The Classic Stroke Revisited

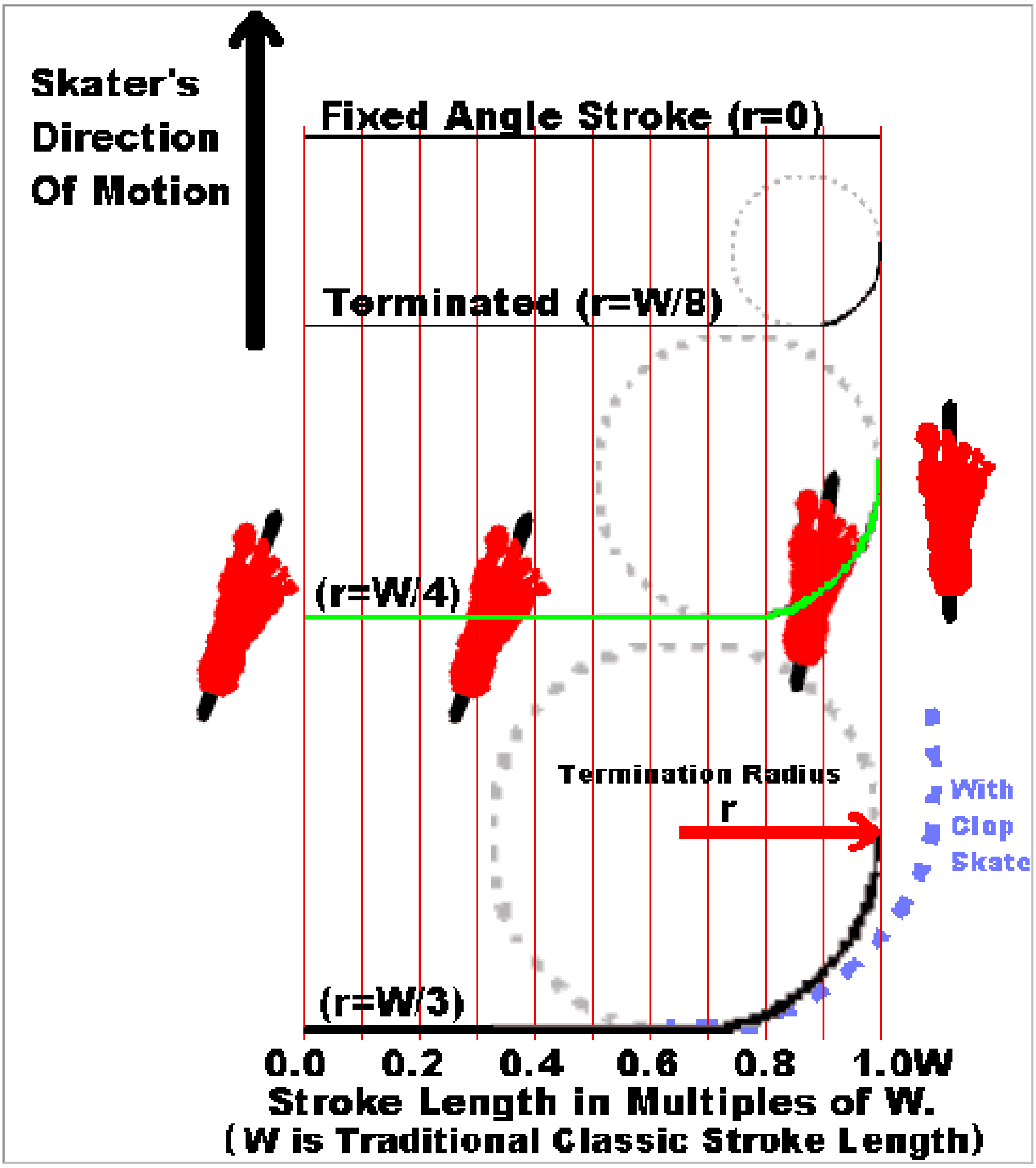
Redefining The Stroke Length For More Energy

c. P.J. Baum, September 1999.

The double-push is not always useful -- for example for indoor short track races. Here I re-examine the classic skating stroke to see what can be said quantitatively about the energy gained per stroke. A reinterpretation of the stroke length will be found in order leading to an additional benefit of clap-skates. The concepts presented here are applicable also to the double-push.
The following figure shows the kinds of strokes examined here. They all concern a straight-line push "sideways" (in the frame of reference of the skater -- not the ground) ending with a termination approximated as a quarter-circle of various radii.

Types
of
Classic
Strokes
Considered

(Right
Leg
Stroke
Only
Shown)



The skater begins pushing sideways with a force, F, over the classic stroke length, W. He can choose the radius of the termination arc, R, and can also choose to "Coast" the corner or "Power" the corner.

- **In the fixed-angle stroke which is unterminated (R=0) the energy exerted by the skater is F*W but only half of that is directed forward, the other half is sideways because the skater has not terminated the stroke by turning it forward (Discussed here).**
- **The next case does have a termination (R=W/4) which the skater "coasts". Now the other half of the energy has been turned forward so the forward energy will be nearly 1.0*F*W . Next the case R=W/4 with a powered turn is considered. The straight path is 0.75*W long and the quarter-circle termination is pi*R/2 in length which is pi*W/8 or 0.39*W . So for this case the total stroke path length is (0.75 + 0.39)*W = 1.14*W . So the energy from this case will be 1.14*F*W which is a 14% increase over what you would have expected from the ttraditional classic stroke. Neglecting energy losses, the velocity gained varies as the square root of the energy so the energy is 1.07 times classic for a 7% velocity gain over classic.**
- **Continuing on to the R=W/3 case, the stroke path length will be (0.67 + 0.52)*W = 1.19*W for a 19% energy gain. In this case the velocity gain is 9% over classic.**
- **Finally, consider a clap-skate where the skate increases the radius of the termination circle by 10% of the stroke width. So the effective radius will be W/3 + W/10. Now the stroke path length will be (0.67 + 0.68)*W = 1.35*W for a 35% gain in stroke energy and a 16% gain in velocity.**

