proposed work

PARAMETER	VALUE
Module (m)	6 mm
No. of Teeth (Z_g)	26
Pressure Angle (α)	20^0 Full Depth Involute
Material	Cast Iron (G 20)
Factor of Safety (N_f)	2.5
Allowable Bending Stress (σ_b)	500 kgf/cm^2
Allowable Compressive Stress (σ_c)	5000 kgf/cm^2
Motor Speed (N)	1440 RPM
Power (P)	1.5 kw
Young's of Modules (E)	137293.1 Mpa

Table – 1. Standard Parameters [4]

<u>MODEL FORMULATION</u> (Solid works 2013)

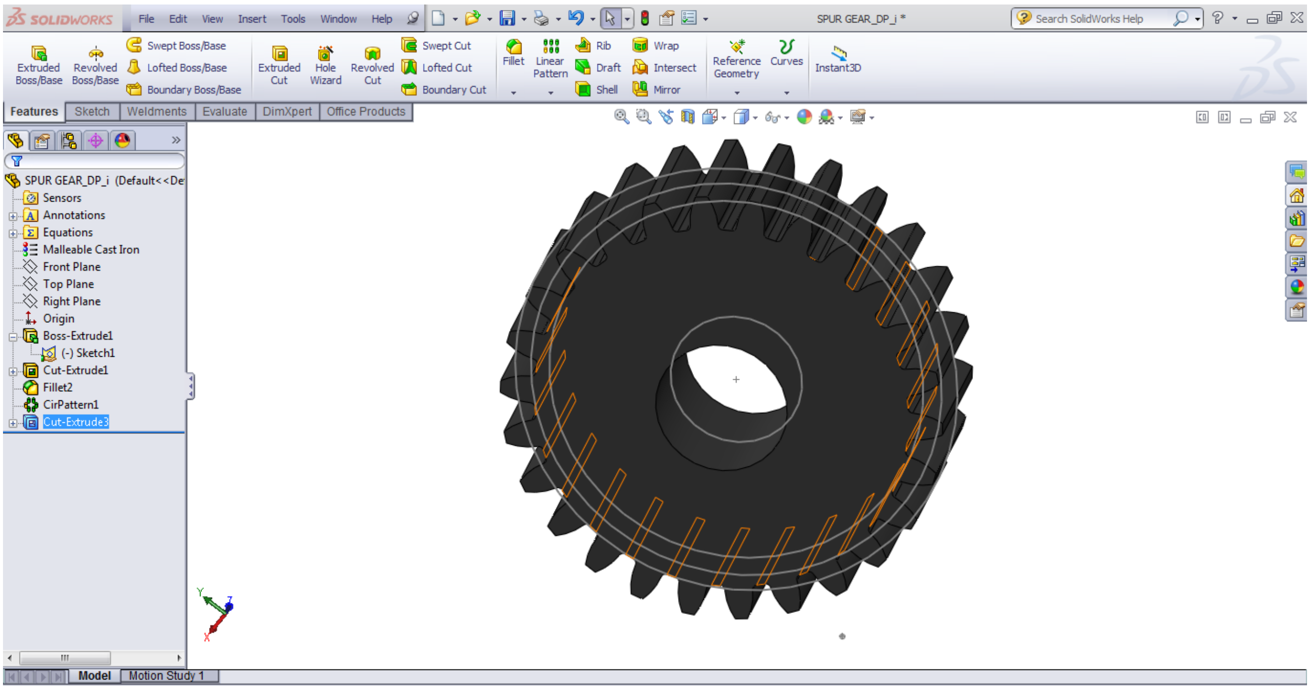


Fig. 6 - Spur Gear Model

<u>ANALYSIS</u> (ANSYS 14.5 WORKBENCH)

