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RESEARCH ARTICLE

TOWARDS AUTOMATED PACKAGING FOR E-COMMERCE LOGISTICS

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ABSTRACT

The conventional supply chain of consumer goods uses corrugated boxes on pallets as the main principle for manipulation, storage and transport of the goods. Apart from dimensions the vertical compression strength is the most important selection criterion for the boxes. In the early days of e-commerce corrugated boxes have been adopted as parcel packaging. However in e-commerce boxes are manipulated individually. They are dropped, thrown, rotated, compressed in all directions, … although they are designed for vertical compression resistance. Additional packaging material is required especially in case of fragile goods. Different types of cushioning materials are being used. Often 5 cm of expandable polystyrene chips on all sides around a fragile product is recommended by couriers and insurance companies. Some types of these chips are recyclable but most types fragment easily in small parts that survive for thousands of years if released in nature. In this research an alternative cushioning method is proposed and compared to the polystyrene chips in terms of shock absorption. Five variants of the new method are studied. The cheapest variant turns out to be the best shock absorber as well. Moreover this variant can easily be produced fully automatically. Therefore the new method is considered extremely promising.

KEYWORDS

recyclable, corrugated board, packaging, cushioning, automated.

1. INTRODUCTION

Figure 1: Korrvu® suspension packaging

E-commerce was born in 1994 in USA where a pizza was ordered via internet and delivered at home. The e-commerce growth in the early years was rather slow but in 2018 about 1.8 billion people worldwide ordered goods over internet[i].

E-commerce forced the logistics sector to develop new concepts for the supply chain at the level of real estate, storage and retrieval equipment, indoor logistics equipment, planning and administrative software [1]. Also new packaging concepts for goods to be shipped are being developed. An important milestone is the USA patent[2] of the Gillette Company for packaging of a specific solid product. Today the term "suspension packaging" is used for a folded corrugated board tray on which a product is fixed by an elastic film (figure 1). Most often the tray with film is produced on beforehand and the product is slipped between the corrugated board and the film when packaging the product [2]. The tray containing the product is put in a (corrugated) box. This kind of suspension packaging is not very suitable for packaging in most e-commerce fulfilment centres for several reasons:

- it is produced on beforehand and optimized for a specific product size. In most e-commerce fulfilment centres a wide variety of product sizes have to be packed and shipped. Packaging that is specific for one product size or even for a small range of product sizes, is very seldom used.
- it currently requires manual placement of the product between the corrugated board and the elastic film. This process is difficult to automate and is considered expensive in terms of labour force.
- it is quite expensive, probably because some patents restrict the number of providers.
- On the other hand companies producing this kind of suspension packaging claim superior cushioning effects of this kind of packaging.

2. AIMS AND OBJECTIVES

Figure 2: General purpose suspension packaging

In this research a new variant of suspension packaging is studied. It does not show the drawbacks of the tailor-made suspension packaging described above [3]. The product to be packed is put on a piece of corrugated board and stretch film is wrapped around the product and the board figure 2). The corrugated board is folded to create an air gap underneath the product and put in a box for shipping [4]. Since the wrapping of stretch film can be done for a wide variety of products, the method is called general purpose suspension packaging (GPSP). The main objectives of this research are:

- to evaluate the cushioning effect claimed for suspension packaging
- to check how the folding of the corrugated board effects the damping of impact forces
- to do an initial parameter evaluation such as dropping height and mass of the product.

The corrugated board for GPSP can be folded in many ways. Five variants that can be produced fast and automatically are evaluated in this research.

3. GENERAL PURPOSE SUSPENSION PACKAGING

The GPSP variants considered in this research (figure 3) consist of a rectangular piece of corrugated board that is creased and bended parallel to the flutes [5]. Any type of corrugated cardboard can be used.

