Strainstall

Taking the load off: technology options, costs and opportunities for the implementation of container weight verification

An objective assessment of the key issues facing regulators and for port and terminal operators in the implementation of robust and cost-effective solutions for accurate, repeatable, and seamless integration of weight verification technology

Executive summary

The need for accurate container weight verification as a core function of port and terminal operations and vessel stowage plans is now widely accepted throughout the shipping industry, not least due to the recent series of high profile vessel losses linked to the mis-declaration of container weights. But while there is a broad consensus on the imperative for action, there remains considerable debate about the nature of the governing regulation required as well as about the many measurement technologies available for implementation.

This paper sets out to provide an objective and positive contribution to this debate, firstly by providing assessment of the strategic regulatory challenge, and secondly by setting out a framework for port and terminal operators to select the technology that is most appropriate to their current needs and future aspirations for automation and integration of operations.

On regulation, Strainstall recommends that in order to provide the maximum scope for future innovation in both port operations and measurement system products, regulations should be framed in technology-neutral terms, defining required outcomes rather than the specific means of measurement.

On implementation by port and terminal operators, the framework presented in this paper clearly shows that there is no one single 'silver bullet' technological solution appropriate to all; yet there are key factors that should be considered to ensure that future efficiency, return on investment and other operational improvements are not unduly constrained. Wherever possible, however, Strainstall recommends that those implementing container weight verification do so by adopting solutions that allow weight to be measured at or close to the twist-locks used for lifting. This approach both provides a universal means of recording the weight of individual containers, while also allowing for automatic calculation of centre of gravity.

1.0 INTRODUCTION

Why the world needs accurate container weight verification

The international shipping industry stands on the verge of one of the most significant changes since the advent of containerization. For many decades cargoes have been shipped based on vessel stowage plans and port operations, each of which are predicated on the individual weight of each container as declared on the advance booking information provided by shippers. These pre-declared weights can vary significantly from the actual mass of the cargo transported, and container weight mis-declaration is endemic. That this leads to unacceptable risk to the lives of seafarers and port operatives is clearly apparent, as is the potential for environmental damage resulting from critical incidents. The losses of the MV Napoli in 2008 and the MV Deneb in 2011 in particular, have both been linked in the media and elsewhere to mis-declared weights, as have numerous cases of container stack collapse. The need for a robust system of checking and verifying the weight of each container throughout its transit from shipper to receiver is therefore now demanded by public and political opinion. It is now almost universally accepted by the industry too.

In addition to this public demand, many recent technological developments mean that the accuracy and robustness of potential weight verification solutions is far better now than was previously the case. Opportunities for the integration and automation of operations have also arisen that can be facilitated through the implementation of such systems.

While there is broad consensus on the need and opportunity for action, the precise nature of the requisite regulation and its technological implementation remains the subject of much debate. For this reason, we have set out in this paper to examine the technology options, costs and opportunities for the implementation of container weight verification. In doing so, our aim is to help inform the debate among regulators about the framework that will govern this new system. In addition to this, we aim to provide port operators with the means with which to evaluate the many technological options available to them for container weight verification, while highlighting some of the potential additional opportunities that they may facilitate.

2.0 STRATEGIC IMPLEMENTATION ISSUES

2.1 Future regulation – and why the principle of technology-neutrality is crucial

Based the Strainstall's extensive experience in the development of load measurement systems – and also as evidenced by the review of current technologies presented in the next section – it is clear that there are many currently available systems offering complementary cost, benefit and ROI profiles in different usage contexts. In short, it appears that there is no single 'silver bullet' technology that will be appropriate to every port and every cargo type. Moreover, as container weight verification is at an early stage of implementation, there must surely remain scope for further technological innovation. ***For these reasons it is crucial that the shipping industry supports regulation which is expressed in technology-neutral terms.***

Technology neutrality is a widely accepted principle of effective regulation. In the case of container weight measurement systems, rather than prescribing use of a particular technology type, regulations should instead specify the outcomes required (for example: measurement accuracy, repeatability, speed and acceptable calibration methods). This principle is extremely important as it will enable port operators to select the measurement technology that is most appropriate to their own operations while meeting the practical objectives of regulation. In addition, it promotes an environment that facilitates future innovation by the load measurement industry as manufacturers will be free to develop new technological solutions that meet regulatory compliance while offering additional benefits of reduced cost or additional functionality. Finally, such an approach will enable port operators to develop new value-added services based on their chosen weight verification system.

