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Workers and Materials Protection: Center of Percussion its Calculations and Mechanical Applications

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Abstract:The quality of hand tools used by industrial workers is very important for workers safety and production, this quality affected by a dynamic quantity called center of percussion. Center of Percussion can be defined as the place on an extended massive item connected to a pivot at which a perpendicular impact creates no reactive shock at the pivot. Translational and rotational motions cancel at the pivot when an impulsive blow is delivered at the center of percussion. A bat, racquet, door, sword, or other long item gripped at one end is usually referred to as the center of percussion. For an object hanging from a pivot as a pendulum, the same place is referred to as the center of oscillation, which indicates that a simple pendulum with all of its mass concentrated at that point will have the same period of oscillation as the complicated pendulum. In sports, the "sweet spot" of a bat or racquet is connected to the center of percussion, although the latter is also related to vibrational bending of the item. In this study a number of hand tools will be tested and examined as a rod and the center of percussion is calculated for them depending on derived empirical relations.

Keywords: Quality, Percussion, hand tools, vibrations, Center, workers safety.

1. Introduction

A bat's or racket's center of percussion (COP) is the point on which it may be struck without eliciting a reaction at the point of support. When a ball is struck at this position, the impact feels good and the ball looks to spring away at full speed, which is why it is sometimes referred to as the sweet spot. The bat or racket may vibrate or sting your hands in places other than this one (HU, 2021).

Consider beam which is rigid and suspended from a wire by a fixture that may freely slide along the wire at point P, as illustrated in Figure 1. Where CP denotes the Center of Percussion and CM denotes the Beam's Center of Mass. From the left, an impetuous strike is delivered. If it is lower than the center of mass (CM), the beam will revolve counterclockwise around the CM and the CM will shift to the right. The center of percussion (COP) is located underneath the CM. If the blow exceeds the COP, the rightward translational motion at P will be greater than the leftward rotational motion, leading the fixture's net initial motion to be rightward. If the blow is under the CP, the fixture will initially move to the left because rotational motion at P is higher than translational motion. Only if the blow exactly strikes the COP will the two components of motion cancel out, resulting in zero net initial movement at point P.

An impulsive blow somewhere other than the COP generates an initial reactive force at the pivot when the sliding fixture is replaced with a pivot that cannot move to the left or right. Figure 1 depicts the percussion center and its relationship to the center of mass (Russell, 2005;Turner,1999;Robert**,** 2014).

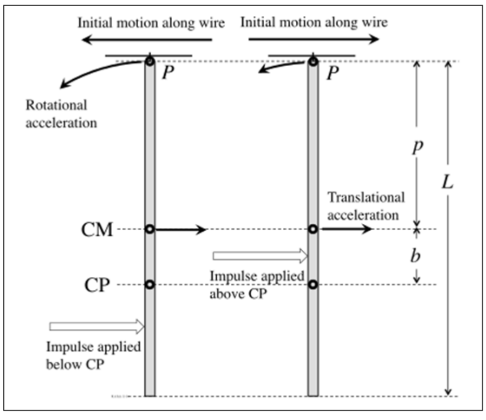

Figure 1. Center of percussion and its relation with center of mass

The importance of center of percussion in such objects and their various applications are studied in (Kondekaret al., 2013). It offered a dynamic study of a compound pendulum exposed to a horizontal force, as well as an alternate analytical and graphical method for locating the center of percussion (COP). The COP is easily determined by the graph depicting the change of the horizontal shock at the pivot point in relation to the position of the impact force. The COP is also called as a "sweet spot" because the horizontal response or shock at the pivot point evaporates, resulting in a "no shock" scenario. This also produces the fewest vibrations to the swinging body. The center of percussion are determined theoretically and experimentally in (Grimshaw, 2019). The experimental results demonstrated that the axis of rotation goes via the hand or wrist for all of the typical impact locations on a hand-held tool. As a result, the optimal impact location is generally the node of the basic vibration mode, rather than the center of percussion.

In (Cross, 2004) COPis defined as the point (or frequently region) on the racket or bat that makes the most efficient contact with the ball. In tennis, for example, a bigger center of percussion area on a racket might reduce the effects of badly struck strokes, according to the study. The term “sweet spot”, which is often used in the media/sports literature to describe the center of percussion point on a racket or bat, is not necessarily the same point as the center of percussion was presented and also it showed that the center of percussion may be a “sweet spot”, but the center of percussion can also change its position and has important implications for both performance and injury prevention.

