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Canoe Stroke Efficiency by George Arimond, Ph. D.

Some experienced canoers make paddling appear effortless. Their canoe moves with amazing speed and yet they don't appear to be working. Their paddle stroke is so fluid that even the novice paddler recognizes its efficiency.

To research this efficiency, years ago a biomechanics professor, mechanical engineering professor and I filmed several top-ranked professional marathon paddlers. Using a high-speed camera and computer digitizing software, we were able to digitize each body segment's movement. We thought this study was important because once a paddler like yourself learned good stroke efficiency, you would then need less strength and endurance to travel farther and faster. To better understand this term efficiency, you could compare it to the sport of mountain biking. In other words, stroke efficiency is like consistently hitting the right gear for the trail terrain. Conversely, stroke inefficiency feels like always being in the wrong gear.

To understand stroke efficiency, it is helpful to visualize the paddle blade's movement under the surface of the water. When the blade reaches a nearly perpendicular—or vertical—position in the water, it can then exert the greatest leverage. The problem is during a paddle stroke the blade is only momentarily vertical in the middle of the stroke. During the non-vertical portions of the stroke "blade paddle slippage" can occur. Paddle slippage is rather like spinning your car tires on ice: the tires turn very fast, but the car makes very little forward progress. The same thing happens whenever the blade is powered so hard it causes the water to move backward, which causes the canoe to barely move. At this point paddle slippage is occurring. Hence, stroke efficiency improves with the reduction of slippage due to water movement.

Physics of the Stroke

The principles of fluid dynamics and laws of motion help to explain stroke efficiency. According to laws of motion and fluid dynamics, maximum efficiency in water is achieved by pressing against the largest amount of water possible for the shortest distance possible while accelerating the paddle as little as possible. There are three elements critical to paddle blade efficiency:
1) the volume of water the blade presses against,
2) the distance the blade moves the water, and
3) how quickly the blade begins to move the water.

To understand this, imagine a paddler violating each principle: She places only half the blade in the water (i.e. press against a small volume), pulls with a quick jerk (i.e. quick acceleration), and takes a very long stroke (i.e. a long distance moved). This stroke causes a very rapid movement of the water—and is the most inefficient stroke a paddler could make.

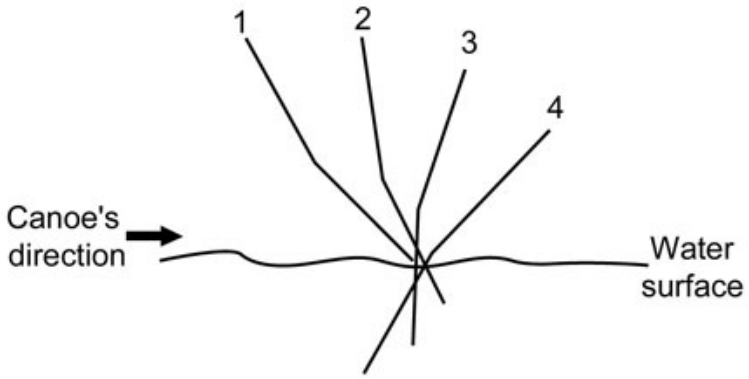
Instead, the blade force should move the canoe and not the water. To achieve this, the blade should press against as much "still water" as is physically possible. Think of "still water" as water standing still or not yet moving paddle blade pressure. Thus, an efficient paddler **inserts the entire blade, exerts power gradually, and ends the stroke as soon as the "still water" begins to move.** This is your most efficient stroke.

Skilled paddlers do three things to reduce blade slippage:
1) **Fully submerge the blade before exerting significant power.** Less power is exerted until the blade nears complete submersion.
2) **Exert the greatest power during the blade's perpendicular phase.** Maximum power is exerted as the blade nears the perpendicular range (plus or minus 25 degrees) and quickly ceases at the end of the perpendicular range.
3) **Extend the duration of the stroke's perpendicular range** by shifting the amount of power exerted by each arm (top and bottom) during the stroke. (How this is done will be explained later in the description of arm movement.)

