THE FIRST WIM SYSTEM DESIGNED IN POLAND

Janusz Gajda   University of Mining and Metallurgy, Faculty of Electrical Engineering, Automatics, Informatics and Electronics, Department of Instrumentation and Measurement, Al. Mickiewicza 30, 30-059 Krakow, POLAND

Ryszard Sroka   University of Mining and Metallurgy, Faculty of Electrical Engineering, Automatics, Informatics and Electronics, Department of Instrumentation and Measurement, Al. Mickiewicza 30, 30-059 Krakow, POLAND

Marek Stencel   University of Mining and Metallurgy, Faculty of Electrical Engineering, Automatics, Informatics and Electronics, Department of Instrumentation and Measurement, Al. Mickiewicza 30, 30-059 Krakow, POLAND

Tadeusz Zeglen   University of Mining and Metallurgy, Faculty of Electrical Engineering, Automatics, Informatics and Electronics, Department of Instrumentation and Measurement, Al. Mickiewicza 30, 30-059 Krakow, POLAND

ABSTRACT

In last years the traffic on Polish roads rapidly increases, more and more of shipment is transported by lorries. The infrastructure and condition of Polish roads isn't god, than appears necessity to protect them. One of possibilities is to control the vehicle overloading. Up to now six weighing sites are installed in Poland. The sites consists of static scale and preselection systems for each direction. Unfortunately the preselection systems equipped with capacitive sensors are damage after a few month. Than the first Weighing in Motion – WIM preselection system, fully designed, programmed and assembled in Poland, has been put into service in April 2001. The system operates in standard configuration, i.e. it is equipped with two strip piezoelectric sensors and one inductive loop located between them. Each axle is weighed twice due to the employment of two WIM sensors. The arithmetic mean value of both results is assumed as the final axle load. The measuring range of the system lies between few hundreds of kilograms to 20 tons for the vehicle velocity included in the range 25 – 100 km/h. The described system allows vehicle detection in the measurement zone as well as estimation of a single axle and the whole vehicle loads, measurement of the vehicle velocity, number of axles, the distance between successive axles. Trailer detection is also possible, based on the vehicle magnetic profile, registered with the inductive loop. The statistical characteristics describing the traffic observed on the chosen road section are presented in the paper, specially the distribution of the vehicles number in the course of a day and night as well as in the course of a week. The effectiveness of detection of permissible parameters, such as velocity and axles load, is also estimated.

WIM SYSTEM DESCRIPTION

Presented in this paper WIM system consists of two piezoelectric strip sensors, each 4m long, placed perpendicularly to traffic direction, with mutual distance 1.7m. Between them inductive loop of dimensions 2m x 1.5m is placed. The sensors used in WIM system, are I Class weighing sensors of Measurement Specialties Inc. [4] [5]. The highly compressed piezoelectric polymer there are used in the sensor, and positive signal is generated as tires pass over. Thanks to its flat shape and proper installation directly in the pavement (see Fig. 1), the effect of "axle ghost" can be significantly reduced.

Result of weighing is calculated by integration of sensor output with respect to time and using calibration coefficient. Two strip weighing sensors in the WIM system make possible repeated weighing of each vehicle axle. The result of axle weighing is calculated as arithmetic mean. The total load of the vehicle is the sum of all its axles load.

Additionally such configuration of the measurement system enables counting of the vehicle axles, measurement of the distance between them, velocity and electrical length measurements, as well as the trailer detection on the basis of magnetic profile. The measurement results enable to include the weighed vehicle to one of thirteen classes according to FHWA classification. The system measures also the road surface temperature to correct weighing

results depending of thermic and mechanical surface properties. The results are transmitted to superior system with the RS232 interface.

The system assignement is preliminary weighing of travelling cars in purpose to select these, whose total load or axle load exceed permissible values. Such vehicles are directed to nearby static scales for final weighing. Fig. 2. shows the electronic part of the preselection system [3].