A novel gait generation technique is proposed, whose objective is to optimize the mechanical design of actuated bipeds to reduce energy consumption. The novelty is the use of the center of percussion of the robot to calculate the equivalent simple pendulum of the system. With the equivalent pendulum, the gait is parameterized using its natural [7]. The center of percussion was commonly regarded as a sweet spot when referring to a baseball bat or a tennis racquet because it was assumed that there would be no sudden motion of the handle concerning the hand if the corresponding axis of rotation passed through the hand. A problem with this interpretation is that the hand extends over a finite length of the handle and exerts an opposing reaction force on the (Cross, 2004) calculations were made using the Mathcad program for four different-size hammers. Only one size hammer positioning of articulation partly accomplished the mentioned recommended condition of the hammer center of percussion. The recommended positions and sizes of articulation holes were determined for the mentioned four size hammers. The results of calculation in compliance of four sizes of manufactured hammers with the condition of the center of percussion at the end point of the hammer showed that only one hammer size partly satisfies this condition. This shows that the hammer mill hammer design so that interaction between the hammer and material occurs at the percussion center of the hammer is still actual (Smits, and Kronbergs, 2017).Measurements of HAV from jackleg drills was presented. The use of hand-attached accelerometers caused a lower recorded vibration level compared with tool-attached accelerometers. This difference is likely to vary depending on how workers grip the tool handle, and a misclassification of exposures will occur if workers grip the tool handle in a way that makes the accelerometer lose contact with the vibrating surface. Individual differences in how workers grip the tool handles should be considered when assessing HAV (Clemm et al., 2021)Investigation the Center of Percussion (COP) of Cricket Bat was proposed. A cricket bat (Reebok yuvi burn) was selected. The variable selected was Center of Percussion (COP). To measure the Center of Percussion (COP) accelerometer sensor was used. The collected data were statistically analyzed by the repeated measures design of ANOVA. In all the cases 0.05 level significances was fixed (Kumar et al., 2023). An approach for minimizing impact reactions was presented, using the Center of Percussion (CoP), a characteristic of rigid bodies rotating around an axis. Application of CoP in multibody systems was demonstrated using the Newton-Euler Algorithm. Implementation guidelines were discussed. Simulations of a planar space robot system, and a three-dimensional PUMA-like manipulator on a satellite base confirmed the benefit of using the CoP during tasks that include impacts [12]. Loading on a member with minimum force and maximum work output was introduced, such as machines and structures also on human beings. In [13] mainly focus on the center of percussion in human body as mainly advantages and disadvantages.

2. Calculation of Center of Percussion

To start calculations consider the following component shown in Figure 2.

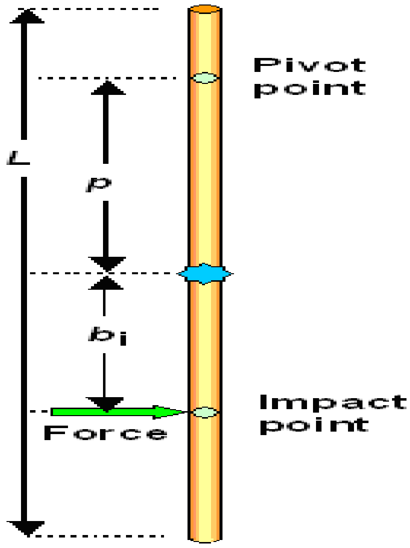

Figure 2. Rod Component

As shown in Figure 2, a rod of length L and mass m is investigated, and a pivot point p from the center of mass is chosen (which is, of course, exactly in the middle of the rod). We hit the rod with a quick blow from the center of mass (and, of course, on the other side of the pivot point).

Newton's second law for pure translations provides us the relation for the velocity vCOM of the center of mass.

$$F = m.\frac{dv_{COM}}{dt}$$

In terms of the pure rotation component, Newton's first law is now stated in terms of torque of F · bi, , the moment of inertia relative to the center of mass ICOM, and the circular frequency ω = 2πν with ν is the frequency in Hertz. We obtain

$$F.b_i = I_{COM} \cdot \frac{dw}{dt}$$

$dv_P = dv_{COM} - p.dw$ gives the change in velocity vP owing to rotation at any location P at a distance p from the center of mass (and rotations). This provides us the overall velocity change of any point P.

$$\frac{dv_p}{dt} = (\frac{1}{m} - \frac{p.b_i}{I_{COM}})$$

If the point P is to be the percussion point, it should not move, which implies it should not change velocity, or dvP/dt should be equal to zero. This necessitates that the content of the bracket in the preceding equation be zero. The sole variable or unknown in that equation is the distance bp from the center of mass to the specific point P, and for that special distance we obtain.

$$b_p = \frac{I_{COM}}{p.m}$$

It is worth noting that reversing the case by putting the pivot point in the location of the percussion point and vice versa has no influence on the computation. The pivot point in real life is, of course, the point around which actual objects revolve. As a result of the impact force, the other point becomes the percussion point (Cross, 2004).

