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A Method for Damage Detection in the Packaging Materials

C. Onwurah[1], S. C. Mamah[2]

[1]Department of Mechanical/Mechatronics Engineering, Faculty of Engineering and Technology, Alex Ekwueme Federal University Ndufu –Alike Ikwo, Ebonyi State, Nigeria
[2]Department of chemical/petroleum Engineering, Faculty of Engineering and Technology, Alex Ekwueme Federal University Ndufu –Alike Ikwo, Ebonyi State, Nigeria

Abstract This research work cantered on developing a classification system that will assist the manufacturing engineer in the process of flaw detection in the packaging of products. The identified various packaging materials are Plastics, Paper and Paperboard, Metals, Glasses and Flexible films. Furthermore, the associated defects were also classified in the research. Our study was motivated by the fact that manufacturing engineers in industries are faced with the challenge of packaging material selection and the appropriate inspection process. Also, existing classifications do not adequately address the link between packaging material classification and the possible defects.

While existing classification schemes of packaging materials focus largely on just one of the platforms/classes say "Plastics or paper", the classification system presented here applies to the entire food packaging materials. The features with their subgroups used for the classification of packaging materials show how these features are combined in a pathway. The generic pathway starts with a platform/class which is narrowed down to products/materials from which the likely defect(s). In addition to this, various schemes for the classification of packaging materials have been presented.

Hence, the multi-faceted nature of the classification system presented here facilitates far richer access to content than is possible with current systems. It is important to note, nonetheless, that the platforms themselves will evolve as the subject matter evolves. This evolution may be most apparent in the need for new/different ways of classification system.

In order to facilitate the retrieval of features (classes, material, defect) based on the developed taxonomy, the classification system should be used by manufacturing engineers not only in selecting packaging materials, but also in the determination of suitable materials with least defects and those that their inspection process are readily available.

Keywords Defects detection, Products, Taxonomy, packaging materials, food

Introduction

Thin layered laminates are known to be used in wide range of industrial applications. They are used mostly in areas like food packaging and pharmaceutical packaging and these areas are known to be safety relevant areas. Packaging is one system whose objective is to protect the contained product against an always-hostile environment of water, water vapour, air and its oxygen, microorganisms, insects, other intruders, dirt, pilferage, and so on because a constant competition exists between humans and their surroundings [1]. Packaging is designed to facilitate the movement of a product from its point of production to its ultimate consumption. If there is no product, there is no need for a package. The words package or packaging has different meanings, intended to convey different images. The package is the physical entity that actually contains the product.

Packaging is the integration of the physical elements through technology to generate the package. Packaging is a discipline. The package is what the consumer must open to obtain the food.

All definitions of packaging centre about a single concept: the protection of the packaged product for the purpose of facilitating its journey to the marketplace and use by the consumer. Packaging is that combination of materials, machinery, people, and economics that together provides protection, unification, and communication.

Food packaging on the other hand, requires non-destructive testing techniques for condition monitoring of the material. The need for one hundred percent on-line package damage detection is a top priority for aseptic food processors [2]. Package integrity is vital to both food quality assurance and food safety [3].

There are numerous package inspection frameworks accessible that depend on physical testing of the package to demonstrate the probability of microbial contamination. A physical test is much faster and more sensitive than a microbial test; be that as it may, a microbial test demonstrates conditions for microbial contamination. Discriminating points of confinement for microbial sullying have not yet been examined completely enough to compare physical tests to microbial tests

In 1988, damage detection and characterization utilizing noncontact test techniques with the point of getting more delicate techniques are continuously developing, yet just few of them fulfill the requirement to be non-contact and non-obtrusive to food packaging materials, for instance, made of container, aluminium foil, tin, glass and plastics In numerous nations it is completely combined into government, business, and institutional, industrial, and a personal use of Several different types. Case in point, a transport package or conveyance package could be the sending container used to ship, store, and handle the item or internal packages. Some distinguish a purchaser package as one which is controlled to a customer or family unit. Some examinations have been accounted for using vibration-based methods for damage detection. These methodologies are more internationally sensitive to damage than localized methods on thin layered adaptable materials, still not yet broadly examined in the field of NDT.

Types of Packaging Materials

There are five (5) packaging materials commonly used, plastics, metals, paper & paperboard, flexible films and glasses

Plastics

There are a few points of interest to utilizing plastics for food packaging. Fluid and moldable plastics could be made into sheets, shapes, and structures, offering impressive design flexibility. For the fact that they are chemically resistant, plastics are less costly and lightweight with an extensive variety of physical and optical properties. Plastics are heat sealable, simple to print, and can be integrated into production processes where the package is shaped and formed, filled, and sealed in the same production line [1].

