ANTHONY NADALIN, TMHE

GOING STEADY

TOYOTA SHARES MANY LONG-LASTING RELATIONSHIPS WITH ITS CUSTOMERS – DUE IN NO SMALL PART TO ITS SYSTEM OF ACTIVE STABILITY HELPING EVERYONE KEEP THEIR FEET ON THE GROUND

Today's global, round-the-clock logistics operations demand safe, productive, cost-effective materials handling equipment. Large, heavy and relatively fast, lift-trucks must move valuable goods safely and efficiently while travelling over a variety of surfaces and sharing the workplace with other vehicles and pedestrians. At the same time, tougher economic conditions mean workplace safety can be a matter of life and death – literally – not just for employees but also for businesses with tight budgets and little margin for error.

It's no surprise then that safety is a top priority for lift-truck purchasers, with market research by Toyota Material Handling Europe (TMHE) indicating that up to 60% of lift-truck customers list safety as their single most important buying criterion. As well as being socially responsible, there are bottom-line benefits of choosing equipment with superior safety features. Lower insurance rates and damages costs for goods and property, fewer repairs and less production time lost due to workplace accidents are all powerful incentives to factor safety into the total cost of ownership. Promoting safer workplaces is also on the agenda of many governments.

When handling loads at height or making sharp turns at speed, safety becomes a top priority. Improving stability is the way forward

Numerous issues come into play when discussing lift-truck safety. Two of the most important are vehicle stability and control of the load. Statistics published by OSHA found that the single largest cause of fatal accidents was vehicle tipover. Falling load material also caused a notable number of fatalities.

As a leading manufacturer of industrial trucks, Toyota created the world's first active safety system for lift-trucks when it launched the Toyota system of active stability (SAS) in 1999. An industry first, and still unique in the business, SAS technology draws on Toyota's leadership in developing automotive safety systems. Developed by more than 30 dedicated engineers over a two-year period and protected by 126 patents, SAS dynamically manages truck stability, protecting drivers, goods and the truck itself.

SAS is based on three types of components – a controller, 10 sensors and three actuators – which make up a dynamic system that continually monitors the lift-truck's operations and automatically takes protective action when necessary. Lateral stability is addressed by the swing lock cylinder and turn speed control functions, while the rear tilt speed control and front tilt angle control manage mast and load stability. The auto levelling and active steering synchroniser functions help operators to drive and handle loads with more confidence and comfort.

By helping to prevent accidents, SAS can help companies save money in terms of driver, insurance and repair costs – areas that can collectively account for more than 70% of the lift-truck's lifetime cost. SAS also provides a more comfortable and confident driving experience to enhance operator productivity, helping businesses to enjoy greater returns on their personnel investment.

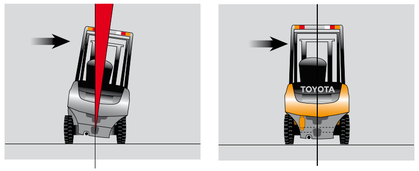
Forklift stability

To understand how SAS works, one starts by considering the stability area – the lift-truck's footprint. As long as its centre of gravity remains within this stability area, the lift-truck remains stable. If the centre of gravity moves outside the stability area, the truck becomes unstable and can tip or turn over.

Typically the rear axle of four-wheel lift-trucks is designed to pivot freely. This enables them to cope with rough or uneven driving surfaces but also gives lift-trucks a triangular – and therefore narrower – stability area. On Toyota trucks with SAS, a patented system of sensors informs the SAS controller when the truck is (potentially) becoming unstable, and the hydraulic swing lock cylinder in the rear axle engages, instantly transforming the lift-truck's stability area from a triangle to a rectangle. By greatly expanding the area in which the centre of gravity can move before it becomes unstable, SAS enhances the truck's lateral truck stability and substantially reduces the risk of lateral overturn accidents.

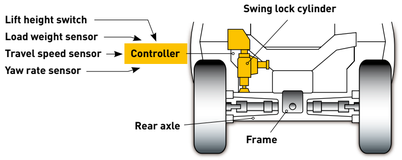
The SAS swing lock cylinder is activated automatically under two conditions: excessive lateral acceleration and/or yawing. When the lift-truck makes a turn, centrifugal force is generated and gravitational acceleration works in a crosswise direction to destabilise the vehicle. Yawing – felt by the operator as a rolling motion – is the twisting or oscillation of the truck around a vertical axis. The swing lock cylinder activates automatically as soon as lateral acceleration and/or the yaw rate exceeds specified values in order to maintain the truck's stability.