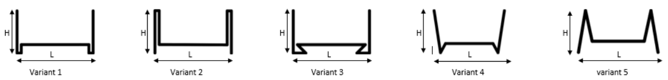

Figure 3: Variants 1 to 5 of creased and bended cardboard for general purpose suspension packaging

The rectangular piece of flat cardboard is referred to as “flat board”, after creasing this cardboard is called “creased board”, the creased corrugated board with the products fixed on it is referred to as “product carrier”, after bending the board along the creasing lines it is called a “pre-packed product” [6]. The pre-packed product fits in a box. Suspension packaging includes the bended cardboard, the fixation of the product on the cardboard and the box.

The length L, the height H and the width W (normal to the plane of the drawing) of the product carrier correspond to the inner length, height and width of the box that is going to be used for shipping [7]. Thanks to its square shape and the parallel creasing and bending lines, the product carrier can be produced very fast, taking into account the actual dimensions of the product to be packed. The flat board is cut to the required width while moving on a conveyor towards the wrapping machine. The 4 creasing lines can be produced by a simple creasing plate moving downwards while the flat board is passing. The flat board is cut to its required length in a similar way by using a guillotine knife.

Figure 4: Stretch wrapping machine

The product(s) to be packed is put in the middle of the creased board. To prevent sliding, rolling or tilting of the product on the creased board, stretch wrap film is wrapped around the product and the creased board. Any type of cast or blown stretch wrap film can be used. Numerous horizontal wrapping machines exist to perform this wrapping, even fully automated. In such a machine a reel of film is mounted on a ring that rotates around the product [8]. During the rotation of the ring the film is unwinded from the reel and wrapped around the product on the creased board. (figure 4). The elasticity of the film allows limited relative movement between product and creased board but on the other hand significant relative movement is prevented.

The board is then bended along the creasing lines to obtain one of the shapes shown in figure 3. Such a pre-packed product is to be put in a box or a box is to be folded around it. Obviously if the product dimensions (l, h, w) are smaller than the inside box dimensions (L, H, W) and since the product cannot move significantly relative to the corrugated board, the product does not touch the walls of the box. The product is surrounded by air on all 6 sides. If the box is dropped either on one of its six sides, on one of its ribs or on one of its corners, the product is well protected. It can be expected that impact energy is absorbed by deformation of the box, the bended cardboard, the elastic stretch film and by the friction between board and product.

4. TEST DESCRIPTION

In this research a square polycarbonate box (product) of 20 x 12 x 9 cm (l x w x h) has been packed in a corrugated box of 30 x 22 x 19 cm (L x W x H). The board consists of C-flute cardboard with top liner of 186 gram kraft paper, flute of 135 gram recycled paper, bottom liner of 180 gram recycled paper. The length of the flutes is about 22cm corresponding to the width W of the corrugated box. The product (PC box) is wrapped on the creased board by 12 revolutions of AFP’s Resinex 541 high performance 21 μ stretch film by using a standard Böhl horizontal stretch wrapper type TVP 600. Resinex 541 is a cast co-extruded LLDPE stretch film with cling effects available on reels of 125mm width. Such a reel is mounted on the ring of the TVP 600 machine. Rotation of the reel of film relative to the ring is hindered by an adjustable brake. When rotating the ring around the creased board with products, the pulling force on the film causes the film to stretch about 100%, meaning that 1m of film on the reel becomes 2m of film wrapped around the product carrier. When cutting the film after 12 revolutions, it remains in place thanks to the cling effect.

