

Development of Test Procedure for Validation of Power Steering Pump Metallic Pulleys

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ABSTRACT

In today's automotive scenario, though Electric power steering system (EPS) is gaining importance, Hydraulic Power steering system is still a common feature in almost all passenger cars in many of the developing countries, basically because of the cost and non-availability of advanced technologies. Power steering pump is heart of entire hydraulic power steering system. Failure of the pump and/or its related sub-assemblies is a threat to the safety of the entire vehicle and its occupants during various maneuvering events on the road.

Power steering pump is coupled to the vehicle engine with its drive derived from the engine in a number of ways. However, the most common method employed by many of the OEMs is a pulley drive. Many test methods are established and followed for validation of power steering pump pulleys. However, for metallic pulleys, very meager published literature is available on the test methods for design validation.

The objective of this paper is to document the various testing procedures developed for validation of power steering Pump metallic Pulleys based on correlation with warranty field failures. Stringent performance, strength & durability test requirements are derived from the field failed samples based on failure modes observed and expected life coverage.

This paper presents a detailed description of problems faced on in-production power steering pump metallic pulleys and test procedures developed for reproduction of the warranty failures & validation of new proposals. Using FEA, the existing pulleys were examined for the failure modes and based on the analysis results new proposals of pulley design were suggested. New & improved performance, strength & durability test procedures were developed and the existing pulleys were tested to reproduce the field failures.

Based on the test procedures developed, the life of the modified power steering pump metallic pulley was examined and the best design was recommended. During the above process, various changes in the metallurgical processes were also recommended. Also, statistical methods were used to predict the B10 life of the pulleys based on the test results collected from various test procedures.

INTRODUCTION

Basically, a steering system is intended to transfer the driver inputs at the steering wheel of a vehicle to the steer wheels i.e. Tires. For the purpose of steering the vehicle with minimum effort, gearing & linkages are used to transfer the driver inputs. The weight of the vehicle (especially FAW-Front Axle weight) makes it difficult for the driver to turn the steering wheel and maneuver the vehicle in the intended direction. Therefore, many steering assistance systems like gears, linkages, hydraulic & electric power are employed on the vehicle to reduce the effort required to steer the vehicle.

The hydraulic power steering system has become a common feature in almost all passenger cars. In a hydraulic system, the pressure of the hydraulic fluid pumped to the steering gear assembly is utilized to assist the driver during various maneuvering events. A typical hydraulic steering system consists of a hydraulic pump, series of hoses/pipes, rack & pinion/steering gear assembly. Out of the entire hydraulic steering system, power steering pump is assumed to be the heart of the system.

Due to change in belt layout of the power steering pump in one of the in-production vehicles, higher loads were experienced by the pulley and hence the design team was forced to carry out design modifications based on the failures reported from field. A detailed FEA has been carried out based on the load cases, and a new, improved design is proposed. Figure 1 below gives details of the Field failure metrics on power steering pump pulleys:

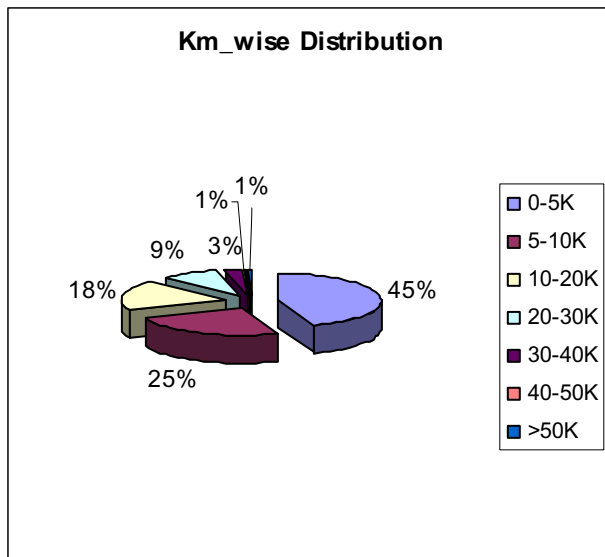


Figure 1: Field Failure Metrics

Failed samples as received from Field:

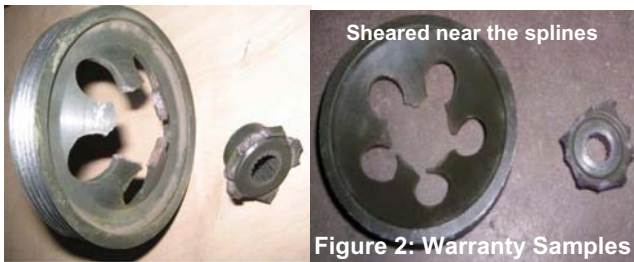


Figure 2: Warranty Samples

FEA OF POWER STEERING PUMP PULLEY

Typical layout of the power steering pump along with pulley and belt are as shown below:

