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INCREASING CAPACITY UTILIZATION OF WASTE GATHERING VEHICLE APPLYING REAL-TIME BASED INFO-COMMUNICATION SYSTEM IN SELECTIVE WASTE GATHERING

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Abstract

Decreasing of available raw materials, fossil energy source and new attitude made recycling necessary and inevitable. For recycling selective waste areas have been placed, where inhabitants can drop their waste for free optionally whether it is uncompressed or compressed, opened or closed. Due to the different bottle forms and compression methods, PET bottles are put into containers at different volume density. As every other waste also PET waste is to be compressed further in the vehicle, if it is possible, due to efficient gathering. PET waste form can significantly influence on further compression. This study deals with differently compressed PET bottle displacement from further compressibility point of view.

Key words: *real-time system, measuring technique, info-communication, waste gathering*

Introduction

Regarding environmental legislation, environmental load and recycling possibilities in Hungary, hundreds of settlements (even only with a few thousands of inhabitants) have established selective waste collection areas and placed various containers. Today the emptying process is based on empirical emptying value and in some cases the collection route is not optimised. In the EU there is a high pressure on waste collection companies in order to provide higher service standard for the same price. Due to decreasing waste gathering load researchers everywhere in the world were really keen on applying such devices, which can enhance efficiency and lower cost in waste gathering.

This study deals with differently compressed PET bottle displacement from further compressibility point of view.

Techniques applied today

In order to develop waste collection efficiency software and GPS service were applied for optimisation. Optimisation included fuel, route and collection time.

A study made by Minghua et al. introduced recommendations for solving waste increasing problems in Pudong province in China. High cost of waste is reduced by a special method applying low-capacity vehicles, which have automated compression unit and waste is placed into a transfer-compression depot. The compressed waste is placed in a closed hooked container, then its final destination is destruction.

Nuortio et al. defined a high-level model for waste gathering, which claims six input parameters including data featuring container, e.g. GPS coordinates, identifier, waste type, waste volume, waste mass. Further data needed about the vehicle, gathering time limit and route matrix.

By the authors containers are divided into two groups. One is for those containers, which are highlighted due to the demand of oft emptying and the other is the rest with normal emptying. Generally, emptying trend is not followed, therefore all containers sign at the same priority, but knowing the trend one can reckon emptying trend change. Simulation in Matlab showed 12% saving in average.

The systems introduced above contribute to optimized route definition, however there is no answer for which containers need to be emptied and what is the degree of waste density in the vehicle for further compression. This study aims at analyzing displacement of differently compressed PET bottles and waste density in the interest of vehicle capacity utilization.

Saturation examination of waste container

The basis of the new real-time based waste gathering system is collecting accurate parameters about waste placed in container. According to literature recently there is no such investigational data, which can show further compression ratio of the differently compressed waste.

For saturation examination the commonly applied POLYDUCT selective waste containers (Figure 1 and 2) and PET bottles at different volumes and forms were used.

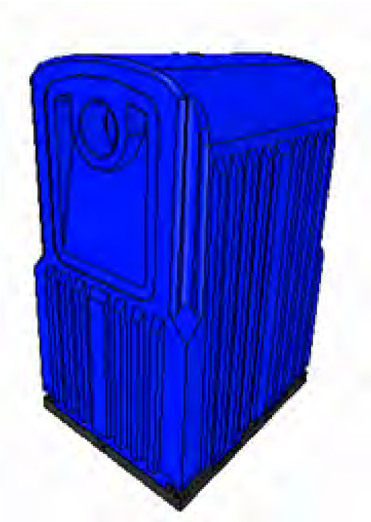

Fig. 1. 3D design of 1,5 m^3 selective waste gathering container

Fig. 2. 3D design of 1,5 m^3 selective waste gathering container

Bottle ratio at certain volume used examination according to a former survey:

- 0,5 l bottle 21%,
- 1 l bottle 9%,
- 1,5 l bottle 41%,
- 2 l bottle 25% ,
- 2,5 l bottle 4%.

Examination data were collected till properly saturated level of container to be emptied from the bottom. Examinations were carried out by differently compressed PET bottles. Regarding compression and further compression, examination of each PET bottle force-compression (in diameter) parameter was a very important task (Figure 3).

