Size Estimation of Plastic Deformation Zone at the Crack Tip of Paper under Fracture Toughness Testing'

Atsushi TANAKA* , Tatsuo YAMAUCHI*

Size estimation of plastic deformation zone at the crack tip of paper under fracture toughness testing was attempted not only by means of thermographic observation but also by means of the calculation based on the linear elastic fracture mechanics (LEFM). Stress concentration at the notch tips occurs at the latter stage of the testing. As developing patterns of plastic deformation zone observed by thermography changes from type(i) to type(ii) arid further to type(iii), the calculated zone size decreases. The zone calculation is useful especially in the brittle paper as a method describing the behavior of plastic deformation zone during the testing.

Keywords : Papers, Fracture mechanics, Fracture toughness, Stress concentration, Infrared thermography

1. Introduction

When a specimen with a crack is strained under in-plane tensile testing, the crack tip region is expected to yield and the plastic deformation zone to appear. Because a large stress concentrates on the region. As paper is known to generate heat during plastic deformation[1),2)], such a region is expected to be detected in terms of temperature rise. Recently, infrared thermography system has been successfully introduced to observe the plastic deformation of paper under loading as a series of temperature distribution images[3)-5)]. And with this technique, the appearance and developing pattern of plastic deformation zone of deep double edge notched tension(DENT) specimen (**Fig. 1**) under fracture toughness testing has been studied[6),7)].

Although thermographic approach is very

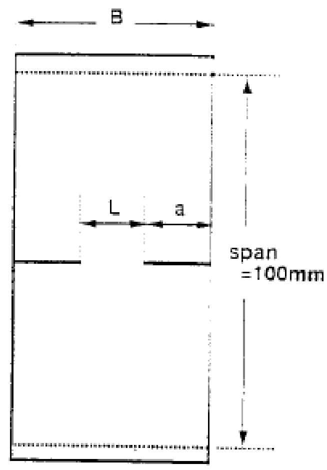

Fig. 1 Deep double edge notched tension specimen (B: specimen width, L : ligament length, a: notch length)

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useful for the estimation of plastic deformation zone, the zone calculation based on the "linear elastic fracture mechanics (LEFM)" is further able to provide the basic knowledge of fracturing mechanism of paper in more detail.

In the present study, plastic deformation zone at or around notch tips during the fracture testing and those in various commercial papers at the maximum load were estimated by the calculation based on LEFM and by the thermographic observation, in order to clarify the stress concentration at the notch tips and the following development of plastic deformation zone.

2. Theory of Plastic Deformation Zone Estimation[8),9)]

Theoretically, stress at the crack tip under in-plane tensile stress is infinite for a perfect elastic material. However for most materials, the region around the crack tip yields and plastic deformation zone appears. Although calculating the precise shape of this zone is complicated, its size in the direction of crack propagation can be approximated easily.

Schematic image at the crack tip is shown in **Fig. 2**. According to LEFM, stress in y-direction on the x-axis is represented as a function of the distance from the crack tip (x) under elastic condition as follow.

$$\sigma y = \frac{K}{\sqrt{2\pi x}} \qquad (1)$$

This is shown as a broken line in **Fig. 2**. And **K** is the stress intensity factor which characterizes the elastic stress field near the crack tip, and calculated as follow under remotely-applied tensile stress σ.

$$K = \sigma\sqrt{\pi a}\ F(\xi) \qquad (2)$$

F(ξ) is a shape correction factor, and given as follow for DENT specimen (**Fig. 1**) after Tada[10)].

$$F(\xi) = \left\{1 + 0.122\cos^4\left(\frac{\pi\xi}{2}\right)\right\}\sqrt{\frac{2}{\pi\xi}\tan\left(\frac{\pi\xi}{2}\right)} \qquad (3)$$

where ξ is the ratio of total crack length (2a) to width (B), i.e. ξ = 2a/B.