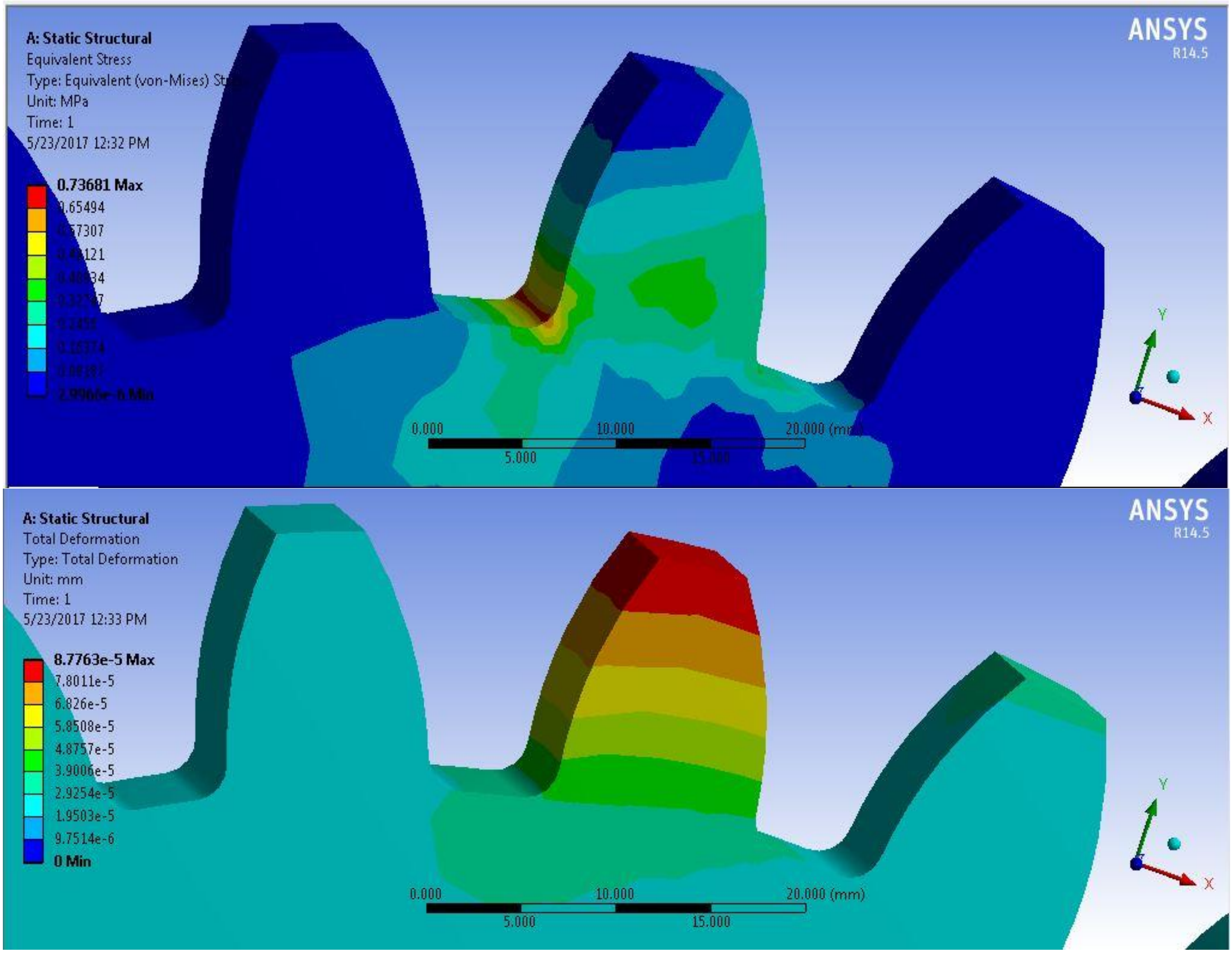


Fig. 7 - Stress/Deformation Analysis – Without SRF

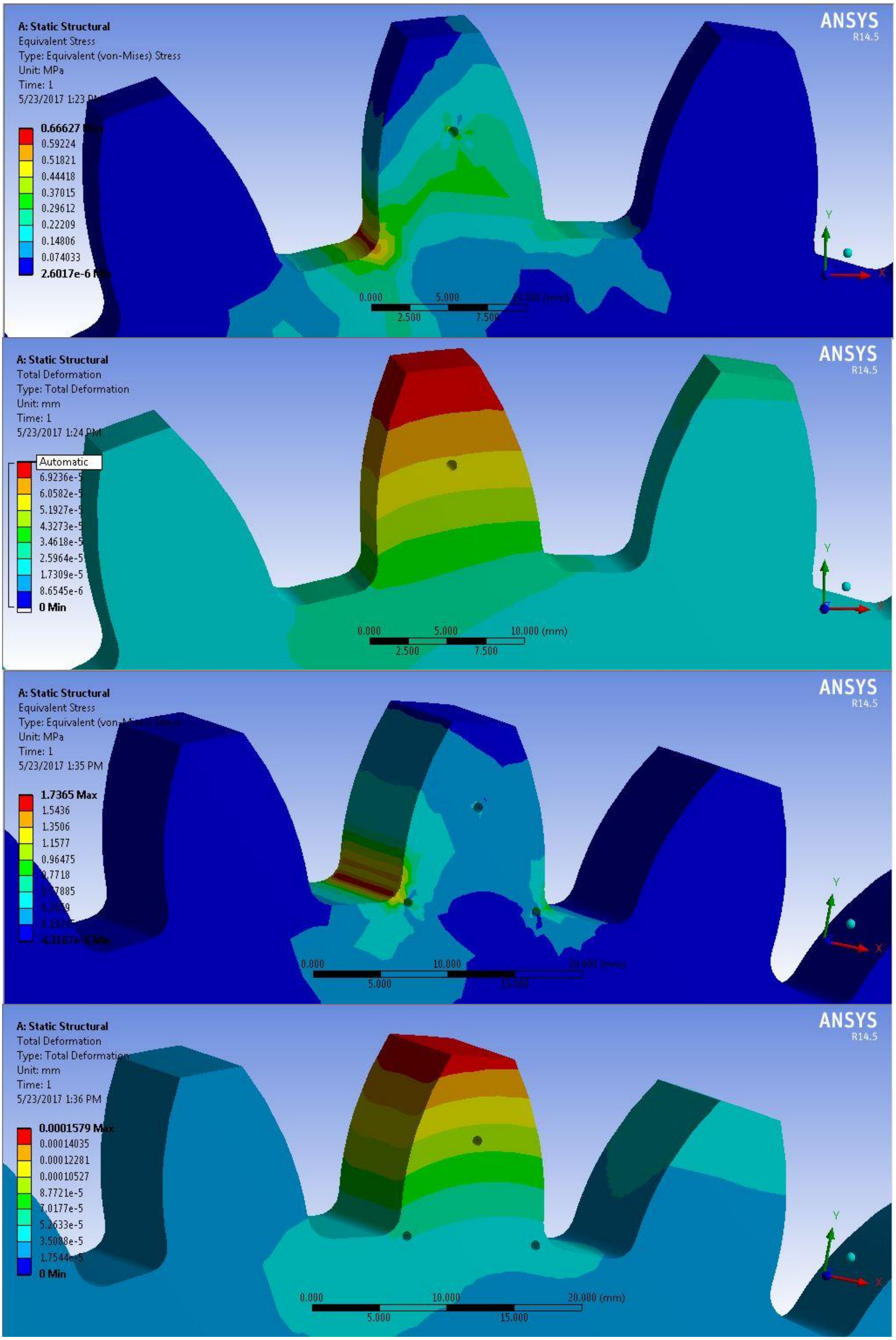


Fig. 8 – Stress/Deformation Analysis – 0.7 mm*1 SRF & 0.7 mm*3 SRF in teeth

