航海氣象講座第 14 講 同步橫搖和參數橫搖
https://youtu.be/W80IK1hfZF4?si=Q11RyGm2eOjVRiME

同步橫搖是在惡劣天氣或一般天氣下，都會發生的現象,與自動舵的設定有關
參數橫搖是由縱搖轉換成橫搖而產生的,與船隻的橫向穩定性變化有關

同步橫搖和參數橫搖都是由於船隻穩定性降低而導致的劇烈橫搖

作為船員需要瞭解同步橫搖和參數橫搖的發生條件,以便在惡劣天氣下，採取正確的應對措施，觀測波浪週期，並合理調整自動舵是關鍵,不能盲目操作
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這是航海氣象講座的第 14 講，上面講到，惡劣天氣下船長的指導書第一部分，今天要做後面後續的講解，瞭解一下什麼叫做同步橫搖跟參數橫搖。現在看到是在實驗室裡面模擬的波浪情況，可以看得出來，波峰大概是船隻長度的一半，然後引起左右的搖晃。
在這邊看，這一條船它的波長大概是等於這條船的長度，因為剛剛前面有撞到浪頭一下，撞擊使船隻失去前進的動量，所以搖的就特別厲害，

橫搖，內行的就會開始算橫搖週期是多少，從左邊搖到這一邊大概是幾秒，這一個來回大概是 18 秒，每條船橫搖 18 秒，它的特性 GM 是多少? 都不一樣，船長應該要有底。

上一節可以說是名詞解釋，這邊就要說明危險的現象是什麼?
第一個危險就是船尾來的浪，船尾來的浪，看起來好像沒有麼危險，但是船尾上來的大浪經常會打到住艙，或是船尾的排煙管，早期貨櫃船還沒經驗的時候，發電機的排煙管裝在船尾，海水打到船尾的發電機排煙管，然後整個發電機跳掉，船上就 BLACK OUT。BLACK OUT 是造成貨櫃落海最大的原因，因為風浪被打下去的貨櫃還不多，因主機失去動力摔下去的貨櫃更多，嚴重的時候當然就是翻船。

船尾來的浪，它的遭遇的週期會比橫浪更長，橫搖時間會更長，是主要的顧慮 CONCERN，因為船隻大型化以後，大型船最怕的是長浪，俗話說的，大船怕大浪/小船怕小浪。

第一個 SURFING，SURFING 衝浪，跟什麼 BROACHING 橫浪，BROACHING 在早期的翻譯書裡面，都叫做橫浪。船在波谷裡面打橫的時候，被一個大浪從正橫方向打過來，導致翻覆。實際上因為大浪覆蓋而翻船的應該不多，大部分的原因都是浮心被抬高位移到浪頭，重心卻還留在原地，造成負的 GM，船是騎在浪頭上，被抬高然後因傾覆力距而翻覆。

當船尾來的浪，船位於大浪前沿時，STEEP FOREFRONT OF A HIGH WAVE(看影片) ，意思騎在坡峰上，船加速向下衝，這就跟人在衝浪 SURFING 一樣，本來船在大浪上面，會就順著浪沿下滑，波浪又是從船尾來，除了船速，向下衝的加速度，這種衝浪型的風浪，當然要看船體

的結構，是不是能夠承受突然大浪的撞擊? 海水雖然看起來是軟的，可是海水的密度非常大，經常大於一些木頭對不對? 這是衝浪型的危險 SURFING。

在巨大波浪之中打橫，船體浮心位移後滑到的波谷，叫 BROACHING 橫浪，也可能產生翻覆或是船首向的突然改變，船首向突然的改變也可能是 GM 為負時，船突然的滑向一邊，或是不可預測的大角度傾側，這都是負的 GM 或變小所造成的現象。

3.1.2 船隻的動態穩定度，一般來講，它的動態穩定度是船騎在浪頭上面的時候最小，波峰在船中的位置時，這是說船尾來浪，浪頭在船中的位置是最危險的，因為一般船隻的船舯浮力最大，波浪在船中對浮心的影響也最大，它的完整穩定度顯著的減少，浸水的部分完全改變。

