Dodge® products: basics of balancing
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Vibration and imbalance questions are fairly common in industrial power transmission applications where parts can rotate at high speeds. Vibration can cause problems especially in power transmission (PT) components like sheaves, sprockets and couplings as these components connect two shafts. Vibration in these components can get passed on to both driver and driven side.

When discussing balance, what is really being discussed is unbalance. To balance a part 100% is not only difficult but also prohibitively expensive. Some amount of unbalance will result due to manufacturing tolerances, voids, porosity etc. Thus, the question is how much unbalance is acceptable. To be able to gage acceptable unbalance, one must first understand what unbalance is and how it affects an application.

When a part rotates, every particle in the part is acted upon by centrifugal force. This force tends to pull these particles from the axis of rotation (AOR) (see **Figure 1**). If the part's center of gravity (COG) is not equal to the AOR, then this leads to vibration. This is because the natural tendency of the body is to rotate about its COG. The level of vibration increases with speed. This is similar to a washing machine on the spin cycle; if the wash load is not evenly distributed the washing machine will have unbalance and vibrate. Excessive vibration can lead to high fatigue stresses and have detrimental effects on the life of bearings and machine components in general. Altering the mass distribution, by balancing, minimizes these forces and provides for smoother operation and longer machine life.
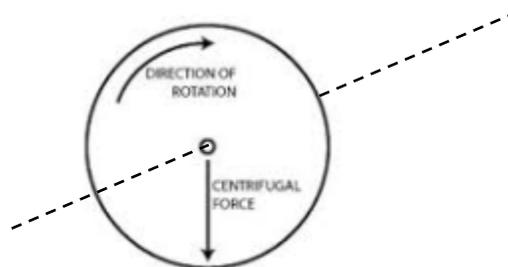

Figure 1.

Mathematically, it is found that the unbalance, and thus centrifugal force, increases with the square of the speed. If the speeds doubles the force will increase four times. The force also increases linearly with weight. If the unbalance weight doubles the force will double. Therefore, the biggest influencing factor on balance is speed, though other factor like weight and size do matter. Since speed is typically defined by the application, balance must be controlled by the amount and location of unbalance.

The center of gravity is the point in a body or system around which its mass or weight is evenly distributed, or balanced, and through which the force of gravity acts. (Webster dictionary). See **Figure 2** below.
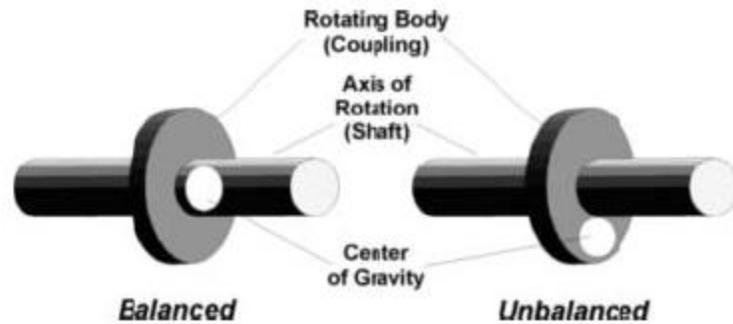
Figure 2.

In a set-up like coupling or drive, where there is unbalance, centrifugal force or the pull is felt by the shaft and the bearings in the form of vibration as shown in **Figure 3** below. Excessive vibration can damage various parts of the drive train. Unbalance also creates dynamic misalignment which can damage the bearings in the system.
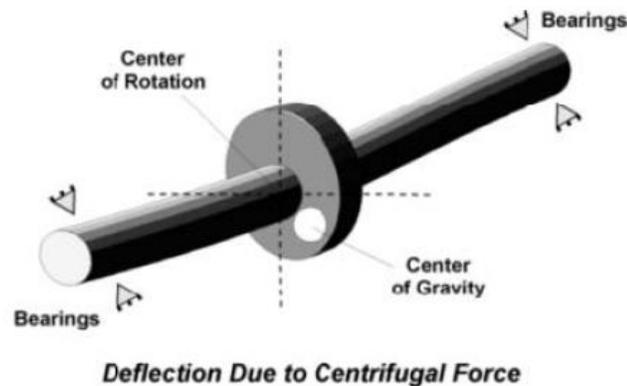

Figure 3.

As mentioned earlier, all parts which rotate will have some degree of unbalance. The application will determine if corrective balance is required. As discussed earlier, the greatest influencing factor is the rotating speed.

There are many standards like the ones mentioned below that give guidelines for determining when speed or weight becomes significant and corrective balance is required. Once it is known that balancing is required, the allowable unbalance value, or class, is determined.

AGMA   ISO   DIN

Most of the Dodge PT components parts manufactured by ABB are covered by the Mechanical Power Transmission Association (MPTA). Under MPTA, balancing has been classified into two categories.