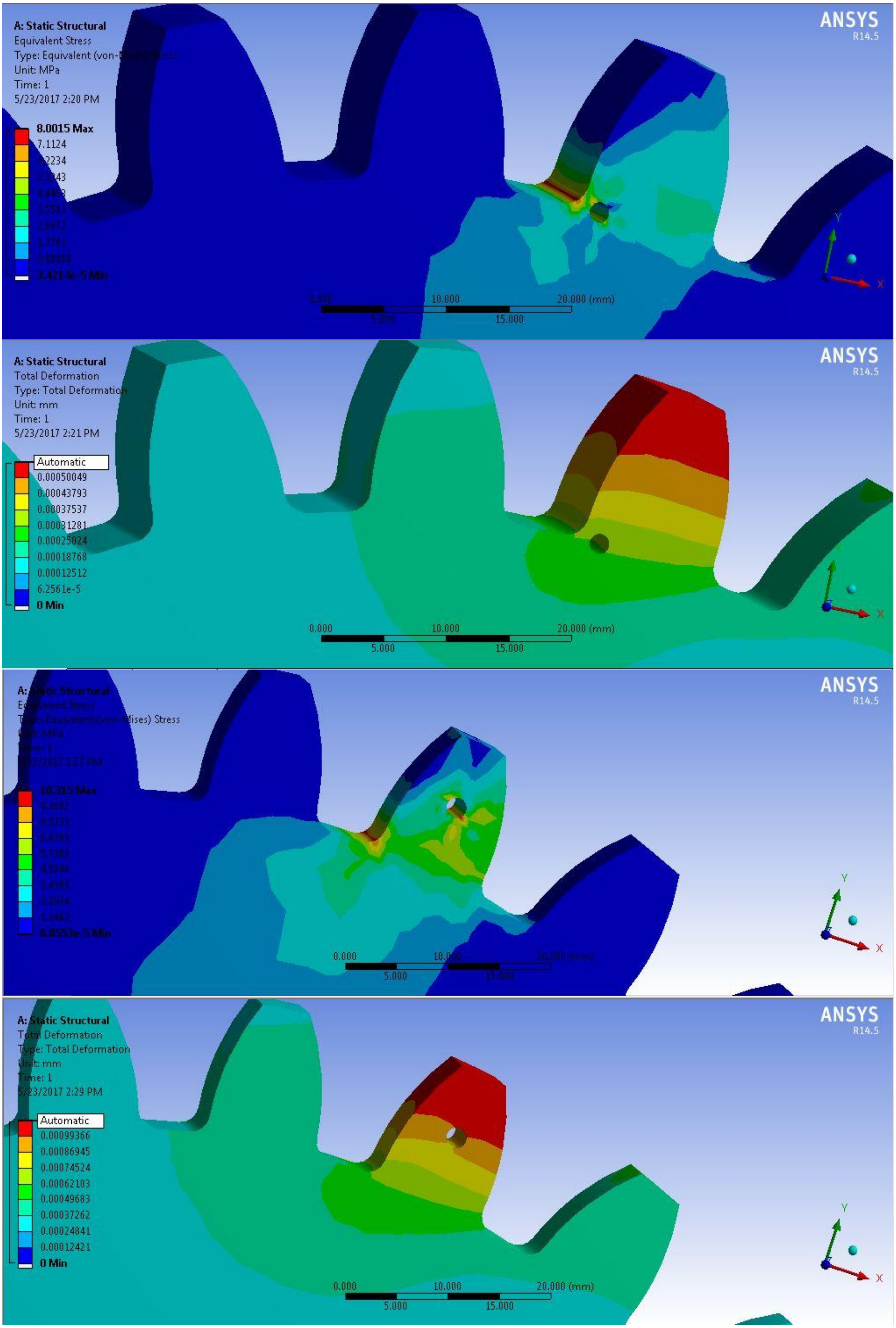


Fig. 9 – Stress/Deformation Analysis – 1.6 mm*1 in Root & 2 mm*1 SRF in teeth

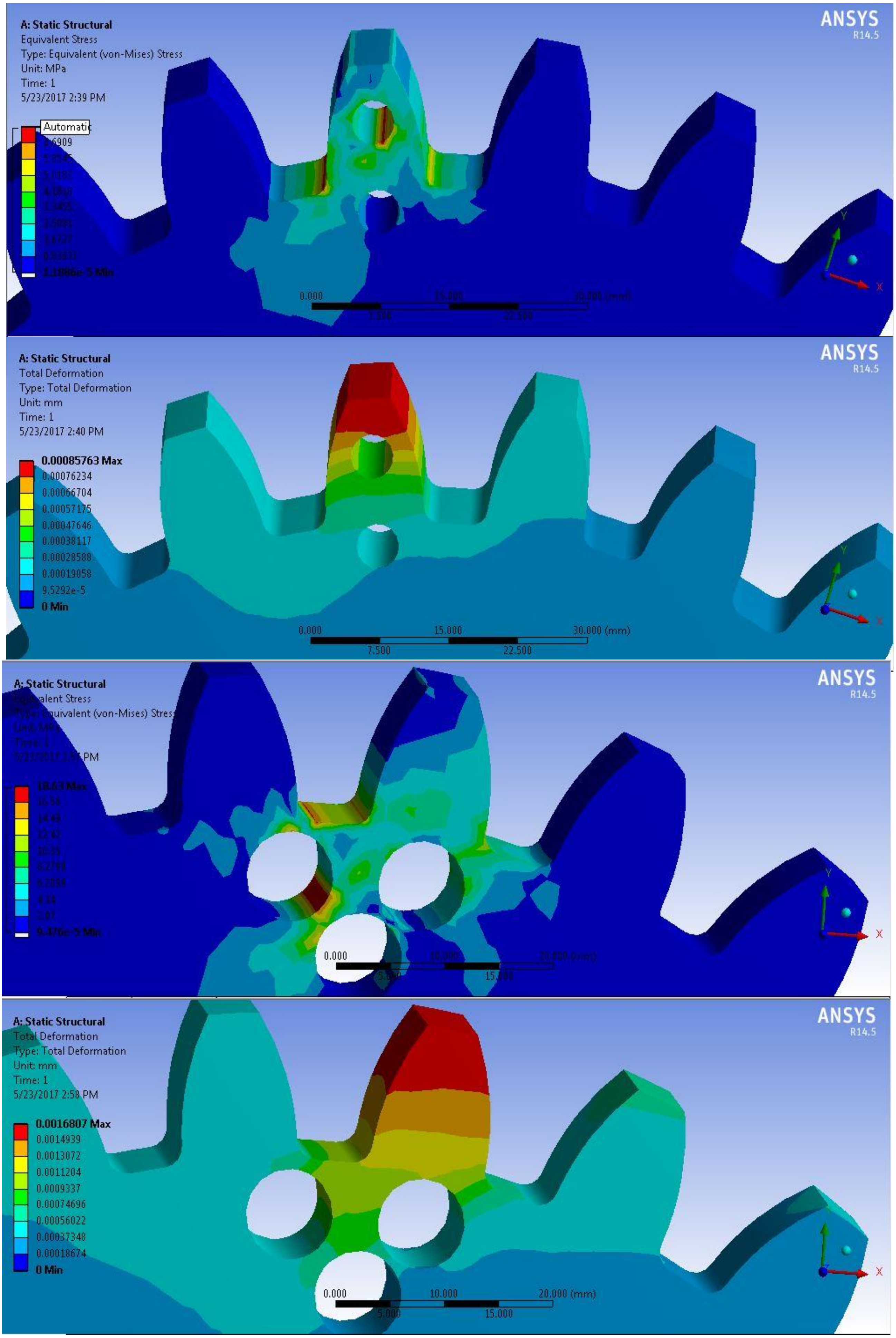