2.2 Implementation considerations for ports and terminals

The implementation of container weight verification technology presents a unique set of challenges and opportunities for port and terminal operators depending on the specific mix of installed equipment and operational processes. The following is a non-exhaustive check-list that we recommend should be considered:

- **Compatibility with installed lifting equipment:** given the very high capital cost and long service life of port equipment, container weight verification solutions should be capable of retro-fitting into existing assets.
- **Maximizing return on investment:** Ideally by exploring opportunities for synergies in the integration and automation of port operations, the benefits of container weight verification may well exceed the required investment for implementation.
- **Measurement accuracy, repeatability and calibration requirements:** these are likely to be defined by future regulation and/or specific operational needs, ranging from simple excess load warnings to regulation-compliant weight verification; they will strongly influence the ideal selection of measurement technology.
- **Downstream and upstream 'smart port' process integration:** the ability to capture real-time container weight verification data will provide potential opportunities for smart port management systems – these may include the implementation of new revenue streams from the

handling of out-of-specification consignments where declared weights deviate from actual values beyond regulatory limits.

- **Required operator training/up-skilling of roles:** many current mechanical handling roles are either low or semi-skilled – the addition of container weight verification processes is likely to have an influence on this depending on the mode of implementation; if smart port management systems are implemented, the change may be completely transparent and may not affect manual job functions.
- **Stowage planning:** container weight verification implemented only at the point of final loading is likely to present significant operational challenges to the processing of out-of-specification containers and, consequently, may cause delays to shipping. Weights will need to be verified at an earlier stage in processing – perhaps on entry to as well as exit from the port – in order to enable stowage plans to be based upon verified data.
- **Opportunity for CoG/eccentric assessment:** some container weight measurement technologies may also be capable of providing centre of gravity, which could be of use in improving the safety of lifting and stacking operations.

It is important that all challenges and opportunities are evaluated in each specific case and in the light of the impending regulatory framework. Failure to take this approach – in effect, seeking merely to find the lowest initial cost solution to meet future container weight verification regulation – may well lead to a less favourable outcome with regard to long-term return on investment potential than would a more integrated approach to integration.

3.0 SELECTING THE RIGHT CONTAINER WEIGHT VERIFICATION FOR EACH APPLICATION

In this section, a logical process is provided through which port and terminal operators may select the container weight verification technology most appropriate to their specific requirements. In each case, the technology solution selected for implementation is likely to be heavily dependent upon the existing infrastructure and operations of the port.

3.1 Where to weigh?

The following is a non-exhaustive list of some of the options that might be considered:

- **Weighbridges at port road entry/exit gate:** potentially high cost but easy to implement – and potentially very significant challenges in establishing the true tare weight of the vehicle and in differentiating the weights of multiple container loads. Possibly an attractive solution in terms of allowing shippers to ensure that their declared weights are correct prior to shipment to the port, thus avoiding the cost and disruption of mis-declaration penalties.
- **Reach stackers and fork-lift trucks:** potential for relatively low cost weight measurement to be integrated into vehicle systems – e.g. inferred from hydraulic pressure. Likely to be of lower accuracy than direct measurement systems.
- **RTGs and straddle carriers:** good opportunity for the implementation of direct weight measurement of individual containers within the port environment but before final vessel loading operations. These systems will in many cases provide the most versatile approach to the implementation of container weight verification. In the early stages of implementation in particular, RTG and straddle carrier installed weight measurement systems may offer a highly flexible solution with minimal disruption to existing port operations and container logistics.
- **Ship-to-shore cranes:** as the final point of departure and the first point of entry for imported containers, weight verification at this stage is highly desirable. For out-going containers, practical operational constraints will require that this process is one of confirmation – weights will need to have been verified at an earlier stage in port operations to avoid any disruption to loading. For incoming containers, the ship-to-shore crane is an ideal location for weight measurement, as any overweight container on an incoming ship is a problem that requires careful attention. In extreme circumstances it may be the case that a decision is made that a container cannot be unloaded safely, while in other more marginal cases it may be unloaded and segregated for handling as a non-compliant load (subject to appropriate additional processing fees). The aim of container weight verification is that an overweight container is NEVER loaded onto a vessel in the first place; the ship-to-shore crane is thus ultimately the ideal location for ensuring future regulatory compliance.

