

Optimization of open gear design for dryer paper machine transmission system

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Optimization of open gear design for dryer paper machine transmission system

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Abstract. In this research, design optimization of the dryer paper machine gear (driven gear) is performed by adding a stress-relieving hole feature. The aim of this research is to find the effect of hole features with a specific position and diameter size in reducing the value of stress that occurs so that the lifetime of the gear will increase. Design optimization begins with finding problem data that occurs in work field and continues with the analysis by mathematical calculations and software simulation by using Autodesk Inventor 2017 education version to find stress distribution that occurs on the gear with the current operating load used. From the analysis carried out on the gear in operational working conditions, the maximum stress value occurs on the fillet radius area with 22.7 MPa. With the addition of a stress-relieving hole feature in the area around the fillet radius, the optimal stress reduction was obtained by 7.05% to 21.08 MPa. **Keywords:** gear, analysis, optimization, hole feature, stress.

1. Introduction

In the present time, the mechanical design of machine cannot only focus on functional aspect but also must emphasize aesthetic design factors. Therefore, designers these days have many considerations in designing a machine. In addition to designing, there is also a term that is familiar in the world of design, namely re-design. Re-design is a method that is carried out to optimize the design that already exists with the aim of improving the performance of a component that has previously been operating; this component re-design will have a big influence in production and work efficiency [1].

The study will mainly discuss the optimization of gear (driven) with helical type by using 20⁰ full-depth involute system that is used as a transmission for dryer section of paper machine at PT. XYZ. This research was conducted to overcome the problems that occur in the work field where the gear often experiences failure by operating loads with an average lifetime ranging from 1-2 years, which afterwards causes failure in the gear tooth and therefore it must be replaced. Bending stress and tooth surface stress are ones of the main factors of failure that occur in gears [2]. By looking at these problems, an optimization of gear design is carried out by adding a stress-relieving hole feature that can alter the stress distribution occurring in the gear and at the same time reduce the stress value which has an impact on increasing lifetime.

2. Method

The method used in the optimization of gear design in dryer paper machine transmission system at PT. XYZ is an analytical method for analyzing the strength by using mathematical calculations with two standard calculations of DIN (Germany) and AGMA (America) [3], [4].



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and by using software simulation design to obtain a comparison of results between calculations and simulation [5], [6], [7]. Gear design will be optimized by placing a stress-relieving hole feature by using various position and various diameter in gear tooth to find the optimal condition. The final result of the optimization is data with a reduced stress value and failure analysis is done by using the educational version of Autodesk Inventor Professional 2017 software.

3. Result and discussion

The following is the problem data of dryer paper machine component occurring in the work field that has been seen over the past three years and also the specifications of the gears used in operations.

Table 1. Problem data of dryer paper machine component

No	Failure Component	Frequency	Time of Failure	Type of Failure
1	Pinion (helical)	1 time in the last 3 years	February, 2018	Fracture tooth leg, cracked tooth wall
2	Gear (helical)	4 time in the last 3 years	April, 2016 March, 2017 March, 2018 August, 2018	Fracture tooth leg, cracked tooth wall (surface stress), deformation
3	Shaft	No failure in the last 3 years	-	There has been no failure in the past 3 years
4	Gearbox and motor drive	No failure in the last 3 years	-	There has been no failure in the past 3 years

Table 2. Gear design specification in work field

No	Technical Data	Symbol	Gear (driven)	Pinion (drive)
1	Helix angle	β	8^0	8^0
2	Normal pressure angle	α_n	20^0	20^0
3	Gear several	z	189	45
4	Module	m	10 mm	10 mm
5	Pitch diameter	D_g, D_p	1908.57 mm	454.42 mm
6	Outside diameter	OD	1928.57 mm	474.42 mm
7	Face width	b	135 mm	135 mm

Gear (driven) used in the dryer paper machine uses thermoplastic material Nylatron MC901 with a tensile strength of 82 MPa. The simulation is done by giving a resultant (tangential and radial) force of 12432.3 N to the 20^0 full-depth involute gear model with specifications according to table 3 and adding a hole feature with variations in position and diameter size to see the optimal results which can reduce the stress that occur on gears.