Fig. 10 – Stress/Deformation Analysis – 4.6 mm*2 in teeth & 8 mm*3 SRF root

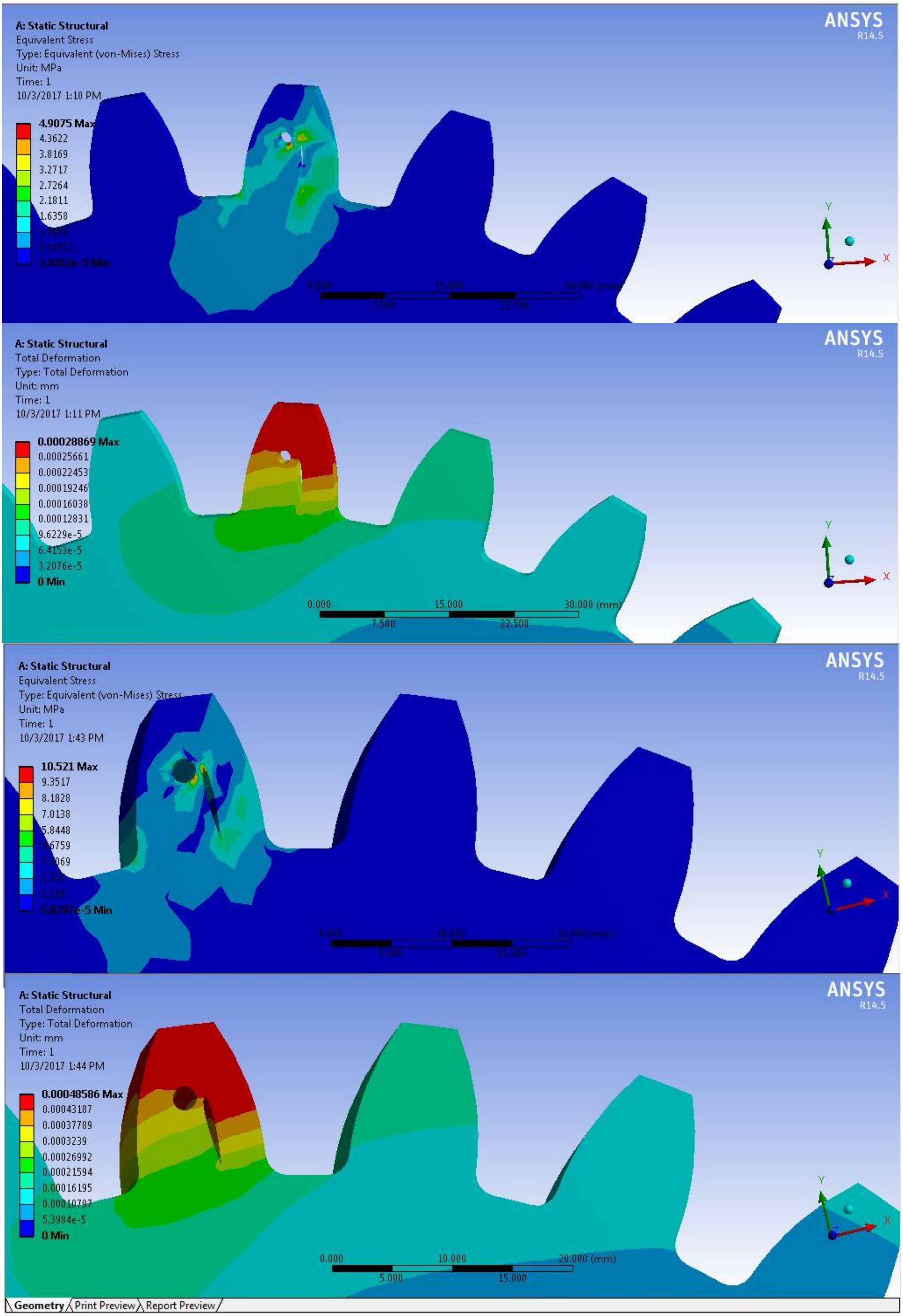


Fig. 11 – Stress/Deformation Analysis – 1.6 mm & 2 mm*1 SRF in teeth with Aero Foil