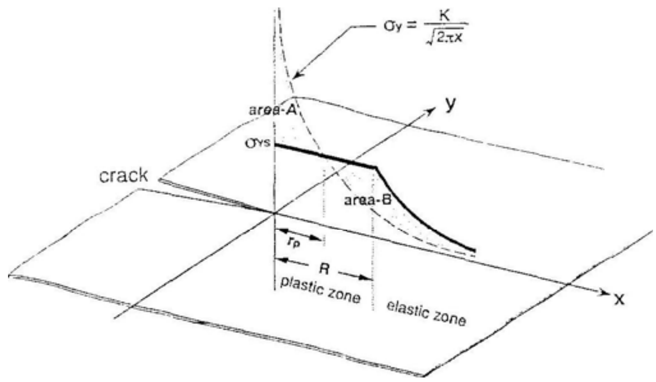

Fig. 2 Schematic image of stress distribution at the crack tip region

Differing from a perfect elastic material, in the case of elastic-plastic material like paper under in-plane stress condition, the region of $0 \leqq x \leqq R$ is considered to be plastically deformed and σ_y is approximately equal to the yield stress (σ_{YS}). The stress distribution is now represented by the solid line (**Fig. 2**). Supposing the distance between the crack tip and the point satisfying $\sigma_y = \sigma_{YS}$ (on the broken line in Fig. 2) as r_P,

$$\sigma_{YS} = \frac{K}{\sqrt{2\pi r_P}} \quad (4)$$

is obtained from eq.(l)- And re is calculated as follow.

$$r_p = \frac{1}{2\pi}\left(\frac{K}{\sigma_{YS}}\right)^2 \quad (5)$$

Then area-A, the sum of stress from x=0 to x=r_P, is calculated as follow.

$$\begin{aligned} \text{area-A} &= \int_0^{r_p}\left(\frac{K}{\sqrt{2\pi x}} - \sigma_{YS}\right)dx \\ &= \sqrt{\frac{2rp}{\pi}}K - \sigma_{YS}r_p \\ &= \sqrt{\frac{2rp}{\pi}}\sqrt{2\pi r_p \sigma_{YS}^2} - \sigma_{YS}r_p \\ &= \sigma_{YS}r_p \end{aligned} \quad (6)$$

Now area-A and area-B should be equal, because the area beneath the broken line and that beneath the solid line must be equal under the same external stress. Supposing that the stress distribution of the x ≧ R region after yielding (solid line) is approximately equal to the x ≧ r_P part of the broken line, area-B is calculated as follow.

$$\textbf{area-B} = \sigma_{YS}(R - r_P) \quad (7)$$

Thus in order to satisfy area-B=area-A= $\sigma_{YS}r_P$, R should be equal to $2r_P$, i.e.

$$R = 2r_p = \frac{1}{\pi}\left(\frac{K}{\sigma_{YS}}\right)^2 \quad (8)$$

After all, R is in proportion to K^2, i.e. σ^2. In the practical use, the shape of the plastic deformation zone can be considered as a circle circumscribing to the notch tip with the diameter of R(=$2r_P$)[9]. It must be noted that this approximation can be applied essentially in the case of "small scale yielding"[11),12)], i.e. plastic deformation zone size should be small enough in comparison with crack length.

3. Experimental

3.1 Materials

Various machine-made papers (sack paper from unbleached kraft pulp, machine grazed paper, newsprint paper, and filter paper), studied in the previous report[7)], were also employed in this study. Their basic properties in both machine and cross machine directions are given in **Table 1**.

A series of DENT specimens (**Fig. 1**) with widths of varying from 3 to 63 mm (9 steps) and with span length of 100mm were prepared. Ligament length (L), distance between double

Table 1 Basic properties of the samples

	UKP-sack		Machine grazed		Newsprint		Filter	
	MD	CD	MD	CD	MD	CD	MD	CD
Basis weight , g/m^2	47	47	41	41	40	40	100	100
Thickness , μm	70	70	55	55	66	66	174	174
Sheet density , kg/m^3	670	670	745	745	611	611	575	575
Tensile index , Nm/g	79.4	33.9	83.3	25.6	75.0	22.6	29.0	18.9
Elongation at failure , %	1.0	3.0	1.8	2.7	1.5	2.2	1.7	2.9
0.2% offset yield stress , Nm/g	77.8	20.9	58.1	18.3	60.0	16.1	22.3	12.6
Elastic modulus , GPa	8.3	2.3	8.1	2.6	5.5	1.4	3.1	1.7

notches, was 1/3 of the specimen width for the essential work of fracture toughness testing6

Every specimen was cautiously notched with a virgin blade using a special transparent guide bar with a scale.

