

# PHYSICAL REQUIREMENTS FOR A TAKEOFF IN SURFING

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The conditions required for a takeoff in surfing, are discussed, with the waves simulated numerically, considering two types of wave breaking, i.e., a plunging type, and a spilling type. First, a surfer is required to obtain a sufficient value for the horizontal component of paddling speed, not to be overtaken by a wave peak. Second, when the surfer stops paddling, he needs to be floating at a location where the force on him is downward, along the wave front face. On the basis of both conditions, the time variation of the required value for the horizontal component of paddling speed, is evaluated for both the plunging-type, and spilling-type, cases. When the paddling speed is sufficient, the surfable area is larger in the former case, than in the latter, on the offshore side of the wave-breaking point.

*Keywords: surfing; takeoff; physical requirement; paddling speed; surfable wave*

## INTRODUCTION

After accelerated by paddling, a surfer stands up on a surfboard; this action, we call, a ‘takeoff’. A takeoff is one of the most important motions in surfing, for a surfing performance starts with a takeoff. Surfers, however, generally judge whether a wave is suitable for surfing, i.e., surfable, only from their own experience. Thus scientific study of takeoff in surfing, ought to bring improvements, in both surfboards, and surfing skills, as well as artificial surf points, proposed by e.g. Walker et al. (1972), West et al. (2003), Schipper (2007), Vries (2007), Schmied et al. (2013), and Kimura et al. (2014).

In the present study, we discuss the necessary conditions for a takeoff in surfing, evaluating the paddling speed, required for a surfer to ride a wave, on the basis of numerical results, obtained by simulating waves of two breaking types, i.e., a plunging type, and a spilling type.

## MOTIONS IN SHORTBOARDING, FROM WAITING FOR A WAVE TO FINISHING A TAKEOFF

Shown in Fig. 1 is an example of a series of motions, for a takeoff in shortboarding. First, a surfer waits for a surfable wave [a]. Once the surfer chooses a wave, he looks forward [b], and begins paddling to generate propulsive force [c]. The buoyancy of a shortboard, is not large enough, such that both the surfboard, and the surfer’s body, are mostly submerged at these stages from [a] to [c]. The surfer keeps paddling, to raise his surfboard gradually, after which the whole surfboard appears on the water surface [d]. Then the surfer stops paddling, to start standing up on the surfboard [e], and finishes the takeoff, sliding down on the wave front face [f]. In this study, we examine the physical conditions, concerning both the velocity, and the force, of a surfer around the stage [e].



Figure 1. An example of a series of motions in shortboarding, from waiting for a wave to finishing a takeoff.

## NUMERICAL METHOD

We obtain physical values, including both water surface displacement, and water velocity, by applying CADMAS-SURF/3D (Suzuki and Arikawa 2010), considering wave breaking, to evaluate the state of waves around a takeoff time. In numerical computation, a sinusoidal wave is generated, at the offshore end of the calculation domain, where the wave height, and the period, of the incident wave are 2.0 m, and 10.0 s, respectively.

The seabed slope starts from the offshore end, where the still water depth is 2.0 m. The seabed gradient  $\beta$ , is 1/10, as shown in Fig. 2(a), or 1/100, as shown in Fig. 2(b). The wave-breaking type, is a

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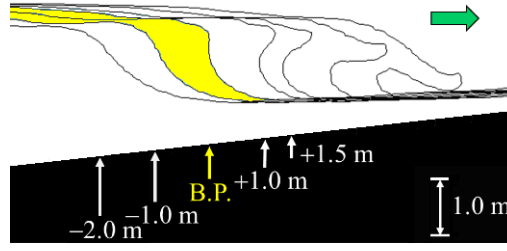
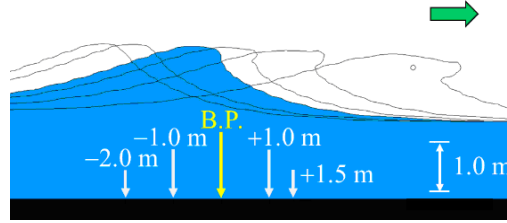
(a) The plunging-type case ( $\beta = 1/10$ )(b) The spilling-type case ( $\beta = 1/100$ )

