7−2−4 Surf-riding (Broaching-to) Phenomena

Broaching-to phenomena occurs when operating in following seas and when the speed of the waves is the same or faster than the ship's speed. It often results in a ship losing steerage when it is being accelerated forwards on the steep forefront of a high wave, which is then followed by surf-riding. This is an extremely dangerous phenomenon as the ship will lose steerage and turn abruptly with great centrifugal inertia exposing her broadside to beam seas, often resulting in instantaneous capsizing.

In the diagram (Fig. 116), the abscissa represents propeller revolutions and the ordinate represents the speed of the model ship. In calm seas, the ship's speed changes, as propeller revolutions (r.p.m.) increase. R.P.M. and ship speed are proportional, however it becomes a loose curve due to propeller slip.

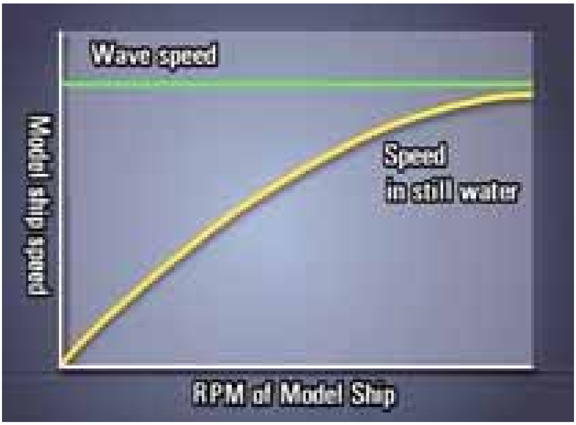


Fig. 116 Japan Captains' Association, DVD

In contrast, in following seas, even if propeller revolutions are increased, the actual speed of the model ship varies between up and down slopes of a wave, because ascending is impeded every up slope of a wave and descending accelerated at each down slop of a wave under the influence of the sea (blue coloured area). The difference between these ascending and descending speeds tends to increase as propeller revolutions increase (Fig. 117).

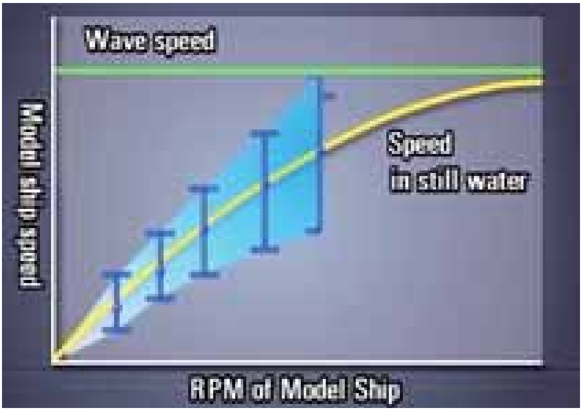


Fig. 117 Japan Captains' Association, DVD

However, if propeller revolutions are increased, this regular repetition of speed change suddenly collapses at a specific number of revolutions, and the ship's speed sharply increases discontinuously (orange coloured area). In other words, the surf-riding phenomenon is created when the maximum speed of these repeating motions of the model ship reaches the same speed as the waves (Fig. 118).

