Technological solutions and innovations within aerosol packaging

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Abstract. Aerosol products combine convenience of use, various possible applications and high performance. Thanks to these features, a steady increase in their sales is observed on the global market. Yearly, over 15 billions units are globally produced and among this more than 5.5 billions are made in Europe [1, 2]. An integral part of the aerosol product is its packaging. As the size of the aerosol market opens the gate for innovations, packaging components’ manufacturers try to develop packaging in both construction, material, technological and marketing directions, to get the bigger share of worldwide aerosol market. The article will review the solutions which are currently used as well as the innovations in the context of aerosol packaging. It will also demonstrate the need for further development within this segment of industry.

1. Introduction
The history of aerosol products begins in 1926, when Norwegian Erik Rotheim patented an aerosol dispenser. The first products in this form were available to American soldiers in the 1940s and in the post-war years, they began to be available also for civilians. The next three decades brought uninterrupted growth in production of aerosol products [3]. The beginning of the 21st century brought new directions for the development of aerosol products. New shapes and forms of packaging and also different types of product applications have been introduced. New solutions are being sought to reduce their prices and increase the efficiency of aerosol products.

2. Law requirements and others within European Union
Requirements for aerosol products, including aerosol packaging and their elements, are defined in applicable international legal regulations, standards and in individual counties’ regulations. These requirements relate both to the resistance parameters of the packaging, its dimensions and tolerances, as well as the required marking. A fundamental European document relating to aerosol products is the Council Directive of the European Union of 20 May 1975 on the approximation of the laws of the Member States relating to aerosol dispensers (75/324/EEC) as amended by directives 94/1/EC, 2008/47/EC and 2013/10/EU. This directive, often called the "Aerosol Dispensers Directive - ADD", has been in operation since 1975 and is one of the oldest European directives relating to product safety [4].

In addition to the regulations specified in laws, directives or regulations, guidelines on requirements are placed also in industry standards, e.g. FEA (European Aerosol Federation) standards.
The full set of FEA standards, provides technical standards developed by and within the European aerosol industry. It includes test methods, dimensional and performance standards. For a large part of FEA standards, also international ISO standards have been developed. Some of them replaced previous FEA standards. This type of standards gives detailed information on each packaging elements what allows aerosol packaging producers, production lines’ producers and aerosol filling companies to achieve the common effective level of cooperation.

3. Aerosol containers

According to Council Directive of the European Union of 20 May 1975 “aerosol dispenser shall mean any non-reusable container made of metal, glass or plastic and containing a gas compressed, liquefied or dissolved under pressure, with or without a liquid, paste or powder, and fitted with a release device allowing the contents to be ejected as solid or liquid particles in suspension in a gas, as a foam, paste or powder or in a liquid state” [4].

Based on above definition, metal (aluminium or steel), glass and plastic containers are used in aerosol products. As it was presented in the European Aerosol Federation’s reports, approximately 90% of aerosol containers are made of metal (49% of which is aluminium and 40% of steel). Glass and plastic remain marginal, mainly due to legal restrictions on the permitted volumes of this type of containers. However the advanced work is carried out in case of PET packaging for example leading by FEA or The Plastic Aerosol Research Group (PARG) [5].

3.1 Metal containers

As mentioned above aluminium and steel containers are the most common materials in the aerosol production. The significant environmental impact on innovation in the field of metal containers is observed. Since 2008 Exal company produce aluminium cans called Coil-to-Can (C2C) with reduced weight. Ball Corporation together with Henkel Beauty Care went one step further and developed a lighter version of the aluminium aerosol container – ReAl. In this container 25% of recycled material is used and additionally they were able to reduce the weight of a standard aluminium container by 15% [6].

Example of innovation in steel container is DigiStripe - container with an "invisible" weld presented by Colep. In these cans the seam’s width was reduced from 5mm to 1.5mm. Due to this modification the three-piece steel containers looks closer to the aluminum ones [7]. Also the LANICO company presented steel can which has the appearance of a complete monoblock. "SteelCare" has excellent printability and tactile properties, as well as a seamless printable surface. For the first time, the proposed technique has made it possible to use the seam inside the container. What is very important, it very resistant to static and burst pressure. In addition, the container is 100% recyclable and as no lubricant is required during the production process, intensive cleaning of its surface is not needed [8].

