PAC Paper No. 8/2005

PILOTAGE ADVISORY COMMITTEE

Information Note
Study on the Development of an Underkeel Clearance System

Purpose

This note is to report the completion of the Study on the Development of an Underkeel Clearance System.

Background

2. The primary objective of the study was to identify and recommend an underkeel clearance (UKC) system that will allow the port to predict UKC with a greater degree of accuracy than the present guidelines.

3. The Consultant presented the findings of the study at the last Pilotage Advisory Committee (PAC) meeting held on 30 June 2005. Subsequent to the presentation, there were 3 comments received from the members. Two comments considered the existing 10% UKC simple, acceptable and practical, and hence no need to introduce any new systems. One comment proposed that a flexible UKC requirement along the vessel transit passage should be considered, as environmental conditions at various locations were different. The comments were found similar to the stakeholders' views collected by the Consultant during the study. The Consultant has taken into account PAC members' comments in finalizing the study report. A copy of the Executive Summary is attached for members' information.

Conclusion

4. On the suitability of existing UKC systems, the study finds that the effectiveness of the existing UKC systems in the market relies on the flexibility of the port operations to permit last-minute changes in cargo loaded or scheduling delays to allow for bad weather to recede. These flexibilities are not part of the operational norms in Hong Kong because container terminals already work to a very tight turnaround time. Therefore the study does not recommend any UKC system at this stage.

5. The consultation with the stakeholders indicates that most consider the existing 10% UKC simple, acceptable and practical. The existing 10% UKC requirements can meet the industry needs both in terms of safety and adequacy in the foreseeable future.

6. The Marine Department will monitor the technological developments and return to the PAC should new technology or a change in demand requirements warrant changes to our present UKC guidelines.

Planning, Development & Port Security Branch
Planning and Services Division
Marine Department
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Curtin

UNIVERSITY OF TECHNOLOGY

Centre for Marine Science and Technology

DEVELOPMENT OF AN UNDERKEEL CLEARANCE SYSTEM FOR HONG KONG: EXECUTIVE SUMMARY

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1 INTRODUCTION

This report is a summary of the findings from the Consultancy Agreement in relation to the Development of an Underkeel Clearance System in Hong Kong, dated 19th January 2005.

The primary goal of the study was to identify and recommend an Under Keel Clearance (UKC) system that will allow the port to predict UKC with a greater degree of accuracy than the present guidelines, such that optimal level of UKC for deep draft containerships with a summer draft of 14.5m or more calling at Hong Kong is achieved. The particular area of interest was from the berth to the Western Fairway at approximately latitude 22º16'N.

It became clear during the course of the study that further environmental data was required in order to identify UKC needs and to meet these objectives. Therefore a pre-requisite task was to identify the environmental monitoring requirements of the port, to provide an improved scientific basis on which to assess the current UKC system requirements.

A field survey was conducted, comprising measurements of squat, heel and speed taken on 16 deep draft containerships covering 20 passages, during the period 3 - 12 February 2005. The results of the field survey were analysed to assist in identifying and evaluating the factors that determine underkeel clearance of vessels. A resource trawl for existing systems was undertaken, in the form of a desktop study focussing on existing UKC systems and existing UKC guidelines for major container ports around the world. This was followed by two questionnaires sent to identified ports.

Discussions were held with 11 stakeholder groups, followed up with two questionnaires to 15 stakeholders. The first questionnaire was issued prior to conducting the field survey and the second one was sent out after dissemination of the field survey findings. The principal objectives of these discussions and questionnaires was to gather perceptions of UKC issues first-hand. Issues included, but were not limited to, views of UKC requirements, determinant factors, expectations on future UKC requirements/system, willingness to accept less UKC and views on reducing UKC. The outcomes of these discussions provided guidance for determining the priorities and critical factors for UKC system requirements for Hong Kong. A presentation of the preliminary findings was made to the Pilotage Advisory Committee, with additional feedback received from them.