當然光看文字是看不懂的啦，在前面的第十一講有動態的波浪講解，才知道穩定度的減少在什麼時候最關鍵? 在波長是船身長度的 0. 6 倍到 2.3 倍之間，在這範圍內，穩定度的減少與波高成正比(任何時候穩定度的減少都是與波高成正比)。0.6 倍到 2.3 倍也就是說，一倍船隻的長度，剛好是兩個波浪的長度(1 船長 = 0.6 倍波長)，或者是船的長度剛好是波浪的一半(1 船長 = 2.3 倍波長)。

如果波浪的長度是船的一半的話，可能船頭有一個波峰/船中有一個波峰/船尾又有一個波峰，就跟剛剛看到在水池裡面的船模擬的情形一樣，半倍的船長。
對船的長度剛好是波浪的一半(300 米的船)來說，如果遇到波浪是它長度的兩倍，波浪長度要到 600 米，能夠看得出波長是 600 米的船長，是大羅神仙吧。要看得出來波浪的長度是船的兩倍的話，也許應該用雷達觀測波浪長度，才有可能。

遇到波浪是船隻長度的兩倍，船頭如果在波谷裡面/船尾就在波峰上面，當然這都要老船長才能夠想像，年輕人可能要去畫圖才能夠瞭解。看到這情形，穩定度的減少與波浪的高度成正比，是因為什麼? 波浪的高度會抬高浮力中心，浮力中心抬的越高(浮心橫向位移減少)，就會越減少 GM，所以穩定度的減少與波浪的高度成正比。船尾來的浪特別危險，騎在波峰的時間上會明顯的加長，同樣穩定度減少的時間也會加長。這話說回來，各位要回去看第 11 講

再來 3.2 同步橫搖 Synchronous Rolling Motion
同步橫搖，同步橫搖不但是惡劣天氣之下會同步橫搖，在一般天氣不太壞的時候，也是會同步橫搖。這跟自動舵的設定有關係，因為在大洋中如果用自動舵航行，如果船船頭向右轉了三度，自動舵就會自動打左舵，要把船從右邊拉回來。它打左舵的時候，就產生一個向左邊迴轉的力矩，這時候右舷又剛好騎在一個波鋒上面，船頭剛好是往左邊滑下來，船本來左舵就有左轉的力距，再加上從浪頭上面滑下來的力量 BROACHING，船就加速向左轉，一到左邊雖然船已經回到原來的航向，可是船是停不住的繼續往左邊衝過去。
如果剛剛在右邊的時候，船隻航向差了三度，它左舵一打，加上浪頭滑下來，衝過頭到航向

左邊的六度，自動舵一看到船首向差了六度，自動舵就會自動加大舵角，打右舵來停止左轉，一壓右舵又剛好波浪走到左舷，船艏向又衝到航向右邊的九度，本來是航向差三度，現在又衝到右邊的九度，越來越大就像同步橫搖，越搖越快越大，時候除了手操舵來抵抗船首向搖擺的太多，另外一個要調整自動舵，每一次調整自動舵的時候，都要注意是否會產生同步橫搖。

3.3 參數橫搖是在縱搖情況下產生的，橫搖都是由於橫向穩定度的變化，船隻在波峰波谷之間發生的，前面說過由 pitching 縱搖轉成橫搖 rolling，就叫做參數橫搖，因為縱搖了幾次以後，好像剛剛看到 OOCL 的船，它波長等於船長。由 pitching 轉成 rolling，參數橫搖會放大，這都是偶然 by chance 看機會，因為大海上的波浪，不像實驗室這麼平均。橫搖的時候，就牽涉到橫向的穩定度變化，這時候 GM 如果為 0 為負的情況之下，船就可能大角度的搖擺。

這裡說參數橫搖造成穩定度的變化，其實只要有波浪，穩定度就一定會變化，只是變化的大小，縱搖跟橫搖的週期如果比例是 1 比 1 的時候，船隻的穩定度變化最大，GM 減到最低，如果船剛好騎在波峰上面，這時候 GM 變化最大，船隻也是剛好要準備開始橫搖，在這樣的搖擺週期中，發生橫搖的振幅(角度)都會遠大於船在波浪的其他位置。