Figure 2. The water surface profiles, around each wave-breaking time, where  $\beta$  denotes the seabed gradient. The wave height, and the period, of the incident wave are 2.0 m, and 10.0 s, respectively, at the offshore calculation-domain end, where the still water depth is 2.0 m. At the wave-breaking point (B.P.),  $x = 0.0$  m in each case. The distance between the offshore calculation-domain end, and the wave-breaking point, is 8.6 m in the plunging-type case (a), while 65.0 m in the spilling-type case (b).

plunging type over the former slope, while a spilling type over the latter slope. In the present paper, the wave-breaking point is defined as the location where the horizontal component of water velocity, first exceeds the wave phase velocity. At the wave-breaking point, which is denoted by 'B.P.' in Figs. 2(a) and 2(b),  $x = 0.0$  m in each case. The distance between the offshore calculation-domain end, and the wave-breaking point, is 8.6 m in the plunging-type case (a), and 65.0 m in the spilling-type case (b). The water surface profiles are also depicted in Fig. 2, around each wave-breaking time. The grid width for computation is as follows:  $\Delta x = 0.1$  m in the wave-propagation direction;  $\Delta y = 0.5$  m in the lateral direction, where the domain width is 1.0 m;  $\Delta z = 0.1$  m in the vertical direction.

Before a takeoff, part of a surfboard, as well as a surfer's body, is under water, as described above, such that the water particle movement, has a great effect on surfer's motion. Thus a surfer without paddling, is assumed to show the same velocity, as the water velocity at his position.

#### A REQUIREMENT CONCERNING VELOCITY

Figure 3 shows an example of the behavior of a styrofoam surfboard model, floating at the water surface in an acrylic wave basin. The specific gravity, and the length, of the surfboard model is 0.025, and 7.5 cm, respectively. The surfboard model was located at a wave front face, as shown in Fig. 3(a), after which the wave peak, traveling to the right, has left the surfboard model behind, as shown in Fig. 3(b). In the present case, the surfboard model failed in riding the wave, because it did not progress by itself.

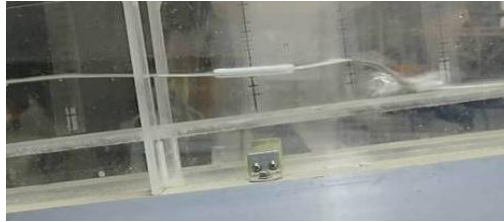
This simple experimental result indicates that a surfer needs to progress by paddling, not to be overtaken by a wave peak. Thus for a takeoff in surfing, the following condition is required to be satisfied, at the location where the surfer is floating:

$$V_{\text{paddling}} \geq V_{\text{paddling},0} = V_{\text{wave}} - V_{\text{surface}}, \quad (1)$$

where  $V_{\text{paddling}}$  denotes the required value for the horizontal component of velocity obtained by paddling, i.e., paddling speed;  $V_{\text{wave}}$  is wave phase velocity;  $V_{\text{surface}}$ , is the horizontal component of the water velocity at the water surface. Note that  $V_{\text{surface}}$  is usually less than, or equal to, zero, at takeoff locations. Shown in Fig. 4(a) is the time variation of  $V_{\text{paddling},0}$ , required for a takeoff at the locations indicated in Fig. 2(a), where  $\beta = 1/10$ , while shown in Fig. 4(b) is that at the locations indicated in Fig. 2(b), where  $\beta = 1/100$ .