Some paddlers might think developing a stroke with a longer perpendicular period in the stroke would

reduce paddle slippage. However, fluid dynamics priniciples tells us it is actually **more advantageous to let the blade tip arc naturally through the perpendicular range**. Figure 1 shows the blade's sequential movement (using a bent shaft paddle), beginning with water entry and ending with the blade exiting the perpendicular range. Note how the blade tip enters the water and then arcs rearward. In other words, as the blade tip arcs, it is continually entering new "still water" during the entire stroke. This natural arc is important because it increases the amount of "still waters" the blade can come in contact with.

Figure 1: Power Phase, Paddle on Right Side



Preparatory Position

To start the stroke properly, first look at how you begin the stroke. Proper positioning in the Preparatory Position is a key factor in learning efficient stroke technique. The preparatory position is where the blade tip first touches water. Think of this position like the preparatory position we assume as we reach to open a door. We stand well away from the door and reach for the doorknob with our arm fully extended, giving us plenty of clearance to open the door without hitting ourselves.

To help visualize this, actually reach for a door knob and then note the position of your arm and shoulder. Your arm is fully extended, and your shoulder is in line with your arm. In other words, the shoulder naturally drops slightly as it points in the direction of the doorknob. (The opposite shoulder will naturally move in somewhat the opposite direction—up and back.) This is the position the bottom arm (the one holding the shaft) should assume.

Another way to picture this position is to think of your arms as the hands of a clock (remembering that the axis of your arms is the shoulder, not the elbow). The bottom arm (the one holding the shaft) will be at 4:00. This is the optimal position for the bottom arm during the Preparatory Position (see Figure 2).

Figure 2: Preparatory Position

With the bottom arm and shoulders in place, how do you then position the top arm (i.e. the arm

holding the top grip)? The elbow of the top arm is at about shoulder level and bent slightly. This means top arm is either at or slightly above 3:00. Equally important, **the top grip hand is positioned over the water on the paddling side** and not over the canoe. Most novice paddlers do not reach across the body far enough, holding the top grip hand directly in front of their face and chest. Finally, looking at the paddle blade angle with the water, the blade should be angled back 40-50 degrees with a straight shaft paddle and with a bent shaft paddle (12 degree bend) 52-62 degrees.

Next is your trunk position. Your trunk should be slightly forward (80 to 75 degrees), but it will actually feel as if you're sitting almost perfectly erect (90 degrees). Avoid excessive leaning or slouching. When you're leaning, you fatigue quicker because you're fighting gravity's pull more. Slouching, on the other hand, makes it difficult to effectively use the strength in your shoulders, which reduces stroke efficiency.

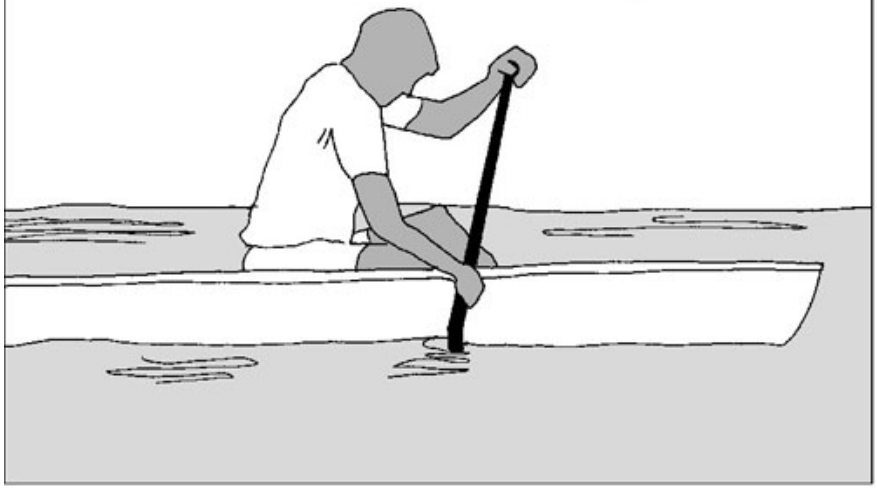
Practice assuming this preparatory position without actually taking a stroke. Hold it momentarily and look at your position. Have someone else look at your position. It takes a certain degree of hand/eye coordination and practice before this position becomes automatic. Once you master this position, the rest of the stroke will come together quite naturally. In fact, the rest of the stroke will become one fluid movement, and you will wonder why you did not discover this sooner. It will seem so natural and very graceful.