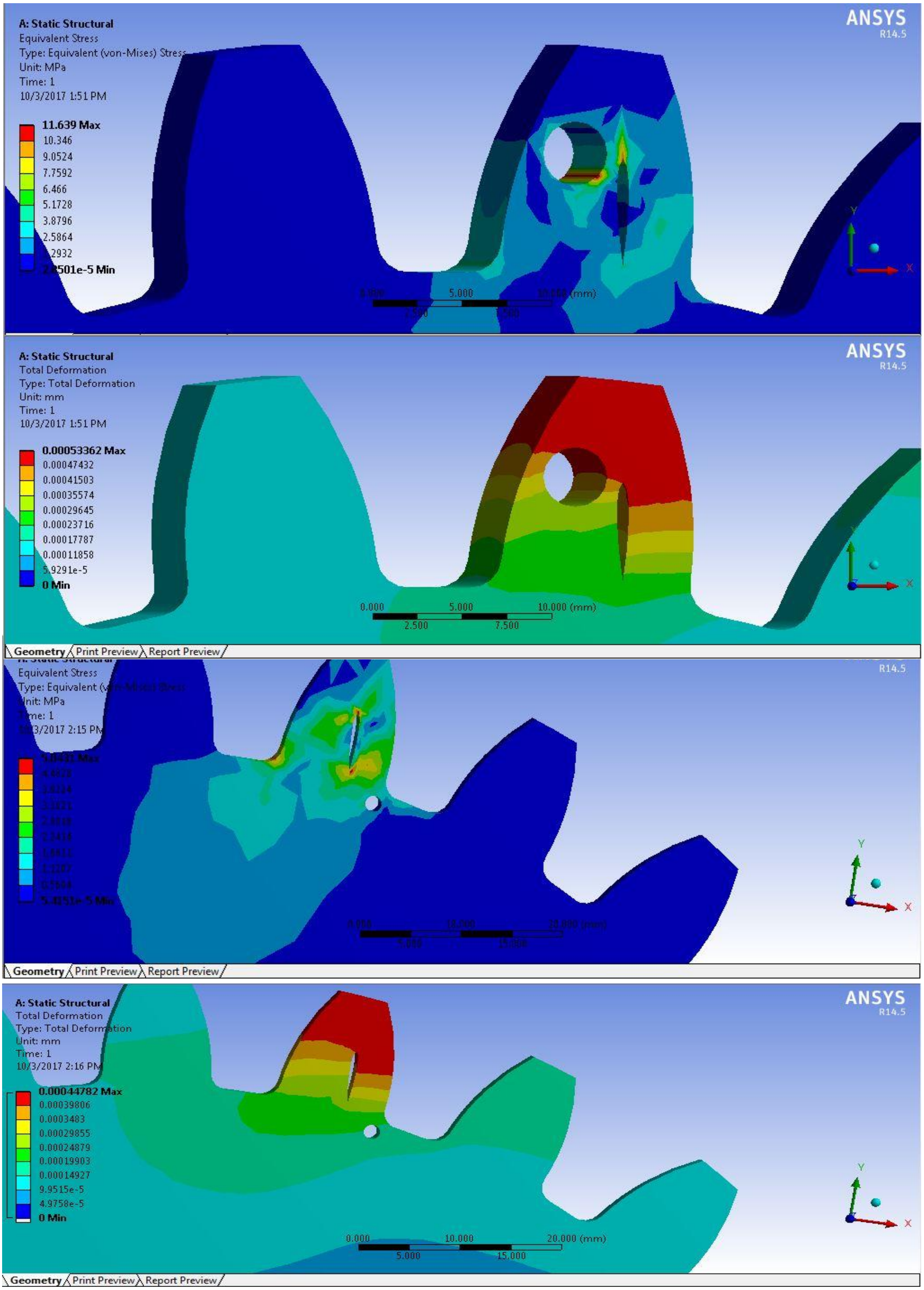


Fig. 12 – Stress/Deformation Analysis – 3.5 mm*1 SRF in teeth & 1.6 mm*1 SRF at root with Aero Foil

STRAIN GAUGE TEST

A strain gauge is a device used to measure strain on an object. Invented by Edward E. Simmons and Arthur C. Ruge in 1938, the most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the object by a suitable adhesive. The object is deformed and then the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the gauge factor.

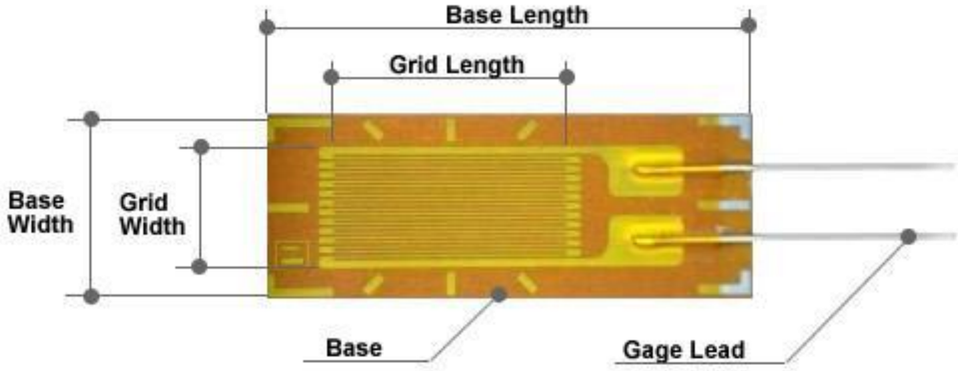


Fig. 13 – Strain Gauge Construction [5]

Bonding Procedures of Semiconductor and Metal Foil Strain Gauges involve following steps.