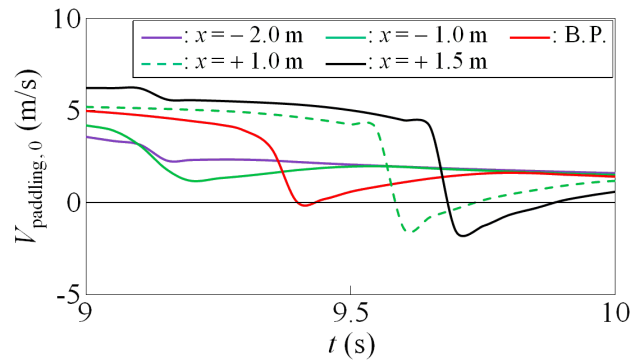


(a) A surfboard model is floating at a wave front face.

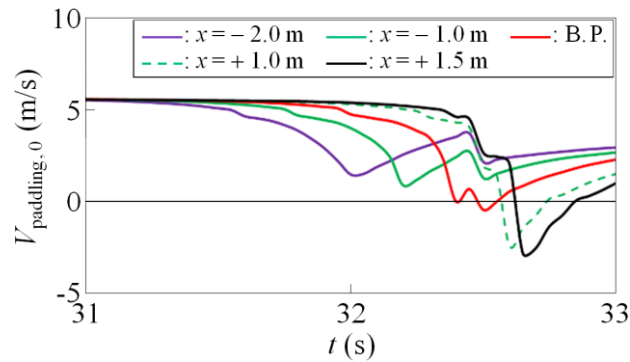


(b) The surfboard model has been overtaken by the wave peak.

Figure 3. An example of the behavior of a styrofoam surfboard model, floating in an acrylic wave basin. The specific gravity, and the length, of the surfboard model is 0.025, and 7.5 cm, respectively. The surfboard model shown in (a), has been overtaken by the wave peak, traveling to the right, as shown in (b).



(a) The plunging-type case ( $\beta = 1/10$ )



(b) The spilling-type case ( $\beta = 1/100$ )

Figure 4. The time variation of the horizontal component of paddling speed,  $V_{\text{paddling},0}$ , required concerning velocity, for a takeoff at the locations indicated in Fig. 2. The wave height, and the period, of the incident wave are 2.0 m, and 10.0 s, respectively. At the wave-breaking point (B.P.),  $x = 0.0$  m in each case.

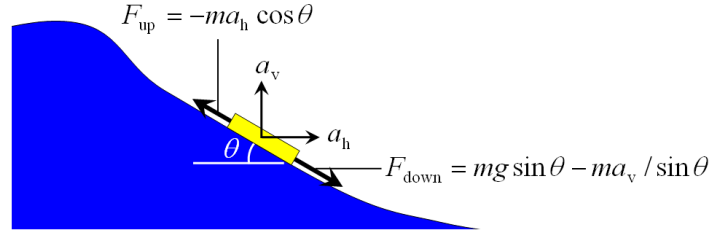


Figure 5. A sketch of the forces on a surfer, along a wave front face, where  $m$  is the total mass of the surfer, and his surfboard, minus the buoyancy;  $\theta$  is the water surface gradient, at the surfer's location;  $a_h$ , and  $a_v$ , are the horizontal, and vertical, components of the water surface acceleration, at the same location, respectively;  $g$  denotes gravitational acceleration.

#### A REQUIREMENT CONCERNING FORCE

Sketched in Fig. 5 are the forces on a surfer, with a surfboard, floating at a wave front face, where  $m$  is the total mass of the surfer, and his surfboard, minus the buoyancy;  $\theta$  is the water surface gradient at the surfer's location;  $a_h$ , and  $a_v$ , are the horizontal, and vertical, components of the water surface acceleration at the same location, respectively;  $g$  denotes gravitational acceleration.