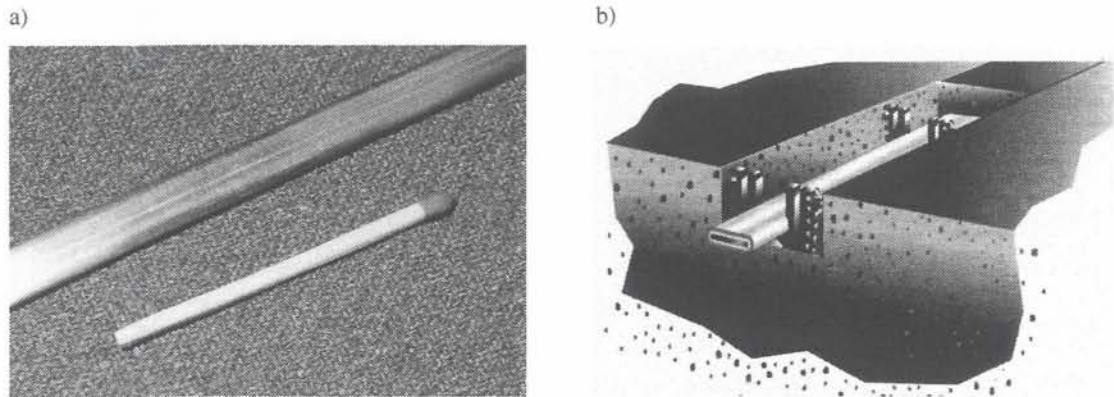a)   b)

Figure 1. The piezoelectric WIM sensor (a), and method of its installation (b).
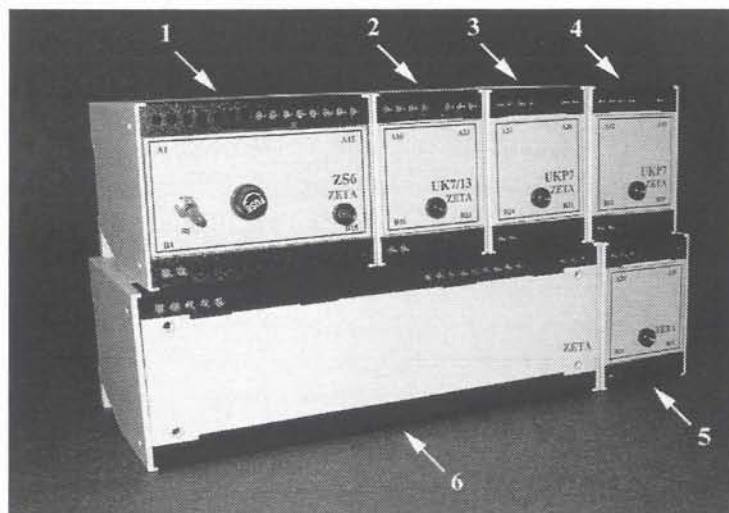

Figure 2 – The electronic part of the WIM system. 1 – power supply, 2 – inductive loop conditioning system, 3,4 – conditioning system of the piezoelectric WIM sensors, 5 – temperature measuring unit, 6 – microprocessor system.

SYSTEM CALIBRATION

The system calibration has been performed using the method of pre-weighed vehicles [1]; two and four axle, with total loads of 17 100 kg and 33 940 kg respectively. The calibration has been done for three different speeds (30, 50 and 70 km/h), 20 runs by each lorry for each speed.

Calibration coefficients calculated on this base for each of WIM sensors allows permanent weighing of moving vehicles for statistical and preselection purposes. The standard deviation of the moving vehicles weighing results, obtained in the described system does not exceed 7% and the bias error is less than 1.5%.

In the Fig. 3. the relative differences between weighing results obtained from two WIM sensors for 162 trucks crossing the tested WIM stand are presented. Their relative average value amounts 3.7%, and its relative standard deviation equals 10.5%.

Since the error of weighing of vehicles moving with road velocities includes significant random component, distribution of weighed vehicles number as a function of weighing error as well as distribution function of

