Title: Weighing instruments for traffic applications

Abstract

The assessment of the mass of large vehicles such as aeroplanes and road freight vehicles is currently only partly based on actual measurements, with resulting safety and economic implications. As each extra kilogram of mass that is driven or flown increases fuel consumption and environmental impact, it is important that the vehicle/aeroplane weight is known as accurately as possible. In the case of land transport, overweight vehicles are a safety threat and can cause significant road surface damage and for aeroplanes the centre of gravity of the plane must be known to calculate safe take off and flight positions. Improvements in the knowledge of the mass of vehicles and aeroplanes are therefore needed and the weighing process should not intrude into daily operation, so dynamic weighing systems are preferable.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008, section on "*Metrology R&D for applied and fundamental metrology"* related to *Industry* on pages 12 and pages 36.

Keywords

Mass, weighing, vehicles, aircraft, aviation industry, dynamic weighing, fuel consumption, road damage, fuel level gauges, force transducers, dynamic system analysis, uncertainty, traceability, dynamic force measurement, weigh in motion (WIM), road traffic, freight transport

Background to the Metrological Challenges

Knowledge of the mass of loaded vehicles and aeroplanes is important for the road transport and aviation industries, and has both safety and economic impact.

To determine the safest position during flight with minimal fuel consumption, a pilot needs to know the centre of gravity of the aircraft. The amount of fuel that should be taken on board is calculated before take-off. Both centre of gravity and amount of fuel are calculated using the total mass of the aircraft, and currently this total mass is only partly based on actual measurements. In Europe the mass of an empty plane is measured once every four years, but when average fleet weights are used, this period may be extended to over eight years. Any change to the configuration in the intervening years needs to be documented in detail in order to calculate the current mass. Though the mass of the cargo for each flight is determined by weighing, many other items are not. Thus the mass of the fuel, food and other liquids is based on calculations, whilst the mass of the passengers and their hand luggage is purely estimated as 84 kg per individual.

When the actual mass of the empty plane is measured it can differ significantly from the calculated mass, for example for a Boeing 747 this difference can be up to 850 kg (0.5 %), and this error may have existed for four years (the usual period between weighings). In addition the fuel level gauges are not very accurate, resulting in a large uncertainty in the total mass for the fuel.

Instead of an uncertainty calculation, airlines work with safety margins. Due to limited accuracy these safety margins are quite large and in many cases more fuel is loaded than would be required if a more accurate method with a reliable uncertainty calculation existed. This extra fuel has to be transported both to flight altitude and for part of the journey, which increases the fuel consumption and environmental impact.

The present method of estimating aircraft mass requires considerable effort and resources. Not only should each item that is taken out of an aircraft or put into it during the frequent modifications be weighed, but they also need to be recorded in extensive databases. For many airline companies this is done for each aeroplane individually, which multiplies the effort involved enormously. The actual weighing of an aircraft is not simple. The inventory needs to be checked in detail and all fluids should be drained. This can take up to 10 hours and keeping a plane that long on the ground is not profitable for airlines. Thus the weighing is usually scheduled during a modification period, which generally complicates matters. Furthermore, the length of the process ensures that it is done as few times as possible, even though more frequent measurement would reduce the uncertainty.

The present method to determine the mass of an aircraft is based upon specifications issued by the plane manufacturer and aviation authorities. This field is regulated by Council Regulation (EEC) No 3922/91 of 16 December 1991 on the harmonization of technical requirements and administrative procedures in the field of civil aviation (OJ L 373, 31.12.1991, p. 4). The regulation was amended several times, the last time in 2008. Procedures related to determination of the total mass and the centre of gravity of aircraft are covered in Annex III of the Regulation: 'Common technical requirements and administrative procedures applicable to commercial transportation by aircraft, OPS 1: Commercial air transportation (aeroplanes), Subpart J — Mass and balance'. Due to these strict regulations, this complicated and resource-intensive procedure is used world-wide, despite its limited accuracy

Transportation on roads and motorways results in maintenance and repair costs that amount to several 10^{11} Euros within the EU each year. For example according to the magazine “polizei verkehr + technik” (published by the Federal German Ministry of the Interior) on German highways alone 4000 bridges out of 38000 have suffered severe damage due overloaded lorries and special heavy goods transport. Much of the costs, not only on bridges, but on all highway and motorways are produced by overloaded trucks whose owners, for the time being, cannot be held responsible because there is no comprehensive surveillance based on legally approved systems.

Millions of tons of material are shipped each year via motorways and roads. Normally non automatic weighing instruments (NAWI) in the shape of wheel load weighers are used to determine the load of a truck and from knowledge of the proper weight of the truck (tare), of the mass of the material loaded. Moreover, the wheel and axle loads determined for these are limited due to safety reasons and wear and tear of the road surface. The accuracy obtained when using wheel load weighers is between 0.1 % and 1 %.

It is more time-consuming to perform a weighing on a wheel / axle load weigher NAWI than on an instrument performing weighing in motion (WIM). State of the Art WIM-Systems reach uncertainties of 7 % to 10 % and are only used for statistical purposes. These WIM Systems do not currently meet the metrological requirements that would enable them to be used under legal control everywhere in Europe. The level of uncertainty is such that current legislation does not allow these instruments to be used for traffic surveillance in many countries. The WIM systems merely serve as a pre-selection means for significantly overloaded vehicles which subsequently have to be weighed on weighbridges or by means of wheel / axle weighers. Improvements in the uncertainties associated with the dynamic weighing of vehicles would facilitate greater use of WIM type systems, with the subsequent reduction in costs and the number of overloaded vehicles.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them, in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP protocol.

The focus of this research topic is the development of new and more accurate methods and instrumentation for the determination of mass over a wide range of real conditions in practical use for different traffic applications, especially aircraft and high speed road truck weighing.

The specific objectives are:

1. Development of methods and instrumentation for dynamic weighing including uncertainty budgets and validation,
    a) with the special objectives for aircraft weighing being:
        - dynamic weighing of total mass of an aircraft with target accuracy 50 kg at 600 ton
        - identification of the centre of gravity of an aircraft,

b) and with special objectives for road vehicle weighing being:

- dynamic weighing at high speed conditions (50 – 80 km/h), independent of truck type including number of axles and axle groups, and with target accuracy 2 %.

The resources needed to meet these objectives are expected to be less than for an average joint research project in TP industry.

Proposers shall give priority to work that meets documented industrial needs and that which supports transfer into industry e.g. by cooperation and/or by standardisation.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links with the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project. In your JRP submission please detail the impact that your proposed JRP will have on any Directives:

You should also detail other impact of your proposed JRP as detailed in the document “Guidance for writing a JRP”

You should detail how your JRP results are going to:

- feed into the development of urgent standards through appropriate standards bodies
- transfer knowledge to the traffic, automotive and aerospace sectors, and associated regulatory and policy makers.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] Council regulation (EEC) No 3922/91 on harmonization of technical requirements and administrative procedures in the field of civil aviation (16 December 1991).

[2] Commission regulation (EC) No 859/2008 amending council regulation (EEC) No 3922/91 as regards common technical requirements and administrative procedures applicable to commercial transportation by aeroplane (20 August 2008).