作為一個船員的自覺，要計算什麼? 船隻 Pitching 縱搖的週期，縱搖的週期跟橫搖的週期接近 1 比 1 的時候，代表遭遇的波長與船長相同，就可能 GM 減少很多，產生同步橫搖。同步橫搖的危險是負的 GM，造成船隻失去穩定度，急劇的向另外一邊傾斜，另外一種可能跟前面講的一樣，縱搖跟橫搖的比例是 1 比 0. 5，橫搖剛好是縱搖週期的一半，代表遭遇的波長是船長的兩倍。

Pitching 剛剛說縱搖週期是波浪的遭遇週期，船隻在波浪中運動產生縱搖 Pitching 時，縱搖的週期是橫搖的兩倍，這時候就會有參數橫搖發生的可能，由縱搖激發激烈的橫搖，作為一個船員的自覺，前面說同步橫搖是什麼情況容易發生? 在波浪的長度是船隻的一半或是兩倍之間，是同步橫搖。

波浪的週期，縱搖的週期是橫搖週期的兩倍，或是縱搖的週期跟橫搖的週期一樣的時候，會產生參數橫搖啊。主要的原因穩定度變成負的，記得這兩點，在海上當班的時候就不會無聊了，知道什麼時候會造成船隻劇烈的橫搖? 一般海上的波浪不是靜態的，好像一個颱風來的時候，四面八方都會有浪，還有湧吹過來。所以在惡劣天氣中，如果是在大洋上，因為沒有地形的影響，波浪可能會取得一些什麼共振，會有一些大小浪的不同週期發生，當然沒有一定週期的啦，說要觀測大概的週期，像前面講過的，什麼三姐妹跟什麼超級巨浪，三姐妹的出現，一般什麼三個大浪，再來九個小浪，八個小浪(三大九小，三大八小)，或者是兩個大浪七個小浪(兩大七小)，都要觀測半個鐘頭以上，才能夠算得出來到底是幾大幾小，算好了以後，荒天中的掉頭，要用什麼? 因為說浪越大船的 GM 減少的越多，穩定度越差，所以船隻

騎在大浪上，一下航向就滑了 20 度，還是 30 度。滑了 20 度以後，船是不會很快就穩定了，還是說船滑了 30 度以後，船好像就回不去原航向，還是繼續向左邊 Rolling 了 30 度，橫搖 30 度，或是船還是停在 30 度的角度，船回正的很慢，是 GM 很差的船。這時候你就不要刺激它，所以要在浪小的時候，趁大浪過了，船已經不會繼續再向兩邊滑的時候，再來用大舵角，甚至加大車來迴轉，要趁浪小的時候轉向，才是最安全的，但是效果不一定是最好。

如果說你的船，向左邊一滑 30 度，滑到 30 度以後，浪頭一過馬上又回正，表示你這是 GM 好的船，像散裝船下面都裝了鐵礦砂，還是裝了一些鐵條，GM 特別好的船，你反而可以利用大浪的時機來協助掉頭。反正船長不能貿然行事，要觀測好波浪的週期，不能一上去駕駛台就說，我船長來，馬上用大車大舵來轉向，造成貨櫃落海，艙蓋落海，嚴重的時候，大艙灌水。一般來講，貨櫃船雖然貨櫃會落海，但是會翻船的很少，GM 特別好的船/或是 GM 特別不好的木材船，甲板貨落海，就很危險了，操船的指導下一講再講。

Lecture 14 of Nautical Meteorology with colleagues Hello everyone, this is the 14th lecture of our Nautical Meteorology course. In the previous segment, we discussed the first part of the captain's guide in two-column weather. Today, we will continue with the explanation of synchronous rolling and parametric rolling. Now, what we see here is a simulation of waves in a laboratory. It can be observed that the wave crest is approximately half the length of the vessel, causing it to sway from side to side. On this side, we see a ship whose waves are roughly equal to its length. Because it just hit a wave head a while ago, this impact caused the vessel to lose its forward momentum, resulting in significant rolling.