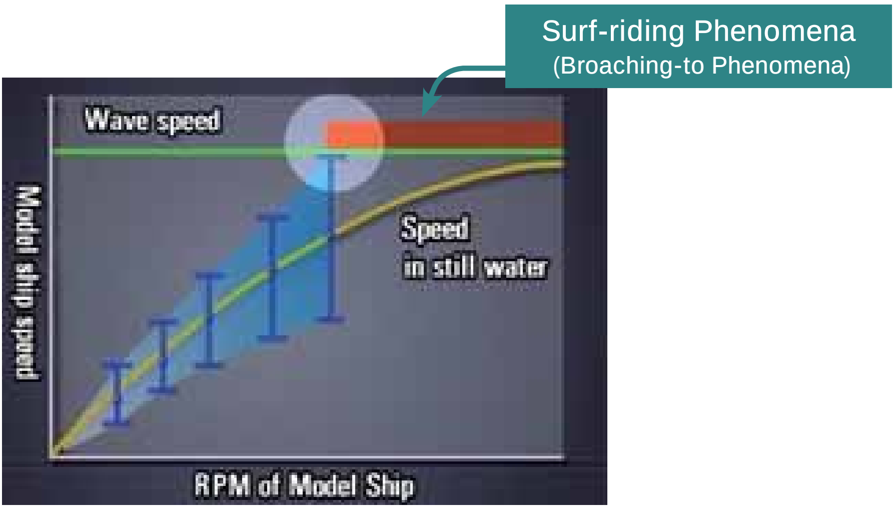


Fig. 118 Japan Captains' Association, DVD

As can be seen in Figs. 119, 120 and 121, the graphs show the patterns of speed changes when a model ship sails while being exposed to following seas at a constant rotation of propeller revolutions. The horizontal axis represents time (seconds) and the vertical axis represents ship speed. The ship speed is accelerated at the down slope of a wave with a resultant greater ratio of period of proceeding with the waves and the ship speed is decelerated at the up slope of wave with a resultant smaller ratio of period. Figure 119 indicates the speed changes that occur when propeller revolutions and speed are low. Speed variations almost draw sinusoidal waves with a resultant smaller ratio of period.

When propeller revolution and speed are low

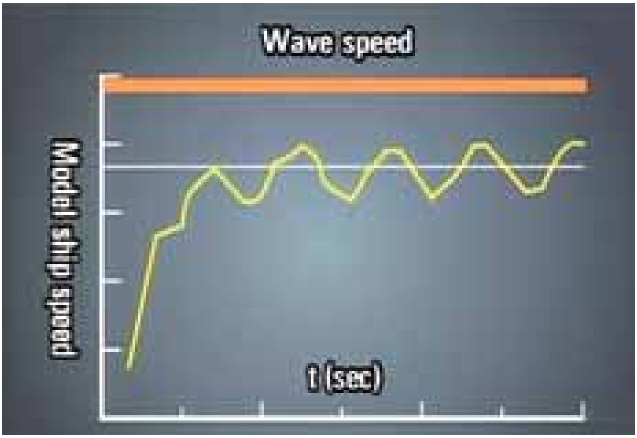


Fig. 119 Japan Captains' Association, DVD

While the ship speed accelerates it closer matches the speed of the wave, the number of the speed variations decrease (Figs. 120 and 121).