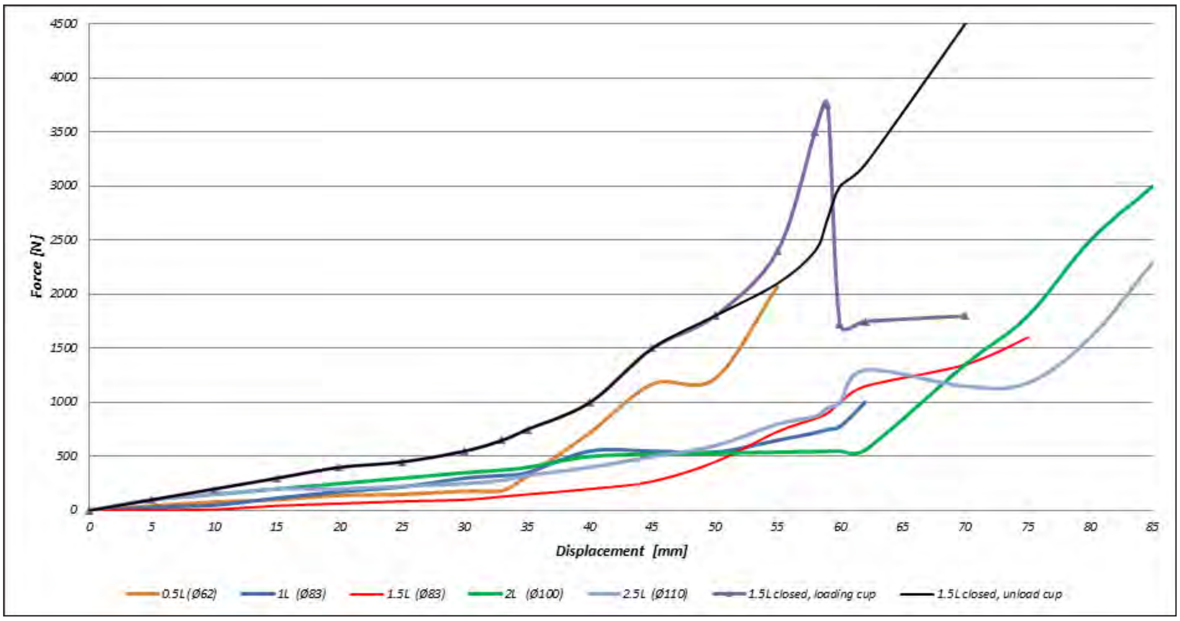

Fig. 3. Force-displacement diagram of opened and closed different volume PET bottle compression

Simulations were executed for container saturation examination with differently compressed PET bottles (Figure 4 and 5, Table 1).

Fig. 4. 1,5m^3 container saturated by PET bottles compressed by leg

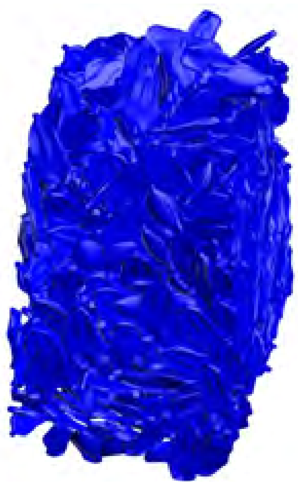

Fig. 5. Form of PET bottles compressed by leg in 1,5m^3 container

Table 1. PET bottles can be placed in container

Container volume	Waste type	Compression method	Waste [piece]	Waste mass [g]	Waste density [kg/m³]	Utilization increase
1500L	mixed PET bottles	none	~480	~14400	9,6	-
		compression by hand	~500	~15000	10	+4,2%
		compression by leg	~852	~25560	17,04	+77,5%
		compression unit	~995	~29850	19,90	+107,3%
2500L	mixed PET bottle	none	~872	~26160	10,46	-
		compression by hand	~890	~26700	10,68	+2,1%
		compression by leg	~1345	~40350	16,14	+54,3%
		compression machine	~1720	~51600	20,64	+97,3%
1500L	1,5L PET bottle	none	~405	~12150	8,1	-
		compression by hand	~482	~14460	9,64	+19,0%
		compression by leg	~790	~23700	15,8	+95,1%
2500L	1,5L PET bottle	none	~810	~24300	9,72	-
		compression by hand	~934	~28020	11,21	+15,3%
		compression by leg	~1410	~42300	16,92	+74,1%

Studying the simulation (Table 1) it can be stated that in case of PET bottle beside volume decrease (compression) the form of compressed bottles has big significance.