Polyolefin**:** Marsh and Bugusu, (2007) explained Polyolefin is an aggregate term for polyethylene and polypropylene, the 2 most generally utilized plastics in food packaging, and different less prevalent part fin polymers.

Polyesters**:** Polyethylene terephthalate (PET or PETE), polycarbonate, and polyethylene naphthalene (PEN) are polyesters; they are condensation polymers made from ester monomers that result from the reaction between carboxylic acid and alcohol. Thermoset commonly used polyester in food packaging is PETE [4].

Polyvinyl chloride: this has a very good resistance to chemicals (acids and bases), grease, and oil; good flow characteristics; and very stable electrical properties. Polyvinyl chloride (PVC), an addition polymer of vinyl chloride, is heavy, stiff, ductile, and a medium strong, amorphous, transparent material [1].

Polyvinylidene Chloride: Major applications include packaging of poultry, cured meats, cheese, snack foods, tea, coffee, and confectionary. This is an addition polymer of vinylidene chloride. It is used in flexible packaging as a monolayer film, a coating, or Part of a co-extruded product.

Figure 1: Plastic Material

Polystyrene: Polystyrene, an addition polymer of styrene, is clear, hard, and brittle with a relatively low melting point. It can be mono-extruded, co-extruded with other plastics injection moulded, or foamed to produce a range of products [1].

Paper and Paperboard

The use of paper and paperboards for food packaging dates back to the 17th century with accelerated usage in the later part of the 19th century [5].

Paper and paperboard are sheet materials made from an interlaced network of cellulose fibres derived from wood by using sulphate and sulphite. The fibres are then pulped and/or bleached and treated with chemicals such as silicide's and strengthening agents to produce the paper product.

Paperboard

Paperboard is thicker than paper with a higher weight per unit area and often made in multiple layers. It is commonly used to make containers for shipping—such as boxes, cartons, and trays—and seldom used for direct food contact. The various types of paperboard are as follows:

Chipboard, Fibreboard, White board, Solid board Paper

Plain paper is known to be almost always treated, coated, laminated, or impregnated with materials such as waxes, resins, or lacquers to improve functional and protective properties. They are not used to protect foods for long periods of time because it has poor barrier properties and is not heat sealable. When used as primary packaging (that is, in contact with food). There are different types of paper used in food packaging are as follows [1-5]:

Greaseproof paper, Parchment paper, Sulphite paper, Kraft paper, Glassine

Figure 2: Paper & paper board packaging materials

Metal containers

Metal is the most versatile of all packaging structures. It offers a blend of magnificent physical protection and restraint properties, formability and decorative potential, recyclability, and consumer satisfaction. There are 2 types of metals that are mostly used in packaging are aluminium and steel [1].

Aluminium

Aluminium is known to have a good flexibility and surface resilience, excellent malleability and formability, and a very good embossing potential. It is also an ideal material for recycling because it is easy to reclaim and process into new products

Unlike many metals, aluminium is highly resistant to most forms of corrosion; its natural coating of aluminium oxide provides a highly effective barrier to the effects of air, temperature, moisture, and chemical attack. Apart from providing a good barrierto moisture, air, odours, light, and microorganisms, aluminium is known to have good excellent malleability and formability, flexibility and surface resilience and outstanding embossing potential [1].

Figure 3: Aluminium container

Aluminium Foil

Aluminium foil are manufactured by rolling pure aluminium metal into very thin sheets, then annealing to achieve dead-folding properties (a crease or fold made in the film will stay in place), which gives it the room to be folded tightly. However, aluminium foil is available in a variety of thicknesses, with thinner foils used to wrap food and thicker foils used for trays [1].

Figure 4: Aluminium Foil

Tinplate

These types of metals are produced from low-carbon steel (that is, black plate), tin plate is the result of coating both sides of black plate with thin layers of tin. Tin provides steel with some corrosion resistance, they are also are often lacquered to provide an inert barrier between the metal and the food product [1].

Figure 5: Metal container

Glasses

Glass has an extremely long history in food packaging; the1st glass objects for holding food are believed to have appeared around 3000BC [6]. Glass containers are used in food packaging, and they are mostly surface-coated to give lubrication in the production line and eliminate scratching or surface abrasion and line jams. And this coatings will also give increase and preserve the strength of the bottle to minimize breakage. Improved break resistance allows manufacturers to use thinner glass, which reduces weight and is better for disposal and transportation [7].

