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New Methods to determine the come-off time of paper labels

In the beverage industry labels are removed from returnable bottles in bottle cleaning machines. For a successful cleaning process the labels come-off time is crucial. If the labels detach too late in this process, they can block rinsing nozzles and affect the cleaning effectiveness of the machine.

The term “come-off time” is defined by DIN 16524-6 as the time a tested label needs, to fully separate from a Petri dish when immersed in a caustic bath. However, the method according to DIN 165246 does not account for any double bonding of neck-ring labels, used on so called long-neck or ale bottles. Furthermore, many procedure steps of DIN 16524-6 are executed manually by the examiner, are not defined precisely or are impractical. Tests performed at the VLB Berlin showed that results between different examiners can differ significantly.

In this paper the results of the IGF research project 15343 N are presented. Within this project the come-off behaviour of different paper labels was tested against various influencing factors. It was found that the amount of labelling glue is of particular importance in combination with metallised paper labels. Deriving from that knowledge, an existing model for the come-off behaviour was extended, allowing to develop a Modified Method and an Extended Method to overcome existing limitations and inaccuracies of DIN 16524-6.

Descriptors: paper labels, metallised paper labels, come-off time, bottle cleaning machine

1 Introduction

1.1 Label removal in bottle cleaning machines

In Germany and many other countries beer and non-alcoholic beverages are filled in returnable glass bottles. After consumption of the beverage the empty bottles are returned to the beverage manufacturer, where they have to be cleaned in bottle cleaning machines, before they are refilled, labelled and packed again, ready for resale.

To fully remove paper labels by means of a bottle cleaning machine, the come-off time of a paper label is crucial. If the come-off time is too short, labels might already detach while pre-soaked in one or more baths at increasing temperatures. Since these first baths of bottle cleaning machines are usually not equipped with a label discharge system, the labels would accumulate in the pre-soaking station. The ideal point for detaching paper labels is after the bottles immerse in the main caustic bath, where, after a residence time, the caustic is jetted over the bottles to remove remaining parts of labels, which have been soaked off but still remain in the bottle cells. Once flushed out of the cells, the labels are removed by the label discharge.

In case the come-off time is too long, the labels will not be flushed from the bottle cells in time before the cells reach the rinsing stations. Here the bottles are jet-rinsed several times inside and outside. The rinsing starts with hot caustic, then each further station with decreased caustic concentration and temperature. At the last station the bottles are rinsed with cold fresh-water. Labels that are carried over to the rinsing stations and are flushed from the bottles cells while rinsing, can block the nozzles of these stations. If too many labels are carried over, it is possible that bottles leave the bottle cleaning machine still with caustic inside, representing a considerable health hazard for the customer.

Another possibility is that labels are not removed by the bottle cleaning machine at all. When checked by the empty bottle inspection machine, these bottles are either sorted out and destroyed or sent back to the bottle cleaning machine for a second cleaning [4; 3].

1.2 Testing paper labels according to DIN 16524-6

To ensure that paper labels used on returnable glass bottles will be removed in the main caustic bath in time, the label come-off time can be tested according to DIN 16524-6 [5]. Here labelling glue is applied to a glass plate with a 50 µm hand-coater. A circle with a diameter of 80 mm ($A_{\text{Label}} = 50.27 \text{ cm}^2$) is cut from the label, put on the glue with its back side and is evenly pressed on. The back side of the label picks up glue and is removed again from the glass plate. With the glued backside the label is then put on the bottom side of a Petri dish and is again evenly pressed on, avoiding enclosures of air. After 24 hours drying, the Petri dish is put bottom side down on a slowly rotating caustic soda solution ($w_{(\text{NaOH})} = 1.0 \%$; $75 \pm 2 \text{ }^\circ\text{C}$) so that it swims on the caustic and the label is in direct contact to the caustic solution. The come-off time

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Figures see Appendix

is defined as the time after which the paper label is fully removed from the Petri dish, measured from the first contact between Petri dish and caustic.

Critical examination of DIN 16524-6

However, DIN 16524-6 is not applicable for neck-ring labels used on so called long-neck or ale bottles. Particular for this type of label is a double bonding where the label is overlapping. This doubles the thickness of the paper at the double bonding and therefore possibly increases the time necessary for the caustic to penetrate through the label and to dissolve the labelling glue fixing the label to the bottle surface. In addition to that, the interaction of the glue between a paper to paper bonding might be different than the bonding of paper to glass, which is tested according to DIN 16524-6. In consequence, the come-off times of neck-ring labels, measured according to DIN 16524-6, might still be below the maximum come-off time agreed between beverage manufacturer and label supplier, while the real come-off time in the bottle cleaning machine is too long. DIN 16524-6 offers no possibility to predict the influence of overlapping labels on the come-off time or the influence of the combination of neck-ring label and labelling glue. As a result papers, glues and combinations of both are used that might not be removed by bottle cleaning machines used in the beverage industry. Examples for such combinations can be seen in Figure 1.

Furthermore, many procedure steps of DIN 16524-6 are executed manually by the examiner, e.g. the pressing on of the paper labels on the glass plate with glue and later on the Petri dish. Other steps are not defined precisely, e.g. the time the paper label sticks to the glass plate with glue before it is removed again by the examiner. If nothing else, the impractical use of Petri dishes swimming on the surface of the caustic solution, which not nearly corresponds to the actual fluid mechanics in bottle cleaning machines.