Toyota chose the swing lock cylinder as the best solution for promoting stability in four-wheel



Without SAS **With SAS**

LEFT: **When it senses instability, SAS instantly engages the swing lock cylinder to stabilise the rear axle, creating the lateral stability needed to help reduce the risk of tipovers**



LEFT: **SAS uses separate sensors to monitor load height and weight, truck travel speed and yaw rate (angular speed) to help ensure that all four tyres remain on the floor**

Swing lock cylinder

In four-wheel forklifts, the centre pin in the rear axle supports the lift-truck's weight, creating a triangular stability area. Toyota's four-wheel forklifts with SAS have a swing lock cylinder installed between the rear axle beam and the frame that can temporarily stop the swinging motion of the rear axle to create a more stable stability rectangle.

The swing lock cylinder is built with two oil-filled chambers connected by a solenoid valve that controls the flow of oil between the two chambers. When the oil flows from one chamber to the other, the cylinder is free to move in response to the swinging motion of the rear axle. During normal operation the solenoid valve is 'Off' and the swing lock cylinder extends or contracts in response to the swinging motion of the rear axle. When SAS sensors detect truck instability, the SAS controller activates the solenoid valve, preventing the flow of oil and locking the rear axle to stabilise the truck.

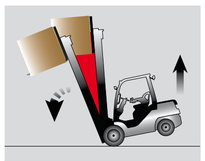
Sensors:
1 Fork height switch
2 Tilt angle sensor
3 Front tilt limit switch
4 Rear tilt limit switch
5 Load sensor
6 Tilt knob switch
7 Vehicle speed sensor
8 Steering wheel angle sensor
9 Tyre angle sensor
10 Yaw rate sensor

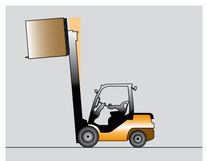
Actuators:
11 Swing lock cylinder
12 Hydraulic oil control valve
13 Steering synchroniser solenoid

14 **The SAS controller**

Tilt angle control

The SAS active mast function controller improves vehicle stability by controlling the mast's front tilt angle and limiting the mast's rear tilt speed, depending on the load and lift height. Six sensors monitor the mast height and load weight and activate the appropriate actuators to reduce the front tilt angle and rear tilt speed. This reduces the risk of falling loads and truck tipovers that might otherwise occur if the operator inadvertently tilts the mast too far forwards or tilts it backwards too quickly.





SAS active mast front tilt angle control monitors the mast height and load weight. It automatically overrides the operator's manual controls to limit forward tilt when needed, decreasing the chance of dropped loads or forward tip-over

trucks after examining a number of methods for maintaining the centre of gravity within the stability area. Other possibilities considered included reducing travel speed, increasing the turning radius and reducing the weight of the truck. Although each of these offered some benefits, they also brought inherent disadvantages including lower productivity, the need for larger aisle widths and incompatibility with load handling. Ultimately Toyota chose the swing lock cylinder for its four-wheel trucks, then set about looking for a stability enhancement solution for three-wheel trucks where the swing lock cylinder was not an option. Using its characteristic kaizen (continuous improvement) approach to product development, Toyota's engineers looked at factors affecting stability in three-wheel models. Aware that travel speed can affect lateral stability, particularly when cornering, they settled on an SAS function that intelligently optimises speed when turning corners. For three-wheel Toyota models such as the new Toyota Traigo 48, the SAS speed reduction when cornering feature overrides manual controls by limiting the drive speed when turning. Sensors monitor the truck's stability and the controller optimises its speed to protect drivers – even when they misjudge their speed or the sharpness of a turn.

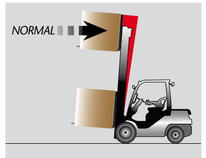
Active mast control

Forward tipover accidents are another serious concern, as are falling loads. Overloading the forks, driving too rapidly with elevated loads and executing fast or abrupt movements of the mast and forks can result in front tipover or loss of control over the load. Load stability can also be compromised if goods are poorly stacked on the pallet or if the pallet is badly positioned on the forks.

The SAS engineers anticipated such risk factors and developed front tilt angle control and rear tilt speed control as countermeasures. The front tilt angle control monitors the load height and mast position and automatically limits the forward tilt angle of the mast for better load control. By overriding the manual controls, this feature reduces the chance of falling loads and truck tipover if the operator inadvertently attempts to tilt the mast too far forward.