The effectiveness of the study was constrained by the accuracy of the field survey measurements, the availability of suitable vessels for the field survey, and the supply of information from the manufacturers of UKC systems.

2 UKC AND HONG KONG – CURRENT SITUATION

2.1 Vessel operations

Hong Kong is one of the busiest harbours in the world, with impressively fast turnaround times for container ships. It holds a good safety record based on sound operational practices and skilled staff.

Container operations are such that many vessels arrive and depart with less than full cargo load. Ships with actual draft over 13m entering Kwai Chung average perhaps one per day. Ship transits with draft greater than 14m are infrequent. Many of the container ships passing through Hong Kong are post Panamax size and the largest vessels currently servicing the port have LOA around 350m. The expectation is that the newer size vessels (LOA >400m) will be increasingly frequent in the future.

2.2 Present UKC guidelines

The Hong Kong Marine Department currently uses a 10% UKC guideline for the Kwai Chung basin based on PIANC recommendations; it is however, a guide, not a regulation. The minimum declared depth in the basin is 15m. A 10% UKC limit at Lowest Astronomical tide equates to a maximum vessel draft of 14.2m. The number of vessels currently entering and leaving Hong Kong Harbour with draft greater than 14m is very low. With due cognisance of the rise of tide and dredging tolerances, it is evident that the existing 10% UKC guideline has rarely, if ever, been approached.

The UKC guideline for “exposed areas” is 15%.

2.3 Hong Kong environmental conditions

The waterway from the berth to approximate latitude 22º16'N includes the turn from Kwai Chung into the Western Fairway past Tsing Yi and the shallow patch just off Green Island. The basin and its immediate approach is dredged to 15.5m and maintained at 15m throughout.

The western edge of the Western Fairway has charted depths of 15.7m. The Hong Kong Marine Department advise that the Western Fairway and the harbour are mud bottom.

No substantiated data has been obtained on sedimentation rates or dilution of salinity and associated seawater density. In addition to the normal tidal silt movement, the rainfall results in additional silt discharge above the normal tidal suspension and deposition. Furthermore, the high annual rainfall is expected to cause a salinity dilution within the terminal and channel during the wet season, resulting in a lower seawater density and deeper draft for any given vessel.

There is generally very little swell in winter. Summer brings either calm conditions or strong SW monsoon. The monsoon wind is accompanied by swell of the order 2m with 6-8 second wave period. An annual wind and wave summary was produced for a deep water location close to Hong Kong, using a numerical oceanographic model. While the values for wind and wave will be higher than those experienced in the East Lamma Channel and Kwai Chung basin they are indicative of the seasonal trends and the likelihood of effect on UKC. The results indicate that the critical periods are associated with the NE and SW monsoons. While the higher average winds and waves are associated with the NE Monsoon they are not expected to significantly affect the under keel clearance of container vessels in the East Lamma Channel due to the shelter offered by Hong Kong Island. However, during the SW Monsoon, even with the lower average conditions, it is expected that a significant effect on UKC and vessel motions will be noticed North of Lamma Island for both inbound and outward transits. The maximum effect is likely to occur during the turn from the Western Fairway past Tsing Yi into Kwai Chung or the reverse transit.

3 CURRENT PRACTICE FOR UKC REQUIREMENTS AND SETTINGS IN MAJOR PORTS

For additional information regarding UKC criteria and guidelines used by other large container terminals, eight of the top fifteen largest ports in terms of TEUs were contacted. Ports of Singapore, Rotterdam and Hamburg were the only ports to respond in an official capacity.

It is clear even from this limited selection of ports that each has unique UKC requirements and operating procedures. The term “underkeel clearance” is given different meanings and the definition of the seabed may vary from port to port. The UKC may be a simple percentage guideline (e.g. Hamburg) or it might relate to the use of a dynamic measuring system (e.g. Rotterdam). The percentage draft approach, currently used by Hong Kong and elsewhere, varies considerably, from 10% inside Hamburg port, to 40% in Richards Bay. The variation is to a large extent a function of the amount of shelter from waves in the port approaches. Some ports use absolute clearances at and near the berth; this is partially justifiable on the grounds of very low vessel speeds and the absence of wave induced motions.