Tests performed at the VLB Berlin with three examiners, using a metallised paper label, showed that single values differ up to 69 % from the average value of all three examiners. Single values of individual examiners fluctuate ± 10 % from the examiners individual average value.

Objective and methodology

Against this background the aim of the IGF research project presented here was to increase the knowledge base of the come-off behaviour of paper labels by measuring the come-off time against various influencing factors. Deriving from that knowledge an existing model for the come-off behaviour was extended which allowed developing a Modified Method and an Extended Method to eliminate existing limitations and inaccuracies of DIN 16524-6.

2 Materials and methods

2.1 Paper labels and glues

According to their composition, paper labels can be divided into two major groups: non-metallised paper labels and metallised

paper labels. Non-metallised labels usually consist of a basic paper with a functional coating on the back side and a surface coating on the front side to improve printing performance. In addition to that, metallised paper labels have an undercoat lacquer on top of the surface coating, on which a thin layer of aluminium is vapour deposited. The metal layer is covered with a primer for printing [4]. These three extra layers increase the grammage of the label and represent a further barrier for the caustic penetration of the label in bottle cleaning machines.

Therefore both types of paper labels were tested. Paper label no. 1 (PL1) was a non-metallised paper with a grammage of 70 g/m². Paper label no. 2 (PL2) was a metallised paper with 71 g/m² grammage. PL1 and PL2 were chosen because their basis papers were comparable in structure, composition and characteristics. The labels were cut in the format 70.00 mm * 71.50 mm which results in 50.05 cm² label size. The fibre direction of the labels followed the 70 mm axis. Both basis papers were used as unprinted labels or printed with offset printing respectively gravure printing (blue, 100 % covering). In addition to that, the labels were optionally imprinted and/or lacquered (pigment-free colour, 100 % covering). PL3 and PL4 were made from the same papers used for PL1 and PL2 but from a later batch and uncut. To identify the kind of label displayed in the diagrams, the following key can be used:

PL1 and PL3 = Non-metallised Paper with 70 g/m²; PL2 and PL4 = Metallised paper with 71 g/m²

NP = No printing; OP = Offset printing; GP = Gravure printing

Mn = Metallization; In = Imprinting; Ln = Lacquering $\Rightarrow n=0$: no / $n=1$: yes

If not mentioned otherwise, a widely-used casein-glue (G1) with a high fraction of casein was used for labelling. Other glues used were an ice-water resistant casein-glue (G2), semi-synthetic glue (G3) with a high fraction of starch and ice-water resistant synthetic glue (G4) without casein but a high fraction of starch.

2.2 Altered version of DIN 16524-6

The first series of tests comprised the influence of the paper label itself on the come-off time. For this series an altered version of DIN 16524-6 [5] was used to determine the come-off times. Considering the criticisms on DIN 165246 described before, the glue was applied by means of a semi-automatic coating machine with a 50 μ m hand-coater. The Petri dishes, once swimming on the caustic solution, were fixed to the beaker glass so that the Petri dishes were in the centre of the caustic solution and could not spin with the rotating caustic solution. In addition to that, all measurements were performed by the same examiner.

2.3 Working Method

Parallel to the first test series with DIN 165246 a so called Working Method was developed, with the aim to copy the industrial labelling process and the conditions in a bottle cleaning machine as close to reality as possible. By means of a Langguth E 98/2

semi-automatic labelling machine the labels were applied directly to hollow glass cylinders. The cylinders were cut from NRW glass bottles, using a circular glass saw. The surface of the glass cylinders had no cold-end-treatment that could wear off when reusing the cylinders. After application the labels and glue dried over night, for at least 12 hours. Following this period the labelled cylinders were placed upright on a tripod in three litres caustic soda solution ($w_{(\text{NaOH})} = 1.0\%$) to wash-off the labels (Fig. 2). The caustic solution had a temperature of 75 ± 1 °C and was rotated with 460 ± 20 rpm by a magnetic stirrer. These values represent the lower limits of washing conditions, used in the beverage industry and therefore place the highest demands on the removal of paper labels within the current range of washing conditions. The come-off time was measured beginning with the first contact between glass cylinder and caustic solution until the label was fully removed from the cylinder and floated in the caustic.

Advantage of the Working Method, compared with DIN 16524-6, was that an influence of the examiner during sample preparation was avoided. In addition to that, the geometry of a glass cylinder is closer to a real bottle than the flat bottom side of a Petri dish. Besides, the streaming of the caustic followed the shape of the cylinder on the tripod. This guaranteed that as soon as the label was detached from the cylinder, the current removed the label allowing a precise determination of the come-off point. Another advantage was that using the Langguth labelling machine offered the possibility to vary the amount of labelling glue applied to the label in contrast to the prescribed $50 \mu\text{m}$ hand-coater in DIN 16524-6.

2.4 Amount of applied labelling glue

The amount of labelling glue put about the labels by the labelling machine or when following DIN 16524-6 was determined by measuring the individual weight of $k = 5$ labels and instantaneously measuring their weight again after gluing. The average coating weight ($M_{(\text{Glue})}$ in g/m^2) on the label was calculated according to following formula ($m = \text{Mass}$ in g ; $A = \text{label area}$ in m^2):

$$M_{(\text{Glue})} = \frac{\sum_{n=1}^k m_{n(\text{Label} + \text{Glue})} - m_{n(\text{Label})}}{k \times A}$$

2.5 Modified Method

According to the Modified Method a self-adhesive note paper (e.g. Post-it®) is placed face down on a plane glass plate. The note paper is fixed to the glass plate with adhesive tape at its self-adhesive strip, leaving approximately 5 mm of the self-adhesive strip free. A circle with a diameter of 80 mm is cut from the label and placed face down on the backside of the note paper. Bordering the adhesive tape, the label is fixed by the free self-adhesive strip of the note paper. The fibre direction of the label is at right angle to the adhesive tape.