In order to evaluate the cushioning effect of the 5 variants of the pre-packed product, a 3-axis accelerometer and shock recorder (Endaq Slam Stick S4, sample rate of 3.2 kHz) is used. The sensor is fixed inside the PC box in the middle of the bottom plane. Accelerations in 3 orthogonal directions are recorded during the impact of the corrugated box on the ground. To evaluate the effectiveness of suspension packaging in terms of shock absorption, measured accelerations are compared to the equivalent values measured for a reference packaging with extruded polystyrene (EPS) chips. In this reference packaging the PC box is put in the cardboard box on top of 5cm of PES chips, then all free space around and on top of the PC box is filled with chips and the cardboard box is closed using tape. 16 different types of drop tests are performed:

1. Light weight product (LW, 450gram) and heavy product (HP, 2000gram). The light weight product is the empty PC box with recorder, the heavy product includes an additional steel plate fixed on top of the PC box.
2. Low drop height (LDH, 60cm) and high drop height (HDH, 120cm).
3. Drop on the box bottom side (1), back side (2), top side (3) and left side (4). Exploratory tests showed that test results for front and back side and for left and right side are identical as expected.

Therefore, in the actual test series no drop tests on the front and right side are included. Each type op drop test has been performed 4 times. Drop tests are performed using a high-performance drop test machine (figure 5) that allows to choose the free drop height between 0-200 cm. Drop tests are filmed using a 300-fps camera.

A new corrugated box and pre-packed product (corrugated board and stretch film) are prepared and used for each single test. Obviously, the PC box and recorder are re-used for all tests.

Figure 5: Drop test machine

5. TEST RESULTS

Acceleration versus time for three orthogonal directions are available as well as the video recordings. Numerous criteria for interpretation of these results can be used: peak acceleration value, duration of first acceleration peak, shock frequency spectrum analysis, video motion tracking, …[3-8] In this research the peak acceleration values measured on the product to be shipped are compared for the reference packaging and the 5 variants of general purpose suspension packaging presented in figure 3. The variation of these values for identical tests is less than 3%. Therefore, the average value for four tests are shown in figures 6 – 11 below.