3.2 Instrumentation

The fracture toughness testings were made with a pair of line-type clamps mounted on an Instron type tensile testing machine(Shimadzu Auto-graph AGS-100) with a span distance of 100mm and crosshead speed of lOmm/min. This pair of clamps are connected with guide bars, which makes the strict plane stress loading possible. The thermography system (NEC-San ' ei Thermo-tracer 6T62) was set up to observe around the notched area with a close-up lens. The minimum spot size to be detected on the temperature distribution images is 0.1mm. Details of the experimental conditions were the same as those described in the previous reports6 7 All testings were made at the standard atmosphere.

4. Results and Discussion

4.1 Classifying the Developing Pattern of Plastic Deformation Zone by Thermography

According to the previous study using thermography7 , developing patterns of plastic deformation zone have been classified into three large types (Fig. 3);

type(i) ; appearing whole through the ligament in a vague manner and developing into a circular (or oval) zone even before or at the maximum load point.

type(ii) ; appearing from both notch tips and amalgamating into a circular (or oval) zone after the maximum load point.

type(iii) ; appearing from both notch tips and not amalgamating together until the final sheet failure.

Plastic deformation of type(ii) and type(iii) is essentially that around crack tips, but plastic deformation of type(i) is essentially that between crack tips. The results of classification for all specimens tested are shown in Table 2. The classification depends on specimen kind, tensile direction, and ligament length. Generally, specimen having smaller L tends to belong to type(i). And it comes to belong to type(ii) and further type(iii) in the same paper as L increases. Among the three, plastic deformation zones of type(ii) and type(iii) specimens are limited around the notch tips up to the maximum load point.

4.2 Change of Calculated Plastic Deformation Zones and the Corresponding Temperature Distribution Images during Straining

Typical example of successive images of calculated plastic deformation zones given by eq.(8) and close-up temperature distribution images given by thermography are shown in Fig. 4-1 for UKP-sack paper (MD/L=5mm), and the corresponding load-displacement relationship is given in Fig.4-2. This specimen belongs to type(iii), which satisfies "small scale yielding condition all through the testing. The initial location of the specimen with notches is superimposed with white lines on temperature

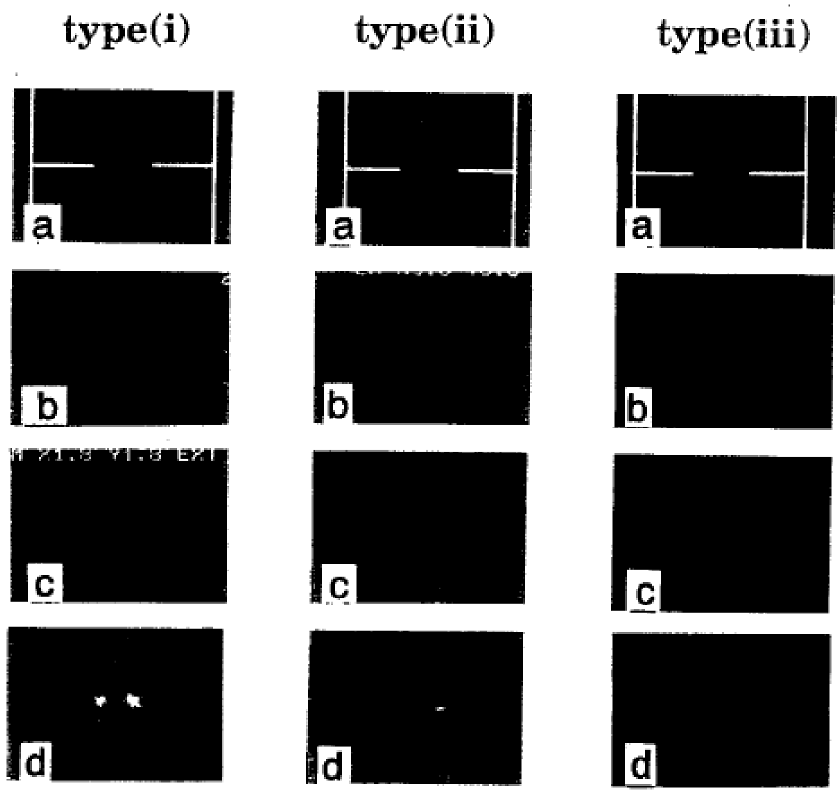

Fig. 3 Typical three developing patterns of the plastic deformation zone[7] (a: before straining, b: before the maximum load point , c: at the maximum load point, d: just before final sheet failure)