A stripe of glue is placed on the length of the adhesive tape. With a $10 \mu\text{m}$ hand-coater the glue is applied to the backside of the label. The amount of glue has to be between $12.0 \text{ g}/\text{m}^2$ and $13.0 \text{ g}/\text{m}^2$.

The performed tests showed that the amount of glue is strongly depending on the examiner and a training period is mandatory before continuing. During this training period the amount of applied labelling glue is measured for each single label ($k = 1$), according to the formula described above. The gluing of the label has to be repeated by the examiner until his last 10 successive trials have an average between $12.0 \text{ g}/\text{m}^2$ and $13.0 \text{ g}/\text{m}^2$ and a standard deviation less than 1.00.

When the examiner is trained to apply the labelling glue within the demanded values, the next label can be glued. Immediately afterwards the label is picked up from the removable note with a pair of tweezers and applied to a glass cylinder of 120 mm height and 70 mm in diameter. The fibre direction of the applied label has to be horizontal. The corners of the label are softly pressed on the glass cylinder and the final fixation of the label is executed with defined pressure by means of a specially designed manual labelling device.

After drying for a minimum duration of 24 hours and a maximum of 48 hours, the glass cylinder is placed on a tripod in a three litre beaker glass. The beaker glass contains 2.5 litres of caustic soda solution ($w_{(\text{NaOH})} = 1.0\%$) with a temperature of 75 ± 1 °C and rotated with 375 ± 20 rpm by a magnetic stirrer. The come-off time is measured beginning with the first contact between glass cylinder and caustic solution until the label is fully removed from the cylinder and floated in the caustic.

After the label is detached, the glass cylinder can be removed from the beaker. To neutralize the caustic on the glass cylinder and to prevent the formation of sodium hydrogen carbonate on the glass surface, the cylinder should immediately be submerged in warm water containing citric acid before it is later cleaned under warm water and rinsed with pure water.

2.6 Extended Method

The Extended Method is based upon the Modified Method described above. Diverging from the Modified Method, a neck-ring label is cut in half along its longitudinal axis, instead of cutting a circle from the label. Both parts of the neck-ring label are placed face down on the backside of the self-adhesive note paper. The cutting edges are adjacent to the adhesive tape and fixed by the free self-adhesive strip of the note paper.

After an equivalent training phase for the examiner, both parts of the neck-ring label are glued at the same time. Immediately afterwards the lower label is picked up first from the removable note with a pair of tweezers and applied to a glass cylinder. Then the upper label is picked up and placed on the glass cylinder, with its end overlapping the end of the lower label for 10 mm. The corners of the labels are softly pressed on the glass cylinder and the final fixation of the label is again executed by means of a specially designed manual labelling device.

The come-off time is measured separately for both parts of the neck-ring label, beginning with the first contact between glass cylinder and caustic solution until each label is fully removed from the cylinder and floats in the caustic.

3 Results

It was expected that the come-off behaviour of paper labels is influenced by a range of factors. One of them is the label composition, regarding the choice between non-metallised and metallised paper but also involving printing technology, additional lacquering and imprinting of the label.

Another group of possible influencing factors are the operating parameters of the bottle cleaning machine. These are mainly temperature and concentration of the caustic solution but also the contamination of the caustic with labelling glue and separating parts of the labels.

In addition to these two groups, the kind of labelling glue and the amount of glue being used might also be of influence.

3.1 Influence of label composition

The tests on the influence of the label composition, performed according to DIN 16524-6, showed that the printing of the label has a significant influence on the measured come-off time. Using non-metallised PL1 with gravure printing increased the come-off time by 39 %. With offset printing the come-off time of the unprinted label was almost doubled (Figure 3). Printing metallised PL2 also caused an increased come-off time but no considerable difference between the printing methods could be detected.

An additional lacquering could be used to amplify the gloss of the label or to print on white areas to counterbalance areas with printing colour. This additional layer of pigment-free colour had no major effect on the come-off time with PL1 and gravure printing; it even reduced the time by 11 s. On the other hand lacquering PL1 with offset printing increased the average come-off time by another 23 s (Fig. 3). This corresponds with what was measured for metallised PL2. The come-off time using gravure printing was slightly reduced, while lacquering with offset colours increased the come-off time by 39 s.

An explanation for the different come-off times is that the pigments of printing colour, independent of what technique is used, presents an additional thin barrier for the caustic before it penetrates the label. However, colours used for offset printing are hydrophobic, compared to solvent-based colours used for gravure printing [1]. Compared to gravure printing, it is likely that the hydrophobic character takes effect on the caustic solution, which consists mainly of water. In consequence the caustic penetration is decelerated, which again increases the come-off time. This also explains why a second layer of hydrophobic offset lacquering increases the come-off time even further, while a second thin layer of gravure pigments shows only a minor influence.

The two paper labels PL1 and PL2 were deliberately chosen because their basis papers are similar in structure and composition as well as physical characteristics. Comparing both papers therefore allows quantifying the effect on the come-off time caused by the metallisation layers on PL2.