According to the examination it can be stated that:

- in case of hand compression beside the average volume decrease at 40,8% the maximal piece of bottles placed in container increased by 2-5% only,
- in case of leg compression 64,4% compression ratio can be reached concerning different PET packages, thus by 50-70% more waste can be placed in container,
- in case of special compression unit the average compression is 45%. Beside volume decrease due to PET bottle deformation more waste can placed in containers, which results in 90-110 % more than in bottles without compression,
- in case of inhabitants no compression unit can be taken into consideration, therefore PET bottle should be compressed lengthways (in diameter) properly as to have more PET bottles placed in container by 50-70% as good.

PET bottles test

Tests have been carried out on an area of 1m*1m by open uncompressed 42 pcs of 1.5L and 37 pcs of 2L PET bottles (Figure 6.).

Test parameters:

- bottle set height: ~280 mm
- compression displacement: 125 mm (bottle set height: 155 mm)
- spring displacement: ~15 mm (bottle set height: 170 mm)
- sum weight of bottles: 2471 g
- default volume: 0.28 m^3
- compressed volume after spring: 0.17 m^3
- compression ratio: ~40%

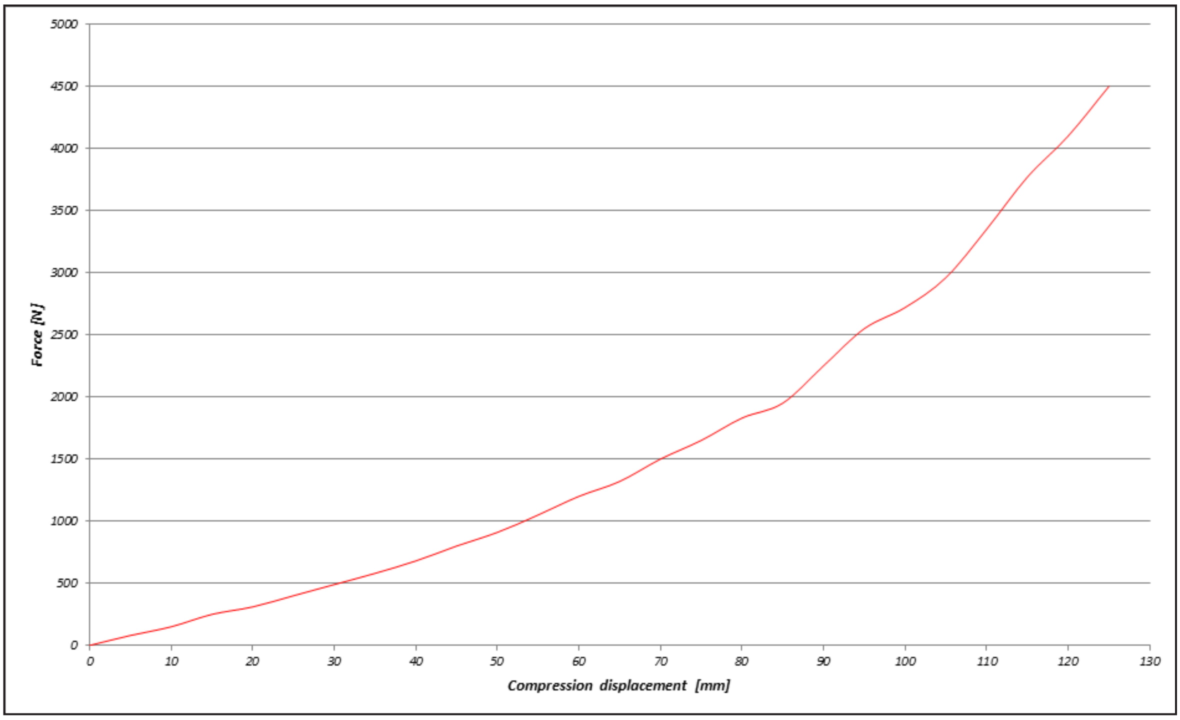

Fig. 6. 80 pcs of 1.5L and 2L open PET bottle compression examination

Tests show that after 4500N load an examined PET bottle volume was decreased by ~40%. 3.5 rows of PET bottles (random placement) were tested, so compression displacement of each row is ~35 mm. Regarding Figure 6 it can be seen that values applied at one PET bottle compression (70N→35mm) are proportional to 80 pcs of PET bottles compression values (4500N→125mm).