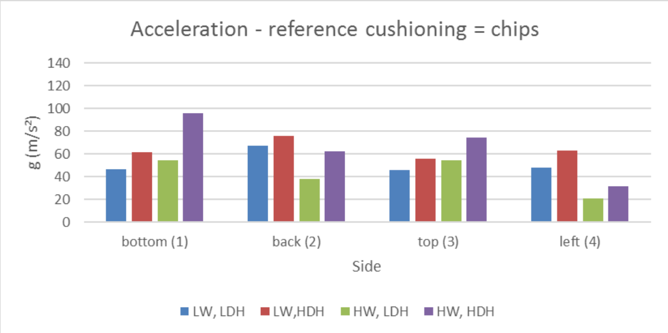

Figure 6: Reference cushioning = chips

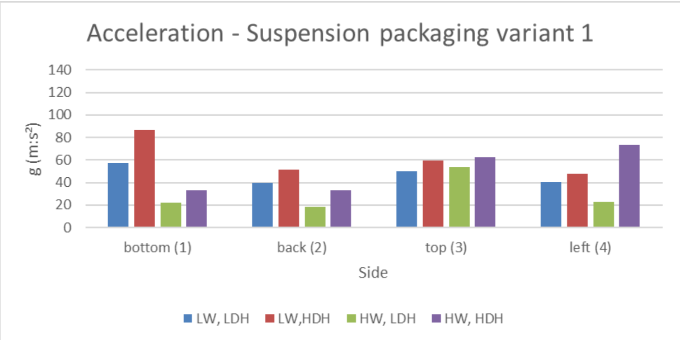

Figure 7: Suspension packaging variant 1

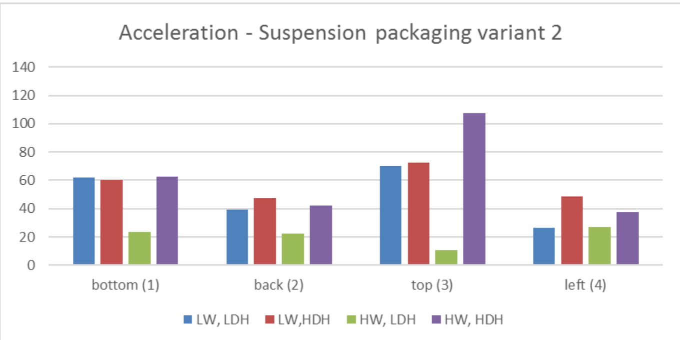

Figure 8: Suspension packaging variant 2

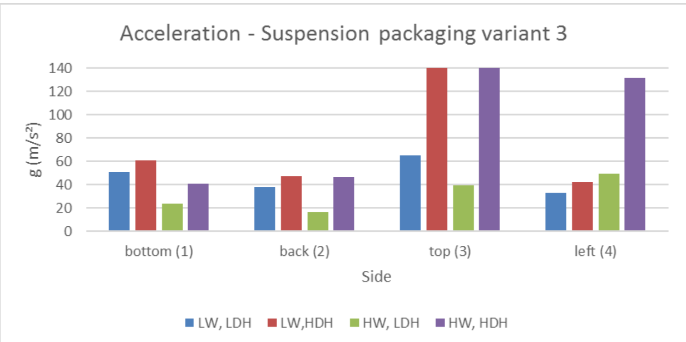

Figure 9: Suspension packaging variant 3

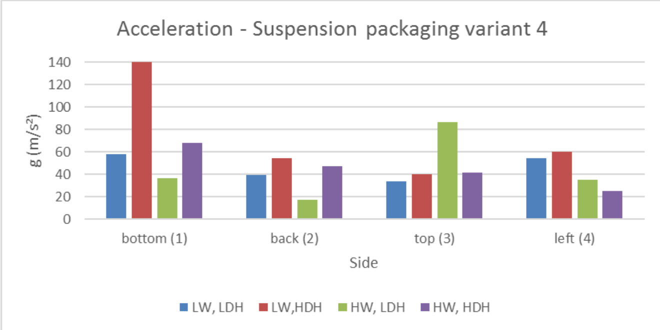

Figure 10: Suspension packaging variant 4

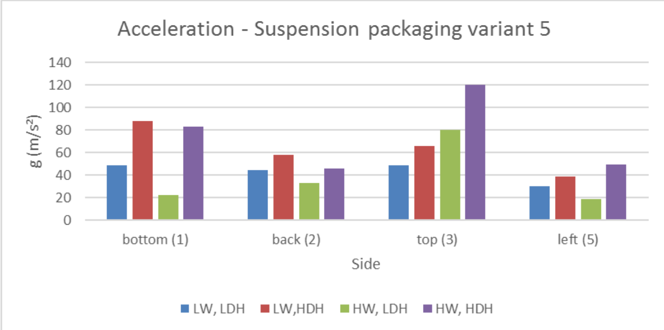

Figure 11: Suspension packaging variant 5

Figures 12 to 15 compare the measured accelerations for 6 types of packaging, respectively for drops on the bottom, back, top and left side of the box.

Some observations:

- None of the 6 packaging types performs extremely good or bad under all conditions

- The maximum acceleration for all tests is $95 m/s^2$ for chips (figure 6) and $85 m/s^2$ for variant 1 (figure 7). For this criterion variant 1 would be the best performer of the general suspension packaging and is even slightly better than the chips.

- Performance classification of the 6 packaging methods depends on product weight, drop height and drop direction.

- Suspension packaging performs extremely good when dropped on the back figures 12 -15). This can be explained by observations made when opening the box after the test. The product is shifted slightly on the board but it is retained by the stretched film. The acceleration of the box does not reach the product. In this direction all variants of suspension packaging perform better than chips for both test weights and drop heights.

- In some cases the acceleration is higher for lower weight and lower drop height, indicating that the suspension packaging was too stiff for these boundary conditions.