3.2 Plastic containers

Although plastic containers are not very popular in the production of aerosols, it may seem that the future can belong to them. Currently, plastic containers are treated similarly to glass with a protective coating or permanently protected in a different way. This is why the Aerosol Directive limits the maximum capacity of plastic containers up to 220 ml. Due to still existing legal restrictions, on the European market only some cosmetic, pharmaceutical and food products are produced in plastic aerosol containers. Despite the European limitations, Plastipak offers their plastic aerosol containers not only in 220 ml but also in 335 ml, which is available in Europe in certain countries. Both sizes pass all of the required tests, and 220 ml are fully compliant with the current European Aerosol and Dispensing Directive [9]. Representatives of the aerosol industry claims that this restriction has a negative impact on the packaging market, constituting a barrier to innovation for this type of products [10]. Therefore, the FEA commissioned the preparation of a comprehensive Impact Assessment Study on the Adaptation to the Technical Progress of the Aerosol Dispensers Directive, in which one
proposal to amend the Directive was: "to increase the capacity of plastic aerosol containers and to introduce the same requirements for them as for metal dispensers "[11]. FEA is also developing their guideline “FEA 647 Plastic aerosol dispensers – Technical requirements”. As restrictions regarding plastic containers on US or Australian markets are not that strict as in Europe, it is believed that also European law requirements will be changed and will be closer to other markets [12].

Restrictions on the capacity of plastic aerosol containers were related to the fact that this type of containers produced in the 70s were less durable than metal ones. Along with technological development today’s plastic aerosol containers are produced in the injection stretch blow molding (ISBM) process. ISBM improvements was firstly used to support the conversion of carbonated soft drinks out of glass and into plastic. This process significantly drove the quality and consistency of wall orientation and other process controls that are now being leveraged into the aerosol container. Thanks to the improvements in the ISBM bottle manufacturing process, also aerosol containers were improved by plastic packaging’s production companies [12].

The plastic aerosol containers are manufactured in two-stage injection stretch blow molding process. In the first injection molding step, the dry polyethylene terephthalate granulate is heated until the granulate becomes plasticized. The plasticized material is injected into the mold under pressure and immediately cooled. In the form of a preform, containers can be transported to locations closer to filling companies, which reduces the transport costs of this type of containers. The next step is heating, typically using infrared heaters, with different temperatures for different zones. It ensures the proper course of the blow molding process. The preform is then placed in a blow mold, where compressed air is pressed through preforms’ neck. Then it is blown into a shape corresponding to the shape of the form [13].

Above mentioned process refers to the containers made of polyethylene terephthalate (PET). This material is characterized by very high, almost any susceptibility to moulding, it is light and, above all, it does not corrode [14]. As manufacturers of this type of solutions ensure, plastic aerosol containers can be manufactured in a shorter time than metal ones, in addition, their transport is cheaper. Despite some of the consumer approaches, plastic can also be recycled. An additional advantage of containers made of plastic is that these containers has "warmer" touch in comparison to their metal counterparts, and their external surface is not so easily scratched or dents. Moreover, plastic containers can be decorated with many different possible solutions. What is also possible in transparent plastic containers, the customer has the opportunity to observe their contents [10, 12]. All those advantages to not impact the resistance of the plastic containers. Their pressure resistance is similar to the metal ones. This kind of containers positively pass the required hydraulic and bursting tests for empty metal containers, dropping test at various temperatures, exposure to hot air over periods of time as well as top load testing. Plastic containers form leading producers are suitable for use with compressed gas, hydrocarbons (where suitable), bag-on-valve and non-flammable combinations of other propellants, and they can withstand burst pressures of up to 22 bar [9, 15].

4. New technological solutions

In classic aerosols the formula itself is mixed with propellant and has direct contact with the can. For some types of products, especially where hygienic conditions are very important, or the products cannot be in contact with the can, another available solutions for aerosol application must be used. One of the biggest advantages of this solution is the fact that formula does not have contact with container. It is commonly used in medicine where formulas are very vulnerable for contamination, as well as in products, where formula is irritant and might have a corrosive effect on the container. Products made in these technologies are protected against oxygen exposure and it benefits in less need for preservatives and longer shelf life for oxygen-sensitive products. What is also very important, this kind of products have also environmental benefits. There is no need to use flammable propellants and instead of this eco-friendly air or nitrogen are used also up to 100% product emptying is possible.
4.1 Bag on Valve technology (BOV)

One of the possibilities is Bag-on-Valve technology. In 1982, the first BOV design patent was filed in Europe [16]. A BOV system consists of multi-layered and flexible pouch welded to an aerosol valve. In the most common filling process, nitrogen or compressed air is injected between the can and pouch, while the aerosol valve with the bag is crimped on the can. This is called under-the-cap gassing process. Another possible propellant filling method is injection through a bottom hole. Then the formula itself is filled through the valve to the pouch [17]. The process is schematically presented on figure 1. Depending on the finished product type, formula can be mixed with another gas or not. For example in shaving or depilatory gels, it is mixed with gas to cause the post-foaming effect after application of the product on the skin. For liquids or lotions there is no need to add any additional gas.