Figure 4 illustrates that metallised PL2 has a significantly higher come-off time than PL1. However, it is also evident that imprint-

ing PL2 fully compensated the effect of the metallisation. These observations have their origin in the additional layers of the metallisation, which slow down the caustic penetration of the labels. Imprinting PL2 prisms these layers open, allowing an accelerated caustic penetration. The effect of imprinting PL1 is comparatively small since the surface of a non-metallised paper is already open for caustic penetration.

3.2 Influence of cleaning parameters

Operating parameters of the bottle cleaning machine are considered to be a further influencing factor on the come-off time. All following tests were performed according to Working Method.

Varying the caustic temperature has a significant effect on the come-off behaviour of the tested paper labels PL1 and PL2, as can be seen in Figure 5. Between 60 °C and 80 °C an almost linear decreasing come-off time is linked to an increase of caustic temperature. With non-metallised PL1 the come-off time is reduced by approximately four seconds per degree Celsius. For PL2, with 2.5 seconds reduction per degree Celsius, the effect is not quite as distinct.

A variation of the caustic concentration between $w_{(\text{NaOH})} = 0.5\%$ and 2.0% had no significant influence on the come-off times. Only PL1, in combination with $w_{(\text{NaOH})} = 0.5\%$, showed an increase of 34 %, compared to the other values of PL1. However, the caustic concentration recommended for bottle cleaning machines, e.g. to ensure the removal of organic residuals, is between $w_{(\text{NaOH})} = 2.0$ and 2.5% [5]. Therefore the effect of the caustic concentration on the come-off time can be neglected.

While operating a bottle cleaning machine the caustic gets polluted with dissolved labelling glue, components of paper labels and dirt from returned bottles. The contamination with glue and labels was simulated in the caustic solution by adding 30 g casein glue and leaching 40 labels PL1, respectively PL2, for 10 minutes. After removing the labels, the COD (chemical oxygen demand) was measured as a global parameter to quantify the contamination. The COD of the caustic solution with PL1 was measured with 4200 mg/l while the caustic solution with PL2 had a COD of 4500 mg/l. These values lie within the range that was found in bottle cleaning machines. The average COD measured in the first caustic bath of six different bottle cleaning machines was 4900 mg/l, with a minimum of 2600 mg/l and a maximum value of 6700 mg/l.

Comparing the come-off times measured with unpolluted and polluted caustic solution, the come-off time with PL1 was increased by 18 s (21 %) while the come-off time of PL2 showed an increase of 16 s (11 %).

3.3 Influence of labelling glue

One series of experiments was performed to determine the influence of the time labels are attached to bottles. The come-off time was measured after one day, as it is prescribed in Working Method. Further come-off times were measured after 10, 15, 21, 25 and 35 days. Within these five weeks no significant change in

the come-off time was detected and fluctuations during the testing period were within standard deviation.

Another aspect investigated was, if cold-end-treatment on the bottle surface and the inevitable reduction of cold-end-treatment, caused by repeated cleaning of the bottles, has an influence on the come-off time. As it is evident in Figure 6, there is no significant difference in come-off time between bottles with and without cold-end-treatment, independent of the type of glue being used.

The amount of labelling glue being used usually ranges between 8 g/m² and 15 g/m² [4]. In exceptional cases, e.g. to reduce problems with label wrinkling, higher amounts can also be used. Figure 7 displays seven test series in which the amount of glue on the label was varied in combination with type of paper and method of testing.

Graph 1 (G1) shows the come-off times of non-metallised paper label PL1, printed with offset printing. Within range of 9 g/m² to 23 g/m² the come-off time increases from 71 s to 84 s. If PL1 is additionally lacquered (graph 2 (G2)), the come-off times are generally increased, while the trend line is parallel shifted. These results confirm observations made earlier for the influence of lacquering (Fig. 3). Using PL1, the influence of the amount of glue is therefore considered to be negligible.

Replacing PL1 by metallised paper label PL2 changes this behaviour fundamentally, as is displayed by graph 3 (G3). Beginning with 23 g/m² and reducing the amount of applied glue to 9 g/m², the come-off time triplicates from 165 s to 492 s. The further the amount of glue is reduced, the stronger the influence on the come-off time gets, which is also reflected by the hyperbolic shape of the graph. Increasing the glue from 23 g/m² up to 43 g/m² on the other hand seems to have no significant influence on the come-off time any more.

Imprinting metallised PL2 reduces the come-off times and the influence of the amount of glue significantly although the hyperbolic increase is still given (graph 4 (G4)).

PL1 and PL2 (offset printing, without imprinting and lacquering) were tested again according to DIN 16524-6. The come-off time of PL1 (graph 5 (G5)) is comparable to the come-off time measured with Working Method (graph 1). DIN 16524-6 come-off time of PL2 (graph 6 (G6)) lays in the area of the lowest values measured according to Working Method (graph 3).

3.4 Influence of double bonding

The double bonding of neck-ring labels on six different beer brands was investigated. The average double bonding area was 414 mm² (minimum: 359 mm²; maximum: 468 mm²). To determine the come-off behaviour of a label with double bonding, the Working Method was altered to simulate the double bonding of neck-ring labels. Instead of one label in the original format 70.00 mm * 71.50 mm, two labels were used. These two labels were cut from original labels in a way that when two cut labels were put together with an overlapping area in the middle, the combined labels had the format of the original labels. The cut went parallel to the horizontal fibre direction. The two smaller labels were labelled one after the other, with the overlapping area of 500 mm² in the middle of the label.

