

AFD Case Study: Walking Bearing Problem

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IDENTIFYING AND DOCUMENTING THE PROBLEM

Problem Description:

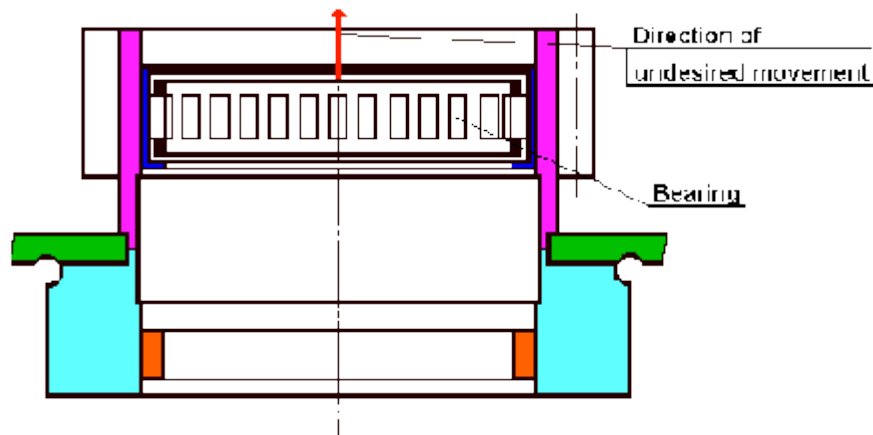
A transaxle bearing in the sun gear of a truck transmission, after some period of use, "walks" out of place. It is necessary to eliminate this walking.

Primary Useful Function of bearing:

Provide rotation of sun gear.

Drawback:

Bearing moves out from its desired place.



History of the drawback:

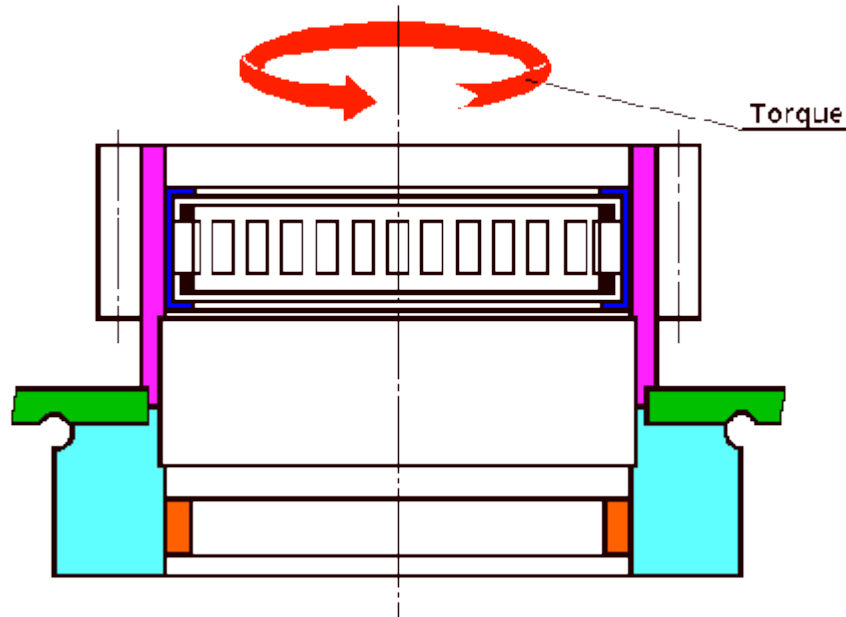
This drawback appeared when the gear box was used with a more powerful engine.

Changes which resulted in the drawback:

Torque and vibration increased.

Mechanism of the drawback:

Unknown.



FORMULATING THE PROBLEM

Formulating the original problem:

The bearing, after some period of use, walks out from its position. How does this phenomenon occur?

Inverting the problem:

How can we *force* the bearing to walk out from its position?

Amplifying the problem:

How can we force the bearing to walk out from its position *using available resources only*?

