Static Wheel Balance

CHAPTER 6

Static Wheel Balance

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Illustrate and describe static wheel balance,
- Illustrate and describe static wheel unbalance,
- Illustrate and describe the principle and operation of a revolving wheel on the surface of the road,
- Explain the term *centrifugal force* as it applies to static wheel unbalance,
- Explain how static wheel unbalance induces destructive forces as the vehicle accelerates in speed.

INTRODUCTION

During the early years of automotive design and production, vehicles were constructed with rigid I-beam front axles and leaf spring suspension. Because of the design of the suspension and the relatively low speeds of vehicles, balancing the wheels was not considered critical to maintaining maximum tire life and vehicle performance.

People have always tried to improve whatever they make. The ride and control of a vehicle is no exception. Since the introduction of independent coil spring suspension and the increase in highway speeds, it has become essential that the wheels of a vehicle be accurately balanced.

Correct wheel balance is vital to:

- Extended tire tread life,
- Extended service suspension life,
- Safe handling performance,
- Lessened driver fatigue.

To understand how wheel balance affects the performance of a vehicle and is an integral factor in maintaining wheel alignment service life, let's start by becoming acquainted with some basic terms and definitions.

STATIC WHEEL BALANCE

Static wheel balance means that a tire and wheel assembly is evenly weighted around the center of its axis. To help you understand the definition, consider the following examples. You have used a floor jack to raise the left front wheel 2 inches off the surface of the garage floor. The brakes are not dragging, and you are able to rotate the wheel. You rotate the wheel 120° (one-third of a revolution) from point A to point B. You stop the wheel so it does not move. You again rotate the left front wheel another 120° in the same direction from point B to point C. You stop the wheel, and it stays in that position (Figure 6-1). The tire and wheel assembly is statically balanced.

To illustrate the definition further, imagine dividing a tire and wheel assembly exactly in two and placing both sections on a scale. If both sections weigh exactly the same (that is, both sides of the scale balance), then the tire and wheel assembly is statically balanced.

STATIC WHEEL UNBALANCE

Static wheel unbalance means that a tire and wheel assembly is unevenly weighted around the center of its axis. To help you understand this definition, consider the following examples. Again, using a floor jack, you raise the left front wheel 2 inches off the surface of the garage floor. You slowly rotate the left front wheel 120°, and then stop the wheel. This time you notice that the wheel rotates in the opposite direction and eventually stops at its original position. Gravity has caused a heavy portion of the tire to return the tire to the original position (Figure 6-2). The tire and wheel assembly is statically unbalanced.

To illustrate the definition further, again imagine dividing the tire and wheel assembly exactly in two and placing both sections on a scale. One section tilts the scale because it is heavier than the opposite section. This tire and wheel assembly is statically unbalanced.

As you study and apply the theory of static wheel balance, you will realize that a wheel is basically a lever. The light portion of a lever or wheel is obviously 180° from the heavy position (Figure 6-3).

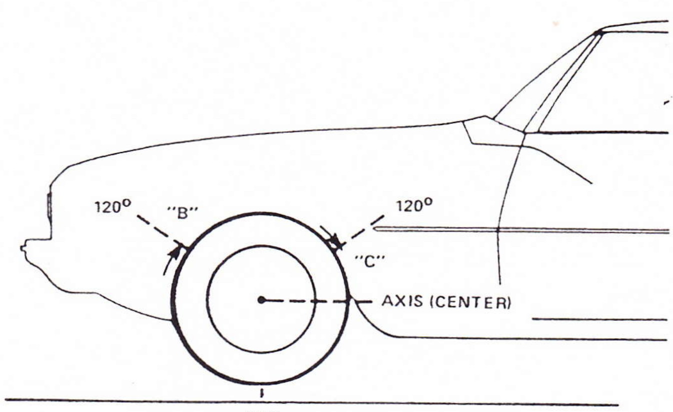

FIGURE 6-1. Static Wheel Balance. If a wheel is statically balanced, gravity will not force it to rotate from its rest position.

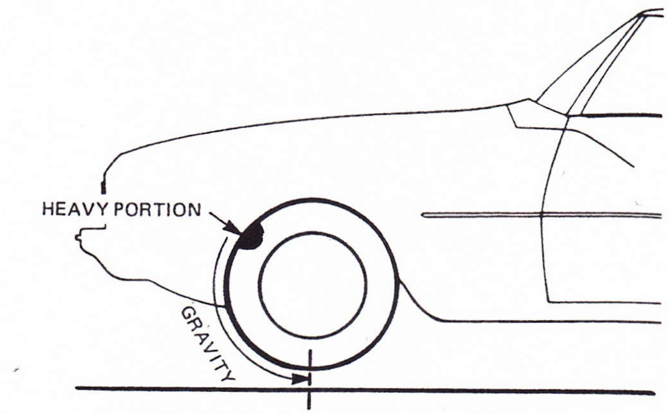

FIGURE 6-2. Static Wheel Unbalance. If a wheel is statically unbalanced, gravity will force it to rotate when the heavy portion of the wheel is not at the closest point to the ground.