Glass bottle

Beer bottle, Wine bottle, Milk bottles

Jar\Mason

Figure 6: Glass container

Flexible Films:

In general, flexible films are relatively low in cost. They have good barrier properties against moisture and gases. Flexible films also are heat sealable to prevent leakage of contents and they have wet and dry strength. They fit closely to the shape of the food, thereby wasting little space during storage and distribution. They are easy to handle and convenient for the manufacturer, retailer and consumer and they add little weight to the product [1].

Figure 7: Flexible films materials

Defects / Flaws in Packaging materials

There are different flaws/ damages that occurs in packaging materials

Plastic Defects

Plastics materials have been known to have some flaws/defects in the course of production.

Abrasion

An abrasion is a scratch through any of the layers of the package. This kind of defect is classified as a major defect if the defect is pronounced.

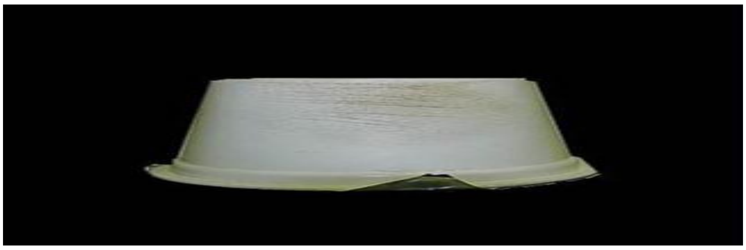


Figure 8: Abrasion defect

Crushed

This type of defect is classed a minor defect if it has not affected the seal area and can be defined as the alteration of the original dimensions of the package by force.

Figure 9: A picture of a Crushed defect

Cut (fracture)

This type of defect happens when a mechanical slash or slicing penetrates the package material, and thereby causing the package material not completely sealed.

Figure 10: A picture of a Cut (fracture) defect

Delamination: Delamination is described as the separation of the package laminate materials.

This is classed as a major defect if it occurs in the seal area, then, delamination, anywhere in the inner or outer plies of the pouch, is in excess of 1 cm2 (or equivalent area).

Flex Cracks: Flex cracks are defined as small breaks in one or more layers of the package. They are classed a minor defect.

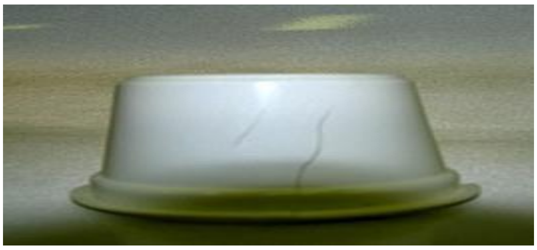


Figure 11: Flex cracks defect

Foreign Matter Inclusion: This happens when an unintended matter is imbedded in the plastic body. This is classed as a minor defect.

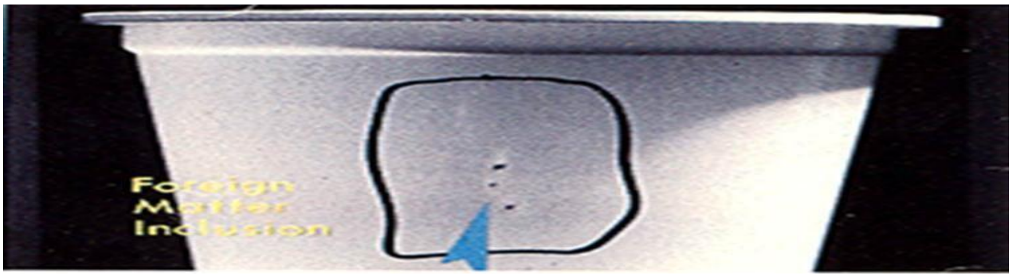


Figure 12: A picture of a Foreign Matter Inclusion

Leaker (Channel): A critical defect. This is a path of non-bonding across the width of the seal that will generally leak.

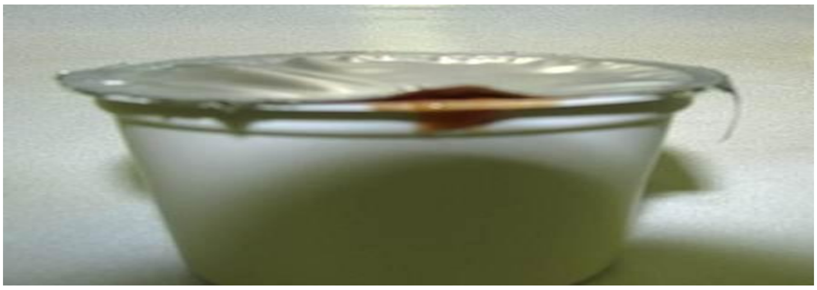


Figure 13: Leaker (Channel)

Malformed: A minor defect this is the plastic container that does not conform to mould contours as designed or material distribution that does not conform to specifications such as waves, thin spots or discontinuous layers.