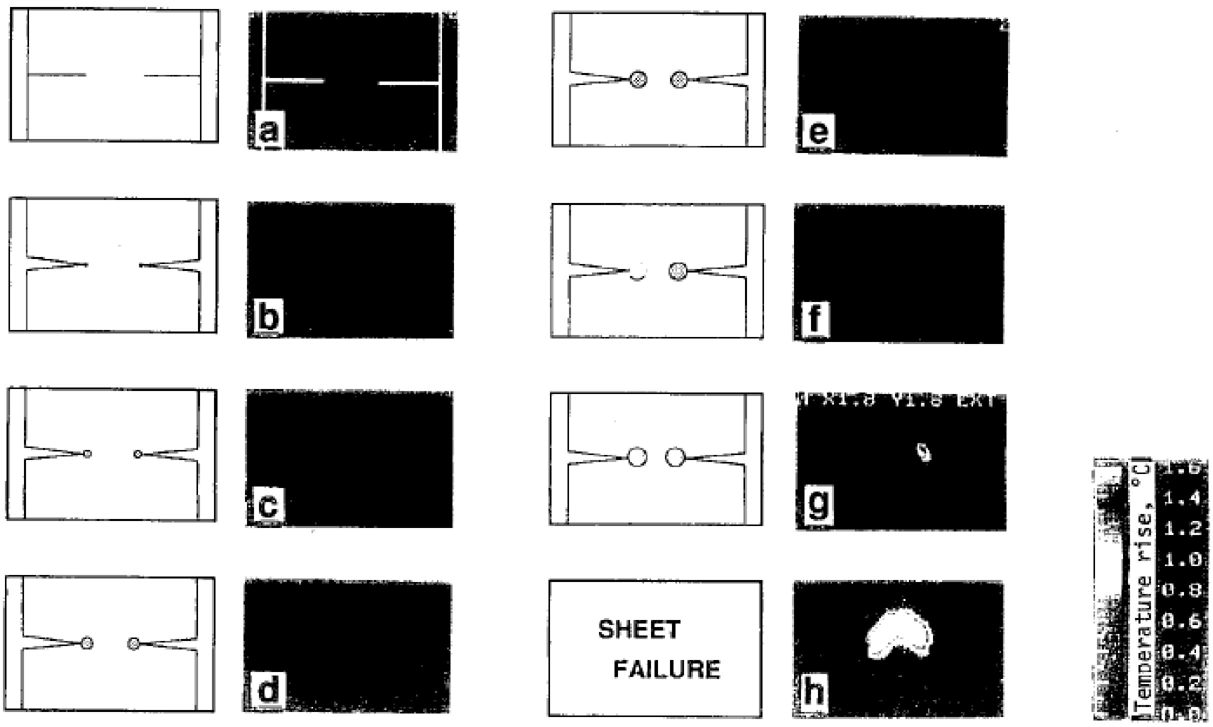

Fig. 4-1 A series of calculative images of plastic deformation zone (left), and close-up temperature distribution images (right) for UKP-sack paper (MD /L:5mm); (a)-(h) correspond to the positions on the load-displacement curve in Fig. 3-2

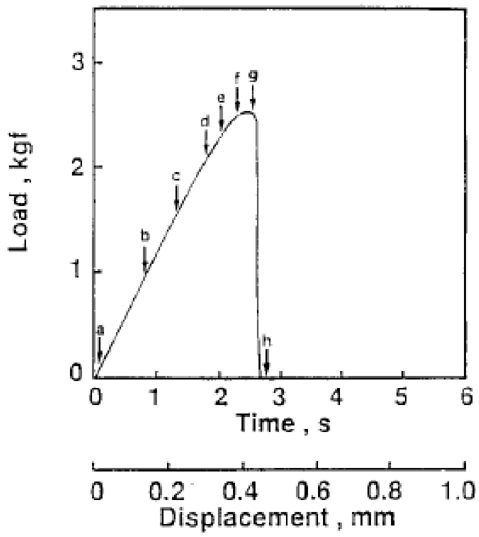

Fig. 4-2 Load-displacement curve under testing for UKP-sack paper (MD/L:5mm)

is graduated by temperature rise compared with initial average temperature of specimen. In the calculation based on LEFM, crack is assumed to initiate at the maximum load point. And 0.2% offset yield stress was used for σ_{YS} instead of the yield stress, as paper material does not show a clear yielding point[13].