For inland vessels, the rolling begins, calculating how long it takes to sway from left to right, which is about a few seconds, with a complete cycle taking about 18 seconds. The characteristics of this rolling will vary for each vessel, so the captain must be well-informed. Let's resume the previous lesson, which was mostly about noun explanations. Now, we will explain the dangerous phenomena. The first danger comes from waves hitting the stern of the ship. While large waves coming from the stern may not seem as dangerous, they often hit the cargo hold or the ship's exhaust pipes at the stern. In the early days of container ships' lack of experience, seawater hitting the generator's exhaust pipe caused the entire generator to go overboard, leading to a breakout onboard.

Breakout is a major cause of containers falling overboard, as the more severe cases are when the ship capsizes. Waves coming from the stern have a longer encounter period than rolling waves, making them a major concern. As ships have become larger, long waves have become the greatest fear of large vessels. There is a saying that goes, 'Big ships fear big waves while small ships fear small

waves.' The first concern is serving, which involves surfing and broaching. Broaching is when a ship in a trough valley is hit sideways by a large wave, causing it to capsize. In fact, there are not many cases of ship capsizing due to waves topping over, as most incidents occur when the ship slides down with a negative GM.

Waves hitting the stern may cause the ship to accelerate downward, especially when the ship is at the forefront of high waves, similar to surfing. The ship slides down along the wave crest, which is dangerous due to the impact of seawater, which has a high density and can be harder than wood. Broaching in the trough of giant waves can lead to capsizing or sudden changes in the ship's heading. Sudden changes in the ship's heading, caused by a negative GM, can result in the ship suddenly sliding downwind or tilting at unpredictable angles. These are all phenomena caused by a negative GM. The stability of the attitude generally refers to the stability when the ship is riding on the waves.

The most dangerous position in the ship is when the wave peak is at the stern of the ship because the ship may slide down, significantly reducing its overall stability. Of course, it is impossible to understand this through the text alone. We need to look at dynamic waves in the eleventh lecture to understand when the stability decreases the most. The crucial point is when the wavelength is 0.6 to 2.6 times the length of the ship. A ship's length is 3 times the length of a wave, meaning the ship's length is exactly the length of two waves or half the length of a wave. If the wavelength is half the length of the ship, there will be one wave peak at the bow, one in the center, and one at the stern, resembling the simulation we just saw in the pool.

For a 600-meter wave, a large ship is needed, while a small boat can still be noticed at 240 meters. When the wavelength is twice the length of the ship, the bow is in the trough, the center is at the peak, and only experienced sailors or drawings can help understand this scenario. The reduction in stability is directly proportional to the wave height, as an increase in wave height raises the center of buoyancy, subsequently decreasing the metacentric height (GM).

Waves hitting the stern pose a particular danger as they significantly lengthen the time the ship rides on the wave peak, thus decreasing stability. Returning to the topic, refer back to Lecture 11 and proceed to the Synchronous Rolling Motion. Synchronous rolling motion occurs not only in severe weather conditions but also in relatively mild weather due to the setting of the autopilot.

In the vast ocean, we rely on autopilot for navigation. For instance, if the ship turns right by three degrees, the autopilot automatically turns the rudder to the left to bring the ship back from the right side. As the autopilot turns the

rudder to the left, it generates a torque for leftward rotation. If a wave happens to be riding on the right side, causing the bow to slide to the left, the ship, being pulled to the left by the left rudder along with the force of sliding down from the wave peak, accelerates the left turn. Even though the ship may return to its original heading, it cannot stop and continues to veer left. If the initial deviation was three degrees to the right, with the left rudder and the force of sliding down, the deviation may increase to six degrees to the left. This will prompt the autopilot to increase the rudder angle to the right to counterbalance, but if another wave pushes the ship further left, from the initial three to nine degrees, it causes a continuous swaying motion known as synchronous rolling, gaining momentum. To counter this, besides turning the wheel sharply to resist the swaying, the autopilot settings must be adjusted carefully each time to avoid synchronous rolling. The rolling motion occurs under the condition of heaving due to changes in lateral stability. The ship experiences rocking between wave peaks and troughs as explained earlier.