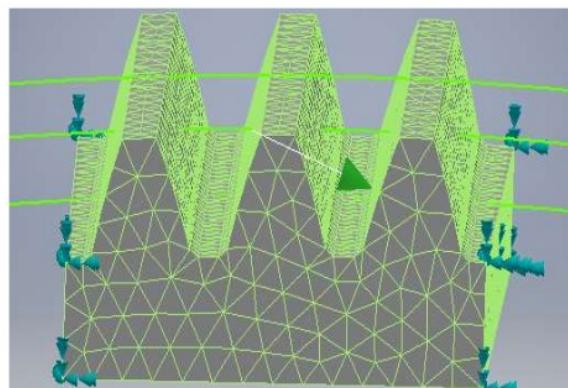


Figure 1. Force direction on teeth

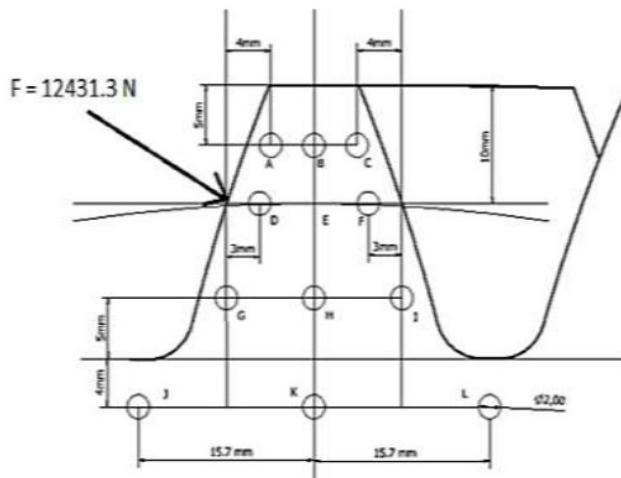


Figure 2. Location of hole placement in teeth

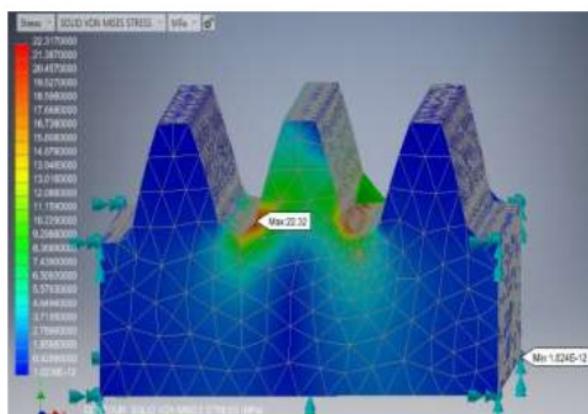


Figure 3. Stress at point L with 1 mm hole

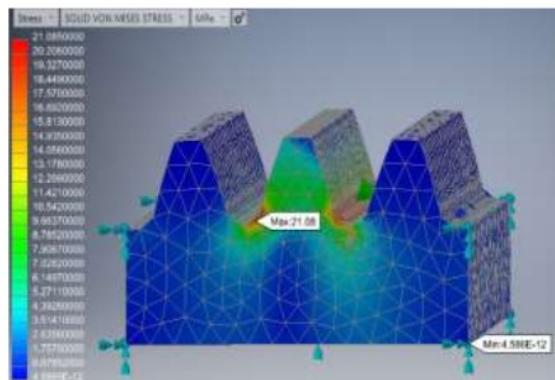


Figure 4. Stress at point L with 2 mm hole

Table 3. Stress value with variations of hole placement position

No	Hole diameter (mm)	Position	Stress Value (MPa)	Reduction (%)
1	0 (without hole)	-	22.70	-
2	2	A	22.94	-0.97
3	2	B	23.06	-1.59
4	2	C	23.23	-2.33
5	2	D	21.80	3.96
6	2	E	22.02	3.00
7	2	F	22.03	2.95
8	2	G	31.02	-36.65
9	2	H	22.36	1.50
10	2	I	33.81	-48.94
11	2	J	22.46	1.06
12	2	K	22.15	2.42
13	2	L	21.08	7.05