PURPOSES OF WHEEL BALANCE

A tire and wheel assembly (based on the average wheel size and highway speed) will revolve approximately 775 to 900 revolutions per minute. A tire and wheel assembly that is statically unbalanced becomes an uncontrolled mass of weight in motion. Since tires and wheels are the chief causes of vehicle

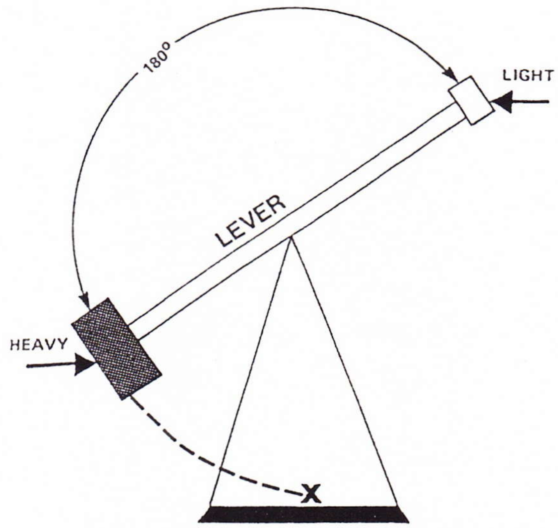

FIGURE 6-3. Unbalanced Wheel.

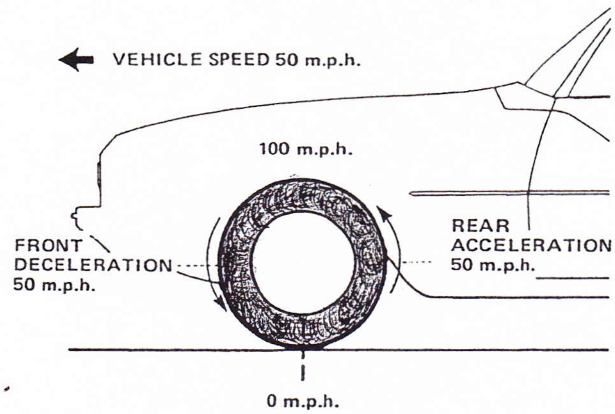

FIGURE 6-4. Wheel Assembly in Motion. The speed of a wheel at different points on its surface also varies.

vibration, it is an absolute necessity that the wheels of a vehicle be accurately balanced. A tire and wheel assembly that is balanced will provide:

1. Increased tire tread life,
2. Increased suspension life,
3. Increased body and chassis life,
4. Increased directional control and stability,
5. Reduced driver fatigue.

In order to achieve these five purposes, the wheel assembly must roll smoothly on the road surface.

BASIC PRINCIPLE OF A REVOLVING WHEEL

To realize what happens when a tire and wheel assembly revolves on the road surface, it is necessary to understand the operation of a wheel assembly in motion. Carefully study Figure 6-4 and these related facts:

1. The vehicle has accelerated to a speed of 80 km/h (50 mph).
2. The bottom of the tire tread (the portion that contacts the surface of the road) momentarily stands still in relation to the road surface regardless of the speed of the vehicle. Figure 6-4 illustrates a side view of the left front wheel.
3. The top of the tire travels at twice the speed of the vehicle and in the same direction—in this case, 160 km/h (100 mph).
4. The back portion of the tire tread travels up and forward and accelerates at a rate that will bring it from 0 km/h (0 mph) to twice the speed of the vehicle in one-half a revolution.
5. The front portion of the tire tread travels down and forward and decelerates at a rate that will bring it from twice the speed of the vehicle to 0 km/h (0 mph) in one-half a revolution.

At this point, you may find it somewhat difficult to accept the fact that the bottom portion of a tire tread stops for a split second. Consider the following illustrations. Figure 6-5 illustrates the operation of a bulldozer. The bottom portion of the track contacts the ground until the large drive gear picks up that portion of track. The bottom portion of the vehicle's track must remain stopped in relation to the ground in order to allow the bottom of the track to gain traction. If the bottom of the track were to slip, the bulldozer would not move. At point A, the track is not moving in relation to the ground. This process is called *static friction.* At point B, the top of the track is moving at twice the speed of the vehicle.

To illustrate this point further, imagine that there has been a light snowfall. You have moved your automobile out of the garage and have stopped it in order to get out and close the garage door. As you walk back to the garage, you notice the imprint left by the tires.

