

# Noise Level Reduction in Planetary Gear Set

S.H. Gawande<sup>1,\*</sup>, S.N. Shaikh<sup>2</sup>, R. N. Yerrawar<sup>1</sup>, K.A. Mahajan<sup>1</sup>

<sup>1</sup>Department of Mechanical Engineering, M. E. Society's College of Engineering, Pune, India

<sup>2</sup>Department of Mechanical Engineering, P. G. Moze College of Engineering, Wagholi Pune, India

\*Corresponding author: shgawande@yahoo.co.in

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**Abstract** Planetary gears are very popular as a power transmission and extensively used in a variety of industrial fields like automobiles, helicopters, aircraft engines, heavy machinery, and a variety of other applications. Despite their advantages, negative impacts on customer perception of quality from noise and vibration are ongoing issue. The noise induced by the vibration of planetary gear systems remains a key concern. Therefore in recent years to reduce gear vibrations different techniques have been proposed. In this paper the experimental work is carried out to study the effect of planet phasing on vibrations of planetary gear set. For this purpose experimental set up is built and trials were performed for two different arrangements i.e with phasing and without phasing. And it is seen that noise level and resulting vibrations were reduced by planet phasing arrangement. So from the experimental results it is observed that by applying the meshing phase difference one can reduce planetary gear set vibrations and noise.

**Keywords:** planetary gear train (PGT), vibration reduction, planet phasing

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## 1. Introduction

Planetary gears are very popular due to their advantages such as high power density, compactness, multiple and large compact gear ratios and load sharing among planets. Gearing arrangement is comprised of four different elements that produce a wide range of speed ratios in compact layout. These elements are, (1) Sun gear, an externally toothed ring gear co-axial with the gear train (2) Annulus, an internally toothed ring gear coaxial with the gear train (3) Planets, externally toothed gears which mesh with the sun and annulus, and (4) Planet Carrier, a support structure for planets, co-axial with the train. Planetary gear system as shown in Figure 1 is typically used to perform speed reduction due to several advantages over conventional parallel shaft gear systems. Planetary gears are also used to obtain high power density, large reduction in small volume, pure torsional reactions and multiple shafting. Another advantage of the planetary gearbox arrangement is load distribution. The more the planets in the system, the greater load ability and the higher the torque density. The planetary gearbox arrangement also creates greater stability due to the even distribution of mass and increased rotational stiffness.

In recent years, enhancement of interior quietness in passenger cars, Automobiles is an important factor for influencing occupant comfort. Planetary gear sets are essential components of automatic transmissions because of their compact size and wide gear ratio range. They produce high speed reductions in compact spaces, greater load sharing, higher torque to weight ratio, diminished bearing loads and reduced noise and vibration. Despite

their advantages, the noise induced by the vibration of planetary gear systems remains a key concern. Planetary gears have received considerably less research attention than single mesh gear pairs. This paper focus on the study of two PGTs with different phasing (angular positions) while keeping every individual set unchanged.

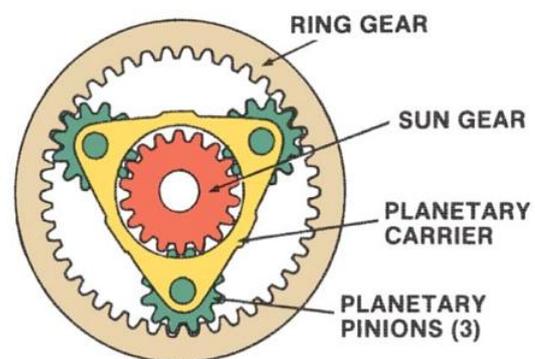


Figure 1. Basic layout of planetary gear box

## 2. Present work on Vibration Reduction in Planetary Gear Set

Vibration and noise is the primary concern for gear trains in various technical applications requiring smooth and quieter operation of machinery. The various active and passive techniques are suggested by many researchers to reduce gear vibrations. Richards and Pines[1] designed a periodic shaft to reduce transmitted vibration of a pair of spur gears and from analytical and experimental results