Figure 14: A picture of a malformed plastics container

Puncture (Pinhole): This is a critical defect. This defect is a mechanical piercing that penetrates the package, causing a loss of hermeticintegrity.

Figure 15: Puncture (Pinhole)

Seal defects (Uneven Impression): A major defect. This is a defect that may lead to an out-of-specification seal.

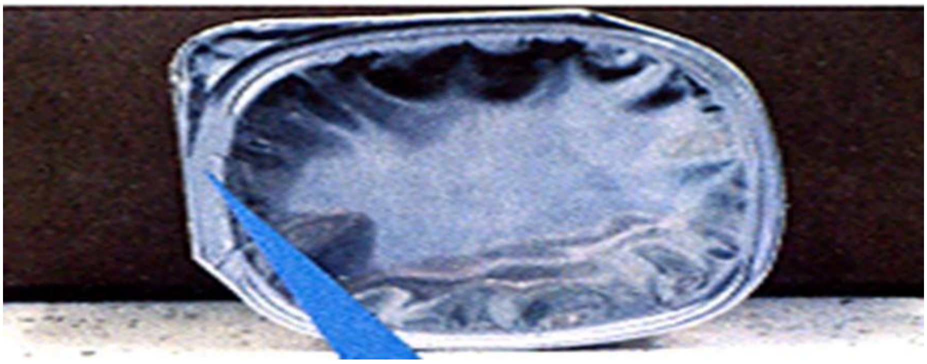


Figure 16: Seal defect

Swell (Swollen Package): A critical defect. The package bulges due to gas formation from bacterial contamination, or excess internal residual air.

Figure 17: Swell (Swollen Package)

Metals

Metals materials have been known to have some flaws/defects in the course of production

Laminated plate

Metal body or end plate which can be separated into two layers of metal which are not bonded.

Figure 18: Laminated plate

Pin-Hole: A hole in the metal plate originating in the rolling mill. These will vary in size from barely visible to large irregular shaped holes with rough edges.

Figure 19: Defect: Pin-Hole

Weld Joint: An obvious, black line (joint) approximately 5 mm (3/16") wide running across the can end or body. They seldom result in leakage although there is potential for corrosion along this weld which may lead to perforation.

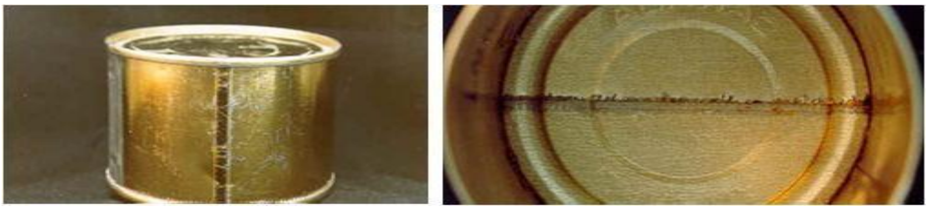


Figure 20: Weld Joint

Cold Solder: A discontinuity (gaps or voids) or a rough and spongy irregularity of the side seam solder fillet which could result in a pathway through the side seam.

Figure 21: Cold solder

Insufficient Solder: Solder voids in the outside side seam fillet resulting in incomplete soldering of the side seam.

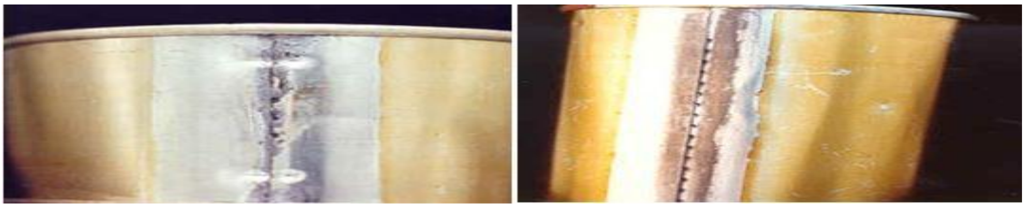


Figure 22: Solder

Open or Weak Lap: A condition where light finger pressure on an empty can will cause the bonded (soldered) lap joint to open.

Figure 23: Weak Lap

Fractured Bottom Profile: A fractured bottom profile radius of a two piece style can or a pinched bottom profile radius which may fracture during processing or handling.