The tire treads left their imprint because they were rolling on the surface of the snow. A tire must momentarily stop in relation to the surface of the snow in order to leave an imprint and allow the

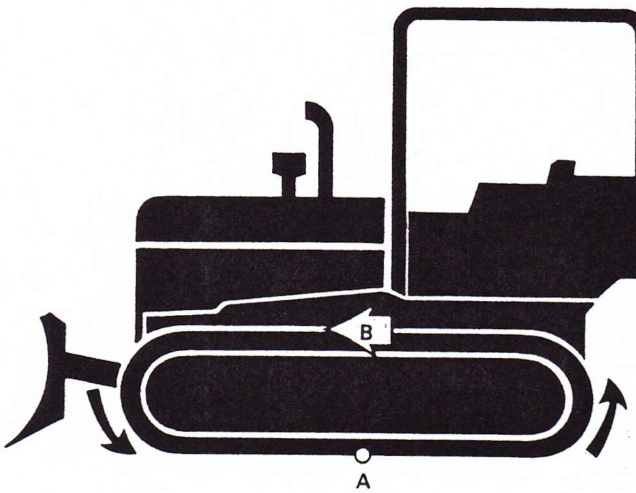

FIGURE 6-5. An Illustration of Traction. A bulldozer's track must momentarily stop when it contacts the ground in order to gain traction.

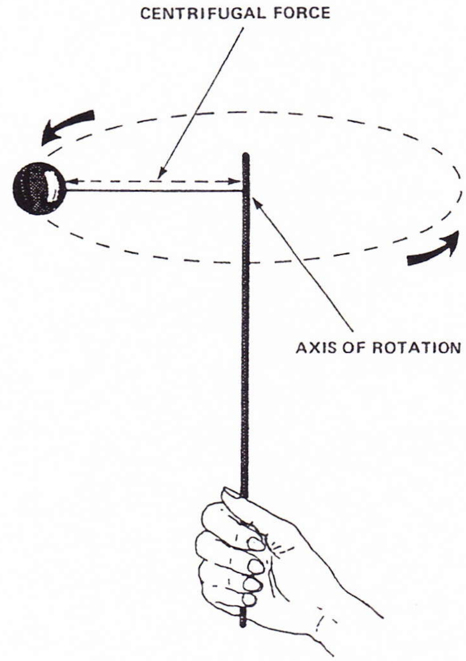

FIGURE 6-6. Centrifugal Force. Centrifugal force will tend to pull an object away from its axis of rotation.

tread to gain traction. If the tire tread were to slip on the surface of the snow, the tread would not leave an imprint, and the vehicle would not move.

Although they differ in shape, a bulldozer's track and an automobile's tire have much in common while in motion. The bottom portion that contacts the ground or road surface must momentarily stop. This momentary stop allows the bulldozer's track and the tire's tread to gain traction. Without traction, the vehicles could not move.

Effects of Static Wheel Unbalance

You have been given a definition of the term *static wheel unbalance*. In order to understand how static wheel unbalance influences a revolving wheel, it is necessary to understand the term *centrifugal force*. Centrifugal force is the force that tends to pull a rotating mass away from its axis (center) of rotation.

Figure 6-6 illustrates the action of centrifugal force on a weight connected by a string to a rotating shaft. As the speed of the shaft's rotation increases, the weight will tend to pull away from its axis of rotation.

Illustrated in Figure 6-7 is the left front wheel of a vehicle. The vehicle has accelerated to a speed of 80 km/h (50 mph). The speed of the top of the

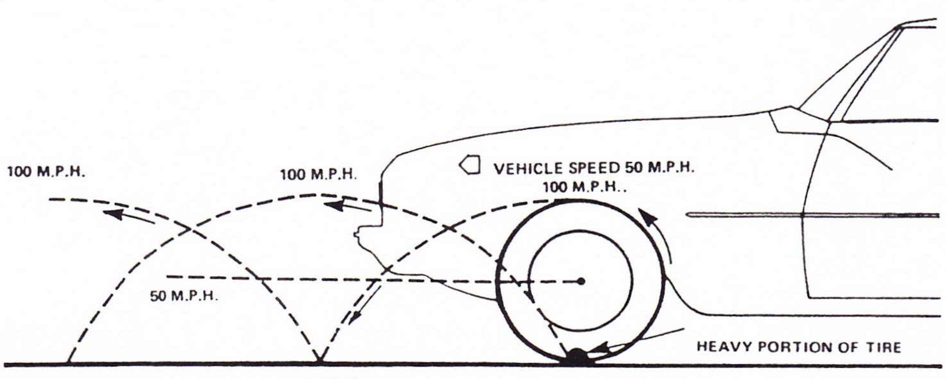

FIGURE 6-7. Normal Rotation Pattern of a Tire along a Road Surface at 80 km/h (50 mph).