they concluded that transmitted vibrations from gear mesh contact to the bearing supports are reduced at variable speed and under static load. Asiri & Pines [2] proposed that passive periodic struts can be used to support gearbox systems on the airframes of helicopter to isolate vibration transmission from helicopter gearboxes to the airframe to produce quiet cabin environment. Cheon Gill-Jeong [3] used nonlinear behavior analysis to verify the effectiveness of a one way clutch for reducing torsional vibration of paired spur gear system under periodic excitation. Many studies have also stated gear dynamics to reduce noise and vibration of gears. In 1979 Hidaka [4] and his co-workers have done a series of experimental works on dynamic behavior of planetary gears. Kahraman et al [5] studied the relationship between ICR and the dynamic performance of a spur gear pair. They investigated experimentally the influence of involute contact ratio on the torsional vibration behavior of eight gear pairs with different contact ratios. Early studies have shown that the mesh phase has a significant impact on the dynamic response and, therefore, it can be used to develop strategies to reduce planetary gear vibration. Schlegel and Mard [6] proposed the new strategy of vibration reduction in planetary gearset. Kahraman and Blankenship [7] studied the use of planet phasing in context of helical planetary systems in which author used the static transmission error to represent the dynamic excitation in a lumped parameter dynamic model. All of these studies focus on planetary gears with equally spaced planet gears. Parkar [8] gave physical explanation for the effectiveness of planet phasing to suppress planetary gear vibration based on the physical forces acting at the sun, planet and ring meshes. Cheon Gill-Jeong [3] also used spur gear pair to analyze planet phasing for reducing vibrations. Yong Chen and Akira Ishibashi [9] investigated the relationship between meshing phase difference and torsional vibration of planet gears.

### 3. Experimentation and measurements

To reduce gear vibrations, numbers of passive and active methods are reported. Many studies have been concentrated on the modification of gear teeth but these methods have limitations on modifications. Passive methods like the use of periodic struts for gearbox support systems, periodic drive shafts are also reported to reduce gear vibrations. But these methods require additional actuators, external power, and signal processing.

It is necessary to develop the method to reduce gear noise and vibrations by gear itself without requiring the additional energy and signal processing techniques which generally results in increase in cost. Viewing this need the method of vibration reduction in planetary gears by phasing is introduced in this research work. In order to study the effect of phasing on noise and vibrations of planetary gear set the required experimental set up was developed as shown in Figure 2 and performance analysis is done by performing many trials with and without phasing. Figure 2 shows schematic layout of test set up developed for the measurement of vibrations of planetary gear set by phasing. Figure 2 also shows the position of various components like motor, planetary gear set 1 & 2, coupling and speed regulator. The experimental work was

carried out to study the effect of meshing phasing on vibrations & noise level of Nylon-6 planetary gear set. For this purpose experimental set up was built as shown in Figure 2. Rectangular plate is placed between planetary gear set 1 & 2 to provide meshing phase difference between ring gear of gear set 1 & 2. Noise is measured for two different arrangements as with phasing and without phasing. Experimental set up shown in Figure 2 consists of different components as PMDC motor, love joy coupling, planetary gear set, and speed selector.

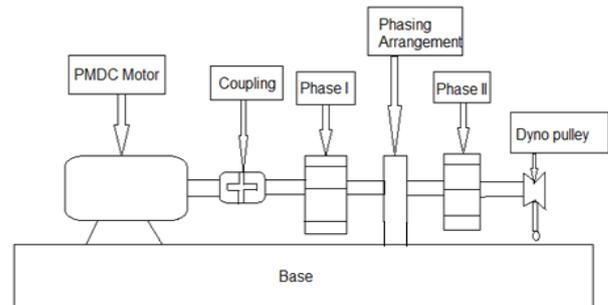


Figure 2. Schematic layout of test set up for measurement of planetary gear set vibrations

### 4. Results & Discussion

To study the effect of phasing number of trial were conducted by using Sound Level meter by varying load from 1Kg to 6Kg and changes in torque, power and resulting noise level are recorded. Results obtained without phasing and with phasing arrangement are shown in Table 1.1 & Table 1.2. From Table 1.1 and Table 1.2 relations between speed, torque, power, mechanical efficiency and noise level are plotted for with and without phasing arrangement.

Table 1.1. Observations by without phasing arrangement

Load (Kg)	Speed (rpm)	Power (W)	Efficiency (%)	Noise (dB)
1	74	12.00	17.14	78
2	73	23.35	33.31	80
3	72	35.52	50.74	83
4	71	46.71	66.73	86
5	71	58.29	83.93	89
6	70	69.03	98.90	91

Table 1.2. Observations by with phasing arrangement

Load (Kg)	Speed (rpm)	Power (W)	Efficiency (%)	Noise (dB)
1	75	12.25	17.50	72
2	74	24.25	34.64	74
3	73.5	36.17	51.67	76
4	72.5	47.60	68.00	79
5	72	59.11	84.44	82
6	71	69.96	99.45	85