4 EXISTING UKC SYSTEMS

A search for available Under Keel Clearance Systems/software has shown that six such systems potentially exist. There are also numerous vessel position measuring systems available, though they do not have the capacity to plan traffic movement or vessel loading; they merely provide real –time vessel position data. There has been a disappointing lack of response from potential suppliers to enquiries regarding their products. This lack of information is an impediment to making judgement on UKC system requirements, but it is self evident that for any UKC system to be effective it will require a range of inputs such as:

- Real time water height measurements
- Tidal height predictions
- Real-time and short term forecast wave height, period and directionality
- Vessel draught, speeds along transit path

- Vessel characteristics as they pertain to prediction of squat and wave-induced motions.
- Water density measurements
- Declared depths along transit
- Any variations from declared depths

The potential benefits of the identified UKC systems, as they relate to Hong Kong operations, are set out below.

British Maritime Technology (BMT) Fluid Mechanics Limited

The system could provide pilots with real-time UKC values, which would aid decision making on safety of transit. The system could also provide information of value to vessel loading optimisation and availability of tide and weather windows, if such issues are pertinent.

CADET – Coastal and Hydraulics Laboratory

Whilst this system is intended more for channel design than operational UKC optimisation, it could be used to aid decision making on future refinement of UKC guidelines, through its mainly predictive capabilities. The system does not appear to have the capacity for input of real time environmental data.

Keelvis – MetOcean Engineers and Curtin University

The system would provide pilots with real-time UKC values, which would aid decision making on safety of transit. The system could also provide information of value to vessel loading optimisation and availability of tide and weather windows, if such issues are pertinent. It can be tailored to meet the specific requirements of the Hong Kong Marine Department.

Navigation Dynamics – Simple UKC calculator

This system provides partial automation of calculations usually performed by the prudent mariner, and presents the information in a user-friendly manner. It is overly simplistic for application to Hong Kong.

DUKC and DUKC-Q – O'Brien Maritime Consultants (OMC)

The DUKC system could provide pilots with real-time UKC values, which would aid decision making on safety of transit. The system could also provide information of value to vessel loading optimisation and availability of tide and weather windows, if such issues are pertinent.

The Q-DUKC system could be used as an aid to long term planning of deep draft vessel schedules with respect to tide and water density, but its value is restricted by the inability to include the effects of real-time wind and wave conditions.

DMAX

There are no details of the system provided. Commercial availability would have to be determined prior to considering this system any further.

Vessel position measuring systems

There is a host of position measuring systems that aid navigation and UKC estimation, though they are not full UKC systems; they simply provide more accurate positional information. One of the more useful products is QASTOR. This system can aid with decision making on UKC issues by linking sub-metre positional accuracy with depth sounder and tidal information to provide UKC-related path plots on an electronic display. It is not a full predictive tool, nor does it add to the information directly available from depth transducers and tide gauges; it merely presents the data in a different format. As such it is of limited benefit to the needs of Hong Kong.

Summary of UKC systems

The most effective systems require that port operations are sufficiently flexible to permit:

- last-minute changes in vessel cargo load and/or
- extension of time alongside (outgoing) or standing off (incoming) to wait for short duration environmental conditions (tide height, bad weather) to improve.

These options are not readily available for Hong Kong harbour because it already works to a very tight turnaround time; therefore much of the benefit of such a system is lost. If this were not the case, then the BMT capability, the O'Brien DUKC and the Curtin/Metocean KeelVis systems would warrant further consideration.

5 HONG KONG FIELD SURVEY

5.1 Objectives

The main objective of the field survey was to calculate the change in Dynamic Draft Change (DDC) due to dynamic effects such as squat, ship motions, heel in turn and wind-induced heel of target ships entering or leaving Kwai Chung via the Western Fairway.