Table 4. Stress value with variations of hole diameter

No	Position	Hole diameter (mm)	Stress Value (MPa)	Reduction (%)
1	L	0.5	22.43	1.19
2	L	1	22.32	1.67
3	L	1.5	21.63	4.71
4	L	2	21.08	7.05
5	L	2.5	22.25	1.98
6	L	3	22.62	0.35
7	L	3.5	24.87	-9.56
8	L	4	27.13	-19.52
9	L	4.5	29.13	-28.33
10	L	5	34.39	-51.50

Based on the results of the simulations that have been done, it can be seen that the most optimal position of the hole is at the L point. The greatest decrease in voltage value occurs at the L point, so it can be concluded that the best distribution of stress concentration is in the position

close to the fillet radius hole diameter of 2 mm. The stress which occurs is 21.08 MPa and the stress is reduced by 7.05% (Table 3). Likewise, with variations in hole diameter at point L, the most optimum value is with a hole diameter of 2 mm (Figure 5). Thus, based on the results of this simulation, the most optimal hole diameter is 2 mm. If observed from a hole diameter of 3-5 mm, the stress value increases continuously, so it can be concluded that after passing a diameter of 3 mm, the stress concentration on the gear will move from the fillet radius to the hole. Therefore, a diameter of more than 3 mm will not produce an optimal value.

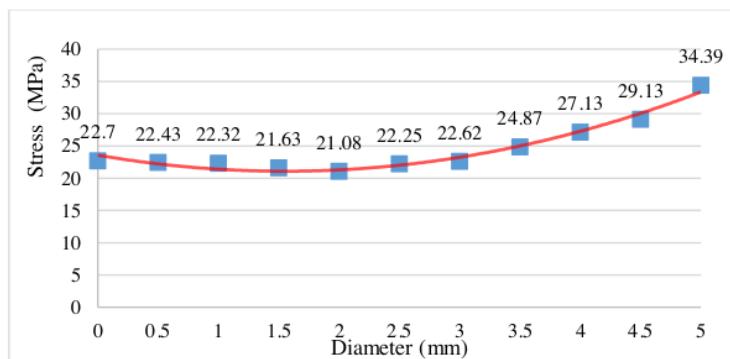


Figure 5. Stress value with variations of hole diameter

4 Conclusion

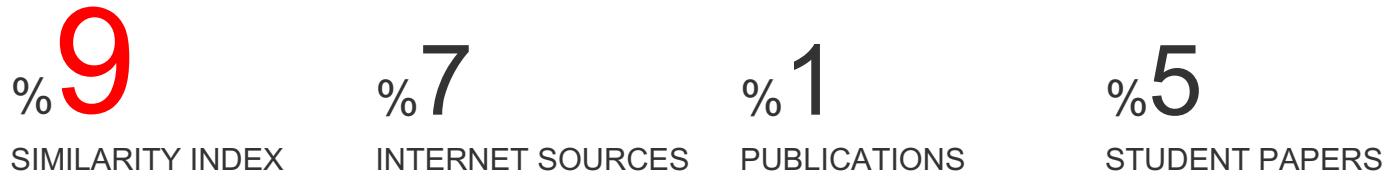
Based on the results of the analysis, it can be seen that many gear failures occur in the fillet radius which is the area of the largest stress concentration in the gear at 22.70 MPa (simulation) and 24.1 MPa (DIN calculation). From the design optimization, it can be concluded that the addition of the hole feature is done as a construction optimization step when the specifications of one of the gear pairs cannot be changed. Design optimization with the addition of hole feature results in the greatest reduction in stress at point L, where the maximum stress (fillet) on the gear decreases by 7.05 % to 21.08 MPa.

5. References

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