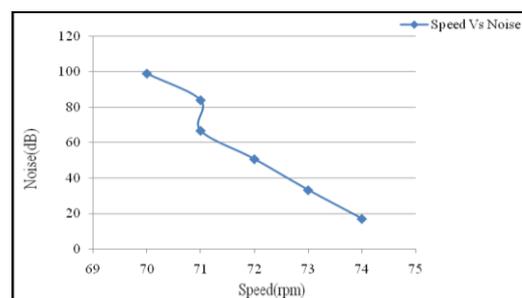


Figure 3. Variation of speed with Noise without phasing

From Figure 3 and Figure 4 it is observed that as speed increases, noise level decreases because speed decreases with increase in load. Noise level in without phasing arrangement as shown in Figure 3 is greater as with phasing arrangement as shown in Figure 4 at motor speed of 1200 rpm. This shows noise level decreases by using with phasing arrangement. Figure 3 and Figure 4 show the effect of the meshing phase difference on the measured noise level. From it is concluded that the level of noise decreases when phase difference is provided. From Figure 5 and Figure 6 it is seen that Power is greater in with phasing arrangement that without phasing arrangement. From Figure 7 and Figure 8 it is observed that as speed increases efficiency decreases. Efficiency of with phasing arrangement is greater as compared to without phasing arrangement at motor speed of 1200 rpm. Efficiency is maximum with 98.90% value at 70 rpm output speed at dyno-pulley for without phasing arrangement. While efficiency is maximum as 99.45% value at 71 rpm output speed at dyno-pulley with phasing arrangement. This shows efficiency is improved by using with phasing arrangement.

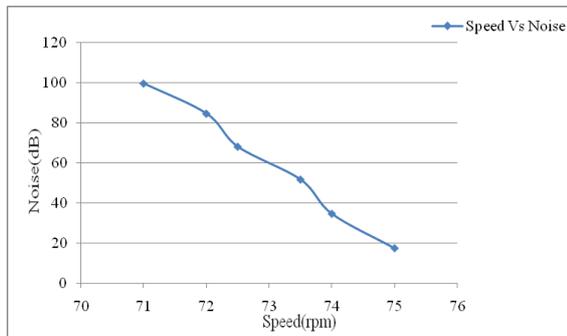


Figure 4. Variation of speed with Noise with phasing

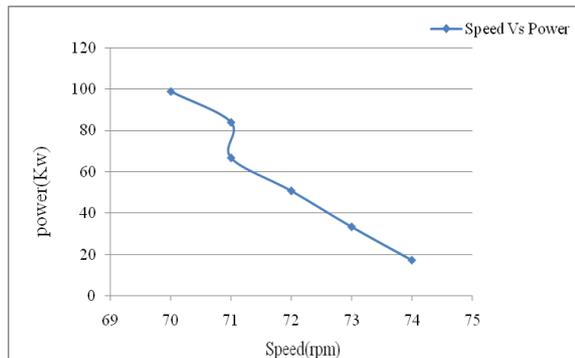


Figure 5. Variation of speed with Power without phasing

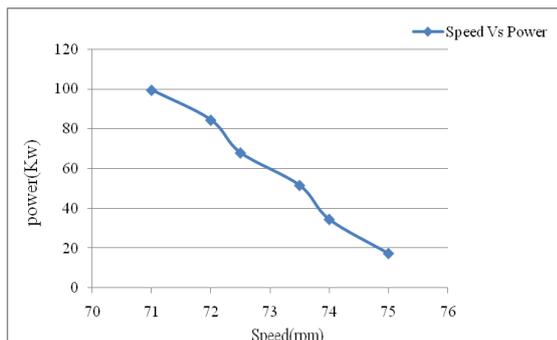


Figure 6. Variation of speed with Power with phasing

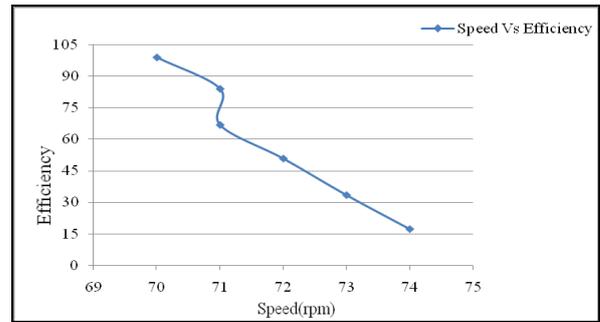


Figure 7. Variation of speed with Efficiency without phasing

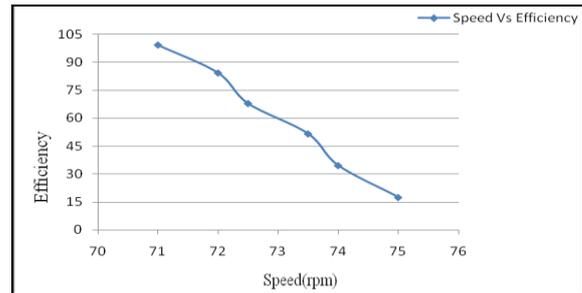


Figure 8. Variation of Speed with Efficiency with phasing

## 5. Conclusion

The primary objective of this research work was to investigate noise reduction in planetary gear set by phasing. This objective was achieved with the help of extensive experimental work. On comparing results obtained by without and with phasing at 1200 rpm it is seen that the level of noise in planetary gear set with meshing phase difference was approximately 6dB to 7dB lower than that of planetary gear set without a meshing phase. So from the experimental results obtained by sound level meter it is concluded that by applying the meshing phase difference one can reduce planetary gear set noise and resulting vibrations.

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