This would then allow us to assess the important factors governing real-time UKC for this transit. The Dynamic Draft Change (DDC) is defined as the maximum change in draft compared with the static conditions as measured at the berth.

The particular area of interest as specified by the Hong Kong Marine Department was to be the turn from the Western Fairway past Tsing Yi into Kwai Chung. After studying the topography it was found that the shallow patch just off Green Island is also an area of concern for UKC. Therefore efforts were made to obtain data for the entire passage from the berth to approximate latitude 22º16'N.

The target ships as specified by the Hong Kong Marine Department were to be those with the largest possible summer draft, preferably exceeding 14.5m.

5.2 Methodology

The field survey provided squat and heel data on 16 deep draft containerships, covering 20 passages of which 17 passages provided good quality data return. The passages were a combination of both inward and outward transits between approach route south of Tsing Yi and the adjoining turning basin at Kwai Chung container port.

The measuring equipment comprised 3 Trimble 5700 GPS receivers on-board ship and one GPS 5700 receiver on-shore. Prior to starting the on-board measurements a shore-based receiver was located at the Kwai Chung Marine Traffic Control Station balcony.

For each of the 20 transits, raw GPS data from the three receivers and base station was analysed to calculate the downward sinkage of each of the three receivers through the entire transit, as compared to the stationary readings taken at the berth, with allowance for changes in tidal height. After much optimisation of the software, sufficiently accurate results were obtained for 17 of the 20 transits.

The geometry of the individual ship was then used to calculate the Dynamic Draft Change (DDC), defined as the maximum change in draft compared with the static conditions as measured at the berth. This quantity was calculated at the four extremities of the vessel.

Heel angle was also output through the transit. The term "heel" is used here to describe the instantaneous angle of rotation about the longitudinal axis of the vessel relative to a zero datum taken when the vessel is at the container berth.

5.3 Results

The maximum sinkage was 0.77m averaged over all the transits, with a maximum of 1.7m. Very little change in trim was generally noted. As a percentage of draft, the average maximum sinkage for all the vessels was 6.2% of the draft, with the greatest value being 11.8%. Three of the seventeen transits produced vertical movements in excess of 10% of the draft. The two ships experiencing the largest sinkage as a percentage of draft were those with the largest drafts.

The maximum heel angle was 1.2º on average, but reached up to 3.5º.

The instances of greatest DDC were recorded when the vessels were travelling in excess of the harbour speed limits – usually just as the vessel was at the change of speed limit.

It was found that the critical points in the vessel transit with respect to DDC are not in the basin. They are at the turn into the Kwai Chung approach past Tsing Yi, and at the shallow region on the west of the Western Fairway.

The weather conditions during the trials were benign, so it seems inevitable that DDC of greater than 10% would be experienced by ships entering or leaving Hong Kong harbour during periods of high or even moderate swell conditions.

5.4 Critical factors affecting UKC

When assessing grounding risk, it must be realised that the final underkeel clearance depends not only on the sinkage at various points on the ship, but also on the static trim of the ship. Most ships are trimmed down by the stern in the static condition, which makes their stern more vulnerable to grounding. There is insufficient environmental data available in order to make quantitative statistical predictions of grounding likelihood.

The Dynamic Draft Change (DDC) is not dominated by any single factor - squat, heel in turn, heel due to wind, and wave-induced motions all contribute significantly. Heel during turn, and roll motion whilst transiting the fairway were found to be major factors affecting DDC.

Most of the heel-induced sinkage was due to oscillating motion, with steady state heel angles usually well below two degrees. The period of oscillation was approximately 20-30 seconds. The cause of the oscillating heel angle cannot be identified with certainty, but it is possibly due either to rudder movements or to long period swell or seiching. It was present in the transits of most vessels. The south-west monsoon season is known to produce significant south-westerly swell, which is expected to have a noticeable effect on the motions of the ship during the transit from Green Island to Kwai Chung. The effect of this swell on DDC should be investigated.