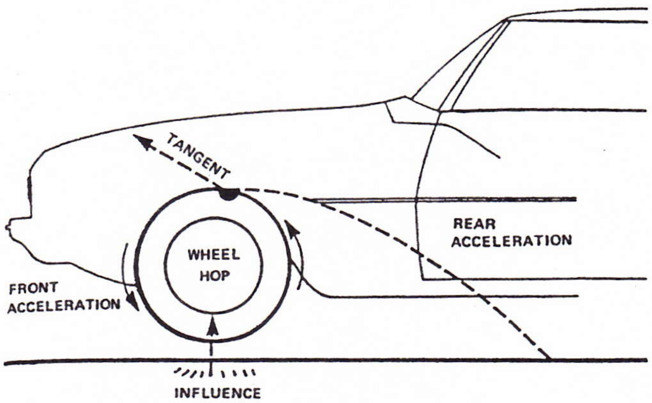

FIGURE 6-8. Wheel Hop Caused by Action of Centrifugal Force on Heavy Portion of Tire.

FIGURE 6-9A. Tire Tread Wear Caused by an Unbalanced Condition. (Courtesy of Moog-Canada Automotive, Ltd.)

FIGURE 6-9B. Tire Tread Wear Caused by Static Wheel Unbalance and Wheel Bearing Looseness. (Courtesy of Moog-Canada Automotive, Ltd.)

wheel is 160 km/h (100 mph). Notice the position of the heavy portion of the tire.

Figure 6-8 illustrates the wheel having revolved almost one-half a revolution. The heavy portion of the tire has accelerated from 0 km/h (0 mph) to almost 160 km/h (100 mph). The heavy portion of the wheel assembly, influenced by centrifugal force, endeavors to move on a tangent line away from the center of the wheel. The effect of this extra force causes the wheel to lift vertically from the road surface. This action is called **wheel hop or wheel tramp.** The vertical lift of the wheel allows the wheel assembly to spin momentarily. As the wheel spins, the heavy portion of the wheel assembly decelerates, causing the tire tread to scuff as it contacts the road surface. The scuffing causes the tire to develop flat spots (*cupping*) on the tread surface (Figure 6-9).

Additional Effects of Static Wheel Unbalance

Since a statically unbalanced wheel is subject to vertical influence, the erratic motion of the wheel is then transmitted to the vehicle's suspension and absorbed by the chassis and body. This condition causes the component parts of the vehicle to vibrate, thereby decreasing the life of the tires, suspension, steering, and body.

Table 6-1 provides proof of the destructive forces resulting from static wheel unbalance. The table shows how the destructive force increases at various speeds according to the number of ounces the wheel are out of balance.

The tire and wheel assembly of a vehicle requires only 28 grams (1 ounce) of weight to balance it statically at 0 km/h (0 mph). Now the vehicle accelerates to a speed of 32 km/h (20 mph). Due to the effect of centrifugal force, the heavy portion of the tire has effectively increased its force to 0.39 kilograms (0.86 pound). At 112 km/h (70 mph), the effect of centrifugal force has increased the pounding force of the 28 grams (1 ounce) of weight to an astounding figure of 4.78 kilograms (10.53 pounds).

TABLE 6-1. Pounding Force at Various Speeds, by Number of Grams the Wheels Are Out of Balance

Grams (Ounces) Out of Balance	Pounding Force in Kilograms (Pounds)					
	32 km/h (20 mph)	48 km/h (30 mph)	64 km/h (40 mph)	80 km/h (50 mph)	97 km/h (60 mph)	112 km/h (70 mph)
			CARS			
28 g (1 oz)	0.39 kg (0.86 lb)	0.87 kg (1.93 lb)	1.56 kg (3.44 lb)	2.42 kg (5.34 lb)	3.51 kg (7.73 lb)	4.78 kg (10.53 lb)
57 g (2 oz)	0.70 kg (1.72 lb)	1.75 kg (3.86 lb)	3.12 kg (6.88 lb)	4.87 kg (10.74 lb)	7.01 kg (15.46 lb)	9.55 kg (21.06 lb)
85 g (3 oz)	1.17 kg (2.58 lb)	2.63 kg (5.79 lb)	4.68 kg (10.32 lb)	7.31 kg (16.11 lb)	10.52 kg (23.19 lb)	14.33 kg (31.59 lb)
113 g (4 oz)	1.56 kg (3.44 lb)	3.50 kg (7.72 lb)	6.24 kg (13.76 lb)	9.74 kg (21.48 lb)	14.02 kg (30.92 lb)	19.10 kg (42.12 lb)
142 g (5 oz)	1.95 kg (4.30 lb)	4.38 kg (9.65 lb)	7.80 kg (17.20 lb)	12.18 kg (26.85 lb)	17.53 kg (38.65 lb)	23.88 kg (52.65 lb)
170 g (6 oz)	2.34 kg (5.16 lb)	5.25 kg (11.58 lb)	9.36 kg (20.64 lb)	14.61 kg (32.22 lb)	21.04 kg (46.38 lb)	28.66 kg (63.18 lb)
			TRUCKS			
170 g (6 oz)	1.77 kg (3.90 lb)	4.00 kg (8.82 lb)	7.13 kg (15.72 lb)	11.07 kg (24.42 lb)	16.08 kg (35.46 lb)	
227 g (8 oz)	2.36 kg (5.20 lb)	5.34 kg (11.76 lb)	9.51 kg (20.96 lb)	14.77 kg (32.56 lb)	21.45 kg (47.28 lb)	
283 g (10 oz)	2.95 kg (6.50 lb)	6.68 kg (14.70 lb)	11.88 kg (26.20 lb)	18.46 kg (40.70 lb)	26.81 kg (59.10 lb)	
340 g (12 oz)	3.54 kg (7.80 lb)	8.00 kg (17.64 lb)	14.26 kg (31.44 lb)	22.15 kg (48.84 lb)	32.17 kg (70.92 lb)	
454 g (16 oz)	4.72 kg (10.40 lb)	10.67 kg (23.52 lb)	19.01 kg (41.92 lb)	29.54 kg (65.12 lb)	42.89 kg (94.56 lb)	
567 g (20 oz)	5.10 kg (13.00 lb)	13.33 kg (29.40 lb)	23.77 kg (52.40 lb)	36.92 kg (81.40 lb)	53.61 kg (118.20 lb)	