weighing error (absolute value) are presented in Fig. 4. Presented characteristics make possible estimation of vehicles weighing uncertainty, coming out in the constructed WIM system. For example, the probability of commiting of weighing errors exceeding 20% (point A on the curve 2) equals 0.22. A half of vehicles however has been weighed with an error not exceeding 10%.
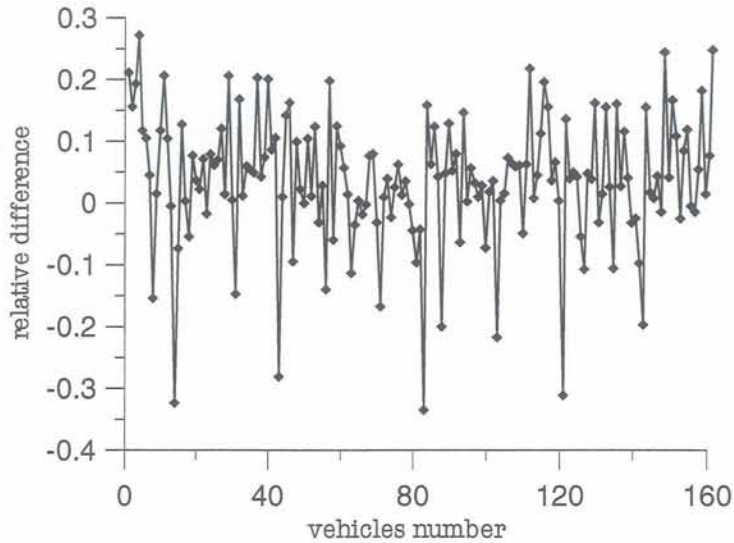

Figure 3 – The relative differences between weighing results issued from two piezoelectric sensors entering into the composition of WIM stand.
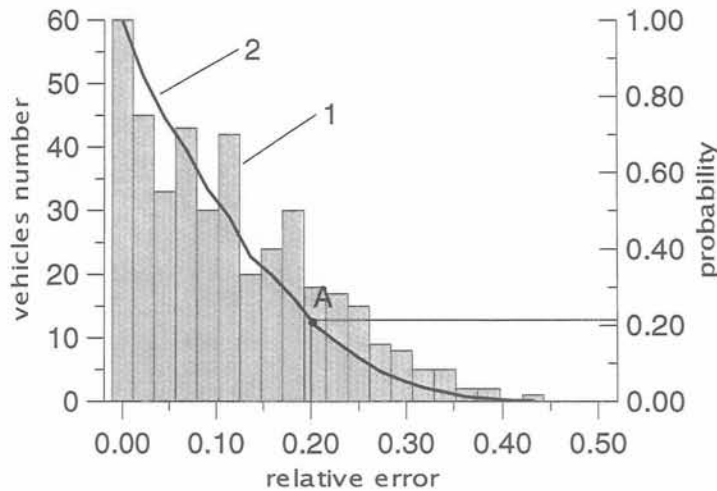

Figure 4 - Distribution of weighed vehicles number as a function of weighing relative error (absolute value).
1 – histogram, 2 – distribution function of absolute weighing error.

WEIGHING RESULTS

Results of traffic parameters measurements, stored by the constructed measurement system, make possible to determine basic characteristics, describing the traffic at the system location. Selected characteristics are, determined on the basis of measurements results, obtained during one week (2001.12.24 – 2001.12.30). The days 25 and 26 December are holidays in Poland; the day 2001.12.30 was Sunday.

The highway, at which the measurement system has been located, shows great differences of traffic between working days and holidays. During working days total load of all vehicles passing one lane within 24 hours exceeds 30 000 tons. During holidays the total load decreases even to 4 000 tons. Much lower differences characterize the total number of passing vehicles. Greater differences are noticed within particular classes, e.g. in the groups of four and five axles vehicles. Detailed data are presented in the Table 1.

Table 1 - Total vehicles number in respective days taking into account partition for lanes and vehicles classes as well as the total load of all vehicles on each lane.

Date	Lane number	Number of vehicles				Total number of vehicles	Total load [tons]
		Vehicle class – number of axles					
		2	3	4	5		
24.12.01	1	3 497	39	51	68	3 655	7 729
	2	4 981	58	73	139	5 251	8 578
25.12.01	1	2 925	14	7	6	2 952	4 056
	2	3 178	19	10	8	3 215	3 640
26.12.01	1	5 183	23	11	23	5 240	8 738
	2	3 309	23	11	23	3 366	4 176
27.12.01	1	7 374	112	169	406	8 061	28 056
	2	5 429	124	132	429	6 114	20 342
28.12.01	1	6 501	127	224	445	7 297	30 228
	2	5 846	140	154	489	6 629	25 683
29.12.01	1	5 399	83	112	234	5 828	17 512
	2	5 195	110	124	319	5 748	16 506
30.12.01	1	4 029	36	50	52	4 167	8 532
	2	3 494	52	39	56	3 641	6 615
31.12.01	1	3 813	35	50	71	3 969	9 689
	2	663	17	17	33	730	2 268