As mentioned in the introduction, it has turned out that heat generation region is stressed to the level of plastic deformation[1-5]. So that stress concentration can be discussed by temperature distribution images.

Calculative estimation indicates the mono-

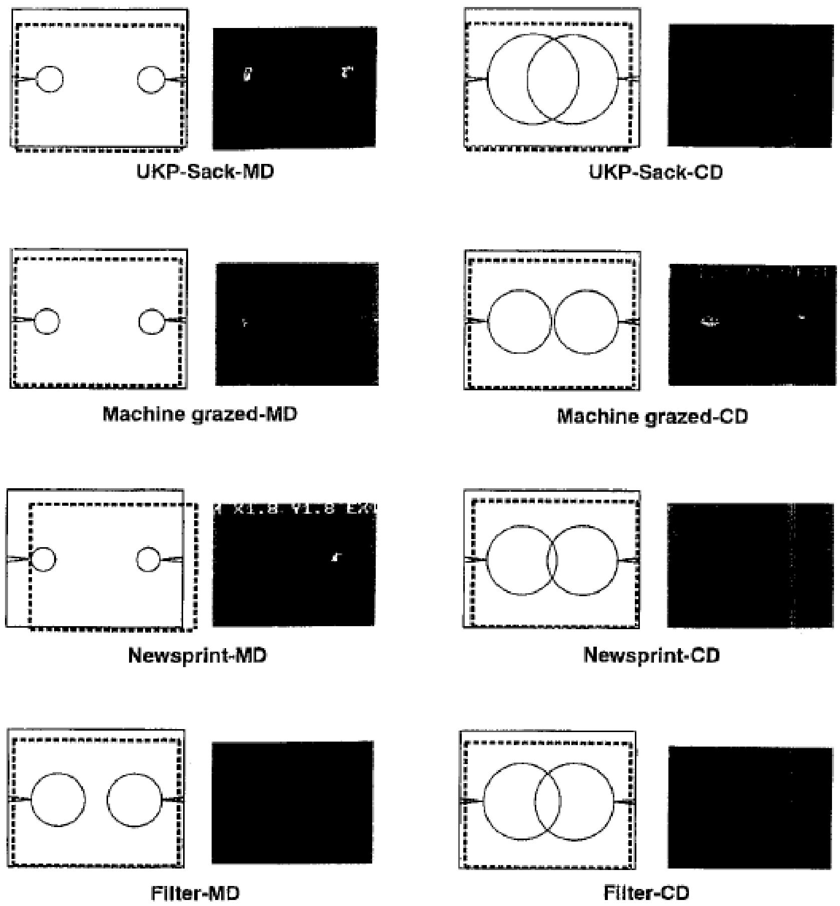

Fig. 5 Calculative images of plastic deformation zone (left) and close-up temperature distribution images (right) for specimens with L:13mm. Frame with dotted line in the left image shows the corresponding position of the right image

tonous increase of the plastic deformation zone up to **e** point as the load increases. And from **e** to **g** point it does not increase so much due to little increase of the load, that is, the size is in proportion to the square of stress (σ^2) as mentioned above. On the other hand, temperature distribution images do not always agree with them. No heat generation is seen around the notch tips in the initial period of straining (**a**, **b**, **c**, **d** point). Then heat generation zone appears at halfway through the plastic deformation region in the load-displacement curve (**e** point) ; blue colored spots whose temperature is higher than that of the surroundings appear in a concentrated manner. And from e point to the maximum load point, heat generation zone increases their area (**f**, **g** point). The final sheet failure occurs soon after the maximum load point (**h** point). The heat generation at the crack tip only at the latter stage of straining was also observed in the single edge notched specimen[3]).

According to the LEFM theory, stress should concentrate at the crack tip from the early stage of straining as shown in **Fig. 4-1** (calculative images of plastic deformation zone). However actually, stress concentration shown as plastic deformation zone, i.e. heated zone, has been observed at the latter stage of straining. These findings suggest that stress of paper materials hardly concentrates up to some level of straining.