The analysis implied that a reduction of ship speed would reduce the DDC in some instances. The trials results indicate that a one knot reduction of ship speed could reduce DDC by approximately 1%, though the benefit would be masked by other factors described above.

6 STAKEHOLDER VIEWPOINTS

Stakeholder views were canvassed both before the field survey was conducted and after the findings of the survey had been issued. Feedback was also obtained from the Marine Department Pilotage Advisory Committee. There was a 45% response rate to the first questionnaire and effectively a 100% response rate to the second questionnaire through collective responses via the various stakeholders’ associations.

Of the initial stakeholder responses, a minority singled out safety as a critical factor. It is possible that other stakeholders may have assumed that safety was a pre-requisite for any UKC system or guideline. There was no consensus on the contributing causes of Dynamic Draft Change. Vessel speed and swell were mentioned on occasions.

Several operators stated that the current 10% guideline was not restrictive, but a majority considered 10% too high. Several suggested an 8% guideline, possibly with a ceiling of 1 to 1.5m for very deep draft vessels. Two stakeholders cited the need for scientific data to support any guidelines. None of the stakeholders reported any UKC incidents, nor any perceived likelihood of such an event occurring, with several providing data that showed their vessels were not constrained by the existing guidelines.

All operators declared an expectation of operating larger vessels in the near future, with draft 15m or greater and length approximately 400m.

Prior to the field survey there was lack of support for the introduction of a complex UKC system, on the grounds of unnecessary administrative and operational burden. The majority preference was for a simple guideline, either a percentage of draft or a combination of a percentage and an upper absolute ceiling of between 1m and 1.5m.

Whilst this view still prevailed after the findings of the field survey were released, some stakeholders suggested a more complex system should be considered if it could be implemented satisfactorily and lead to cost benefits. Maintaining port competitiveness was seen as a critical issue.

The view that the present UKC guidelines are too restrictive is not supported by the field survey conducted as part of this consultancy. The suggestion that an absolute ceiling be placed on draft is not supported by scientific understanding of UKC effects – many contributing factors increase in proportion to vessel size.

7 NEEDS ANALYSIS FOR HONG KONG UKC SYSTEM

The critical factors in identifying the needs for a UKC system in Hong Kong are:

- The harbour operations utilize rapid turn around times and sailing schedules that change at short notice. This makes it very difficult to take advantage of high tides and weather windows.
- The field survey provides scientific evidence that roll motion is a major factor in DDC.
- The field survey demonstrates that the Dynamic Draft Change (DDC) results from a combination of many factors - squat, heel in turn, and wave-induced motions all contribute significantly.
- The critical points in the vessel transit with respect to DDC are not in the basin. They are at the turn into the Kwai Chung approach past Tsing Yi, and more significantly at the shallow region on the west of the Western Fairway.
- There is reluctance from container ship and terminal operators to introduce a complex UKC system; simple guidelines were preferred unless a cost benefit could be demonstrated.
- The absence of environmental data restricts the needs analysis.

There are two distinct paths that can be followed with respect to underkeel clearance:

- Simple guideline
- Semi-automated computer system

7.1 Simple guideline

Within this approach are two sub-options:

Fixed absolute clearance

The circumstances for Hong Kong harbour are such that the DDC is partly a function of vessel squat, which is a function of vessel size. Therefore there is no scientific justification for adopting a fixed clearance. Other ports work to such a guideline, but it should be borne in mind that their DDC might not be squat-dependent, or their guidelines might be scientifically unsound.

Percentage of vessel draft

The advantages of such a system are that it is easy to understand and implement, and it has a reasonable scientific basis. The difficulty with adopting a percentage guideline lies in selecting a value that allows maximum cargo load without impacting on safety. It is not possible to arrive at a figure deterministically because estimating grounding likelihood due to vessel motions is a stochastic process, requiring judgements to be made on an acceptable probability of grounding – it is not possible to be completely certain that a grounding will not occur, because an unexpectedly large wave occurring at low tide might, one day, be encountered by a deep draft vessel whilst transiting the channel.