Available resources:

Energy:

Substances:

- torque
- vibration
- sun gear
- satellite gears

SEARCH FOR PHENOMENA

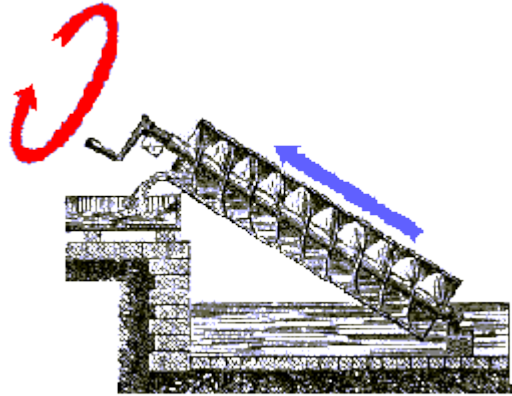
Result of undesired phenomena: Onward movement of the object with rotational torque and vibration.

To find the required phenomena, we should use the *simplest* analogies, for example:

- rotation results in onward movement, as shown below

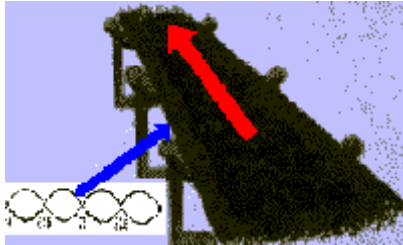
screw

sprial

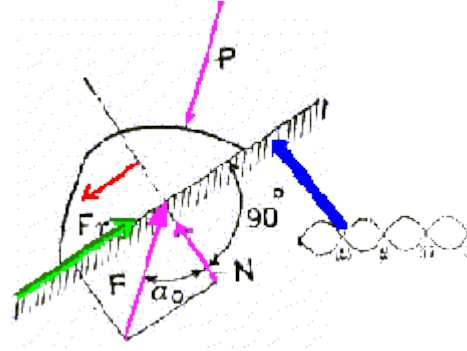


- vibration results in onward movement, as shown below

vibro-transportation



reduction of friction



Thus, we have found the following phenomena:

**Known Phenomena
with Similar Result:**

Required Resources:

Onward movement of nut along screw

- screw surface contacts object
- rotational torque

Onward movement of object if torque is directed along spiral

- torque directed along spiral

Movement of object under vibration (vibro-transportation)

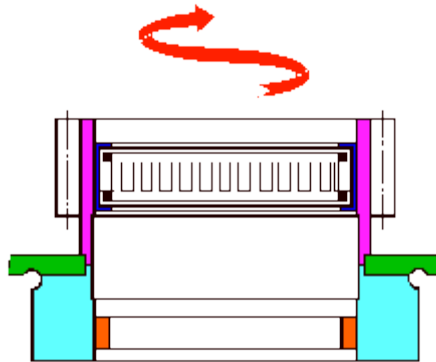
- vibration
- guide for movement of object

Reducing friction under vibration

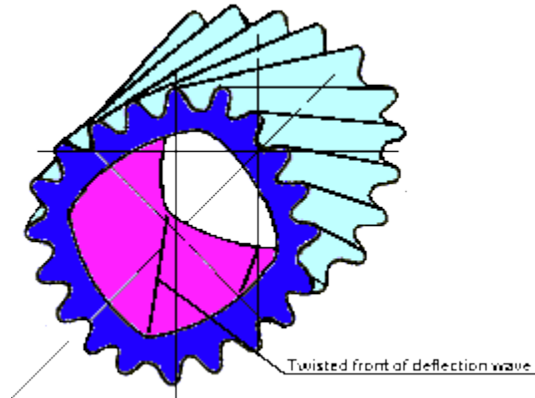
- vibration
- additional force moving the object

CREATING AND VERIFYING HYPOTHESES

Hypothesis 1: Torque forces the bearing to move along spiral.

