DESIGN OF POWER TAKE-OFF (PTO) SHAFTS AND ITS FAILURE DURING OPERATION

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Abstract: In this work, the problem of PTO shaft of Agricultural tractor fail was investigated. The specifications of the shaft design were determined, after that the reasons that cause these issues were presented. The outcomes shown several reasons that can lead to PTO shaft broken. The most likely factor in this case is the leakage or discontinuity of hydraulic oil in the system. A solution was recommended to put the oil pump inside the oil reservoir to guarantee the flow of oil during the operation.

Key words: PTO shaft, Design, Tractor, Failure, Oil, Solution.

Cite this article

1. Introduction

Currently the population of the world is rapidly increasing, therefore, the agricultural and food production required have been more significant [Mahajan et al. (2018), Al-Juthery et al. (2020)]. The upcoming predictions refer that providing sufficient food for the people has been a significant issue [Hamza and AL-Taey (2020), Singh et al. (2021)]. In order to provide the huge amounts of food and agricultural productions required, vast lands must be cultivated. This made implementing a large number of agricultural machines and equipment becoming an essential factor [Hussain et al. (2021), AL-Taey and Burhan (2021)].

The international agricultural tractor market request was estimated at $60.15 billion in 2021 and expected up to $83.33 billion by 2026 at a Compound Annual Growth Rate (CAGR) 6.66% (Global report cited in http://www.researchandmarkets.com). The quantity of machinery has grown into a significant factor in food and agricultural yield efficiency. The best sign of the rate of agricultural mechanization in an area are the quantity of tractors. In this situation, robust design and reliable engineering manufacturing process for agricultural equipment and machinery in the industry sector ought to be carefully considered, where, the fail on the equipment and machinery during agricultural operations are key factors [Ali and Ali (2019)]. Frequently, farmers are killed or seriously got hurt; in accidents relating broken of machine parts used in systems of agricultural machinery like power take-off (PTO) shafts [Triantafyllidis et al. (2015)] in addition to some rattle noise that sometime happen [Park and Kim (2006)]. Examining the mechanical failures happen in various mechanical systems have attracted investigators since many decades. In the failure analyses process, the researchers use three techniques analytical examines, numerical studies, and experimental exams. Deal with an experiment exams approach may expose challenges, and usually expensive. The numerical

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analyses such as final elements analyses FEA) can provides faster and cheaper results [Celik et al. (2018)].

The equipment that run using power take-off (PTO) (Fig. 1) are widely used for numerous field operations such as plowing, rotary ditching, and sowing [Kim et al. (2019)]. Most tractors utilize a power take-off (PTO) shaft to deliver rotational power to equipment that may be pulled or stationary. Important modernizations have been achieved to the tractor’s PTO delivery from the time when being commercially available on 1918 by model 15-30 of the International Harvester Company (IHC). PTO shaft torque can be measured using torque sensor that is typically between 3-23 N.m [Roeber et al. (2017)]. The PTO shaft in general is located at the back of the agricultural tractor, and can be attached to equipment that is a three-point hitch or pulled by a drawbar. A power take-off (PTO) is a grooved drive shaft that can be utilized to deliver power to a separate or a connect equipment or machine. It was designed to be easy to joining and detaching. The power take-off allows equipment and machines to obtain energy from the IC engine of tractor. The PTO shaft ought to obtain separately and it is essential to match the space and geometry interface of the transmission part with a convenient with the PTO shaft dimensions. Agricultural tractors PTOs have standard specifications in speeds and dimensions. The ISO specifications standard for PTOs is defined in ISO 500 and that of the 2004 version was divided into three sections

ISO 500-1: Universal specifications recorded dimensions for main shield, safety requirements, and district of clearance.

ISO 500-2: tight path tractors, clearance zone and dimensions recorded for main shield.

ISO 500-3: spline dimensions, master PTO specific dimensions and PTO location [Yuvanarasimman and Rajeswari (2014)]

The operation agricultural tractor PTO shaft is typically at 540 revolutions per minute (rpm). Numerous failures recognized in the tractor application system were recorded from the feedback received from the direct farmers.
The telescoping PTO shaft consists of solid rectangular member inserted in tubular in rectangular member. This assembly was in turn covered by a floating cylindrical PTO guard. The use of rectangular cross-section guaranteed the proper alignment of the thus universal joints eliminating improper phasing as a causative factor. Furthermore, there was no indication that proper telescoping action of the PTO shaft. In this work, the PTO shaft fail during the agricultural operations will be explored to identify and justify the reasons behind the fail, then provide a suitable solution.

2. Methodology

The most frequent PTO failure during agricultural operations that occurs within the three-year warranty period of the manufacturing company is the breaking of the PTO shaft into two or, occasionally, more parts. This issue costs the manufacturers many thousand dollars annually. Moreover, these can be very dangerous for the tractor’s drivers and farmers.

In order to explore the reasons of this problem, these steps should be followed.

- Firstly, comprehensive study about the tractor and equipments.
- Secondly, Problem identification.
- Thirdly, gather the feedback used to verify the issue.
- Fourthly, clearly identify the reasons of failure.
- Finally, recommend a suitable solution.

In order to identify the reasons behind the fail of the PTO shaft, the shaft design specifications were investigated that show the PTO shaft sizes: PTO stub shaft diameter for a 540 rpm shaft is 35mm with six splines. The 1000 rpm stub shaft with twenty one teeth or splines is 44.5 mm. The 1000 rpm stub shaft with twenty teeth or splines a diameter of 35 mm. The most PTO shaft broken happens after the fracture of the gear box [Brickman and Barnett (1994)]. In regular operation, a PTO shaft is a two force member whose end act as hinges and who’s loading is only through the hinge points. All trusts through such a member must lie along an axis through the hinge points, that is, through the member. The telescoping nature of PTO shaft grantee almost zeros trust and consequently the force derived to the gear box input shaft will have zero components in x, y and z directions \( F_x = 0, F_y = 0 \) and \( F_z = 0 \) as shown in (Fig. 2). Universal joints can only transmit torsion, consequently, \( M_y = 0, M_z = 0 \). Therefore, the only resultant load that can be transmitted to the gear box input shaft is the torsional load \( M_x = T_x \), where the \( T \) is the output torque of the tractor PTO neglecting inefficiencies. Theoretically, the torque \( T \) will be transmitted to the output shaft through the gear box. Since the shear bolt limits the magnitude of the output torque. The input shaft exposed to a limited torque with all other force moment components begin zero. There is no structure loading on the input is simpler than the theoretical loading in the input shaft.

3. Results and Discussion

The outcomes refer that unbalanced disturbed power delivered by the transmission shaft can cause improper sharing of power. The main reason for that is the shorting or cutout of oil supply in the hydraulic system during the operation, in addition to less common cases.

4. Conclusion

As shown above, the most likely reason causes the P.T.O shaft fracture is the shorting of hydraulic oil of the system, in addition to more reasons such as unexpected load, sharp angle connection, and heavy stroke. Therefore, it is recommended to put the oil pump into the hydraulic tank. By this way the main reason of PTO. shaft failure can be skipped.

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References