Also individual customers can feel the difference between classic aerosols and BOV technologies. The content of the product can be dispensed smoothly and evenly, giving the control of the dispensed amount. BOV can also be used from any angle without losing any force in spray and no pumping motions are needed. What is more, as propellent is not the part of formula, there is not chilling effect during usage [17, 18].

![Figure 1. Bag-on-Valve filling technology [17].](image)

Based on all those facts, the Bag-on-Valve products are commonly used for shaving gels, depilatory creams, sun care products, self-tanning sprays, seawater nasal sprays, wound cleaning and also edible oil sprays. The number of products manufactured in this technology is still raising.

4.2 Can-in-Can technology

Based on the Bag-on-Valve success, Nussbaum company provides Can-in-Can system which is very convenient for high-viscosity active substances like pastes, greases or silicones. The inner aluminium can is firmly connected to the outer can – see figure 2. This ensures the absolute separation of the formula and pressure medium, in the same time providing the most effective diffusion barrier of all comparable systems. The filling of the propellant is carried out through a bottom hole or through the already used closure plug [19].

4.3 Bag-in-Can technology

Similar to Can-in-Can is Bag-in-Can (BICAN) technology which was introduced by Crown company. The difference is that this bi-compartmented aerosol technology incorporates a plastic inner bag instead of can. But similarly, it prevents the product from coming in contact with the aerosol can itself and the propellant. The gas is injected through bottom hole after filling the formula into the bag [20].
4.4 Piston technology

Next solution for gels, waxes, industrial products such as caulks, silicones, greases, adhesives and sealants is Piston Aerosol Filling. It ensures separation of the product from the propellant. It can be used both with aluminium and plastic cans. At the center of this innovative system (patented for example by ZIMA and presented on figure 4 is a plastic piston, which separates the liquid from the propellant. First, the liquid is filled into the top part of the can and the spray valves seal the can. Next, the propellant – sometimes nothing more than air – is compressed into the bottom section through a base valve [21].

5. Other possible innovations

An interesting solution is the use of a colorless plastic container with a Bag-on-Valve technology, which is also transparent. This combination was created jointly by Appe and Power Container Corp. In this kind of packaging presented on figure 5, the customer for the first time is sure about the amount of product that remains to be used [22].

**Figure 2.** Can-in-Can system [19]

**Figure 3.** BICAN Technology [20]

**Figure 4.** Piston aerosol filling [21]

**Figure 5.** Transparent Bag-on-Valve in colorless plastic container [22].

**Figure 6.** Dual dispensing using double Bag-on-Valve in the can [23].
Another innovation is dual dispensing using double Bag-on-Valve in the can. This is a perfect solution for products containing two different formulas, which cannot be mixed before usage, for example hair colouring cosmetics or technical products such as glues. The discharge of two separately stored components is made with one push. A joint venture Toyo & Deutsche aerosol GmbH introduced dual dispensing aerosol called The DUAL presented on figure 6.

The second version of dual dispensing was presented by Lindal Group. In “Bi-Power Valve” it can be chosen between pre-mixing or separate dispensing of the mediums. Those two possible dispensing processes are presented on figure 7 and 8.

6. Conclusion
According to the data provided in the European Commission report "Evaluation of the Aerosols Dispensers Directive 75/324 / EC", it is expected that in 2020 the demand for aerosol products will reach over 18 billion units [24]. This visible quantitative increase in the aerosol products market indicates at the same time the need for innovation in this industry segment. Based on researches in aerosol industry magazines, data presented on fairs or on the websites, one of the leading purpose of innovations within aerosols is environment. Both manufacturers of metal and plastic containers try to find innovative solutions in their trade [25]. Aluminium and stainless steel containers have the limitations related to the specificity of the material. The advantages of using plastic as the material for containers are: elimination of rust, reduction of packaging weight, more flexible lead times and what is also very important due to the environmental issues – modern plastic materials have low carbon footprint.

Also ongoing developments of BOV technology should be observed. This technology not only has less negative impact on environment with air and nitrogen used as propellants, but also with its pro-consumer attitude reduce the preservative usage, prolong shelf life of the product and simplifies the application of the formula.

For more and more aware consumers, such approaches are very important and indicate directions for further development. Aerosol products should therefore not only be safe, environmentally friendly but also encourage with their appearance for purchase [26].

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