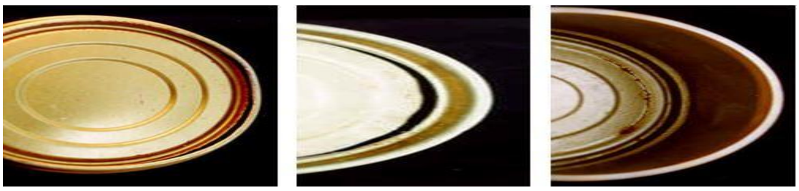


Figure 24: Fractured Bottom Profile

Scrap-In-DieMarks: An abnormal mark or impression in the metal plate 1which may vary in size, shape, and depth. If the scrap mark affects the formation of the flange, double seam defects may result.

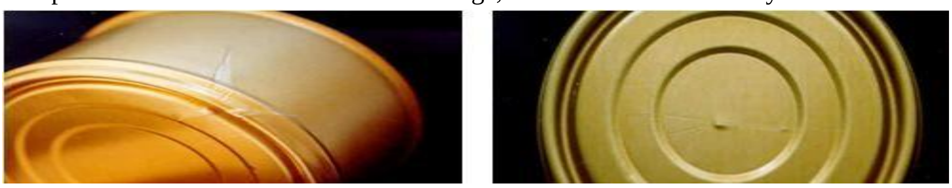


Figure 25: Scrap-In-Die Marks

Wrinkled flange: Wrinkles in the walls of a two piece style can body extending into the flange area.

Figure 26: Wrinkled flange

Abrasion: A mechanical wearing of the metal plate. Abrasion results in the weakening of the metal plate making the abraded area susceptible to either fracture or corrosion which could eventually perforate the metal plate.

Figure 27: Abrasion defect in metals

Crushed: An extreme mechanical deformation of the metal container.

Figure 28: Crushed defect

Flexible Film Packaging Defect: Flexible films materials have been known to have some flaws/defects in the course of production

Abrasion: An abrasion is a scratch through any of the layers of the package.

Figure 29: Abrasion defect

Blister: A blister appears as a void within the bonded seal. A blister resembles a bubble or has a raised appearance in the sealed area of the retort pouch.

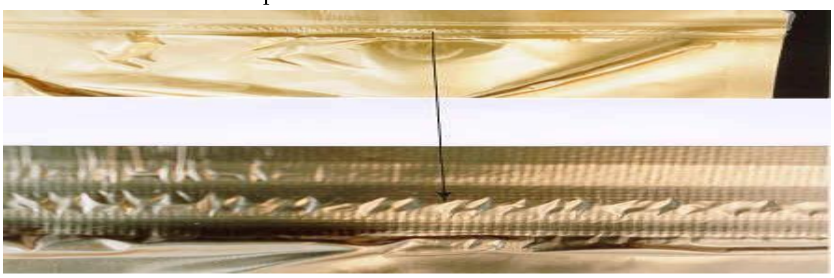


Figure 30: Blister defect in flexible film materials

Channel Leaker: This is an area of "non-bonding" across the width of the seal that will generally leak. If a retort pouch has a channel leaker, it can usually be detected by applying pressure towards the seal.

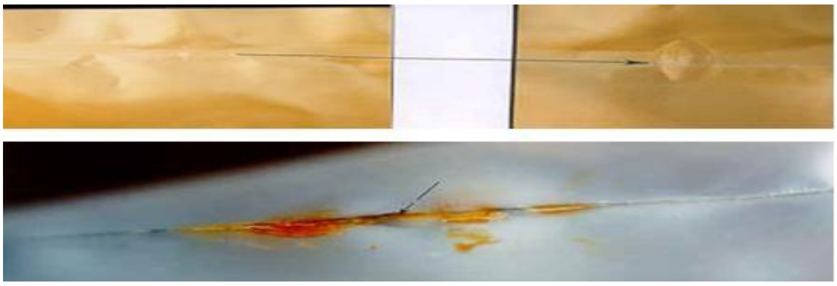


Figure 31: Channel Leaker defect

Cut (Or Fracture): This defect is a breach of all layers of the laminate, where the hermetic integrity of the package has been compromised. This can be a manufacturer defect if there is equipment damage or "scrap" between the laminate plies during formation. Compare to puncture.

Figure 32: Cut (Or Fracture) defect

Delamination: The laminate materials separate, often resulting in subsequent loss of the hermetic integrity of the pouch. This can occur anywhere on the pouch.