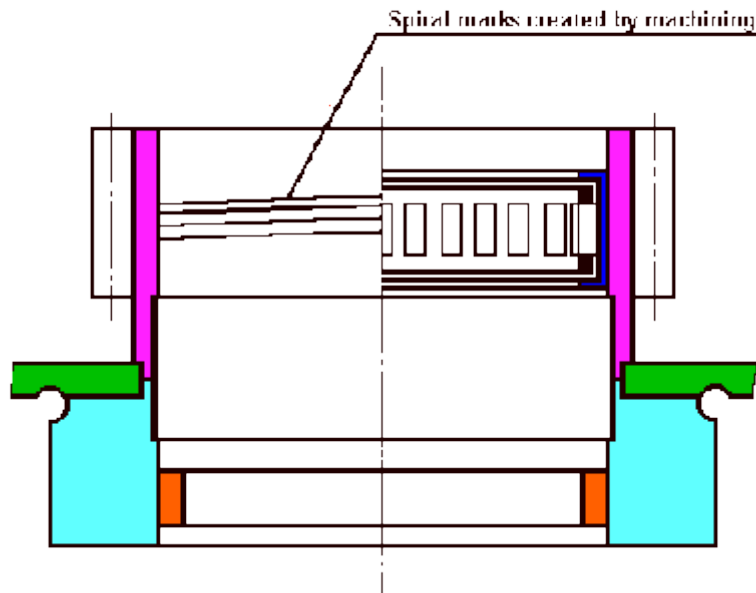


Hypothesis 1a: Torque creates deformation which results in deflection wave in sun gear. Teeth of gear have some angle with axle; it results in twisted front of deflection wave. This wave moves and forces bearing to move along spiral.

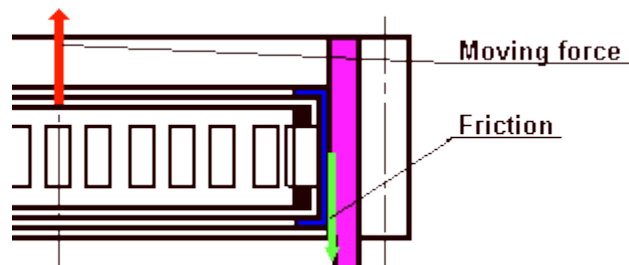


Hypothesis 1b: Bearing interacts with internal surface of sun gear. This surface has spiral marks created by machining. Under load bearing and spiral marks create a "screw-nut" pair. Deflection

wave rotates bearing and forces it to move along spiral marks.



Hypothesis 2: Vibration reduces friction between bearing and central bore; as a result, bearing walk-out becomes easier.



Hypothesis Verification Method

torque creates deflection wave with twisted front

- test gearbox with teeth directed along axle of rotation
- test gearbox with opposite angle of teeth

torque creates deflection wave; internal surface of sun gear has spiral marks

- render analysis of internal surface of sun gear
- correlate direction of movement of bearing, possible direction of deflection wave and direction of movement of cutting tool during machining

vibration reduces friction between bearing and central bore

- create vibrations similar to working ones and measure friction between bearing and central bore

ELIMINATION OF UNDESIRED PHENOMENON

Mechanism of Drawback

Directions for Elimination

deflection wave with twisted front

- strengthen sun gear
- reduce forces in gear mesh
- redirect deflection wave
- redirect tensions in sun gear

movement along spiral marks

- redirect spiral marks

decreasing friction between bearing and gear

- increase friction between bearing and gear

Direction for Elimination

Solution Concept

strengthen sun gear

increase thickness of sun gear

reduce forces in gear mesh

increase amount of satellite gears

redirect deflection wave

change direction of teeth in gear mesh

redirect tensions in sun gear

render an additional groove in the central bore; this groove redistributes tensions and works like a barrier for walking bearing

redirect spiral marks

change direction of rotation of machining tool

increase friction between bearing and gear

use press-fit bushing produced from material with a higher thermal expansion coefficient