When the ship's speed increases a little

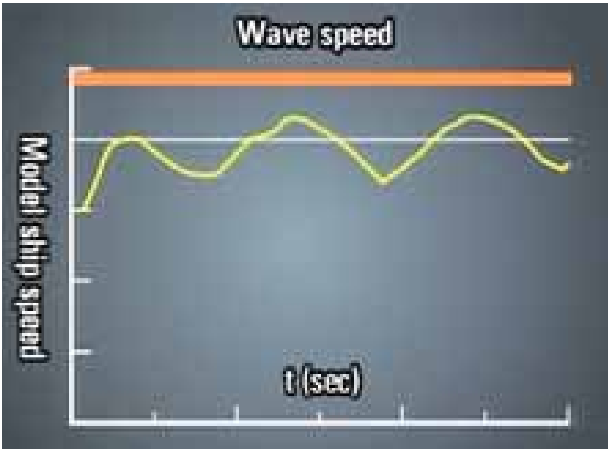


Fig. 120 Japan Captains' Association, DVD

When the ship's speed is increased further

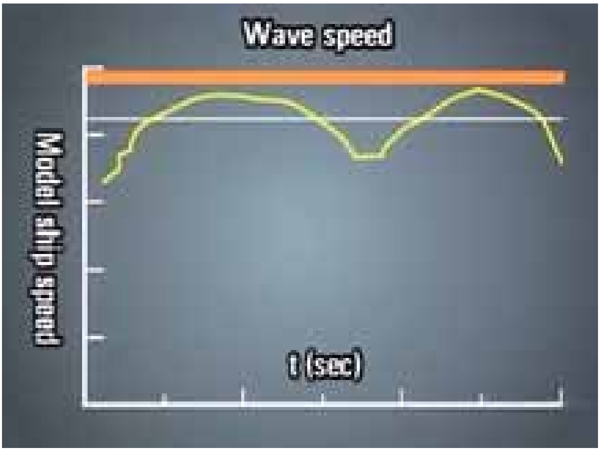


Fig. 121 Japan Captains' Association, DVD

As can be seen in Figure 122, the ship speed is accelerated at the down slope of a wave with a resultant greater ratio of period of proceeding with the waves and the ship speed is decelerated at the up slope of wave with a resultant smaller ratio of period.

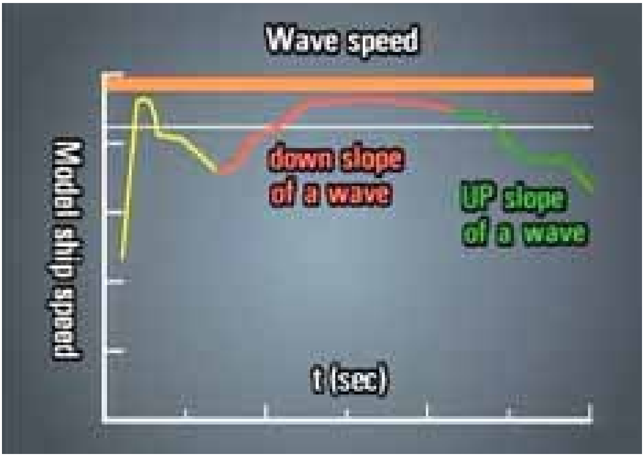


Fig. 122 Japan Captains' Association, DVD

Even if propeller revolutions are further increased, ship speed does not fluctuate any more when the ship comes under the grip of surf-riding (Fig. 123).

Transfer to Surf-riding (Broaching-to)

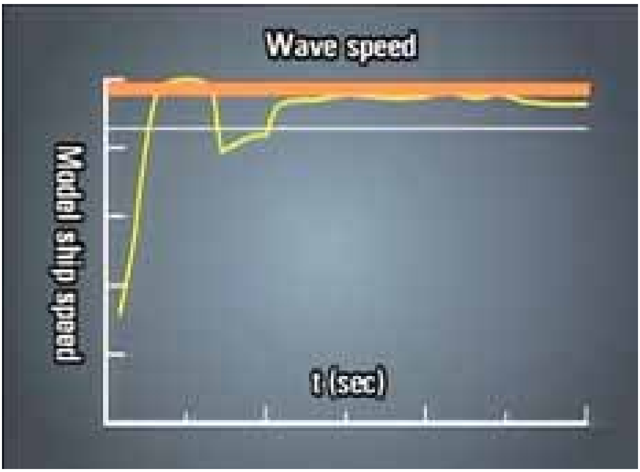


Fig. 123 Japan Captains' Association, DVD

To avoid surf-riding (broaching-to), one should be aware of the ship's critical speed that causes this phenomenon. The critical speed varies according to wave length and wave height. According to 4.2.1 of the Guidlines (MSC.1/Circ.1228), the following formula (Calculation formula 124) for a ship's critical speed is set forth.

Broaching Occurence **Critical Ship's speed (kts)** =

$$1.8 \times \sqrt{\text{Ship's Length (Lpp)}} \div \cos(180 - \alpha)$$

$$\text{Range of } \alpha : \quad 135° < \alpha < 225°$$

Calculating formula 124

Therefore, the ship's speed should be reduced to less than 1.8 multiplied by root L. (length of ship) in order to avoid surf-riding.