FACTS TO REMEMBER

1. Wheel balance is an integral part of wheel alignment service life.
2. Static wheel unbalance induces vehicle vibration and decreases the suspension life of a vehicle.
3. Static wheel unbalance causes a tire and wheel assembly to lift off the road surface.
4. As the speed of the vehicle increases, the effects due to the heavy portion of the wheel acted on by centrifugal force are greatly multiplied.

REVIEW TEST

1. Define the term *static wheel balance.*
2. Define the term *static wheel unbalance.*
3. List five reasons why a wheel should be balanced.
4. Describe the principle and operation of a wheel as it rolls on the road.
5. Define the term *centrifugal force.* Draw a picture illustrating this concept.
6. Explain why a tire will develop flat spots on the surface of the tread when the wheel is statically unbalanced.

CHAPTER 8

Dynamic Wheel Balance

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Illustrate and describe dynamic wheel balance,
- Illustrate and describe dynamic wheel unbalance,
- Illustrate and describe how dynamic wheel unbalance induces a wheel to shake laterally as it revolves on the surface of the road,
- Explain how dynamic wheel unbalance affects tire tread life and the vehicle's suspension and produces driver fatigue,
- Illustrate and describe how dynamic wheel unbalance is corrected.

INTRODUCTION

Wheel balance is divided into two distinct categories: static balance (Chapter 6) and dynamic balance. When the entire wheel assembly is in static balance, the weight of the assembly is evenly distributed around the axis (center) of the wheel. However, it is possible for a wheel to be in perfect static balance and at the same time be dynamically unbalanced.

Dynamic unbalance produces lateral forces that influence the wheel assembly to wobble or shake from side to side. This condition drastically reduces tire tread life expectancy and causes premature failure of all suspension and steering parts. Dynamically balanced wheels contribute to the smooth ride and good handling characteristics of a vehicle. This chapter will help you to understand the importance of dynamic wheel balance.

DYNAMIC WHEEL BALANCE

The meaning of the term **dynamic wheel balance** can be explained by dividing a wheel assembly into four equal sections. Figure 8-1 illustrates a top sectional view of a dynamically balanced wheel. If sections A and C (the two outside sections) are equal in weight and if sections B and D (the two inside sections) are equal in weight, the wheel assembly is dynamically balanced. To understand the meaning of the term **dynamic wheel unbalance**, again divide the wheel assembly into four equal sections. Figure 8-2 illustrates a top view of a dynamically unbalanced wheel. Section D is the heaviest section. Sections A and C (the two outside sections) are equal in weight; however, since sections B and D (the two inside sections) are not equal in weight, the wheel assembly is dynamically unbalanced.

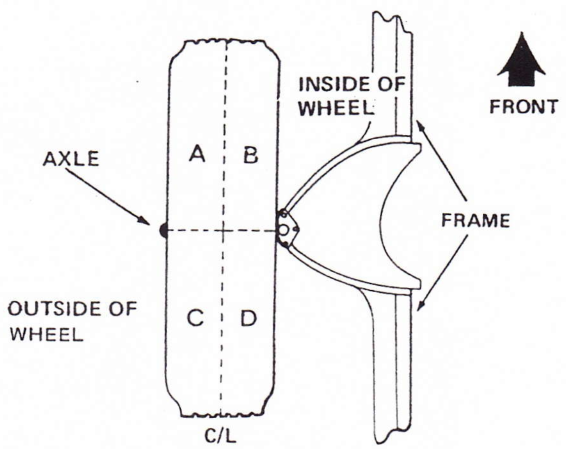

FIGURE 8-1. Top Sectional View of a Dynamically Balanced Wheel.