We said that when this parameter shifts from pitching to rolling, it is called the sway parameter. After several times of longitudinal waves, it seems like we just saw the OOCL ship, its wavelength is equal to the ship's length. When the parameter shifts from pitching to rolling, the sway parameter will be amplified. This is all chance by chance because we said that the waves on the sea are not as uniform as in the laboratory. When swaying horizontally, it involves our lateral stability. At this point, if GM is 0, the ship may swing at a large angle. The variability of the sway stability parameter will change as long as there is wave stability, it's just the magnitude of the change.

It is said here that if the ratio of the period of rolling to swaying is 1:1, then the ship's stability is minimal when it is just riding on the wave peak. At this time, the ship is just about to start swaying. The change in GM is the largest when swaying occurs during each swing is far greater than the wave carrier at other positions. This makes it dizzy, which means that as sailors, we need to calculate the ship's pitching cycle, the longitudinal wave cycle, and the sway cycle are close to a 1:1 ratio, which may greatly reduce GM, avoiding the dangerous synchronized swaying. Negative GM can cause the ship to lose stability rapidly and tilt to the other side. Another possibility is as mentioned earlier, when the ratio of swaying to rolling is 1:0.

5 is just half of it. We can see that pitching is the encounter cycle of waves we just encountered. When our ship moves in waves, the period of pitching and rolling is twice that of swaying. At this point, there will be a sway parameter that is excited intensely by rolling. This is our self-awareness as sailors. What

is the situation of synchronous swaying as mentioned earlier? It is easy to occur when the length of the wavelength of a wave is half or twice the ship's length. The period of the wave and the swaying period is twice the swaying period, or the swaying period is the same as the rolling period. This will cause sway parameters. The main reason is that stability becomes negative.

Remember these two points, it won't be boring on duty at sea, knowing when the ship will cause severe swaying. In general, the waves at sea are not static. When a typhoon comes, waves will come from all directions, and there will be surges too. Therefore, at sea, especially in bad weather, if it is in the open ocean without the influence of terrain, the waves may resonate and have a certain period. Of course, it's not fixed. That is to say, we need to observe the approximate period. Like we mentioned earlier, the three sisters and super waves, the occurrence of the three sisters generally consists of three big waves or nine small waves, eight small waves, or two big waves and seven small waves. You need to observe for at least half an hour to figure out the size.

After calculating, in inclement weather, we need to consider what because the larger the wave, the more the ship's GM decreases, and the stability worsens. So we need to see if our ship is riding on a big wave; the heading is After sliding 20 degrees or 30 degrees, after sliding 20 degrees, is the ship stabilizing quickly or is it, after the ship slides 30 degrees, then, it seems like the ship can't come back and continue to roll to the left for 30 degrees. The ship still stays at 30 degrees until the GM returns slowly, this is a ship with poor GM. At this time, you should not provoke it. So, when the waves are small, take advantage of the big waves.

When the ship no longer continues to slide to the left, use a large rudder or even increase the throttle to turn while the waves are small. This is the safest, but the effect may not be the best. If your ship slides 30 degrees to the left, when it slides to 30 degrees and then immediately returns when the wave passes, it means that your ship has good GM. So what about bulk carriers loaded with iron ore or some iron bars underneath, and ships with especially good GM, you can use the opportunity of big waves to help turn around, but never act recklessly. Observe the wave cycle well. You can't just say, 'I'm the captain. I have a big throttle and a big rudder.' Otherwise, either the containers fall into the sea or the hatch covers fall; in severe cases, flooding in the cargo hold is generally considered. Container ships, although containers fall into the sea, capsizing is rare. Ships with especially good GM, or ships made of particularly poor wood, or ships with particularly poor wood and GM, are very dangerous. The guidance on ship stability will be discussed in the next lecture.