Power Phase

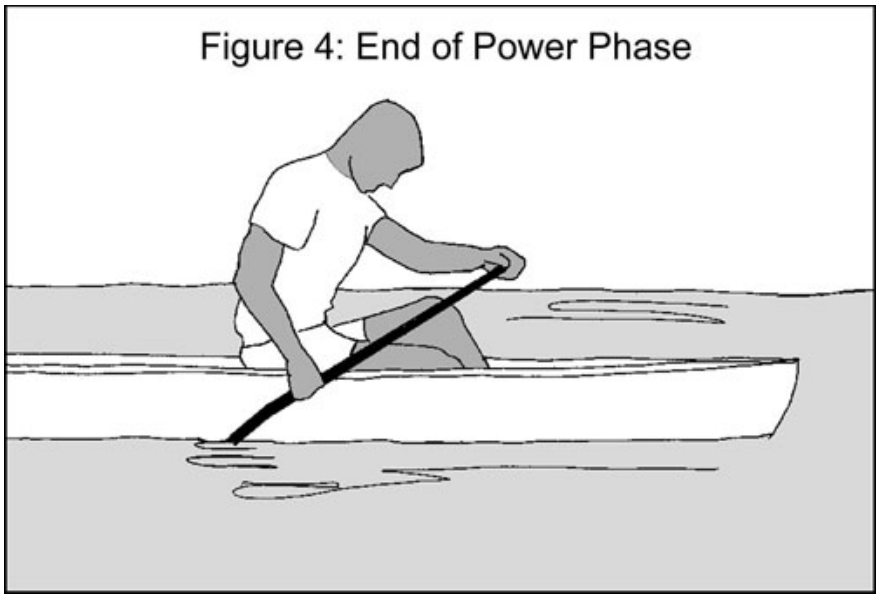
The next phase of the stroke is submerging the paddle and exerting power: the "power phase" or "water phase" of the stroke. To effectively execute this phase, envision pulling yourself forward to the paddle blade's entry point. This is, in fact, what happens if you are getting an efficient stroke: the blade stays nearly stationary in the water while you and your canoe move forward.

To get this efficiency, the bottom arm (i.e. the arm holding the shaft) moves in a downward arc like the arm on a clock. Done properly, your elbow will actually have a slight 140 degree bend (perfectly straight arm is 180 degrees). This bend is held throughout the entire power phase (see Figure 3). The likely reason for this bend the professional paddlers displayed is that arm strength research has demonstrated arm strength is greatest when elbow is flexed to the 140 degree range.

Figure 3: Middle of Power Phase



In looking at arm positioning, best efficiency is achieved if your bottom arm starts at 4:00 (see Figure 2) and finishes at 7:00 (see Figure 4). Two things should be noted here:
1) the power phase ends at the point the bicep aligns with the trunk (i.e. at 7:00);
2) the upper arm and forearm move as one, which mimics a clock arm with the shoulder as the pivot point or fulcrum.



This semi-rigid clock-like arm movement has a very important advantage. It allows you to use more of the shoulder, chest, and back muscles. Novice paddlers tend to flex the elbow beyond 40 degrees to as much as 85 degrees during the stroke. Excessive elbow flexion not only forces you to use more arm muscle, but it also reduces your effective use of the torso muscles. Why is this important? **The torso muscles are not only stronger than your arms, but they have significantly more endurance.** This is particularly important during lengthy paddles or when you are paddling in strong winds and current.

Having looked at the bottom arm movement, we next address the top arm movement. The top arm (i.e. the arm holding the top grip) moves with the bottom arm, but instead of pulling it presses in a forward/downward arc (see Figure 1). First, look at how the bicep moves (see Figure 2 and 4). It starts slightly above 3:00 and ends its downward press at 4:30. Next, look at how the forearm moves. During the press, the elbow, which is slightly flexed at the preparatory phase, will gradually straighten during the power phase. **How quickly or slowly your elbow straightens will be driven by paddle blade slippage.** As you feel blade slippage, you try to minimize this slippage by altering the extension and downward press of the grip hand.