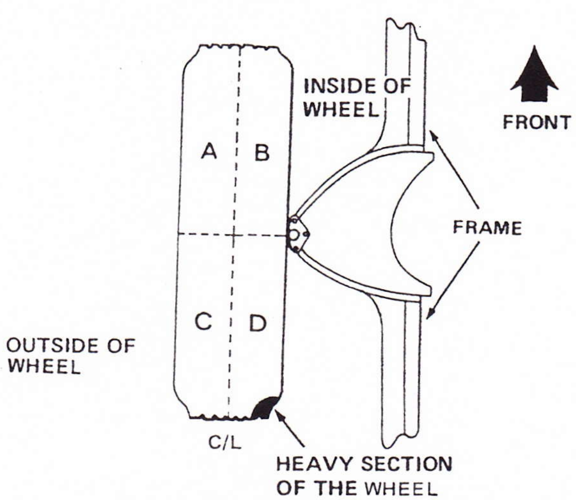

FIGURE 8-2. Top Sectional View of a Dynamically Unbalanced Wheel.

EFFECTS OF DYNAMIC WHEEL UNBALANCE

Lateral Wheel Movement

Dynamic wheel unbalance induces *lateral* (side to side) wheel movement. To understand how this happens, remember that centrifugal force is the force that tends to pull a rotating mass away from its *axis* (center) of rotation (see Figure 6-6). Now let's apply the definition to a dynamically unbalanced wheel using the following example.

Figure 8-3 shows a heavy spot on a tire on a dynamically unbalanced left front wheel. When the wheel rotates, centrifugal force will endeavor to influence the heavy portion of the tire to move to the centerline of the wheel, thereby forming a 90° angle to the axle shaft. The hub and wheel assembly are attached to the front axle shaft, which is made of tempered metal and will not bend. The shaft and steering knuckle are attached to the upper and lower ball joints. The ball joints allow the steering knuckle to pivot.

To see the action of centrifugal force, the vehicle must be accelerated to a speed of 100 km/hr (60 mph), and you must take a stop-action, X-ray photo of the left front wheel. The photo would show the heavy spot has, in fact, moved to the centerline of

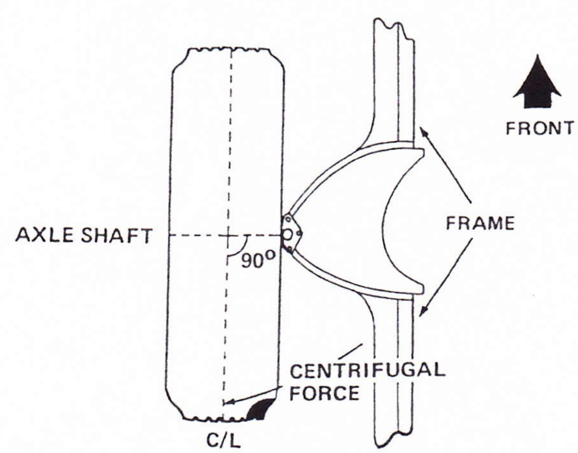

FIGURE 8-3. Action of Centrifugal Force on Heavy Portion of a Dynamically Unbalanced Wheel.

the wheel, thus forcing the rear of the wheel outward (Figure 8-4).

If you were to take a second stop-action photo of the rotating wheel when the heavy spot has revolved 180° (one-half revolution), you would see from the photo that the front of the wheel is now forced outward and the rear of the wheel inward (Figure 8-5). Dynamic wheel imbalance, due to the effect of centrifugal force, induces the wheel assembly to move laterally (shake) from side to side.

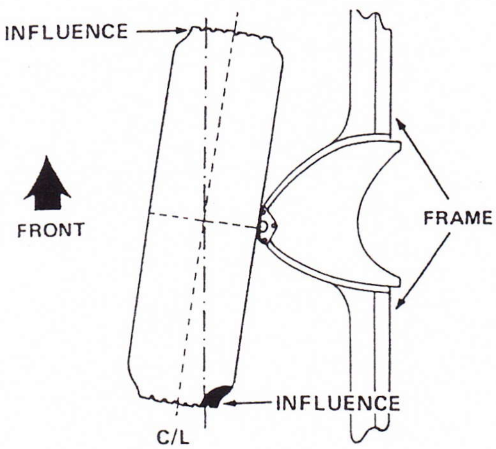

FIGURE 8-4. Outward Movement of the Rear Portion of a Rotating Wheel due to Influence of Centrifugal Force and the Position of the Unbalanced Weight.

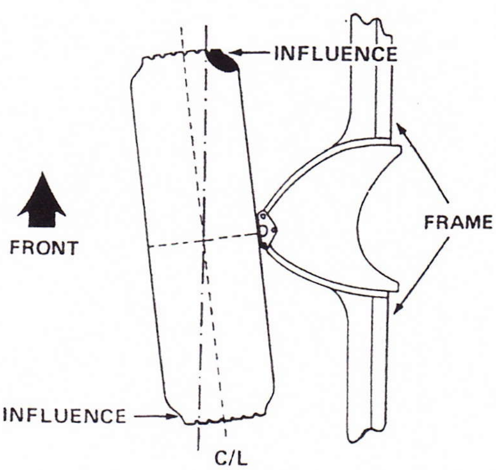

FIGURE 8-5. Outward Movement of the Front Portion of a Rotating Wheel due to Influence of Centrifugal Force and the Position of the Unbalanced Weight.