As expected, the upper label generally detached first, followed by the lower label. Compared to originally uncut labels, the lower labels of non-metallised PL1 and metallised PL2 had an increased come-off time of 45 s respectively 48 s.

When reducing the overlapping area to 400 mm² and later 300 mm², the come-off times of the lower labels of PL1 were still higher than the come-off time of uncut labels, although the difference was decreasing. After reducing the overlapping area of PL2, there was no longer a significant difference between lower labels and original labels.

4 Discussion

4.1 Model for the come-off behaviour as an explanatory approach

According to the model described by [3], the caustic penetrates the labelling glue from the side and through the label surface at the same time. As soon as the caustic has fully penetrated the label, it dissolves the boundary layer of labelling glue at the contact surface between label and glue. Once the adhesive power, linking the label to the glue, is annihilated, the label detaches from the bottle.

Since non-metallised paper labels are rapidly penetrated by hot caustic, detaching the contact surface should preponderate over sidewise caustic penetration (see schematic illustration in Fig. 8). Therefore it is to be expected, that the whole detaching process is independent from the layer thickness of the labelling glue.

This assumption was confirmed by the measured come-off times with non-metallised PL1. Graph ① and ②, in Figure 7 show, that the come-off time is basically not influenced by the amount of labelling glue used. The slight increase that was measured might be caused by a growing number of contact points between label surface and glue, when the amount of labelling glue is raised.

Graph ②, also shows, that if the caustic penetration is slightly slowed down, e.g. by a thin additional layer of hydrophobic lacquer on the label, the come-off times are higher because it takes longer for the caustic to reach the contact surface. Nonetheless, the label removal is caused by the detachment of the contact surface and is therefore not affected by the amount of labelling glue.

4.2 Extended model for the come-off behaviour

However, an explanation for the apparently paradoxical behaviour of metallised paper labels – less glue causes higher come-off times – cannot be derived from the known model. Not until it is extended by the influence of labelling glue layer thickness on the rate of sidewise caustic penetration.

According to the original model, the caustic penetrates the labelling glue from the side and through the label surface at the same time. Since the penetration through the label is considerably restrained by the additional layers of metallised paper labels, the label detachment will be accomplished by the sidewise caustic penetration.

The rate with which the caustic can penetrate the glue is strongly depending on the layer thickness of the glue. The thinner the layer, the smaller becomes the lateral contact surface for the caustic, which again slows down caustic penetration. The thicker the layer, the faster the glue can get washed out and the shorter the come-off time gets. This coherence is pointed out by the different sizes of the penetration arrows in Figure 9. When continuously increased, the layer thickness reaches a point where further glue is no longer reducing come-off time. For the tested PL2 this limiting value seems to be reached at 23 g/m², since an increase to 43 g/m² did not affect the come off time any more (graph ③ in Figure 7).

The extended model also provides an explanation on the different come-off behaviour of glues in combination with PL1 and PL2 (see Fig. 6). To detach PL1, the caustic has to dissolve just the boundary layer, which is very thin by nature. On the other hand, for disconnecting PL2, the caustic has to penetrate the labelling glue all the way from the side of the label to the label centre. Therefore the influence of the type of glue being used on the come-off time must be higher with PL2 than with PL1, since with PL2 a much more intense interaction between caustic and labelling glue is necessary. Regarding the difference between lowest and highest measured come-off times of both paper labels, 54 s for PL1 and 118 s for PL2 confirms the assumption.

In addition to that, the ice-water resistant glues show the highest come-off times with PL2. These glues were especially designed to withstand dissolution by water, which in consequence also leads to an increased resistance against caustic in bottle cleaning machines. With this attribute and in combination with the interaction described above, this result can also be explained.

The transition between both extremes, non-metallised paper on one hand and non-imprinted metallised paper on the other hand, is fluent. E.g. by imprinting a metallised paper label the caustic penetration is increased and the come-off time is being reduced (graph ④ compared with ③ in Fig. 7). However, the come-off time is still affected by the layer thickness as it is still depending on the amount of labelling glue.

4.3 Verification of the extended model

According to the extended model, a highly penetrable, non-metallised paper label is separated from the bottle by caustic penetration and detaching the contact surface between label and labelling glue. In consequence, the size of the label should have no influence on the come-off time of the label since the caustic penetration takes place over the whole surface at the same time.

On the other hand a metallised paper label with limited caustic penetration is removed by sidewise caustic penetration through the labelling glue. Therefore one would expect a linear correlation between the length of the labels edge and the come-off time.

These assumptions were tested using an imprinted, non-metallised paper label (PL3_OP_M0-I1-L0) with high penetration rate compared to a second label, which was a non-imprinted, metallised paper label (PL4_OP_M1-I0-L0). The edge length of the square labels was increased from 5 cm to 9 cm in steps of 2 cm.

The graphs in Figure 10 confirm the assumptions based upon the extended model. The come-off time of PL3 is independent from the labels size. There is no significant difference between a label with 25 cm² and a label with 81 cm² area. In contrast to that, the come-off time of metallised PL4 increases linear as the length of the labels edges is increased.

4.4 Consequences for the use of DIN 16524-6

Aim of DIN 16524-6 is to ensure that paper labels used on returnable glass bottles will be removed in the main caustic bath in time, before they get carried over to the rinsing stations of the bottle cleaning machine.