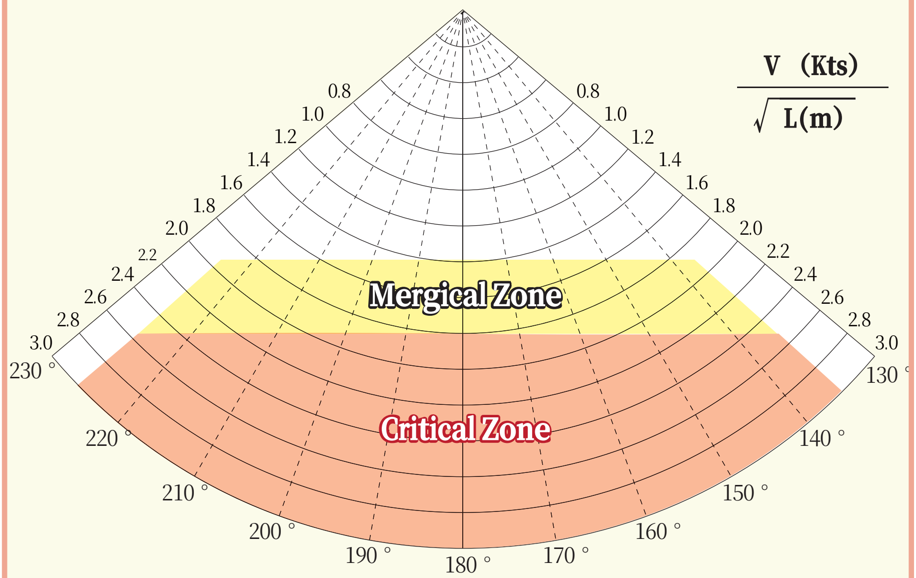
Although this cannot be found in the MSC.1/Circ 1228, in the previous MSC.1/Circ .707(19 October 1995), the following formula (Calculating formula 125) is shown as "Surf-Riding (Broaching-to) marginal zone" in order to avoid huge speed changes. This speed change runs the risk of causing broaching-to, although it does not reach the "Surf-Riding (Broaching-to) dangerous zone" and surf-riding. To be on the safe side, it is necessary not to enter this zone.

Broaching Occurence **Merginal Ship's speed (kts)** =

$$1.4 \times \sqrt{\text{Ship's Length (Lpp)}} \div \cos(180 - \alpha)$$

Calculating formula 125

Figure 126 shows the "Surf-Riding Dangerous Zone" (area in pink colour) which is introduced in the Guidlines (MSC.1/Circ.1228). In addition, "Surf-Riding (Broaching-to) marginal zone (area in yellow colour)" shown in MSC.1/Circ .707(19 October 1995) has been added.



Broaching Occurence **Critical Ship's speed (kts)** =

$$1.8 \times \sqrt{\text{Ship's Length (Lpp)}} \div \text{COS}(180 - \alpha)$$

Broaching Occurence **Merginal Ship's speed (kts)** =

$$1.4 \times \sqrt{\text{Ship's Length (Lpp)}} \div \text{COS}(180 - \alpha)$$

In Fig. 126 "Surf-Riding (Broaching-to) marginal zone speed" has been added to MSC.1/1228 4.2.1

Table 127 shows the ship's Critical speed at which broaching-to phenomena will occur. When deciding on the optimum speed, you should take the extra speed added by acceleration at the down slope of a wave into consideration. Even for a vessel whose Lpp is longer than 200m, it is important to be aware of this phenomenon that may more commonly be associated with high speed crafts.

Broaching Occurences Critical Speed								
Ship's Length (Lpp)	10 m	20 m	50 m	70 m	100 m	150 m	200 m	300 m
$1.8 \times \sqrt{Lpp}$	6 Kts	8 Kts	13 Kts	15 Kts	18 Kts	22 Kts	25 Kts	31 Kts
Broaching Occurences Mergical Speed								
$1.4 \times \sqrt{Lpp}$	4 Kts	6 Kts	10 Kts	12 Kts	14 Kts	17 Kts	20 Kts	24 Kts

Table 127

When a ship is sailing in shallow waters, the surf-riding phenomenon can occur even when a ship is sailing at a comparatively low speed. This is because the propagation of waves is deterred in shallow waters, so the critical point may be comparatively attainable even when a ship is sailing at a low speed. This should be borne in mind in particular by seafarers operating high-speed pleasure boats and fishing vessels.