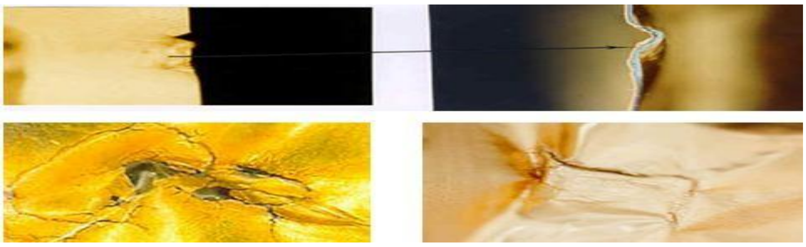


Figure 33: Side view of notch delamination

Flex Cracks: Flex cracks are small breaks in the foil layer of the laminate; they appear as small cracks in the pouch surface, where only one layer of laminate is affected. The defect is similar to a delamination.

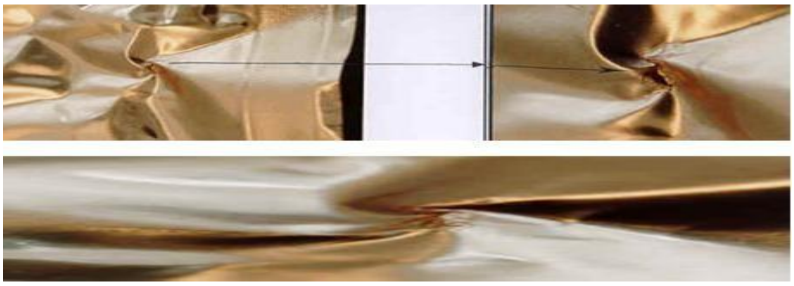


Figure 34: Flexible Flex Crack defect in flexible film

Swollen: The pouch bulges due to gas formation from bacterial contamination, or excess internal residual air.

Figure 35: picture of a swollen defect

Puncture: A puncture appears as a mechanical piercing of the pouch that results in the loss of hermetic integrity. Compare to cut.

Figure 35: Puncture defect

Incomplete Seal: The seal area does not extend completely across the width of the pouch. This defect can be detected visually by the sealing bar impression on the retort pouch seal.

Figure 36: Incomplete Seal

Leaker: A leaker is a retort pouch that is unsealed or in some way has lost container integrity. Contents generally seep from the pouch. The leak may occur anywhere on the pouch.

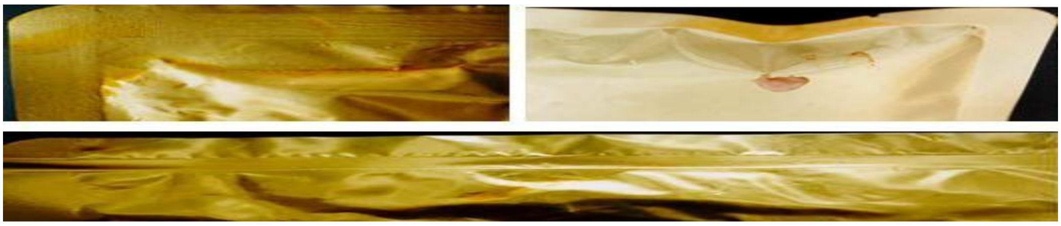


Figure 37: Leaker defect

Common Defects in Glasses

Flexible films materials have been known to have some flaws/defects in the course of production

There are 6 broad classifications of glass defects:

- Checks
- Seams
- Non-glass inclusions
- Dirt, dope, adhering particles or oil parks
- Freaks and malformations
- Mark

Defects are classified as:

- Critical: These are known to be those that make the container completely unusable and are hazardous to the user.
- Major defects: are those that are materially reduce the usability of the container or its contents
- Minor defects: are known to be those that do not affect the usability of the container, but detract from its appearance or acceptability to the customer.

Common defects in paper and paperboard

- Abrasion
- Corner dent
- Crushed Deformed

- Deformed seal
- Delamination
- Loose flaps
- Puncture,
- Seal leaker, Swell (swollen package), Weak seal

Table 1: Summary of the Packaging Materials

Plastics	**Metals**	**Paper & Paper Board**		**Glasses**		**Flexible Films**
		Paper	**Paperboard**	**Bottle**	**Jar**	
Polyolefin	Aluminium	Greaseproof Paper	Chipboard	Beer Bottle	Mansion	Cellulose
Polyesters	Aluminium Foil	Parchment Paper	Fibreboard	Milk Bottle		Polypropylene
Polyvinyl Chloride	Laminates Metallized Films	Sulphite Paper	White Board	Wine Bottle		Other Films
Polyvinylidene Chloride	Tinplate	Kraft Paper	Solid Board			Flexible And Semi- Rigid Packages
Polystyrene		Glassine				