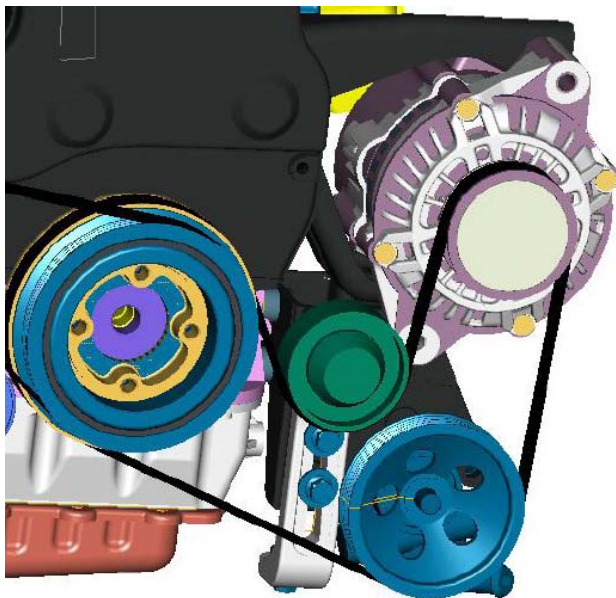


Figure 3: Power steering Pump, Pulley Layout

BOUNDARY CONDITIONS USED IN FEA MODEL:

For creating the boundary conditions of load cases on power steering pump pulley, the working of the power steering pump along with the belt wrap angle are required to be considered. Refer Figure 3 wherein the layout of the pump is shown. The wrap angle of the belt over the pulley is found ranging from $75^\circ \sim 80^\circ$. Radial & Tangential loads are encountered by the pulley due to rotation of pump at various engine RPMs. As tangential & Radial direction is continuously changing in real time operating conditions, $1/3^{\text{rd}}$ of the belt contact patch on pulley (i.e. Wrap angle) is assumed to have same Tangential & Radial direction as a node in center of each region as shown in figure 4 below:

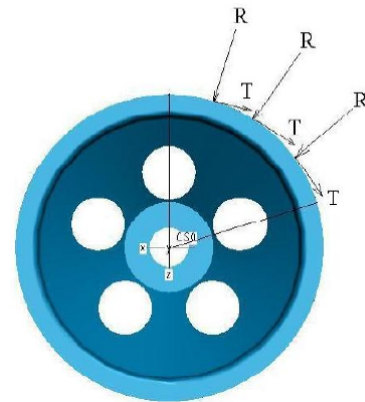


Figure 4: Pulley loading direction

Based on the above assumption, pulley is restrained at both the ends in FEA model as shown below in Figure 5.

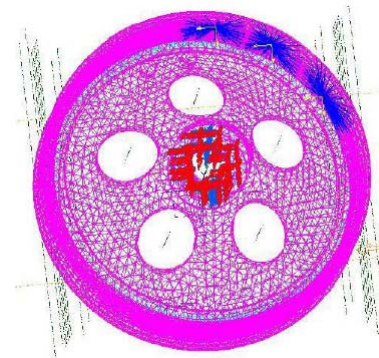


Figure 5: Pulley FEA model with boundary conditions

Load Cases:

For the purpose of deriving load cases on the pulley surface, torque required by the pump shaft and in turn the power consumption of power steering pump is considered. Energy consumption of Power steering pump from engine while on highway is minimal and is maximum while traversing a curve or during a parking event. A typical Power consumption graph of the subject pump reveals the following data:

Type of Steering Event	Pump	
	RPM	Power consumption(kW)
Highway	4500 ~ 6000	0.25 ~ 0.5
Traversing a Curve	3000 ~ 4500	0.5 ~ 0.75
Low Speed Parking	1000 ~ 1500	1.0 ~ 1.5

Table 1: Pump Power Consumption Details

With the above data, the torque transformed at the spline area of the pulley is 12 ~ 13 N-m and accordingly the Radial & Tangential loads at each load point with a node at the centre is 2000 ~ 2500 N respectively. Figure 6 below gives the stress induced in the pulley with the said load case:

