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DYMANIC FORCE SENSING – DYNAMIC AXIS SCALE WITH HIGH SPEED AND HEAVY RUNNING VEHICLE

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Abstract: As the dynamic force for measuring objects in any motion is required for a system to measure inertia mass in dynamic motion. The authors have proved that it is possible to obtain in no-time the inertia mass of the moving object under dynamic states, by solving numerically the Lagrange's differential equations of motion using by dynamic forces, dynamic accelerations and non-modelled theory.

The force measurement of a dynamic motion requires both high speed scanning of signal at 0.1μs to 1.0 μs and normal vertical direction forces. Measuring them, it can conform the inertia mass of the running vehicle with high accuracy within +- 1 to 5 % at 0 Km/h to 120 Km/h.

Keywords: dynamic mass, vehicle mass measuring

1. INTRODUCTION

Mechanics of Physics is the science concerned with the motion of bodies under the action of forces. Mechanics may be divided into three branches; Statics, Kinematics, and Dynamics (Kinetics). Dynamics (Kinetics), which analyzes the relation between the forces acted upon bodies and the motions of moving bodies, deals with the laws of motions to predict the motion (from among all those possible) that will occur in given situations.

2. SENSING OF DYNAMICS

Dynamics of Mechanics analyzes a relation between the forces and the motions of moving bodies. The relationship between the forces and the motions is obtained from Newton's second law of motion as follows;

(1) A body continues in its state of rest of uniform motion unless acted upon by the external force,

(2) Forces equals product of acceleration induced times the mass of the body,

(3) Action and reaction are equal and opposite.

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The Lagrange's equations of motion derived from Newton's second law of motion or applying D'Alambert's dynamic equilibrium. The matrix of the Lagrange's equations is numerically solved by using time simultaneous sampling data on dynamic forces of the measuring object and data on dynamic motions.

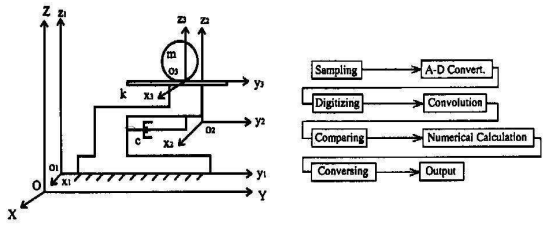

Fig.1. Inertial coordinate and kinetic moving coordinate and calculation processing of Dynamic Load Sensors (DLS)

2.1 Dynamic Axis Scale

The Momentum Quantifier – Dynamic Axis Scale provides a measurement system that provides reliable results at low and high noise levels. The measurement system consists of Dynamic Load Sensors (DLS) using technology based on Newton's second law of motion.

The DLS consists of two force sensors and one gravitational sensor. The force sensors measure the total force one tire applies onto the system including external forces. The gravitational sensor is used to measure only the external forces. The force sensors are in direct contact with the top plate and the gravitational sensor is located at the base of the road, grand and soil structures.

The Dynamic Axis Scale constructed of four Dynamic Load Sensors which capture the movement of vehicle's tire mass, speed, acceleration and flatness. The vertical external force applied on the DAS by a horizontally moving vehicle is measured by high speed sampling of the sensors at a rate of 0.1μs to 1μs .

This vertical external force on the DAS is directly correlated to the momentum theory (2) .

$$p = m\,v \qquad (2)$$

where v is the vehicle velocity, m the mass.

This vertical vibration acceleration of the DAS vessel with grand and soil structurescalculation makes an induced vibration force.

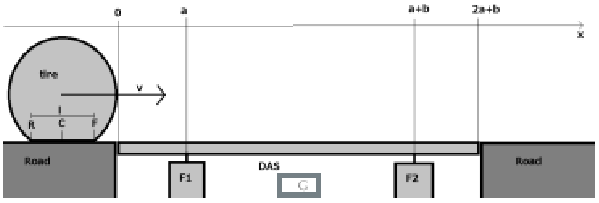

Fig. 2 Side view of the Dynamic Load Sensor consisting of two force sensors (F) and one gravitational sensor (G). The DAS consists of two DTS with 3.5m x 0.3 m x 75mm, The DTS has two DLSs, a Top Plate and an Inner Vessel.

3. DYNAMIC FORCE SENSOR

The external force acting upon the DAS system is measured from the Dynamic Force Sensor shown in Table 1.