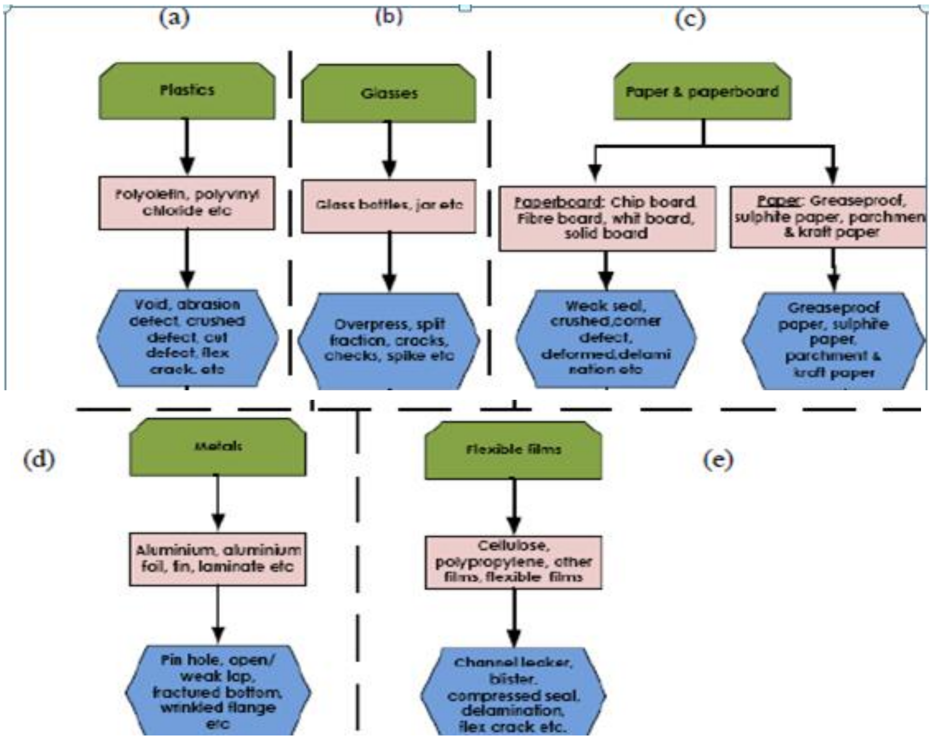
Table 2: Summary of the Defects that occurs in the Packaging Materials

Plastics	**Metals**	**Paper and Paperboard**	**Glasses**	**Flexible Films**
Abrasion	Laminated plate	Abrasion	Stuck plug	Abrasion
Crushed	Defect: pin-hole	Corner dent	Over press	Blister
Cut (fracture)	Weld joint	Crushed Deformed	Split	Channel leaker
Delamination	Cold solder	Deformed seal	Check	Compressed seal
Puncture	Insufficient solder	Delamination	Freaks	Cut (or fracture)
Swell (swollen package)	Open / weak	Loose flaps	Cracks	Delamination
Flex crack	Fractured bottom	Puncture	Pin hole	Flex crack
Foreign matter inclusion	Wrinkled flange	Seal leaker	Filament	Swollen
Gels	Knocked-down end	Swell (swollen package)	Spike	Puncture
Label folder	Abrasion	Weak seal	Bird swing	Incomplete seal
Leaker channel	Crushed			Leaker
Malformed				
Seal defects				

Results and Discussion

Packaging is arguably the single most important link in the distribution chain that places a product into the hands of the consumer. In a very real sense, in today's society, packaging might be regarded as an integral component of the product contained. There is still no known generalized method to assist manufacturing engineers in the process of flaw/damage detection in the packaging of food products. As such, the aim of this work is to develop a tool to assist the manufacturing engineer in the process of flaw detection in the packaging of products. The specific objectives of the study are : to understand the current state of art for NDT of packaging; to review and understand the processes of packaging; to review the types of defect in packaging; and to develop a taxonomy of NDT processes for packaging.

This classification procedure is applied in the following examples, where the taxonomy systems are classified (their schemes are shown in Figure 38).



Example (a): One – platform (plastics) with materials, possible defects
Example (b): One – platform (glasses) with materials, possible defects
Example (c): One – platform (paper & paperboard) with two subdivision s of materials
Example (d): One – platform (metals) with materials, possible defects
Example (e): One – platform (flexible films) with materials, possible defects.