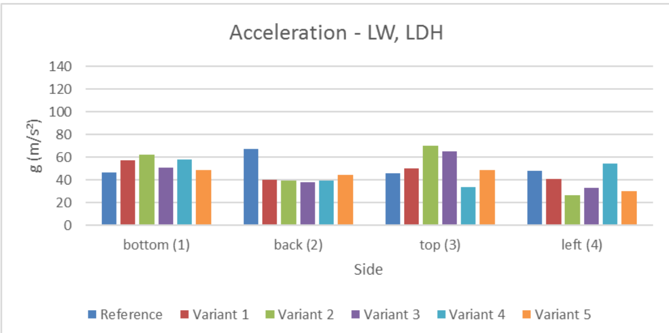

Figure 12: Acceleration - LW, LDH

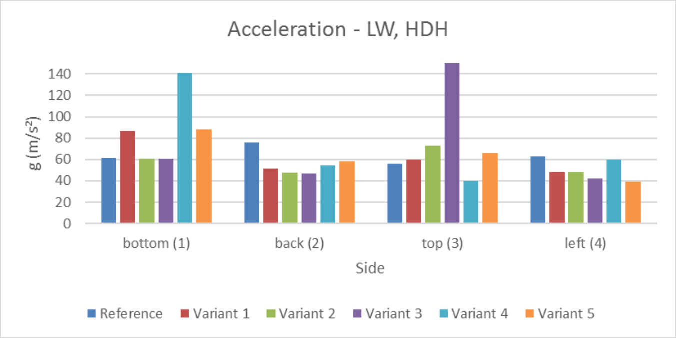

Figure 13: Acceleration - LW, HDH

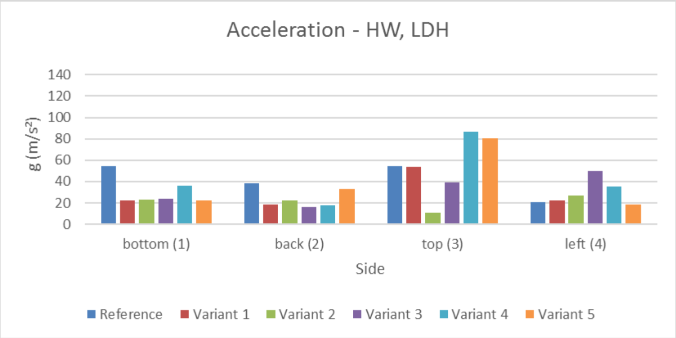

Figure 14: Acceleration - HW, LDH

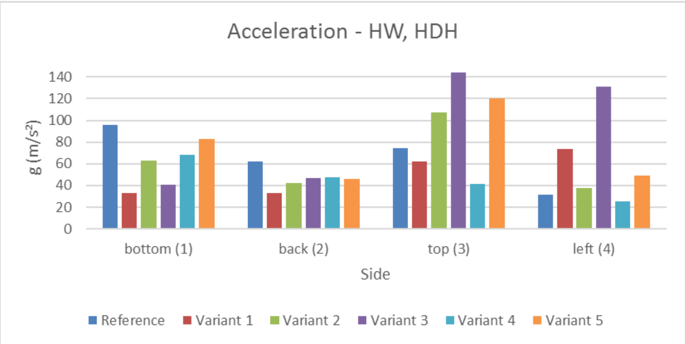

Figure 15: Acceleration - HW, HDH

6. CONCLUSIONS

1. General purpose suspension packaging can be produced automatically in an e-commerce fulfilment centre. Fanfold corrugated board is supplied, creased, cut and bended. Products are fixed automatically on a piece of board and existing machinery can be used to fold a box around the pre-packed product. Automated packaging can be organised 24/7.
2. Cushioning properties of general purpose suspension packaging are comparable to those of properly applied polystyrene chips. Since GPSP is an automated process, the cushioning effects do not depend on proper human operations as is the case with filling the gaps with chips.
3. The use of suspension packaging is very promising but further research is required. The initial parameter evaluation in this research shows that it is worthwhile to optimise the cushioning in all directions by choosing an appropriate type of corrugated board, choosing the most appropriate type of film and by optimising the wrapping of the stretch wrap film.

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