The trunk movement in the Power Phase is quite minimal. During the power phase, efficient paddlers actually flex forward first and then back, but the movement is almost undetectable--less than 10 degrees. It is so small they don't even have a conscious feeling they are moving their trunk. What is most important in terms of trunk movement is to avoid flexion beyond 10 degrees. It causes significant stroke inefficiency because it shortens the duration of the perpendicular phase (i.e. 5:00 to 7:00) of the stroke.

Refining the Stroke by Feel

You now know how the body should move, but now the question becomes, *"How can I tell when I'm doing it right?"* You learn by sensory feel. The expert paddlers filmed in this study had no formal training in fluid dynamics or human movement. Instead, they perfected their stroke by feel. They used their kinesthetic sense of feel to monitor two things; 1) their arm and trunk movements, and 2) the water resistance against their paddle blade. Another strategy they used was to try different strokes while paddling along side other skilled canoers and watch for speed changes in the canoes.

With an inefficient stroke you can actually feel water movement (i.e. paddle slippage) around the paddle blade. You actually feel a vibration in the lower hand that comes from water moving around the blade. To develop a feel for this vibration, take a series of really hard strokes where the water is visibly swirling around the blade. Feel the vibration? The vibration is actually very subtle. Consequently, it takes concentration and practice to acquire this feel.

As you reach good stroke efficiency, you will experience the feeling as though your blade were anchored in cement. In other words, no matter how hard you pull, it doesn't slip. Remember, however, exerting very little power while practicing this technique can fool you into thinking your stroke is efficient. You need to paddle hard or semi-hard to properly judge your technique. So when practicing, paddle for short intervals with rest in between.

If your blade is slipping, you need to do three things:
1) visually check to see whether your preparatory position is correct;
2) check whether your stroke is ending as your bottom arm approaches 7:00; and
3) check the degree of power you are exerting with each arm during the power phase.

During the power phase, it is important to remember the bottom arm is pulling while the top arm is pressing down and slightly forward. **Too much or too little power exerted by either arm causes**

paddle slippage. Thus, there is an optimum ratio of power between the two arms. Over powering the top arm at the beginning and end of the power phase does little to propel the canoe forward and can cause the canoe to porpoise up and down, which further slows forward movement. Nonetheless, the right degree of power is needed so the blade arcs through the largest amount of "still water" possible. The bottom arm can also cause blade slippage in two ways. If you apply too much power in relation to the top arm's power or if you take too long a stroke (moving the bottom arm beyond the 7:00 position), you will experience stroke inefficiency and blade slippage. The key is to maintain the optimum power ratio between the two arms and shorten the end of your stroke.

To conclude, striving for this kind of stroke efficiency takes time and practice, but you will be richly rewarded. If you are a canoe tripper, you will find yourself paddling farther while enjoying a full day's paddle even more than you had in the past. If you are also canoe racer, you will take great delight in the faster times you achieve in your canoe race events.

The author is a University of Wisconsin – La Crosse professor with degrees in biomechanics and recreation. He has been teaching canoeing and guiding wilderness canoe trips for over 30 years, and is a former successful marathon canoe racer.

Figure 4: Correct Shaft Angle

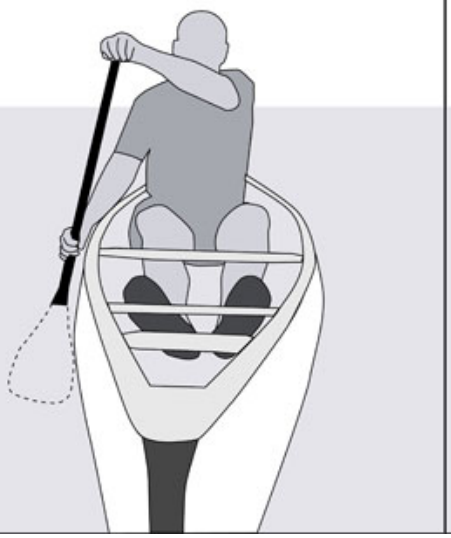


Figure 5: Incorrect Shaft Angle