Described measurement system makes also possible traffic monitoring with simultaneous vehicles classification. Fig. 5. presents distribution of vehicles number in time for all types and for 5 – axles vehicles. Both characteristics are in different degree sensitive to holidays. The traffic of 5 – axles vehicles during holidays practically decays. Characteristics of vehicle number distribution in time enable to notice distinct 24 hours fluctuations of vehicles number passing chosen traffic lane. These characteristics show for instance that during holidays maximal traffic intensity (vehicles number per hour) is two times less than during working days. Distortion of distribution during the day 24 December is plainly visible. Traffic intensity maximum is on similar level as during working days, but the distribution characteristic is much more concentrated around the mean value. Also the minimum between holidays has decidedly lower value. The peak of traffic during working days occurs at afternoon hours, while during holidays is delayed about 4 hours.
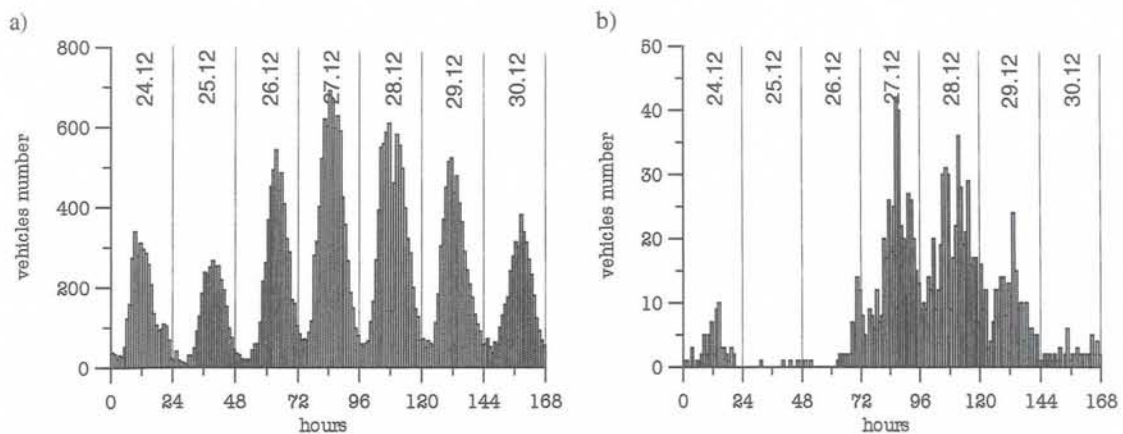

Figure 5 - Time distributions of: a) vehicles total number, b) 5 – axles vehicles number.

Characteristics describing the vehicles load distribution in time allow to observe the changes of transported load depending on the time of day, and the day of a week. Presented characteristics (Fig. 6.) show distinct transport decrease during holidays. The load amount increases at midnight between 26 and 27 December. Minimal amount of transported load occurs about 2 a.m. (500 tons per hour), maximal amount – between 2 p.m. and 4 p.m. (2 200 tons per hour).

From the Fig. 6b. it is evident, that during holidays goods traffic is quite marginal. In Sunday (30 December) observed goods traffic was 4 times less than during working days. In working days the total mass of the load transported by single lane of investigated road reaches even 1000 tons per hour.