Close PET bottle damage force

Close PET bottle has maximal loadability at ~10 bar over pressure, which equals to 0.1N/mm². In order to reach this value the bottle should be compressed to this volume:

$$p_1 * V_1 = p_2 * V_2$$

$$V_2 = \frac{0.1 * 1.5 * 10^6}{1.1} = 1.364 * 10^5 m^3 = \underline{136.4 cm^3}$$

Volume decrease: 90.1%

parallel compression on curved surface: $A_{PET\ bottle}$ ~30000mm²

pressure: p=10 bar→ 1N/mm²

Damage force:

$$F = p * A = 1 * 30000 = \underline{30000 N}$$

This value should be overcome by the compression unit for one close PET bottle assuming that the cap stays intact providing the lasting volume decrease.

Waste COLLECTING Vehicle compression unit examination

Also in the European countries and Hungary rear-loading waste gathering vehicle is typical, thus its compression unit parameters have been examined:

- Hydraulics cylinder piston diameter: D=Ø110mm
- Maximum system pressure: p=320bar→32N/mm²
- Hydraulics cylinder maximum force:

$$F=p*A=(55^2*\pi)=30400N$$

- Hydraulic cylinder number: 2 pcs

$$\Sigma F = 2 * 304000 = \underline{608000N}$$

force can be realized by two hydraulics cylinder.

In case of close uncompressed bottles at the compression of around 20 pcs of PET bottles the system is able to produce the force, which can damage the bottle causing permanent deformation assuming that the cap stays intact and over pressure can be released. Based on the calculation it seems that open PET bottle placement has a very significant role as well as the application of PET bottle damage-compression unit.

Waste gathering vehicle compression unit dimension: 2m*0.9m

Volume to be compressed: 2m*0.9m*0.8m=1.44m³

Optimization of waste COLLECTING vehicle saturation

Concerning the results above culture of PET bottle waste selective gathering has great significance. Wide-spread waste gathering vehicles in the EU and Hungary has a capacity of 22m³, thus such vehicle tests have been carried out.

Considerations based on container volume-weight ratio

22kg waste in a 1.5m³ container means that the compression ratio of PET bottles is high and volume decrease is ~70%. Further waste compression in waste gathering vehicle can hardly be reached. ~70% volume decrease equals to compressing in diameter of 60mm. In case of 70% volume decrease there is room for ~750 pcs of PET bottles in the compression unit (1.44m³), see Table 1. In Figure 6 it can be seen that compression at 60mm average PET bottle reaction force is 800-850N. In case of that huge amount of PET bottles further compression needs to provide the maximum compression force made by hydraulic system for compression unit. For more precise data test should be carried out with different type and level compressed PET bottles and various vehicle equipped with different compressing unit.

Based on the data provided by the waste gathering company compressed waste weight was divided by the number of 2.5 m³ container at vehicle emptying. However, the values have big dispersion (between 28kg and 52 kg), 40 kg (compressed)/container (2.5m³) values are considered in average. 1088 pcs of 2.5m³ totally saturated container were involved in tests having been carried out. The value is in line with the data in Table 1 and examination on further compression introduced in this chapter.

Data needed for optimization:

- Density value of waste at its compression limit (PET, open, homogenous 15kg/m³)
- Container volume and homogenous waste weight (input for waste density value)

Comparing these two data number of containers can still be emptied can be forecasted, thus place of vehicle saturation.

Factors influencing optimization:

- waste homogeneity,
- quality of gathering culture,
- vehicle compression unit parameters,
- compressed waste volume in one compressing cycle.

Concerning these factors optimization has big uncertainty, which can be calculated by correction factors examining in real circumstances.

Summary

More livable cities can be organized by applying real-time based info-communication system in waste gathering since reasonable emptying processes are accomplished in time, while not required gathering tasks are left out.

For maximization of vehicle capacity utilization determination of waste density value was successful, which cannot be or only hardly can be decreased by further compression. Applying this value dividing vehicle capacity by container waste volume is it capable to give a prognosis on vehicle saturation, which can handled as input parameter in optimization. High-level waste gathering can be planned by such system application resulting in environmental care, enhanced traffic safety and waste gathering efficiency increase.

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