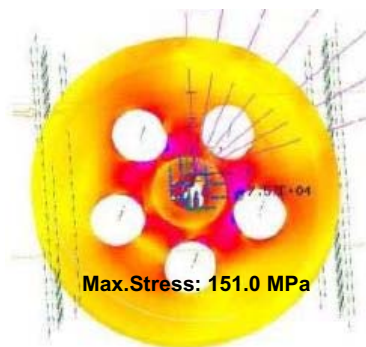


Figure 6: Stress Plot of Existing Pulley

From the S-N curve of Pulley material (FG-260), it is observed that for infinite life of the pulley, the maximum stress that can be induced shall always be less than 110 MPa, which is Fatigue limit of the material. However, considering the excursions of the pump under various steering maneuvers, pulley shall be designed in such a way that the maximum stress in a pulley under any circumstances shall not be more than 0.25 ~ 0.4 times the UTS limit of the pulley material (UTS of FG-260 is 252 MPa). Accordingly, various design options were considered and evaluated with the above established load cases.

Proposed Design Options Vs Maximum Stress:

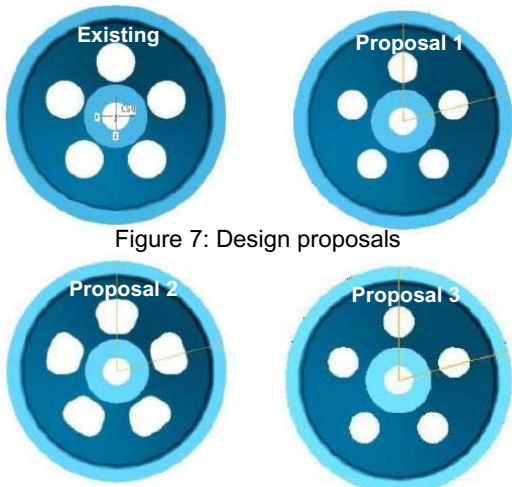


Figure 7: Design proposals

Maximum Stress (MPa)	Design Options				
	Type of Steering Event	Existing design (Ø 18 mm holes on 50 PCD)	Proposal 1 (Ø 14 mm holes on 50 PCD)	Proposal 2 (Modified Cutouts with centre at 50 PCD)	Proposal 3 (Ø 14 mm holes on 53PCD)
	Highway	75.7	53.3	71.6	46.0
	Traversing a Curve	103.0	72.0	97.2	62.0
	Low Speed Parking	151.0	106.0	143.0	91.3

Table 2: Stress levels of proposed design options

Refer Appendix for Stress plots of proposed design options.

Based on the FEA results and S-N curve of the pulley material, Proposal 3 i.e. 5 holes on 53 PCD was selected for further analysis & Testing. Accordingly, modifications were finalized as shown in Figure 8 below:

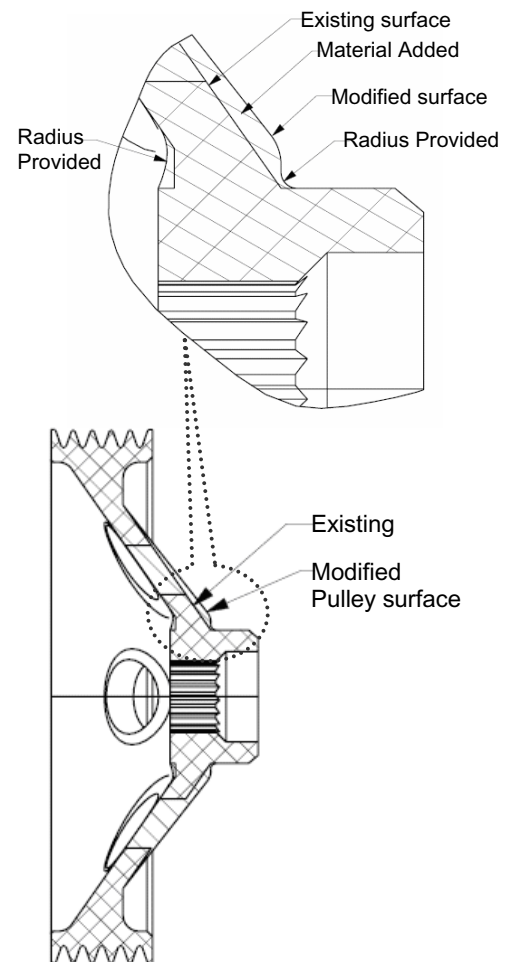


Figure 8: Modified Pulley Drawing

With the above proposed modifications, pulleys were manufactured and processed for further testing.