1. Surface Preparation
2. Handling and Cleaning of Strain Gauges
3. Bonding of Strain Gauges
4. Clamping Tools
5. Curing of Adhesives
6. Inspection of Bonding Quality
7. Soldering Tools and Stuffs
8. Soldering of Strain Gauges
9. Inspection of Solder Joint
10. Checking of Insulation Resistance

NICTECH Dam series is our data-logger which includes 1-4 channel with multi-parameters. It is an indicator for display the real time reading and also there is a facility to save real time data in flash drive. The data will also come in PC via RS-232 cable in real time basis. The software named as micro- scada. It can also shows 2 graphs at a time and 1 needle meter also there in software. It is very handy equipment and very user friendly. [5]

Fig. 14 – Multi Channel Data Logger [()]

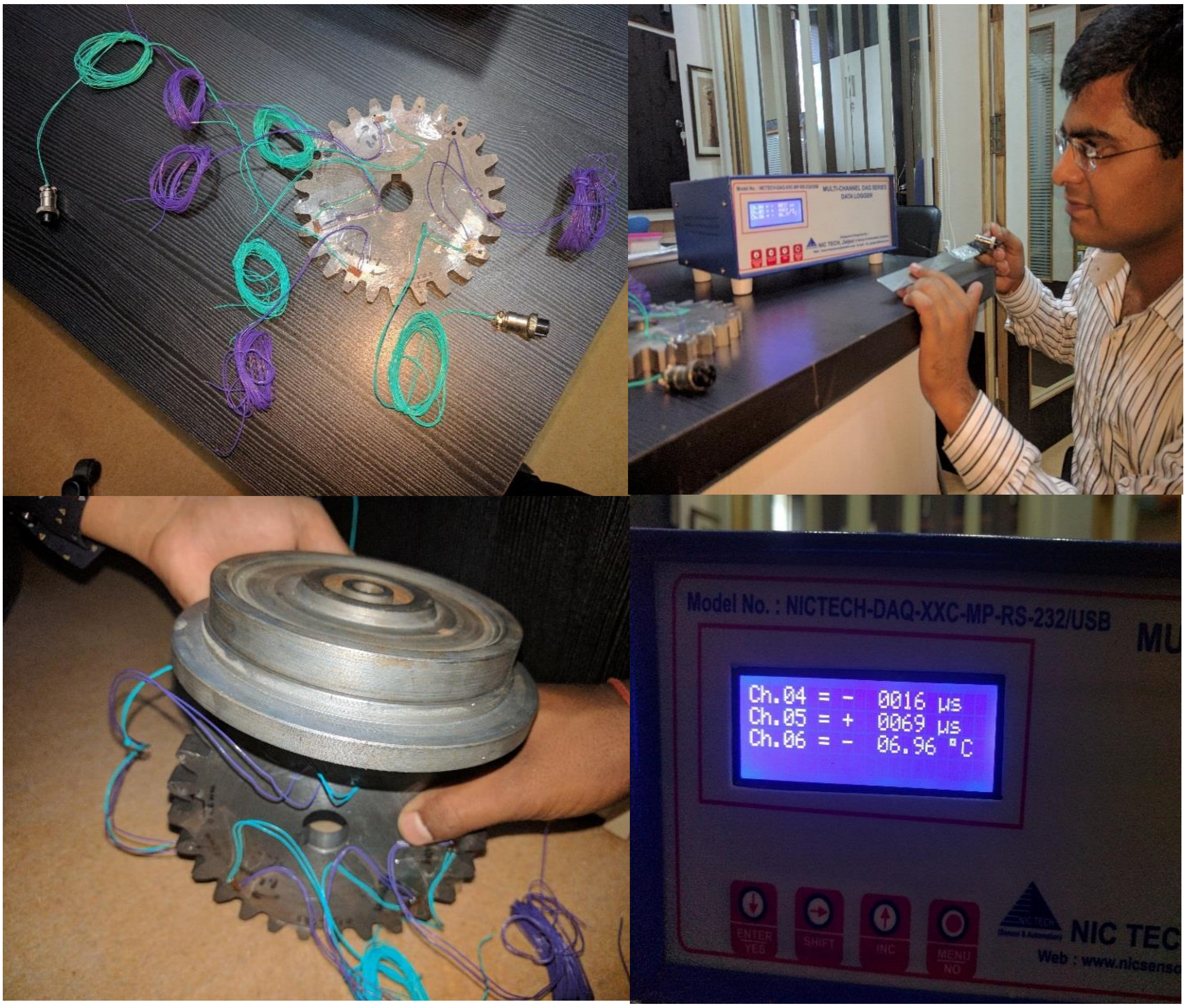


Fig. 15 – Strain Test (Setup and Testing) [(5)]

RESULT COMPARISION

SR. NO.	LOAD (Kg)	FORCE (N)		SRF LOCATION	YOUNG'S MODULES [E] - Mpa	STRAIN [ε]	STRESS [σ] – Mpa	
		x axis	*y axis*				ANSYS	ACTUAL
1	0.5	4.9	10.907	Without Stress Relieving Features (SRF)	137293.1	0.00000528	0.7368	0.7249
2	1	9.81	21.837		137293.1	0.00000777	1.0693	1.0668
3	1.5	14.71	32.744		137293.1	0.00001326	1.8173	1.8205
4	2	19.61	43.652		137293.1	0.00002051	2.7048	2.8159
5	2.5	24.51	54.559		137293.1	0.00002564	3.3592	3.5202
6	3	29.41	65.467		137293.1	0.00003552	4.7900	4.8767
7	3.5	34.32	76.396		137293.1	0.00004132	5.6351	5.673
8	5	49.03	109.15		137293.1	0.00005936	8.1065	8.149
9	7.5	73.55	163.72		137293.1	0.00008868	12.075	12.175
10	10	98.06	218.28		137293.1	0.00058705	16.044	16.120
11	3.5	34.32	76.396	1.6 mm SRF in teeth	137293.1	0.00003752	5.0740	5.1512
12	5	49.03	109.15	1.6 mm SRF near root	137293.1	0.00005978	8.0015	8.2074
13	7.5	73.55	163.72	2 mm SRF in teeth	137293.1	0.00007847	10.315	10.773
14	10	98.06	218.28	3.57 mm SRF in teeth	137293.1	0.00007838	10.660	10.761