7－2－6　Countermeasures for Rough Weather Following Seas

The most effective countermeasure in head and countering seas in rough weather is to reduce speed, however, in following seas, the combination of dynamically changing heading course and ship speed reduction are required in order to avoid the aforementioned phenomena from occurring. In addition, a great deal of ship operating skill will be needed because of the decreased steerage ability experienced when attempting to change heading course.

In particular, when there are wind and waves and several huge swells from a quarter stern, the countermeasures should be taken while at the same time appropriately judging which wind and waves or which direction of swell are causing the ship’s pitching and rolling. The length, height, period and speed of the waves must also be precisely grasped.　Prior to all of this, it should be noted that, prompt maneuvering in order to avoid even coming into contact with such phenomena should be taken at the earliest possible moment.

§ 8 Conclusion

In 4-1-4, based on his own experiences, the author introduced how to choose an appropriate route when navigating the North Pacific Ocean en route North America to Japan during the winter season. In anticipation of operating a ship in areas of rough weather, such as head and countering or following seas, the Master is duty-bound to: obtain as much information as possible on weather and sea conditions, select the most suitable sea route while taking into account the ETA, be aware of the amount of fuel being consumed and possible cargo damage that can occur as a result of rough weather. The charterer will demand that a tight schedule and minimized amount of fuel usage be adhered to in order to improve profitability of the vessel.

Needless to say, the final choice of route lies with the Master and the safety of his vessel. With this in mind, all information between the charterer, the shipowner, the ship management company and the WRS (Weather Routing Service) provider must be shared. However, first and foremost, it is necessary to set the course with the agreement of those concerned and the Master - who stands on the front line of ship handling, whose opinions and intentions are to be well valued - before departing the port and before the ship is exposed to rough sea.

Although the precise prediction of weather and sea conditions has improved over the recent years, it is still not 100% guaranteed. Naturally, although one may choose a route with a detour, there may be a situation whereby a shorter voyage was not taken due to a misinformed rough sea forecast. The author also experienced occasions whereby weather and sea conditions fell outside of his prediction in the winter season of the North Pacific Ocean, especially when navigating en route from North America to Japan. However, this came about as a result of weather and sea conditions which are difficult to forecast in advance correctly. Therefore, through the cooperation and understanding of all concerned parties including the charterers/operators, shipowners and ship management companies it should be understood that external and unpredictable phenomena that are beyond the control of the seafarer are existent and that those seafarers should not be held singularly accountable as an afterthought.

Attachment: MSC.1/Circ. 1228 (11 January 2007)

References

- MSC.1/Circ. 1228 (11 January 2007) : Attachments
  imo.udhb.gov.tr/dosyam/EKLER/1228.pdf
- " Safety measure for ferries and RORO vessels " in Maritime Bureau of Ministry of Land, Infrastructure, Transport and Tourism. "(28April 2011)
  http://www.mlit.go.jp/common/000144432.pdf
- Japan Captains ' Association, DVD
  SHIP HANDLING IN FOLLOWING SEAS
  SHIP HANDLING IN HEAD AND COUNTERING SEAS
  Weather and Sea States around Japan and Characteristics of Major Ports and Bay in Japan
  Many of the figures and photographs are cited from the above DVD. We are deeply grateful for being allowed to use the above references.
- From the Japan Meteorological Agency website
  https://www.jma.go.jp/jma/index.html
  We would also like express our gratitude to the Japan Meteorological Agency for allowing us refer to their website for figures and explanations.
- Masanori Shiraki, 2007, Shin Hyakuman-nin no Tenki Kyōshitsu: Seizando
- From the Japan Weather Association website