After stopping paddling, a surfer cannot go forward by himself, such that when he stops paddling, he needs to be floating at a position where the direction of force on him, is downward along the wave front face, not to be overtaken by the wave peak, during his takeoff. Therefore, on the basis of Fig. 5, the following condition is required to be satisfied for a takeoff:

$$F_{\text{down}} \geq F_{\text{up}}, \quad (2)$$

$$F_{\text{down}} = mg \sin \theta - ma_v / \sin \theta, \quad (3)$$

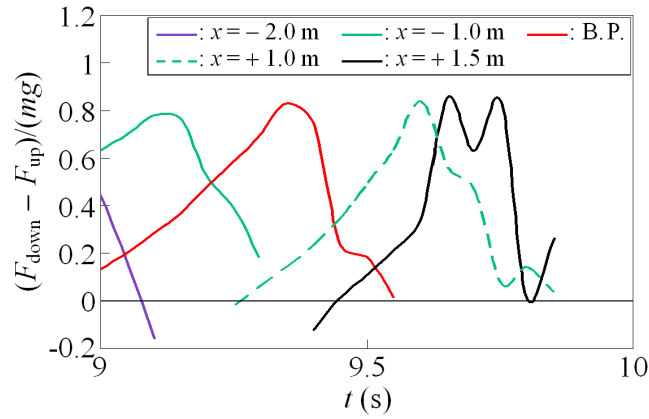
$$F_{\text{up}} = -ma_h \cos \theta. \quad (4)$$

Illustrated in Fig. 6(a) is the time variation of  $(F_{\text{down}} - F_{\text{up}})/(mg)$ , at the locations indicated in Fig. 2(a), where  $\beta = 1/10$ , while shown in Fig. 6(b) is that at the locations indicated in Fig. 2(b), where  $\beta = 1/100$ . It should be noted that the graph is not plotted for the time when the water surface gradient  $\theta$  is less than  $2.0^\circ$ , for a surfer cannot take off, at such a level water surface. If the value of  $(F_{\text{down}} - F_{\text{up}})/(mg)$  is larger, the surfer feels forward/downward acceleration, resulting in an easier takeoff.

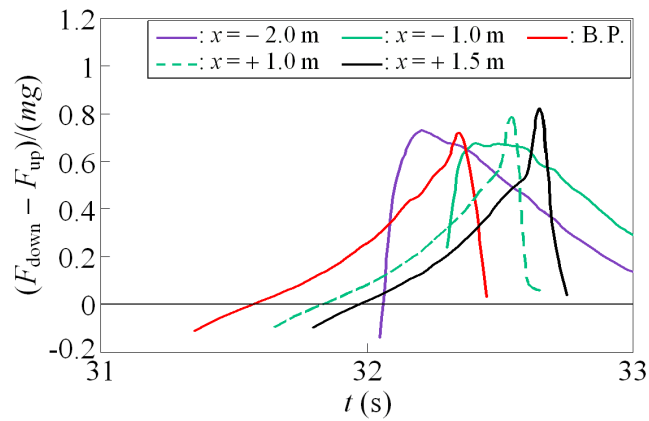
#### PHYSICAL REQUIREMENTS FOR A TAKEOFF

If both of the requirements described above, are satisfied, a surfer, with a sufficient paddling speed, is floating at a position where the direction of force on him, is downward along a wave front face, such that he can take off, in front of the wave peak. On the basis of both Figs. 4(a), and 6(a), we obtain Fig. 7(a), which depicts the time variation of the horizontal component of paddling speed,  $V_{\text{paddling}}$ , required for a takeoff at the locations indicated in Fig. 2(a). Although  $V_{\text{paddling}}$  is shown only for the time before the wave-peak arrival at each location,  $V_{\text{paddling}}$  is the same as  $V_{\text{paddling},0}$  during  $F_{\text{down}}$  is not less than  $F_{\text{up}}$ . It should also be noted that the graph is not plotted for the time when the water surface gradient  $\theta$  is less than  $2.0^\circ$ . A takeoff is possible, only at the time with the graph plotted for each location. If the maximum value in the paddling speed obtained by a surfer, is 1.0 m/s, then he can ride the wave at neither  $x = -2.0$  m, nor  $x = -1.0$  m, for the set of the requirements for a takeoff, is not satisfied at these locations.