Table – 2. Result (Ansys vs. Actual Test at Various Condition)

SR. NO.	STRESS [σ] – Mpa								
	Without SRF	1.6 mm	% Reduction	2 mm	% Reduction	3.57 mm	% Reduction	1.6 mm (root fillet)	% Reduction
1	**0.7249**	0.3556	***50.95***	0.3185	10.42	0.2512	21.12	0.7208	0.57
2	**1.0668**	0.9075	14.93	0.7208	20.57	0.5025	30.29	1.5926	-49.29
3	**1.8205**	1.4416	20.81	1.0379	28.00	0.8114	21.83	1.7587	3.39
4	**2.8159**	2.4699	12.29	2.4499	***0.48***	1.3743	44.36	2.437	13.46
5	**3.5202**	3.387	3.78	2.993	11.63	2.2187	25.87	3.0328	13.85
6	**4.8767**	4.3989	9.80	4.0996	6.80	3.0328	26.02	4.8162	1.24
7	**5.673**	5.1512	9.20	4.5952	10.79	3.4982	23.87	5.9132	-4.24
8	**8.1497**	7.9369	2.61	5.7045	28.13	4.0447	29.10	7.3383	9.96
9	**12.175**	11.511	5.46	10.773	6.41	9.7231	9.75	11.946	1.88
10	**16.12**	14.677	8.95	11.883	19.04	10.761	9.44	13.346	17.20

Table – 3. Result Comparison of Stress Reduction at Various Condition by Strain Test

SR. NO.	LOAD (Kg)	FORCE (N)		SRF LOCATION	YOUNG'S MODULES [E] - Mpa	STRAIN [ε]	ANSYS STRESS [σ] – Mpa	
		x axis	*y axis*				Circular SRF	Both (C+R) SRF
1	1.5	14.71	32.744	Without Stress Relieving Features (SRF)	137293.1	0.00001326	1.8173	1.3237
2	3.5	34.32	76.396	1.6 mm SRF in teeth	137293.1	0.00003752	5.0740	4.9075
3	10	98.06	218.28	1.6 mm SRF near root	137293.1	0.00005978	8.0015	5.0431
4	7.5	73.55	163.72	2 mm SRF in teeth	137293.1	0.00007847	10.315	10.521
5	3.5	34.32	76.396	3.57 mm SRF in teeth	137293.1	0.00005812	7.8023	11.639

Table – 4. Result (Ansys Analysis – With Combined SRF at Various Condition)

FATIGUE ANALYSIS

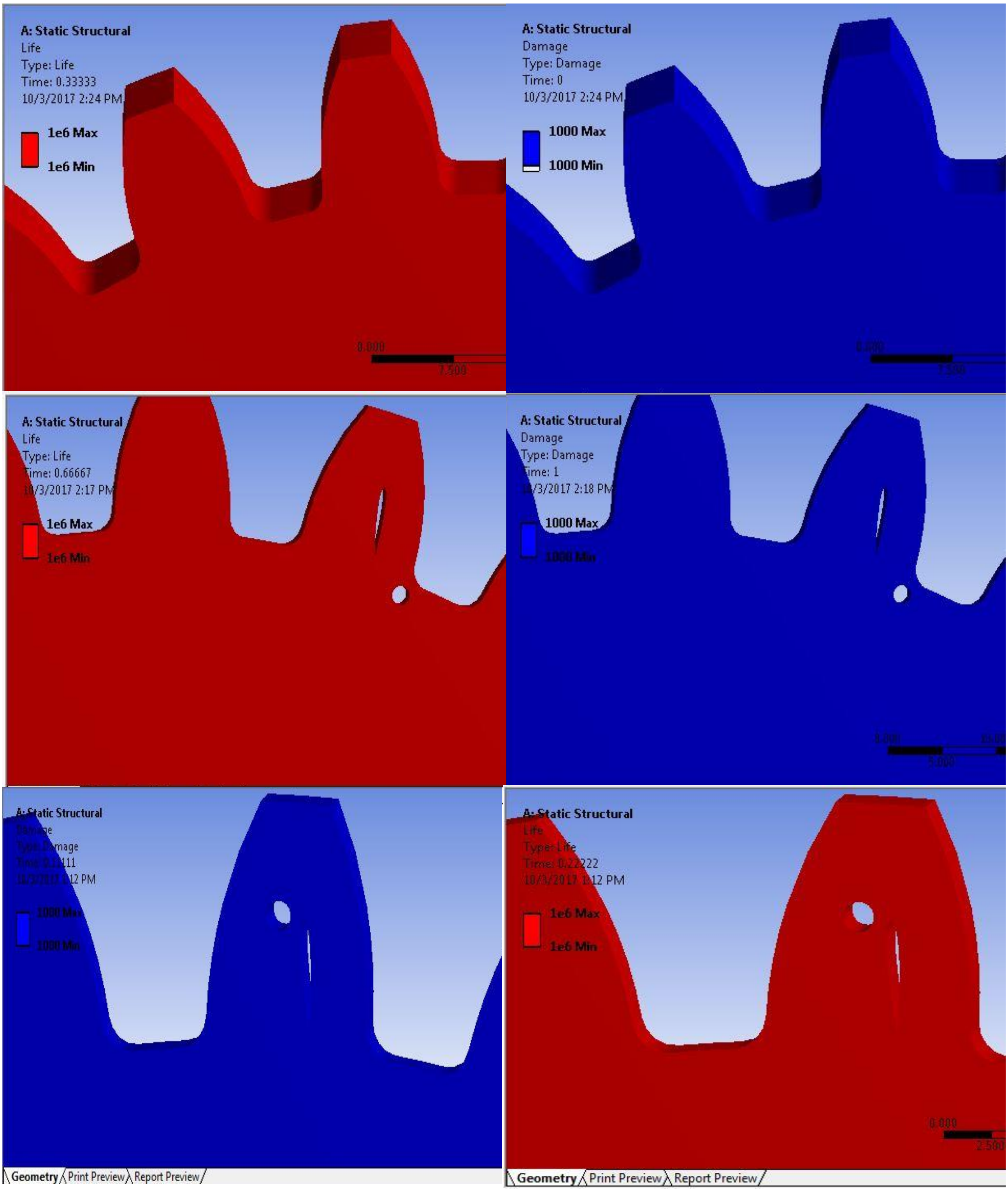


Fig. 16 – Fatigue Life/Damage Analysis – Without SRF, 1.6 mm near root * 1 SRF, 1.6 mm * 1 SRF in teeth with Aero Foil SRF