Figure 38: Schemes for the classification of packaging materials

Platforms

Platforms are intermediates which link materials, defect and final inspection processes. The platform concept is similar to that used in the classification of materials, where materials are classified based on their physical, chemical or physicochemical properties. These platforms are recognized as the main ‘pillars’ of this taxonomy system, since they are the first feature to be considered in the taxonomy system for packaging materials and their likely defect detection.

The most important platforms for packaging materials are the following:

- Plastics
- Glasses
- Metals
- Paper & paperboard
- Flexible films

Defects

Leak is a common example of defect in packaging materials. Leaks in food packages may result in the ingress of unwanted gases (most commonly oxygen), harmful microbiological or particulate contaminants. Package leaks may appear as imperfections in the package components themselves or at the seal juncture between mated components. The ability to detect leaks is necessary to ensure consistency and integrity of packages.

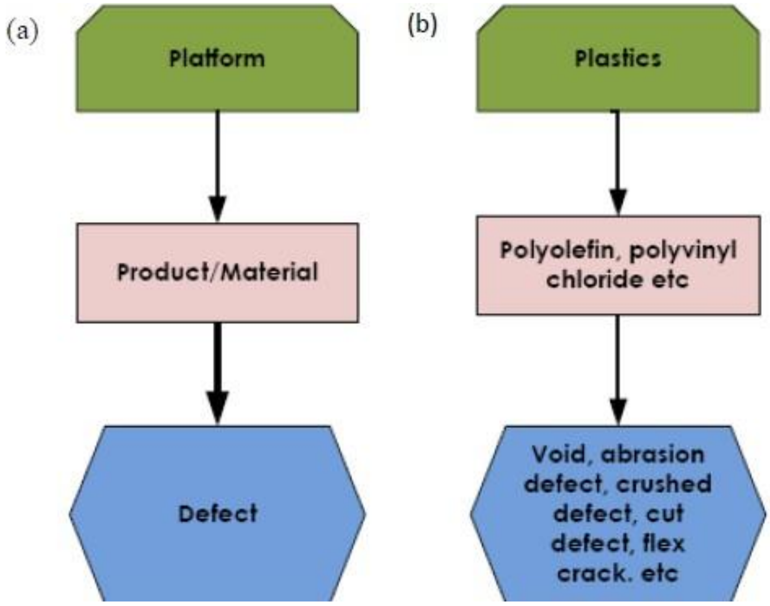


Figure 39: Example on the combination of the features for the classification of packaging material: (a) generic system and (b) example.

Conclusion

This research work cantered on developing a classification system that will assist the manufacturing engineer in the process of flaw detection in the packaging of products. Our study was motivated by the fact that manufacturing engineers in industries are faced with the challenge of packaging material selection and the appropriate inspection process. Also, existing classifications do not adequately address the link between packaging material classification, possible defects .

While existing classification schemes of packaging materials focus largely on just one of the platforms/classes say "Plastics or paper", the classification system presented here applies to the entire food packaging materials. The features with their subgroups used for the classification of packaging materials show how these features are combined in a pathway. The generic pathway starts with a platform/class which is narrowed down to products/materials from which the likely defect(s). In addition to this, various schemes for the classification of packaging materials have been presented.

Hence, the multi-faceted nature of the classification system presented here facilitates far richer access to content than is possible with current systems. It is important to note, nonetheless, that the platforms themselves will evolve as the subject matter evolves. This evolution may be most apparent in the need for new/different ways of classification system.

In order to facilitate the retrieval of features (classes, material, defect) based on the developed taxonomy, the classification system should be used by manufacturing engineers not only in selecting packaging materials, but also in the determination of suitable materials with least defects and those that their inspection process are readily available.

No doubt researchers in these areas could also use our classification system to create a personalized, accurate, and searchable repository of knowledge on packaging materials, their defects and inspection processes. Such a repository, which could be stored as a simple Access database, could then be used to supplement commonly-used databases.

Finally, the advantage of having such a repository is that it allows manufacturing engineers to receive precise answers to complex queries such as: "Retrieve details of all inspection processes, retrieve details of all packaging materials" which before now, the likelihood of the results of such a query producing complete and accurate results is very low.

The main remarks arising from the application of this classification approach are the following:

1) It is a classification with a relatively simple and schematic approach.

2) Individual classification systems are classified with an attempt to fit in a generic systems and this classification is based on systematic and homogeneous criteria, which results in no overlaps, inconsistencies and misunderstandings.

3) Unlike previous methods, this classification approach offers the possibility of combining different platforms into one scheme, of which all agrees with the generic system approach.

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