Vehicle Handling Characteristics

A dynamically unbalanced wheel produces lateral wheel movement. The action of the wheel causes the suspension, steering, and body of the vehicle to react. This condition is reflected in the oscillation of the steering wheel at medium and high speeds. The driver of a vehicle may be exceptionally strong and hold the steering wheel with a viselike grip; however, even that person cannot prevent the steering wheel from oscillating. This condition produces driver fatigue and affects the directional control and stability of the vehicle.

Tire Tread Life. Tire tread life is also reduced by the lateral movement of a dynamically unbalanced wheel. Chapter 6 stated that the bottom of the tire's tread (the portion contacting the surface of the road) momentarily stops in relation to the road surface regardless of the speed of the vehicle in order to allow the tread to gain the necessary traction. If a revolving tire is subject to lateral movement, the tire's tread cannot momentarily stand still and is forced to pivot (scuff) at the road surface. This additional movement of the tire's tread increases tread wear.

To illustrate this explanation, obtain a lead pencil with an eraser. Turn the pencil upside down; hold the pencil in a vertical position and rotate the pencil. The result will be that the eraser will wear due to the constant rotation and friction. The same result applies to the tread of a tire; the more the tread is subjected to movement, the greater the tread wear.

CORRECTING DYNAMIC WHEEL UNBALANCE

To correct dynamic wheel unbalance, the service technician may balance the wheel assembly by using a wheel balancer that is designed to balance a wheel both statically and dynamically when the wheel assembly has been removed from the vehicle (Figure 8-6). This type of equipment is designed to detect the light portion of the wheel and to indicate the amount of weight required to balance the wheel dynamically.

Two important facts form the basis for understanding wheel balance:

1. When a service technician dynamically balances a wheel, he or she attaches lead weights

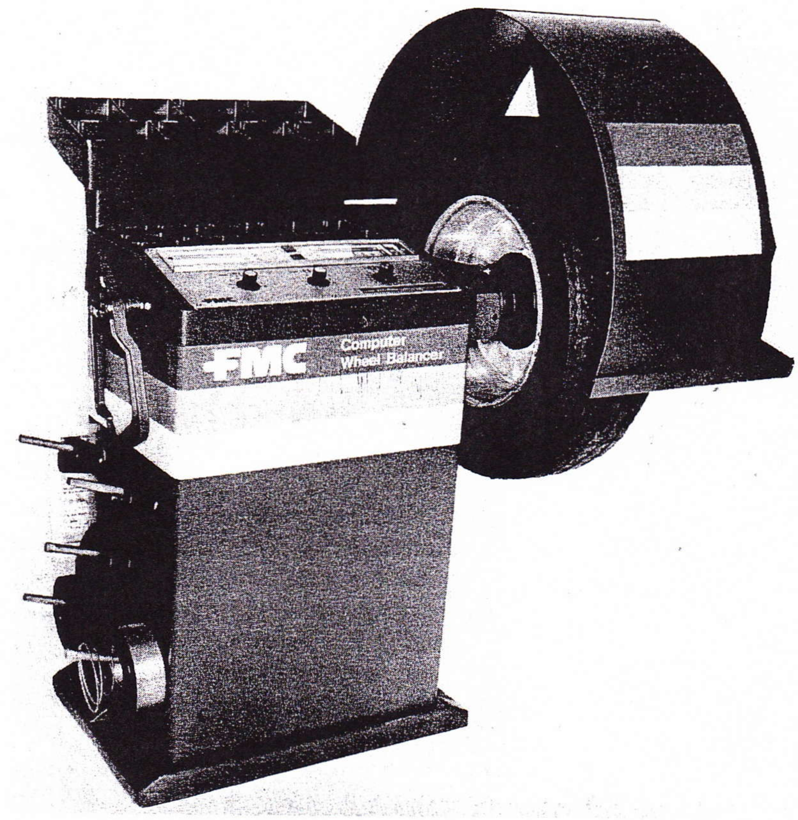

FIGURE 8-6. Combination Static and Dynamic Wheel Balancer. (Courtesy of FMC Corporation, Automotive Service Equipment Division)

to the wheel rim to counteract the lateral influence of the heavy portion of the wheel assembly.

2. A wheel assembly that is accurately balanced must be statically and dynamically balanced.

Before proceeding further, let's consider an example problem. Figure 8-7 illustrates a top view of a wheel that is unbalanced. Determine where, at the rim, you would attach weight to correctly balance the wheel.

If your answer was position Z, you have missed the whole point of the chapter. Go back to the beginning. If your answer was position W, you did not understand important fact 2. By placing a weight at position W, you have balanced the wheel dynamically but not statically. Sections C and D are heavier than sections A and B. If your answer was position X, you did not understand important fact 2. By placing a weight at position X, you have balanced the wheel statically but not dynamically. Sections A and C are not equal in weight; sections B and D are not equal in weight.