1. Single plane balancing or static balancing (Preferred term is single plane)
2. Two plane balancing or dynamic balancing (Preferred term is two plane)

Single plane balancing: Single plane balancing can be defined as the eccentricity of the center of gravity of the part, caused by a point mass at a radius from the center of rotation as seen below in **Figure 4 and 5**. An equal mass placed at 180° to the unbalanced mass and at the same radius is required to move the center of gravity to the center of rotation. In static balance, all of this is done in one geometric plane.
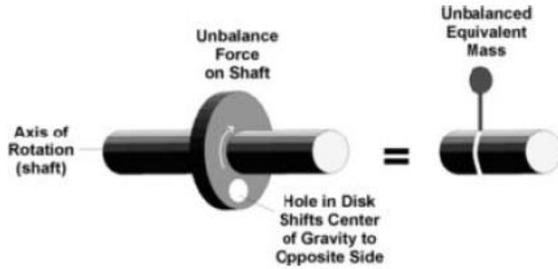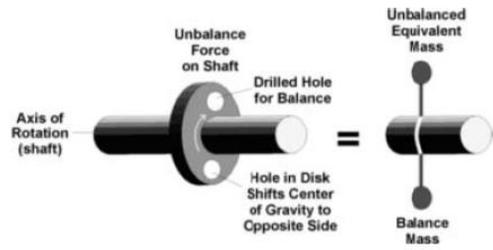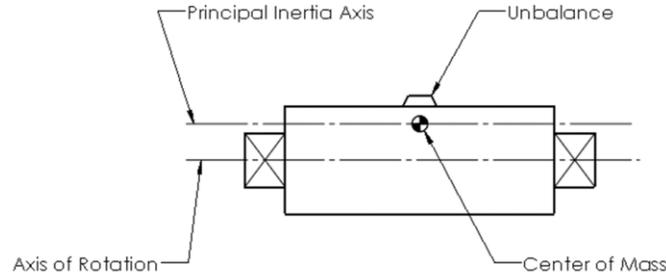
Figure 4.

Figure 5.

STATIC UNBALANCE

Two plane balancing: Two plane balancing is an operation where balance corrections are made on two different geometric planes about the component's axis. These locations must be well separated to produce two plane balance. This separation helps in deciding if the component should be balanced in two planes or not. The longer the component along its axis, the more likely that it needs two plane balancing. In two plane balancing, the unbalanced masses do not lie in narrow plane; they lie far apart or are spread apart. This is shown in **Figure 6** below.
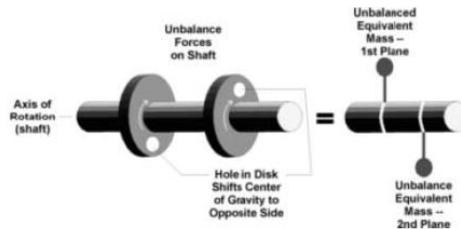

Figure 6

In two plane balancing, each component is balanced, and the center of shaft does not vibrate (**Figure 7**). If the two planes are close to each other, then the effect of unbalance is less. Therefore, in two plane balancing the mass of unbalance, its location from the center of rotation, the speed (RPM) and distance between unbalance along axial length affect the amount the unbalance.

The type of balancing, single or two plane, is usually determined by the axial length of the component.
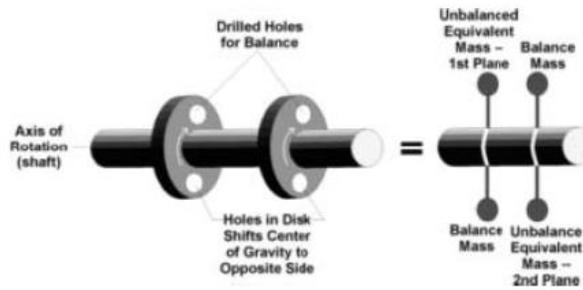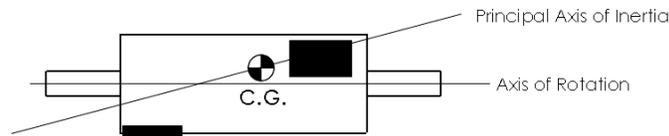
Figure 7

DYNAMIC UNBALANCE

However, the decision to dynamic balance a part is typically customer driven. The customer is the only one who knows the required vibration criteria, which is usually based upon their experience with the intended machinery. Although most customers seek to minimize or eliminate unbalance in applications, several customers have applications that exploit it. Applications such as vibration screens and gyratory crushers harness sheave eccentricity to induce vibration in a manner that accomplishes the intent of the machinery. Special MTO sheaves can be designed specifically for this purpose.

For v-belt sheaves and synchronous belt sprockets, the following equation is typically a good rule of thumb to determine at what RPM dynamic balancing is required.

$$\text{DYN BAL RPM} = 15{,}600 \mathbin{/} \text{SQRT (Diameter x Face Width)}$$

All Dodge sheaves and sprockets are static balanced per MPTA requirements. Dodge can dynamic balance sheaves or sprockets per customer's request as made-to-order. Dynamic balance is more precise and more expensive than static balance. Just because the sheave is dynamically balanced does not guarantee it will be balanced once it is on the equipment. A true dynamic balance depends on bearing centers, bearing mounting methods, shaft length, shaft diameter, and the bushing mount. With these variables, a dynamically balanced sheave may make no overall difference to the vibration levels of the system. If the customer desires a true dynamic balance, the balance should take place when the machine is assembled as a unit or at a minimum balanced with the proposed bushing of use.

Bibliography: MPTA-C3c 2010 Balancing Primer

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