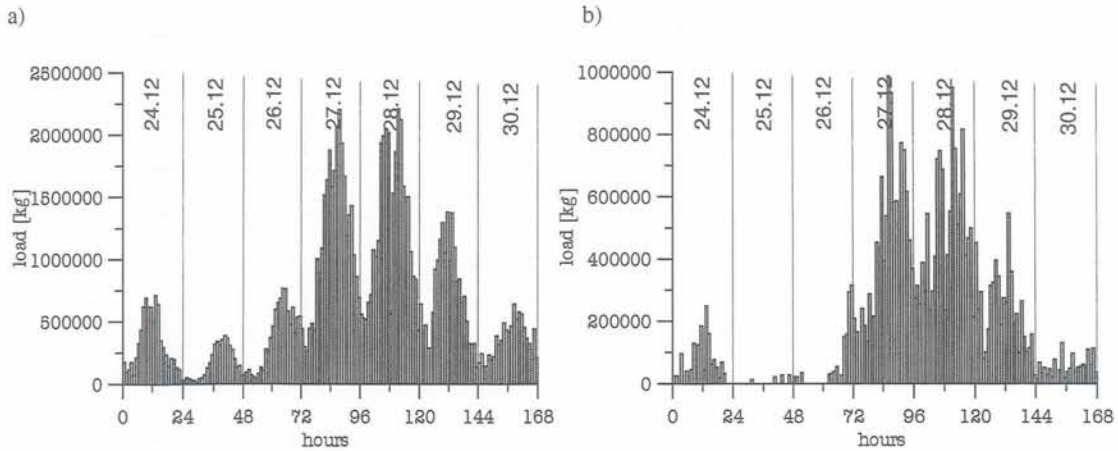a)   b)

Figure 6 - Time distributions of total load: a) for all vehicles, b) for 5 – axles vehicles.

Characteristics in the Fig. 7. present time variability of average load of 2 - and 5 - axles vehicles. Since the class of 2- axles vehicles includes passenger cars as well as lorries and trucks, observed changes of average load are caused by the change of proportions of these types within the whole population. The increase of lorries number is particularly well noticeable at 4 a.m., when the average load of 2 – axle vehicle increases even up to 5 tons (Fig. 7a.).

The time distribution of the average load of 5 – axles vehicles allows to choose these times of day, in which the probability of overloaded vehicles detection increases. The characteristic presented in the Fig. 7b. shows, that such periods are 2 hours before and after midnight. Just in this time control weighing of the vehicles should be particularly profoundly performed.

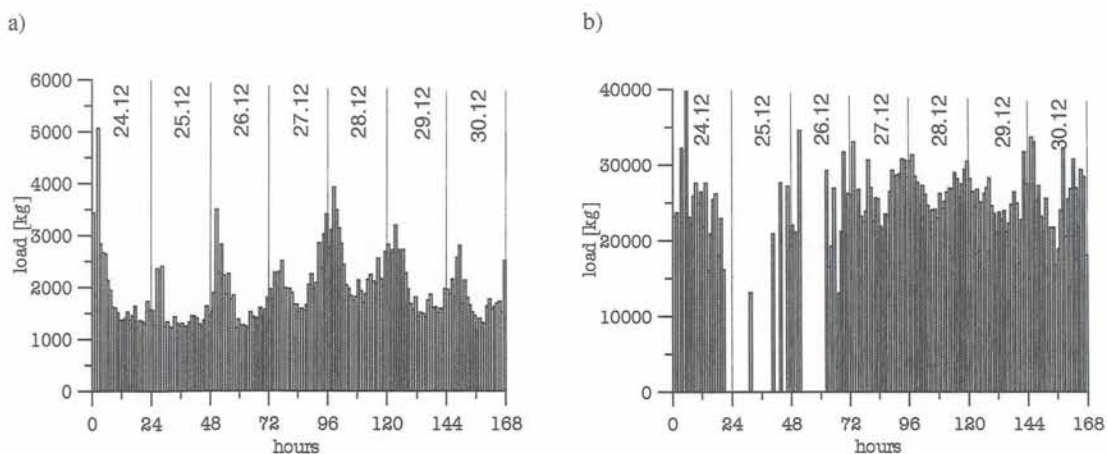a)   b)

Figure 7 - Time distribution of the average load of: a) 2 – axles vehicles, b) 5 – axles vehicles.

The data concerning exceeding of permissible axle load are compiled in the Table 2. Most of permissible load exceedings are observed in working days within the class of 5 – axles vehicles (65 in one lane). 10 tons was assumed as permissible load of single axle. However, on the road chosen for investigations vehicles may be found exceeding this limitation even over 50% (Fig.8.).

Table 2. Number of permissible axle load exceedings in subsequent days for particular classes.