Comparing graph ① and ⑤ in Figure 7 shows, that the actual come-off time of non-metallised PL1 is represented by the results measured according to DIN 16524-6. However, considering graph ③ and ④ it gets obvious that the come-off time of metallised PL2 measured according to DIN 16524-6 (graph †) is on no account representative for the actual come-off behaviour of the tested metallised label. This is due to the fact that DIN 16524-6, using approximately 45 g/m² of glue, neglects the strong influence of the labelling glue layer thickness.

PL2, measured according to DIN 16524-6, has a come-off time of 145 s. This is clearly within a range on which beverage manufacturers and label suppliers usually agree. Therefore this label would not be rejected at receiving inspection. If this label is then labelled with a normal amount of glue (8 g/m² to 15 g/m²), the actual come-off time would range between approximately four to eight minutes, causing problems with labels being carried over to the rinsing stations, as described in the introduction.

For that reason DIN 16524-6 cannot be recommended as a test for receiving inspection of all kinds of paper labels.

4.5 Modified Method

The results of this research project showed, that the influence of the labelling glue layer thickness has to be considered, when testing the come-off time of paper labels. Therefore a Modified Method, as described in Materials and Methods, was developed to overcome the insufficiencies of DIN 16524-6. Main advantages of the Modified Method compared to DIN 16524-6 are the prescribed amount of labelling glue between 12 g/m² and 13 g/m² and the use of close to reality glass cylinders, instead of flat Petri dishes.

Graph ⑦ in Figure 7 shows the come-off time of metallised PL2, measured according to the Modified Method. With 392 s come-off time, the Modified Method clearly identified PL2_OP_M1-I0-L0 as a paper label not suitable for the use in bottle cleaning machines in the beverage industry.

4.6 Extended Method

One major point of critique was that the influence of the double bonding of neck-ring labels cannot be evaluated with DIN 16524-6. The analyses showed that the influence of the double bonding is significant, when using highly penetrable paper labels. However,

since the come-off time of this kind of labels is comparatively short, the influence on the applicability seems to be negligible.

If paper labels with slow caustic penetration are being used, the influence of the double bonding was also found to be significant for an overlapping area of 500 mm². When reducing the overlapping area to 400 mm², which is close to the average overlapping area, this influence was no longer detectable. In consequence, neck-ring labels should be designed in consideration of minimising the overlapping area.

To determine the influence of the double bonding on the come-off time, an Extended Method was developed within this research project. This Extended Method, as described in Materials and Methods, is based on the Modified Method and offers the possibility to evaluate the additional come-off time, caused by the double bonding.

5 Conclusion

This work shows the effects of various influencing factors on the come-off time of paper labels in a caustic bath. It was found that the amount of labelling glue applied to metallised paper labels has an exceptional influence on the come-off time: less glue causes higher come-off times. Due to the difference between the amount of glue applied according to test method DIN 165246 and the actual amount of glue being used for industrial labelling, the existing method does not provide information about the actual come-off time of metallised paper labels. Therefore it cannot be recommended as a test for receiving inspection of paper labels.

Based on the knowledge of the influencing factors on the come-off behaviour of paper labels an existing model for the come-off behaviour was extended, which allowed developing a Modified Method and an Extended Method to measure the come-off time, eliminating existing limitations and inaccuracies of DIN 16524-6.

6 Acknowledgement

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7 References

1. Bückle, J. and Leykamm, D.: Handbuch der Etikettiertechnik – Grundlagen und Praxis erfolgreicher Produktausstattung, 6th ed., V. Kronseder, Neutraubling, 2001.
2. Knettel, K.: Was geht ab? – Ablöseverhalten von Etiketten in der Flaschenwaschmaschine, Brauindustrie, no. 10 (2009), pp. 42-45.
3. Kompetenzforum Getränkebehälter: Praxis-Handbuch für die Reinigung von Mehrwegflaschen aus Glas oder PET, 2th ed., Versuchs- und Lehranstalt für Brauerei in Berlin (VLB) e.V., Berlin, 2005.
4. Kunze, W.: Technologie Brauer und Mälzer, 9th ed., Versuchs- und Lehranstalt für Brauerei in Berlin (VLB) e.V., Berlin, 2007.
5. Norm DIN 16524-6 2000: Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse – Teil 6: Verhalten von Getränkeflaschenetiketten gegen heiße Reinigungslauge, Laugendurchdringung und Ablösezeit.

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Appendix



Fig. 1 Long-neck bottles with non-removed neck-ring labels after cleaning

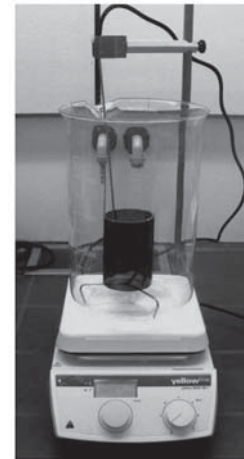


Fig. 2 Labelled glass cylinders and wash-off set-up with glass cylinder on a tripod