4.3 Limitation of the Calculative Estimation of Plastic Deformation Zone

Plastic deformation zone sizes ($R=2r_P$) at the maximum load point were calculated, and for convenience of comparison, their size ratios to the ligament length ($2r_P/L$) are shown in **Table 2**. There is a tendency in general that type(iii) specimens have smaller $2r_P/L$ ratio than type(ii) specimens, and type(ii) specimens have smaller $2r_P/L$ ratio than type(i) specimens. But it must be noted that the ratio cannot be an absolute standard to classify the type. The boundary ratio between type(i), type(ii) and type(iii) is defferent from

Table 2 Type of the plastic deformation zone appearance and the ratio of the calculated plastic zone diameter to ligament length ($2r_P/L$) for all specimens

		L=1mm	L=2mm	L=3mm	L=4mm	L=5mm	L=9mm	L=13mm	L=17mm	L=21mm
UKP -sack	MD	type(i) 0.43	type(i) 0.40	type(ii) 0.33	type(iii) 0.32	type(iii) 0.32	type(iii) 0.29	type(iii) 0.22	type(iii) 0.15	type(iii) 0.17
	CD	type(i) 1.15	type(i) 1.15	type(i) 1.05	type(i) 0.90	type(i) 0.67	type(ii) 0.71	type(ii) 0.70	type(ii) 0.60	type(ii) 0.58
Machine grazed	MD	type(i) 0.34	type(i) 0.31	type(i) 0.36	type(ii) 0.38	type(iii) 0.29	type(iii) 0.22	type(iii) 0.18	type(iii) 0.13	type(iii) 0.16
	CD	type(i) 0.80	type(i) 0.86	type(i) 0.82	type(i) 0.55	type(ii) 0.62	type(ii) 0.46	type(ii) 0.49	type(ii) 0.42	type(ii) 0.39
News print	MD	type(i) 0.45	type(i) 0.50	type(ii) 0.36	type(iii) 0.34	type(iii) 0.31	type(iii) 0.25	type(iii) 0.20	type(iii) 0.18	type(iii) 0.17
	CD	type(i) 0.99	type(i) 1.02	type(i) 0.79	type(i) 0.70	type(ii) 0.64	type(iii) 0.57	type(iii) 0.55	type(iii) 0.47	type(iii) 0.49
Filter	MD	type(i) 0.55	type(i) 0.56	type(i) 0.52	type(i) 0.50	type(ii) 0.47	type(iii) 0.47	type(iii) 0.42	type(iii) 0.38	type(iii) 0.35
	CD	type(i) 0.84	type(i) 0.95	type(i) 0.87	type(i) 0.87	type(i) 0.72	type(ii) 0.61	type(iii) 0.61	type(iii) 0.54	type(iii) 0.47

paper to paper.

In terms of the calculative estimation, $2r_P/L$ ratio over 0.50 means connection and amalgamation of plastic deformation zones from both notch tips. Such a specimen is considered to be out of the "small scale yielding" condition. The ratio of most CD specimens are over 0.50 or nearly 0.50 irrespective of the type. Therefore, the calculative estimation is improper for the CD specimens at the maximum load point. On the other hand, every type(ii) and type(iii) MD specimen has the $2r_P/L$ ratio smaller than 0.50, that is, a necessary condition of "small scale yielding" is fulfilled.

The comparison between the calculative estimation image and temperature distribution image at the maximum load point is shown in **Fig. 5** for MD and CD specimens with L=13mm for example. The correspondence of both images is not good for CD specimens but is good for MD specimens. Especially a good agreement in size and shape between those images is found for brittle paper such as machine-grazed and newsprint having smaller $2r_P/L$ ratio.

As described above, the calculative estimation based on LEFM is fundamentally applicable to the latter stage of the fracture toughness testing. In the calculation, crack length and yield stress are needed as shown in eq.(2) and eq.(8). The notch length and 0.2% offset yield stress have been used for them, however, a crack growth before the maximum load has been pointed out[6] and the crack length for calculation should be longer than the notch length. Substitution of 0.2% offset yield stress for the yield stress is also questionable. These factors may contribute the disagreement between calculative and thermal size estimations in CD specimens.

5. Concluding Remarks

Size estimation of plastic deformation zone at the crack tip of paper under fracture toughness testing was attempted not only by means of thermographic observation but also by means of the calculation based on the linear elastic fracture mechanics (LEFM). A detailed comparison of both results provides some characteristic features of paper fracturing and plastic deformation as follows.