3.2 Direct versus indirect methods

As outlined above, some of the potential locations of container weight verification are based upon direct measurement of container weight while others are inferred indirectly from gross vehicle weights, hydraulic fluid pressure or from the loads of multiple containers (e.g. in twin lifts). While many indirect methods may not provide sufficient accuracy and resolution to meet future regulations, they can offer a cost-effective means of approximate weight verification for purposes such as equipment overload protection. ***For future regulatory compliant applications, direct***

measurement as close as possible to the point at which the container is lifted will offer the most accurate as well as the least operationally disruptive solution. It follows that measurement integrated with twist-lock systems is perhaps the most attractive location for applications where accuracy is of paramount importance.

3.3 Direct measurement systems based on strain gauge and fibre optic technology

There are two commonly applied categories of direct measurement technologies for container weight verification. Strain gauge technology is used almost universally in weighing applications ranging from load cells and pins through to twist-lock based systems. The alternative, fibre optic systems, tend to be used primarily on twist locks. Given good quality design, the accuracy of both measurement technologies is broadly similar.

Considerations that should be applied in specifying technologies for container weighing solutions include:

System robustness: while measurement solutions integrated with twist-locks offers perhaps the most attractive approach to accurate container weight measurement, the need for robustness here is significant. It is widely accepted that the most abused part of a crane is the spreader mechanism, which is exposed to numerous impact loads can be significantly in excess of static load of the container being lifted. ***Any measurement solution must be sufficiently robust to withstand these repeated loading cycles and excess loads while also maintaining its calibration accuracy.***

Integration with consumable or non-consumable parts: many direct load measurement solutions are integrated with specially manufactured or adapted twist-locks. This offers an excellent means of measuring weight directly at the four corners of each container as it is lifted, enabling calculation of container centre of gravity location as well as overall mass. However, the twist locks themselves have a service life which is typically less than that of the measurement technology. ***Next-generation solutions can integrate measurement into the twist-lock collar – thus enabling the load sensing components to exceed the life of each twist-lock.***

Accuracy and calibration requirements: as yet, the regulatory requirements for certification have yet to be defined but in practice, a range of methods are likely to be offered. Given the complexity of the mechanical handling systems involved, however, ***load testing of the lifting equipment on which weight verification systems are installed is likely to be the most accurate and repeatable means of calibration certification.*** In most cases this will be achieved through the lifting of an evenly loaded container (hence CoG at its horizontal centre) whose weight has been previously established and validated on a calibrated weigh bridge.

Ease of mechanical integration: the ability to retrofit measurement technology into existing equipment without impacting upon operational performance or requirement for significant adaptation is essential. ***Measurement solutions should wherever possible replicate or integrate with existing standard parts of the lifting system to which it is applied.***

Data integration opportunities: many systems will offer an immediate, cab level read-out of container weight. While this may well be sufficient for future regulatory compliance, we believe that significant benefits will accrue from the integration of this data with other port management systems. ***It is important to consider the full synergistic opportunities for 'smart' port management systems when considering the selection of container weight verification technology.***

Table 1: Summary of technical characteristics, strengths and weaknesses, accuracy and cost of strain gauge and fibre optic measurement technologies that are capable of integration with most container lifting equipment types