In a similar manner, on the basis of both Figs. 4(b), and 6(b), we obtain Fig. 7(b), for the spilling-type case, where  $\beta = 1/100$ . No graph is plotted for  $x = -2.0$  m, and  $-1.0$  m, where the set of the requirements for a takeoff is not satisfied: surfers cannot ride the wave at these locations. If a surfer floating at  $x = -1.0$  m, obtains a paddling speed larger than around 2.0 m/s, he can ride the plunging-type wave, and not the spilling-type wave, such that the area where the present wave is surfable for him, is larger in the plunging-type case, than in the spilling-type case, on the offshore side of the wave-breaking point.



(a) The plunging-type case ( $\beta = 1/10$ )



(b) The spilling-type case ( $\beta = 1/100$ )

Figure 6. The time variation of the relative downward force on a surfer, along a wave front face,  $(F_{\text{down}} - F_{\text{up}})/(mg)$ , at the locations indicated in Fig. 2. The graph is not plotted for the time when the water surface gradient  $\theta$  is less than  $2.0^\circ$ . The wave height, and the period, of the incident wave are 2.0 m, and 10.0 s, respectively. At the wave-breaking point (B.P.),  $x = 0.0$  m in each case.

**CONCLUSIONS**

The conditions required for a takeoff in surfing, were discussed, with the waves simulated numerically, considering two types of wave breaking, i.e., the plunging, and spilling, types. First, a surfer is required to obtain a sufficient value for the horizontal component of paddling speed, not to be overtaken by a wave peak. Second, when the surfer stops paddling to try to take off, he needs to be floating at a location where the force on him is downward, along the wave front face. On the basis of both conditions, the time variation of the required value for the horizontal component of paddling speed, was evaluated for both the plunging-type, and spilling-type, cases. When the paddling speed is sufficient, the surfable area was larger in the former case, than in the latter, on the offshore side of the wave-breaking point.

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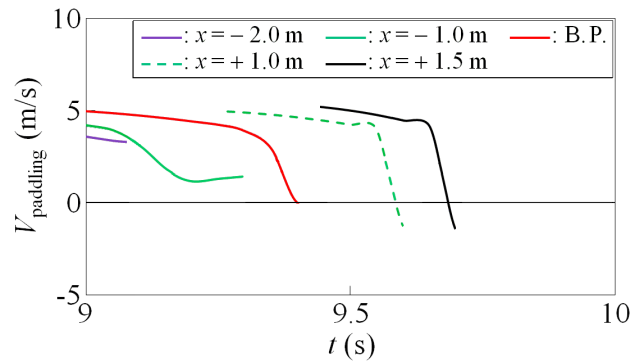
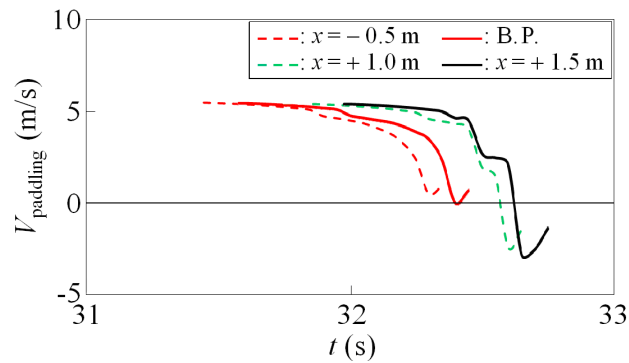
(a) The plunging-type case ( $\beta = 1/10$ )(b) The spilling-type case ( $\beta = 1/100$ )

Figure 7. The time variation of the horizontal component of paddling speed,  $V_{\text{paddling}}$ , required for a takeoff, where  $V_{\text{paddling}}$  is shown only for the time before the wave-peak arrival at each location. The graph is not plotted for the time when the water surface gradient  $\theta$  is less than  $2.0^\circ$ . The wave height, and the period, of the incident wave are 2.0 m, and 10.0 s, respectively. At the wave-breaking point (B.P.),  $x = 0.0$  m in each case.

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