That was a reasonably painless procedure. Let's take a closer look at what it means. Assume the pivot point is at the top of the rod (p = L/2), and remember that the moment of inertia of a (thin) rod for the rotation axis / pivot point illustrated as I_{Rod} = (1/12) · m · L^2 (Ignore the component that contains the rod diameter r), and you get b_p=(L/6).

In other words, the percussion point is one-third of the way down the rod's length. This is also true for a sheet (looking like the rod above if seen "on edge"). Because the door is consider as a sheet with a fixed pivot point at one end, you should place a doorstop where the door strikes it on two-thirds of its width. In this case, there will be no bumping and shaking. There are no vibrations either since the percussion point for these fundamental geometries is also a node for the second vibration harmonics, as shown below (Russell, 2005;Cross, 2004).

This brings us to a pretty problematic topic, which I_{COM} will address in more detail later. We only mention this because a percussion point's location relative to a particular pivot point can be equal to the position of a vibration node. However, this is a unique outcome, not a universal feature. This is typically not true for complicated geometries (such as your swords) (Cross, 2004).

Some Applications

Because the hinged end is subjected to no net reactive force, a swinging door stopped by a doorstop located two-thirds the width of the door will complete the job with little shaking. (This position is also a node in the second vibrational harmonic, which helps to decrease vibration.) (Russell, 2005).

A baseball bat's sweet spot is typically defined as the point at which the hitter feels most at ease with the impact. When the batter's bat strikes the ball and his hands are at the pivot point, the center of percussion is defined as the point at which he feels no sudden reactive force. However, because a bat is consider as a not hard object, the vibrations produced by the hit also play a role. Furthermore, the pivot point of the swing may be different from the location of the batter's hands. According to research, the arrangement of nodes in the vibrational modes of the bat, rather than the position of the center of percussion, is the primary physical process in determining where the sweet spot sits (Cross, 2004).

Swords can benefit from the concept of the center of percussion. Because these cutting weapons are flexible, the "sweet spot" is defined not only by the center of percussion, but also by the bending and vibrating characteristics (Russell, 2005;Turner, 1999).

Results and Discussion

Figure 3 shows the relation between the location of center of percussion and length of the tool at constant m =0.75 kg (wood) and P=L/2 m where (ICOM= (1/12) ML^2).

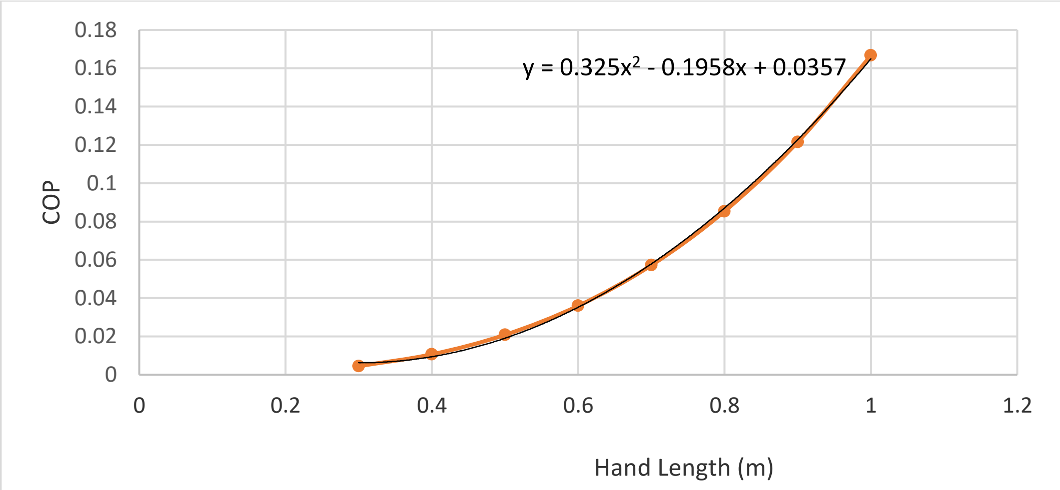

Figure 3. Relation between center of percussion location and length of the hand of the tool

It can be noticed that as the length of the tools' hand increases the center of percussion location changes- increases- with nonlinear relation which can be expressed as:

$COP=0.325L^2-0.1958L+0.0358$

3. Conclusion

Center of percussion is a very important design parameter when designing any hand of working tool, it is very important for workers safety, it depends mainly on mass of the tool, length and center of mass of the tool. The results showed a nonlinear relationship between COP and hand tool length.Another name for a center of percussion is the "sweet spot" where a ball hits a bat or racquet. It is the impact position that prevents the user's hand from reacting, which would otherwise cause painful shocks to their wrist and arm.

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