Rear tilt-speed control limits the mast's backward tilting speed depending on the lift height, reducing the risk of dropped goods for greater load control and easier and more productive handling of loads at height. Without this feature the backward tilting speed of the mast could result in it reaching its maximum backward angle abruptly, causing goods to slip backwards over the mast.

The SAS active steering synchroniser and auto levelling features – while not directly linked to stability – also support efficient, ergonomic operation. The active steering synchroniser continually aligns the steering wheel with the drive wheels after each of the thousands of steering movements that drivers make during their working day. A solenoid controls the oil flow rate to the power steering cylinder to correct the relation between the steering knob and the wheels, and auto levelling levels the forks at the push of a button for fast, confident, damage-free load handling.



Active mast rear tilt speed control limits the backward tilting speed at height, helping to prevent loose loads from dropping onto the driver's cabin

Stability factors

While SAS actively safeguards truck stability, other factors also play an important role in keeping lift-trucks on course and operating safely. These include good-quality tyres, as well as regular maintenance and responsible driving habits.

Tyres should be examined daily for cracks or excessive wear and the pressure on pneumatic tyres should also be inspected. Research has indicated that trucks fitted with pneumatic tyres tip more easily when making wide turns, and lift-trucks with solid tyres tip more easily during sharp turns at high speeds. Of course, the type of turning manoeuvre will depend to a large degree on the operator's skill and driving behaviour, highlighting the need for good driving practices as well as well-engineered trucks and advanced stability technologies.

A final factor to consider is the effect of braking on truck and load stability. Abrupt or sudden braking can rapidly shift the load centre, leading to instability of the lift-truck and load – particularly when handling loads at height. Driver training and good operating practices such as driving at safe speeds and with loads positioned close to the floor can lessen the need for sudden stops and reduce the risk of instability when such stops are unavoidable.

Teaching drivers good operating practices enables them to work more efficiently and reduces the urge to hurry at the expense of safe operating practices. The speed and acceleration control with load-at-height feature on Toyota counterbalanced forklifts also promotes safe driving by progressively limiting the drive speed with lifted loads and controlling sudden acceleration, reducing the need to brake suddenly.

Ultimately, manufacturers can only do so much in terms of providing for safe lift-truck operation and the financial benefits that come with it. Technologies such as Toyota SAS are an important way to build-in safeguards that support safe operation and good materials handling practices.

Employers and drivers must also play their parts by following safe operating practices, ensuring that trucks are kept in good repair and observing simple yet effective safety practices such as wearing seatbelts and observing safe driving speeds – all of which can help to reduce costs as well as save lives. **iVT**

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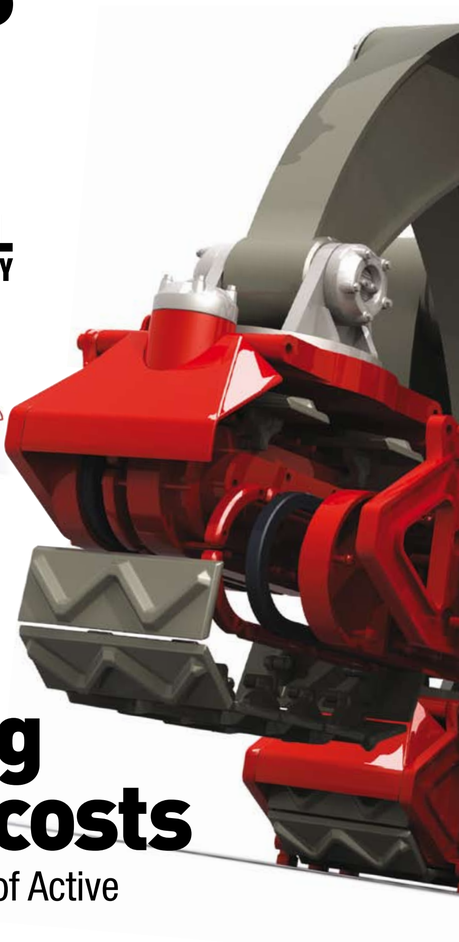
THE MAGAZINE FOR INDUSTRIAL VEHICLE TECHNOLOGY, DESIGN & ENGINEERING

June 2009

iVT INTERNATIONAL
INDUSTRIAL VEHICLE TECHNOLOGY



Driving down costs

Toyota System of Active Stability (SAS)