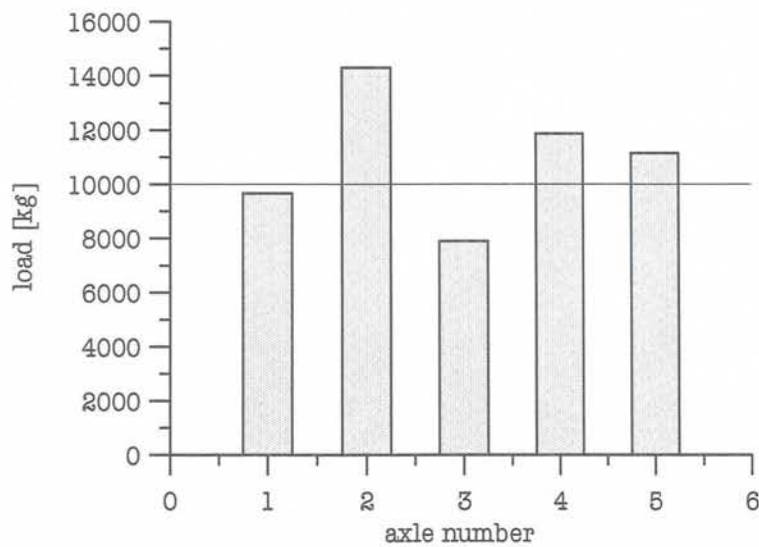| Date	Lane number	Number of vehicles exceedings permissible axle load			
		Vehicle class – number of axles			
		2	3	4	5
24.12.01	1	1	1	0	5
	2	0	0	0	2
25.12.01	1	0	0	0	0
	2	0	0	0	0
26.12.01	1	3	0	0	6
	2	0	0	0	2
27.12.01	1	11	0	1	65
	2	2	0	0	7
28.12.01	1	8	4	5	61
	2	4	1	0	16
29.12.01	1	9	2	8	24
	2	0	0	1	11
30.12.01	1	3	1	1	7
	2	0	0	0	4
31.12.01	1	1	2	0	13
	2	0	0	0	2

Figure 8 - Axle load distribution for exemplary overloaded 5 – axle vehicle.

Presented system also enables registration of permissible velocity limit breaking. On the road section, where measuring system has been installed, the velocity limit is equal to 70 km/h. Majority of drivers are breaking this limit (see Fig. 9.).
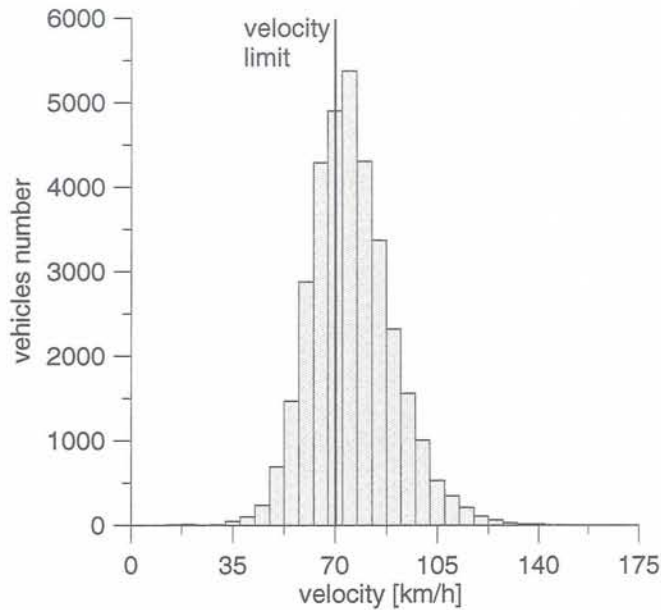
Figure 9 - Velocity distribution characteristic.

CONCLUSIONS

Presented in the paper WIM system is the first one completely designed and constructed in Poland. Over 1 year exploitation period in changeable climatic conditions confirmed its reliability and efficiency. In 100 % of events vehicles indicated as overloaded, actually exceeded permissible axle load. It was confirmed by means of static weighing. Measurements results yielded by described system are stored in superior system and are used for elaborating of summary reports characterizing traffic conditions on selected highway. For authorized persons these informations are accessible through Internet.

REFERENCES

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[3]   Gajda J., Sroka R., Stencel M.,   egle T.: „Weighing in Motion Systems", *Drogownictwo, nr 3, 2001.(in Polish)*

[4]   Halvorsen D.: „The Colossus of Roads…", *Traffic Technology International*, Feb/Mar 2002, pp. 47-49.

[5]   *www.msiusa.com*