If your answer was position Y, you were right. Placing a correct weight at position Y will counter-

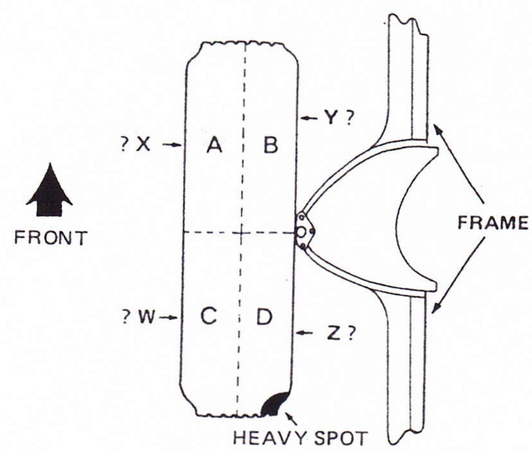

FIGURE 8-7. Example Unbalanced Wheel for Determining the Position of Added Weight to Dynamically Balance the Wheel.

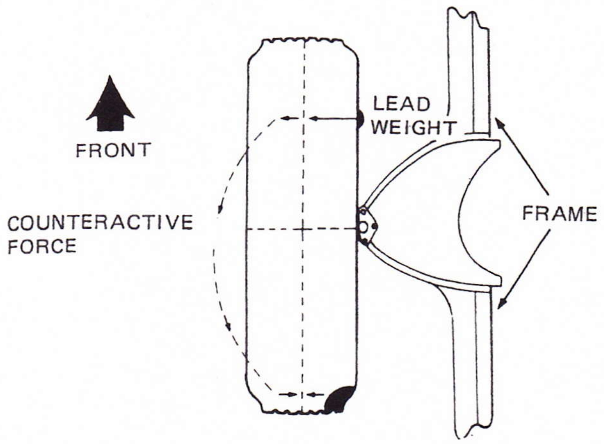

FIGURE 8-8. Correct Position of the Balancing Weight.

act the lateral force of the heavy portion of the tire. *Note:* The influence of a lead weight attached to the rim will always attempt to move (due to centrifugal force) to the centerline position of the wheel (Figure 8-8).

Electronic On-the-Car Balancer

The electronic on-the-car wheel balancer is designed to balance the wheel statically and dynamically. The electronic balancer balances the entire wheel assembly, including the brake rotor or brake drum. An electronic sensor placed under the suspension or against the backing plate will detect any lateral or vertical movement and transmit a signal to the strobe unit while the wheel is spinning.

Regardless of the type of equipment in your shop, correcting dynamic wheel unbalance is simply a matter of adding sufficient weight to the light section of a wheel to counteract the forces on the heavier section. The manufacturer's operating instructions should always be followed when using any wheel balancing equipment.

FACTS TO REMEMBER

1. Normal tire wear will cause wheels to become unbalanced.
2. Vehicle owners should have the wheels checked for correct balance at intervals of 16,000 kilometers (10,000 miles).
3. A wheel assembly must be statically and dynamically balanced if the wheel is to be balanced accurately.

REVIEW TEST

1. Define and illustrate the term *dynamic wheel balance.*
2. Define and illustrate the term *dynamic wheel unbalance.*
3. Describe and illustrate how dynamic wheel unbalance influences a revolving wheel.
4. Explain how dynamic wheel unbalance decreases tire tread life.

Note: Use Figure 8-9 to answer questions 5 through 8.

5. By placing a lead wheel weight at position 1, the wheel assembly would be ___ balanced and ___ unbalanced.
6. By placing a lead wheel weight at position 2, the wheel assembly would be ___ balanced but ___ unbalanced.
7. By placing lead wheel weights at positions 2 and 3, the wheel assembly would be ___ balanced but ___ unbalanced.
8. By placing a lead wheel weight at position 3, the wheel assembly would be ___ and ______ ______.

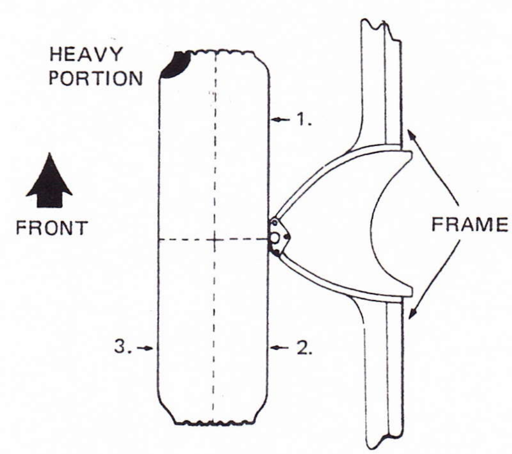

FIGURE 8-9. Illustration for review questions 5 through 8.