	Technical description	Strengths and weaknesses	Nominal accuracy	Relative cost of implementation
Load cells and pins integrated at single point within lifting equipment	Strain gauges integrated into key load bearing components of the lifting equipment.	Simple to implement and extremely robust. Particularly effective for overload protection. Unable to distinguish individual containers on multiple lifts.	90% - 95%	Extremely cost-effective solution where additional accuracy and resolution of CoG is not required.
Strain gauged twist-locks	Strain gauges integrated into each of the spreader twist-locks (four for each container lifted).	Extremely robust but requires at least four sensors. Allows calculation of container CoG.	99% - 99.5%	Medium: life of strain gauges is limited to that of each twist-lock
Fibre-optic systems incorporated into twist-locks	Fibre optics sensors integrated into each of the spreader twist-locks (four for each container lifted).	Requires at least four sensors. Allows calculation of container CoG. Potentially less robust and higher cost than strain gauged twist-locks.	99% - 99.5%	Medium-high: life of fibre-optic sensors limited to that of each twist-lock.
Strain gauged twist-lock collars	Strain gauges integrated into the collar of each of the twist-locks (four for each container lifted).	Extremely robust and cost effective. Allows calculation of container CoG.	99% – 99.5%	Low-medium: extended life of strain gauges as not directly integrated with consumable parts.

4. SUMMARY OF RECOMMENDATIONS & CONCLUDING REMARKS

While the nature of the required governing regulation remains a subject for continued debate, the imperative to implement container weight verification throughout the global shipping industry is now widely accepted. In this paper the perspective of Strainstall as a leading multi-industry developer and provider of load measurement technology has been provided based on the company's extensive experience of load measurement in ports and terminals as well as many other applications from marine engineering to construction. The following is a summary of our recommendations:

4.1 **Development of governing regulation:** It is clear from many other industries that technology neutral regulation is the only reliable means of delivering compliance without constraining future innovation. If regulation is expressed in terms of the required outcomes rather than the technology with which they must be delivered, competitive action within the load measurement industry, ports and terminals will act to spur future developments aimed at delivering additional benefits such as increased automation and process integration along with opportunities for reduced costs.

4.2 **Direct versus indirect weight measurement:** Production level implementation of container weight verification should be based on direct methods capable of accurately resolving the mass (and ideally the centre of gravity) of individual containers. Indirect methods such as vehicle weigh bridges may well be used as a second tier of measurement, for example, by shippers wishing to establish container weights prior to despatch.

4.3 **System selection considerations:** There is no single 'silver bullet' technology solution appropriate to all situations. Key criteria for container weight verification technology selection include:

- **System robustness** – must be sufficiently robust to withstand these repeated loading cycles and excess loads while also maintaining its calibration accuracy.
- **Measurement at or close to the point of lifting** – should be integrated with the twist-locks or ideally, as a next-generation solution integrated with the non-consumable twist-lock collar – thus enabling the load sensing components to exceed the life of each twist-lock.
- **Accuracy and calibration requirements** – load testing of the lifting equipment on which is likely to be the most accurate and repeatable means of calibration certification.
- **Mechanical integration** – measurement solutions should wherever possible replicate or integrate with existing standard parts of the lifting system to which it is applied.
- **Data integration opportunities** – it is important to consider the full synergistic opportunities for 'smart' port management systems when considering the selection of container weight verification technology.

Consideration of the above criteria using the approach described in this paper will help to enable port and terminal operators to gain the maximum overall return on their investment while achieving compliance with a future technology-neutral container weight verification regulatory framework. Implementation based on this approach will not only provide a potentially much safer and more environmentally sustainable future for the shipping industry, but will also act as a key enabler for a much higher level of process integration and automation.

ABOUT STRAINSTALL MARINE

Strainstall Marine is a member of the James Fisher & Sons plc group. The company is a broad-based engineering business, specializing in load measurement and sensor based safety technology. Based in Cowes, Isle of Wight, it has long been associated with the manufacture of standard and bespoke load cells, and has over 45 years' experience in assisting industries to operate safely by ensuring that structures, equipment and infrastructure are safe to use. Through continuous innovation and development, Strainstall has a range of world-class monitoring technologies that continuously monitor physical and performance parameters such as load, stress, temperature, acceleration, pressure and displacement for industries ranging from the global shipping and marine engineering sector to construction and renewable energy. For more information see www.strainstall.com.