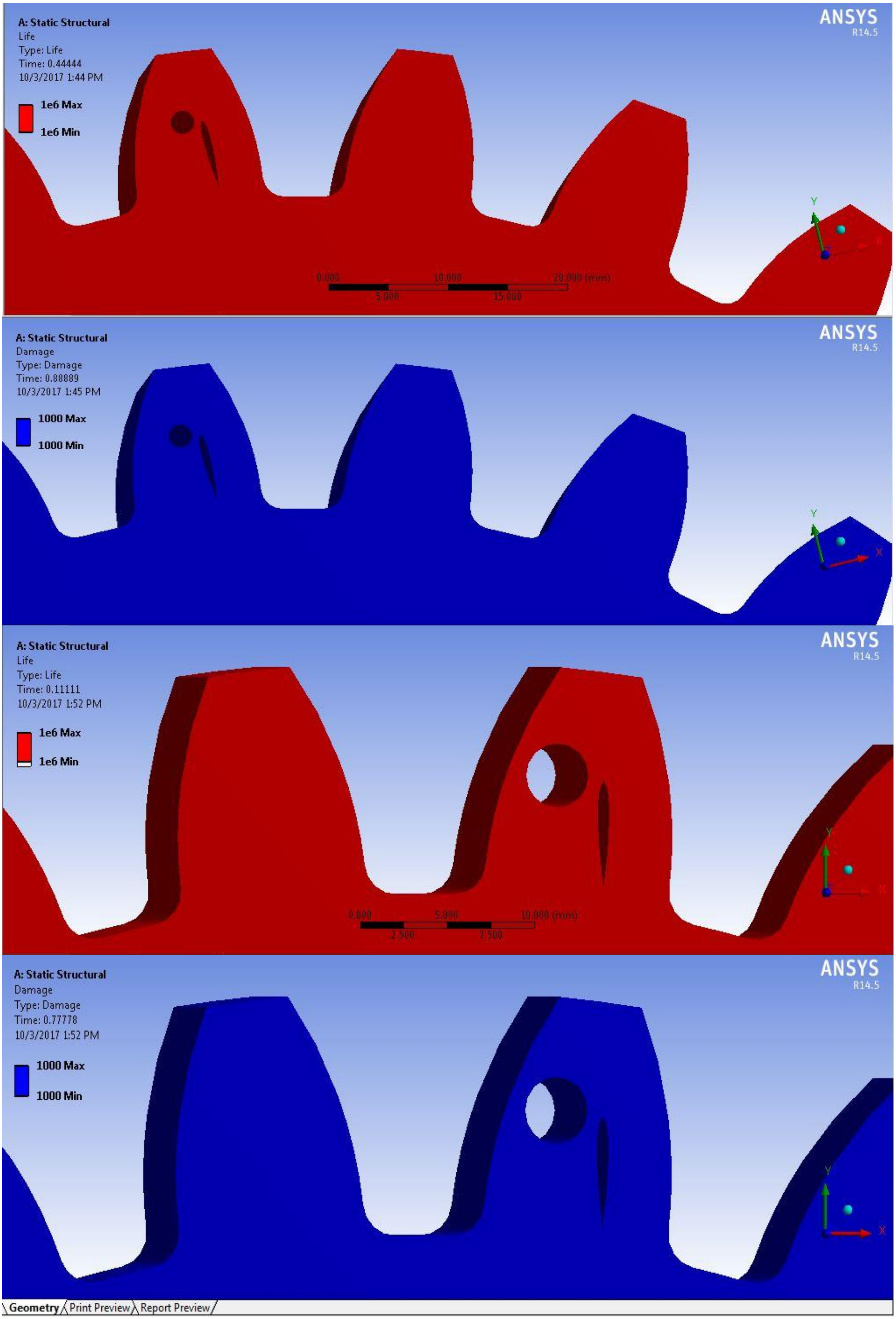


Fig. 17 – Fatigue Life/Damage Analysis – 2 mm * 1 SRF in teeth, 3.5 mm * 1 SRF in teeth with Aero Foil SRF

CONCLUSION

- With the help of design examination software with change in shape, size, location and combination of two SRF and its effect on gear parameters. Main impartial is to minimize the stress value without disturbing working factors of spur gear.
- Examine practical test of gear stress under various loading and SRF condition.
- Conclusion of an ansys analysis and experimental procedure for various size circular Stress Relieving Features (SRF) is that up to 3.57 mm SRF is applied on gear tooth.
- Stress reduction outcome obtained within the range of 0.48% to 50.95%.
- More than 4 mm diameter will increase in stress for this gear.
- Most suitable location for applying SRF is in teeth.
- Circular SRF up to 4 mm diameter is suitable for presented work.
- Holes near root fillet does not provide always coverage to decrease in stress.
- Combination of Circular and Aero Foil were provide similar result with compare to circular shaped SRF.
- Stress reduction within the range of 3.28% to 36.97% achieved by SRF combination only up to 1.6 mm.
- Fatigue Life and Damage analysis results by Ansys Workbench for each case provide constant value result.
- It proved that life cycle of gear does not affected by introducing SRF. But it is effective in manner of reducing stress.

SCOPE

- Various Location will be implemented with various gear types
- Actual Implementation of Aero Foil Shape

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