The electric sensing devices on the DAS system have a high reliability.

Otherwise, the sensor block is necessary to consider the following items in order to obtain a clear signal and a quick response one,

1. Material selection
2. Precision machining proccess
3. Compact and thin block
4. Quick response and deformation noise
5. High Reproducibility
6. Long life

Table 1 shows the specification of sensor block of DAS.

Table 1. Specification of Dynamic Force Sensor

Information	DAS
High speed sampling	Photo sensing; 0.1 to 1μs
Compact size	Thin type; 400 ^{L}x 100^{B}x 35 ^{H}mm
Acting force	Normal direction force
High reliability	10 million times at full load
Maintenance	Free
High response sensor block	Aluminum, SCM
Circumstance	-50 C degree to 80 C degree
Life period	20 years

For example, a comparrison table with Alminum Alloy and Steel is shown in Figure 2.

Table 2. Comparison table of Dynamic Force Sensor

DAS	Alminum alloy	Steel
High speed sampling	good	better
High response	good	better
Stress noise	better	worse
Weight	light	heavy

3.1. Sensor Signal Processing

Figure 3 shows an example of signals of Force and Gravitation applied from a running vehicle on DAS.

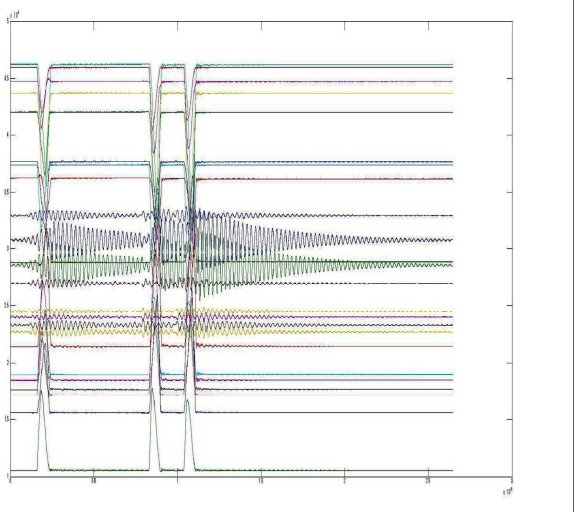

Fig. 3. Force sensors and g sensors signals from a 16 ton truck running at 80km/h.

The force sensing signal has a peek point in high speed. It is depend on a balance between road structure damping factors, the momentum of running vehicles, and impulsive axis kicking force induced by approach road surface roughness.

Fig.4 Field testing with the DAS system. Truck with 16 ton measured for running test up to 100 km/h.

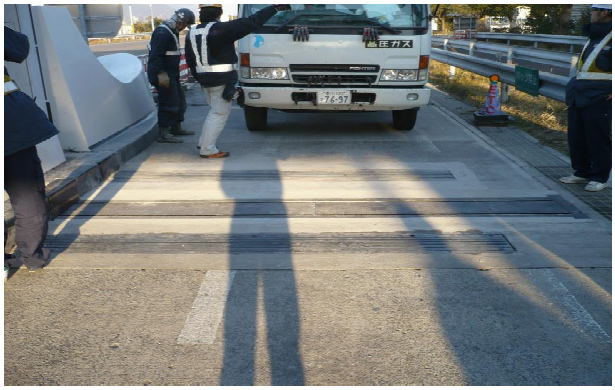

Fig 5 Setting up the DAS in ETC gate.

In March 2012, the DAS system has already served in ETC gates of W-NEXCO for detecting overloaded vehicles. The 6,000 vehicles per day are running on DAS in ETC.

4. FUTURE WORKS

It is possible to construct a measurement system on road that can measure the kicking force to road of vehicles at speed up to 360 km/h with a sampling frequency of 0.1μs to 1μs. It is required to arrange 30 DAS sets on road and to make a signal data analysing system.

5. CONCLUSIONS

The dynamic force sensor can be used for vehicles running from 0 – 120 km/h (0 – 75 mph) with error tolerance of ± 5% of axis mass in highway and normal road. Now, it is operating in ETC gate of W-NEXCO highway.

Integrating the dynamic force sensors into a system used for managing traffic by accurately providing the mass of vehicles moving at high speeds can prevent dangerous and overloaded vehicles from creating accidents.

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