Summary Of Results For These Strokes

Stroke Type	Cornering	Forward Energy Generated, E/Eclassic	Forward Velocity Generated, v/vclassic	Velocity Gain Over Classic
Unterminated, R=0	None	0.50	0.71	-29%
Terminated, R=W/4	Coast	~ 1.0	~1.0	~0%
Terminated, R=W/4	Power	1.14	1.07	+7%
Terminated, R=W/3	Power	1.19	1.09	+9%
Terminated, R=W/3 With Clap Skate	Power	1.35	1.16	+16%

**Traditional Classic Energy: Eclassic = F*W;
Traditional Classic Velocity: vclassic = [2*F*W/M]**0.5 .
Energy losses have been neglected for this estimate based on E = (1/2)Mv**2.**

Further Considerations

Some of these strokes do provide significantly more energy for forward propulsion of the skater. However, it is not obvious what radius of

termination circle is optimum. I suppose the shorter radii turns are best for sprints and the longer radii better for lower cadence power skating. The longer stroke path length can make the interstroke time longer leading to a lower stroke rate. The tradeoffs between longer strokes and faster strokes has not been done yet.

Stroke Length Vs. Stroke Path Length

The concept of *stroke length* (the distance sideways that the skater pushes) is a helpful parameter but seems to have reached the limit of its usefulness. To go further I introduced the concept of *stroke path length* which is the actual distance travelled by the skate as the skater applies force for forward propulsion. The generalization occurs because now skaters apply force in more than the sideways direction. If this were not so the classic stroke would not be terminated forward and the double-push would have little appeal. To avoid any confusion on the meaning, I have made the stroke path length blink alternately black-to-green on one of the strokes in the figure at the top of this page. The classic stroke length has length W, the straight line at the very top of that figure. *Althought this analysis is carried out in the reference frame of the skater, the results are not dependent on this since energy is conserved in all frames.* One could just as well do the analysis relative to the ground but it gets more complicated then for little additional payback.

The Clap Skate:

The R=W/3 case was done with and without clap skates. The clap skate was assumed to increase the traditional stroke length by 10%. Yet with the R=W/3 termination circle the *clap skate's stroke path length was increased by 16%* (1.35 -1.19 = 0.16). The velocity gain (neglecting losses) for this case was 7% (16%-9%). This suggests that present clap skate designs are not working to their full potential and there is room for considerable improvment.

How The Strokes Are Accomplished

The traditional prescription is to push from the heels. This admonition works well for advanced skaters but is probably nearly useless for beginners. The reason is that it fails to explain what you do with the front wheels, where the skate should be at the start of the turn, and when to start the termination turn. Neatly enough, if you have started the stroke right the front wheels roll around the corner nicely so long as they grip the ground and you push the heel sideways hard enough (without sliding). Beginners usually get the skate out of position making it very difficult to complete the termination turn. A common problem is hesitation in completing the linear part of the stroke allowing the skate to move behind the body. It is not hard for a good skater to have a little of this problem when adversity sets in-- headwind, uphill, other skaters grab your jersey, or just plain fatigue. So how do you get out of this trap once your stroke has gotten "behind the curve"? Well, take a look at the foot-and-skate positions on the top figure. The skate moves to the right then starts to straighten out so that the front of the skate moves forward faster than the rear, and the heel moves sideway faster than

the toe. So once you get behind in the stroke picture yourself pushing the toe forward and the heel sideways. Do not push the toe sideways as this will only slow the turn. Once the stroke has recovered it is best to go back to pushing the skate around the corner from the heel because you can push the heel farther forward than the toe (because the heel is closer to your body it will still be on the ground when your toes have started to lift off).

The Double Push

In the case of the Double Push both legs push to the right and the left of the body sequentially. In the classic case the right leg only pushes to the right side and the left leg only pushes left. The double push skate path looks like a pair of "snakes" or in-phase sine waves (in the frame of reference of the ground now). In the skater's reference frame the stroke path woul look a lot like the classic but the stroke would continue around the termination circle another quarter-circle and return straight back to the left side of the body. The skate's path would be somewhere between 2*W and 3*W and the skater can apply power over a significant portion of the path. So I would estimate that the stroke path length might be about 2*W for the double push leading to an energy gain per stroke of about 2.0*F*W.

Various Energy Losses

While you are generating energy by stroking it is being eaten away by other mechanisms. The most serious is wind-drag which will ultimately eat up your energy about as fast as you can generate it. The wheels have rolling resistance which probably eats up a few % of your stroke energy. Finally, I looked at the "loss" from spinning the wheels up to speed. The wheels have a moment of inertia and the wheel rotation stores energy in the spin (the rotation rate gets pretty high at speed). The spin energy is not really lost (if your bearings are good) but it is also not available for your use. This spin energy is the price of rolling (if you drop the spin energy to zero by stopping its rotation it ceases to roll). Assuming the weight evenly distributed radially throughout the wheel, I estimate the ratio of the wheel spin energy to skater forward energy to be 2*N*m/M where N is the number of wheels (~10 total, 5 per skate), m is the mass of a single wheel, and M is the skater's mass. So it works out to be 2-3% of the skater's energy stored in wheel spin. Then a 1-2 % efficiency gain is available to someone who can make wheels lighter or reduce their moment of inertia. Clap skates and aerodynamic drap strips are said to produce 3% improvments so the wheel spin improvment would not be far behind these. Maybe it is time to re-examine the air-filled skate wheel.

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