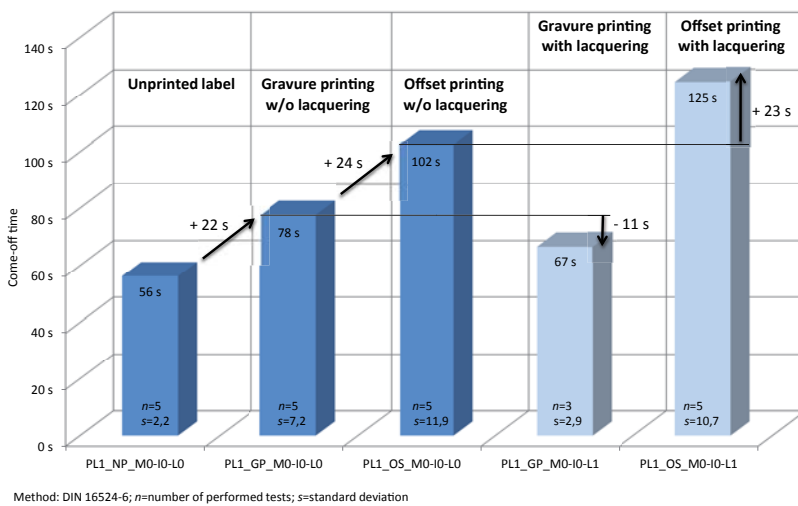


Fig. 3 Come-off time against printing method and lacquering

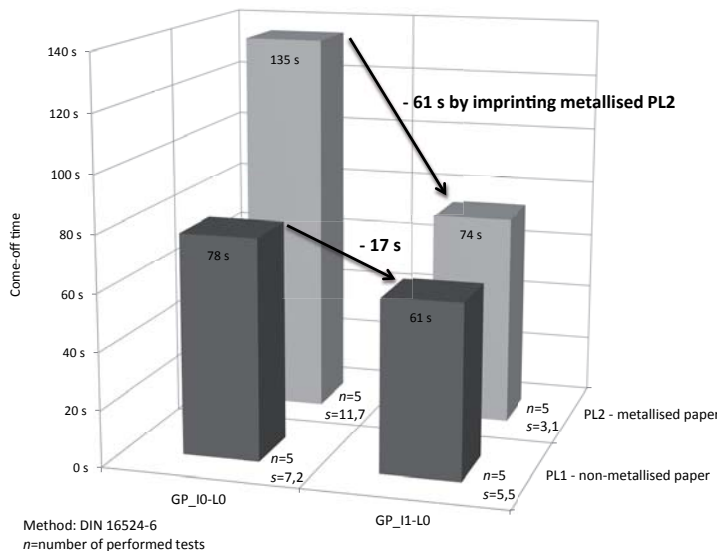


Fig. 4 Come-off time against metallisation and imprinting

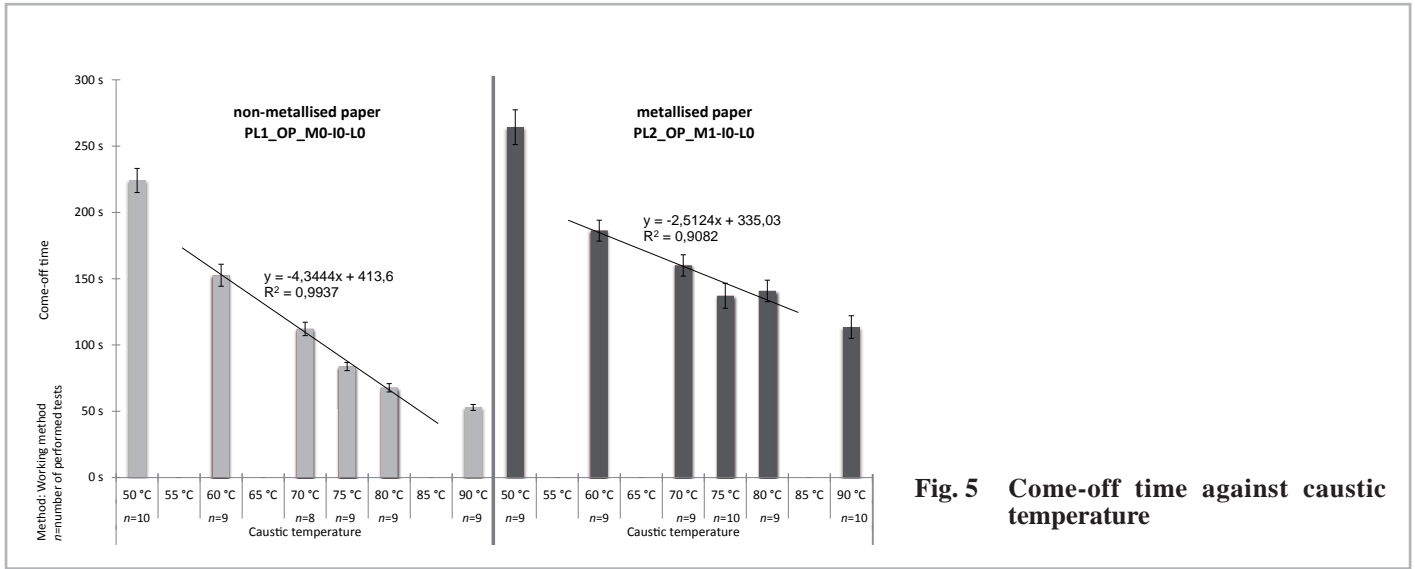