7.2 Semi-automated computer system

The available systems reviewed require that port operations are sufficiently flexible to permit:

- last-minute changes in vessel cargo load and/or
- extension of time alongside (outgoing) or standing off (incoming) to wait for short duration environmental conditions (tide height, bad weather) to improve.

These options are not readily available for Hong Kong harbour because it is so busy; much of the benefit of such a system is then lost.

If it were possible to reduce UKC by reducing vessel speed, then a semi-automated system might be capable of calculating maximum vessel speed for a given vessel under prevailing weather conditions. However, the circumstances of Hong Kong are unlikely to permit this. The field survey results show that in Hong Kong the UKC is a function of both vessel motions and speed-dependant squat; in the outer approaches the DDC is strongly dependent on roll motion, which may be wave-induced. Similarly, a reduction in vessel speed near the channel turn may reduce the DDC due to heel in turn, but that is not necessarily the critical UKC point in the transit. There is no certainty that a reduction in vessel speed will reduce the UKC at the critical point(s) in the transit, and it is possible to end up with a vessel that is loaded too heavily to make the transit safely. The only options then are to either wait until the weather conditions subside, tide height increases or, for a vessel at dock, to offload cargo. None of these options appears to be workable for Hong Kong in the current operating environment.

7.3 Other considerations

The UKC in the immediate vicinity of the basin can be less than elsewhere in the vessel transit, but this does not really have any beneficial impact on port operations because the depths at the turn and on the west of the Western Fairway are essentially the same as in the basin itself. If these two areas could be dredged or avoided then there would be some advantage in allowing a lower UKC at the basin compared with at the turn and the outer approaches, without compromising safety.

The field survey provides evidence that the basin does not have to be dredged to the same depth as the channels. It may be possible for cost savings to be made in future by optimising the harbour dredging so as to make the probability of grounding constant along the vessel transit.

8 RECOMMENDED OPTION FOR HONG KONG UKC SYSTEM

UKC systems require that port operations are sufficiently flexible to permit last-minute changes in vessel cargo load or scheduling delays to allow for bad weather to recede. These options are not readily available for Hong Kong harbour because it already works to a very tight turnaround time ; much of the benefit of such a system is then lost. Therefore a UKC system is not recommended at this point in time.

A two-staged approach is proposed. The first stage is to implement a data collection program. The second stage is to review the UKC guidelines in light of the acquired data, then reconsider installation of a dynamic UKC system.

8.1 Stage 1: Data collection

It is recommended that the following factors be quantified by environmental measurements, as these impact directly on the vessel UKC when calling at Kwai Chung Harbour:

- Conductivity, temperature and pressure (CTD) field measurement studies during the wet season to determine salinity/density dilution and likely effect on UKC due to freshwater influx from the Pearl River outflow.
- Wind and Wave Measurements - Data for these parameters should be obtained during the SW Monsoon, so as to identify the causes of the DDC and to aid extrapolation of DDC measurements and predictions.
- Sedimentation - The rate of sedimentation of the harbour and approach channels should be determined to provide a value for the change in UKC over a period of time. The value of this data in determining maintenance dredging requirements and specific locations requiring additional maintenance dredging cannot be overstated.

It should be noted that other parties might already have collected some or all of this data; a desktop study of available data may be an economical solution.

An extension of the field survey to include DDC measurements during the SW monsoon should also be considered.

8.2 Stage 2: Review of guidelines

On completion of stage 1 the acquired data should be analysed in order to better understand the underlying causes of the DDC measured during the field survey. This could assist in a refinement of the UKC guideline, possibly in the form of a change in the percentage, or a variation of percentage guideline along the vessel transit. The option of installing a semi-automated UKC system might also be reviewed at this point.