Fig. 5 Come-off time against caustic temperature

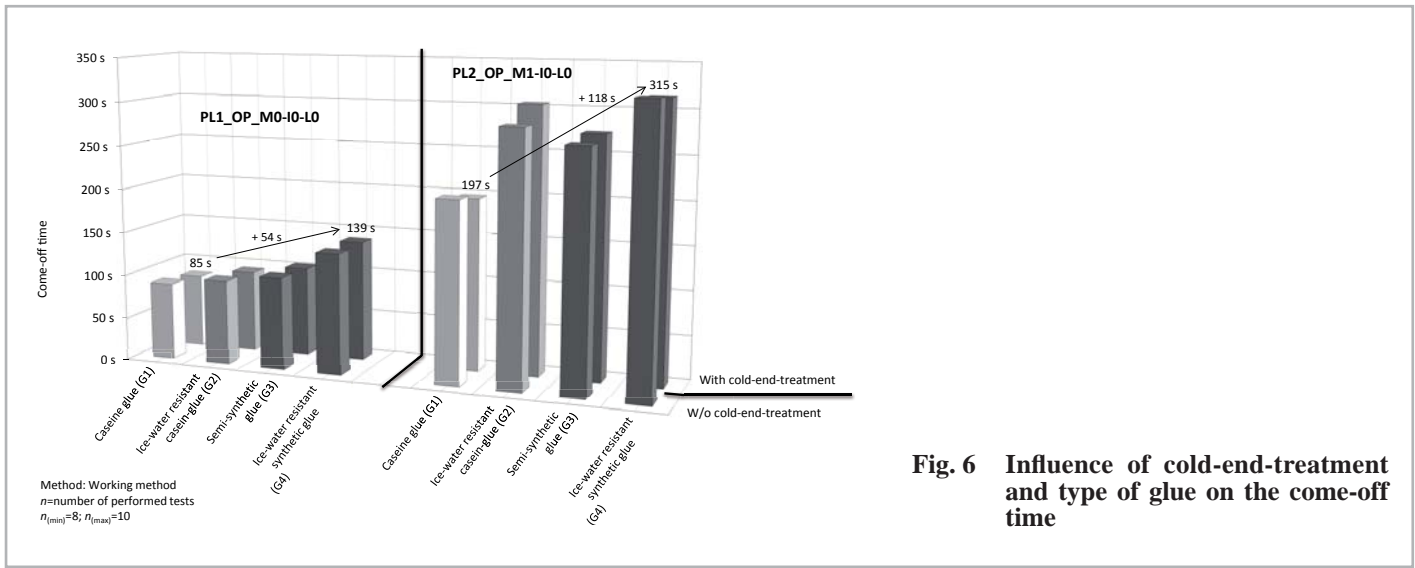


Fig. 6 Influence of cold-end-treatment and type of glue on the come-off time

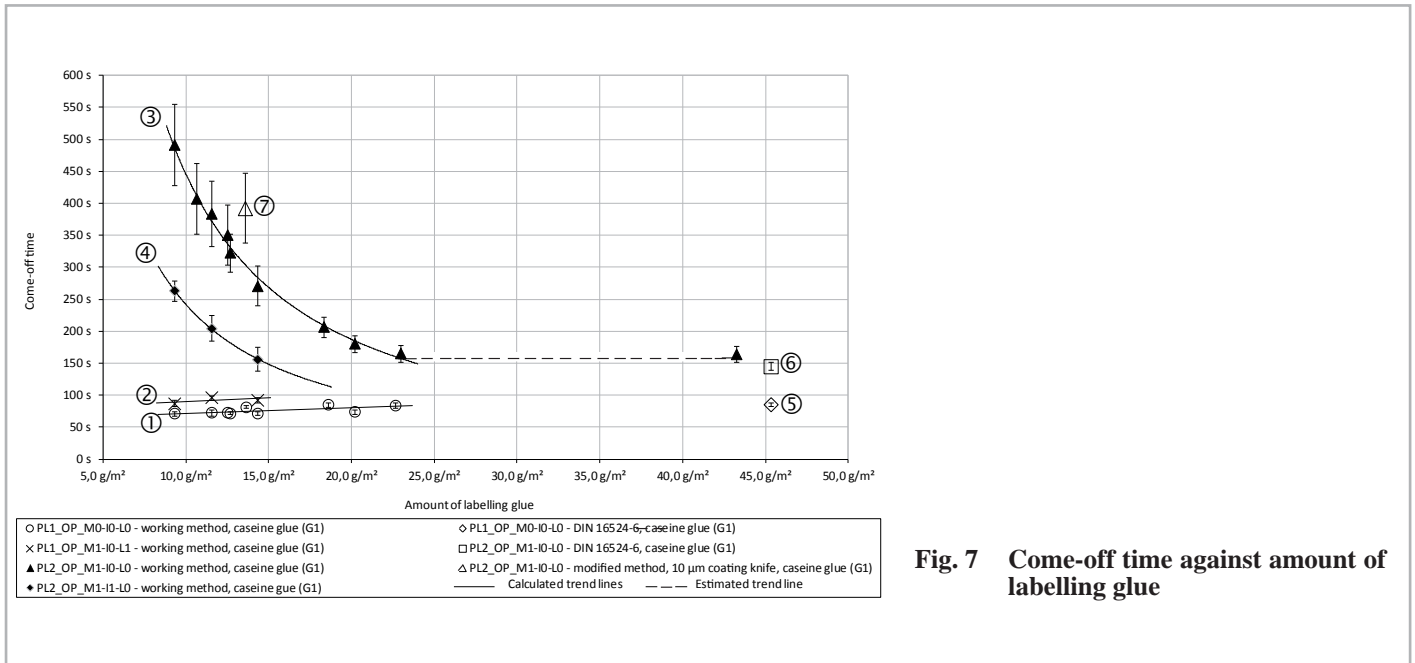


Fig. 7 Come-off time against amount of labelling glue