Stress concentration recognized as plastic deformation zone at the notch tips occurs at the latter stage of fracture toughness testing.

The calculated zone size ratio $2r_P/L$ decreases with the change of thermographic classification from type(i) to type(ii) and further to type(iii).

The zone calculation based on LEFM is useful for the brittle paper as a method describing the behavior of plastic deformation zone occurred in the latter stage of fracture toughness testing.

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破壊靭性試験下における紙のクラック先端塑性変形域の寸法評価*

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紙において破壊靭性試験を行う際に生じるクラック先端塑性変形域の寸法を熱画像法（サーモグラフィー）による観察、および線形破壊力学（LEFM）にもとづく計算から評価した。その結果、切り欠き先端における応用力集中は試験の後半に生じること、また熱画像法で観察される塑性変形域の発達パターンが（i）型、（ii）型、さらに（iii）型となるとともに、計算される塑性域寸法の減少することが明らかになった。この計算は延性の小さい紙を試験する際の塑性域挙動を記述する方法として有効である。

キーワード：紙、破壊力学、破壊靭性、応用集中、赤外線熱画像法

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Packaging Education: a Driver for Innovation in Packaging

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Abstract

Education in packaging science and technology is a relatively young discipline. In most countries around the world it has suffered of lack of support for years, either by industry or education institutions. With the packaging science and technology coining on age and a significant change from industry driven technology push towards a market driven technology pull in recent years a need for qualified packaging professionals has emerged.

In this paper an analysis is given as to why education in packaging has been struggling, which market developments arc of influence to this phenomena, how education effects innovation in packaging and what the expected needs for packaging education will be in the near future. Attention is also given to the responsibilities and duties of the modern packaging manager.

Finally the actual situation on education in packaging in Australia is discussed.

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Introduction

A career in packaging? What is packaging? People sec more about it and think less about it than probably any other thing touching their life. The fact is that they just are not conscious of packaging, except when packaging becomes waste at the end of its life cycle. This shows how effectively it works - it's just taken for granted.
Without packaging, the standard of living would fall far below the level people now enjoy. In fact, without it, people might not be around to enjoy any standard of living.

Packaging represents one of the most widely spread activities of the modern, sophisticated society: it reflects not only the advancement of knowledge in material sciences but also the mastery of technological achievements. Thanks to modern packaging technology products can economically be distributed over a wide geographical area as well as over a long period of time without unacceptable loss of quality.

In the past three decades, packaging technology has gone through a fast change. New technologies such as aseptic packaging and modified atmosphere packaging have been introduced on a large scale, while consumer demands have driven the market to convenience foods which can be prepared quickly. New products, manufactured with advanced production techniques and packaging systems, have enlarged the assortment of products significantly. In today's modern supermarkets one can easily find over 15000 different articles imported from all over the world.

Despite this fast change of the packaging scene, education in packaging science and technology around the world is a relatively young discipline and in many countries around the world not recognised as valuable in commercial operations.
Around the world, the teaching of packaging science and technology is carried out by both the education sector and by commercial organisations. The education sector offers some recognition in terms of certificates, diplomas or degrees. Most of these qualifications tend to be broad based, encompassing what can be termed as 'Packaging Technology'. The commercial sector tends to offer training in more focused areas, typically one or two day short courses or seminars aimed at imparting knowledge about various specific areas of packaging.

Current status of packaging Education.

Both the education and commercial sectors have important roles lo play in the improvement of skill levels in the industry. The problem with packaging education is that it has traditionally been taught on a local basis, requiring attendance at a college, university or, in the case of short courses, a conference venue. The nature of the courses constrain the student to study at a certain place, at a certain time and at certain pace. Many people are therefore unable to participate because of work or social commitments.
This touches the core problem in packaging education. It would be very beneficial to industry and society if young people could be educated in packaging. However, the experience around the world is that it is very difficult to attract young students to enrol in a first degree packaging course. The reason for this lies in the fact that young people do not recognise the packaging profession as a career opportunity. Their perception of packaging is similar to the perception of the average consumer: packaging causes a lot of waste! And careers in waste production arc not the careers young people are looking for. Several initiatives set up by tertiary education institutions to develop a sustainable first degree program in packaging have failed because of this reason.

My perception is that in majority industry' is to blame for this. Over the years, the packaging industry as well as their customers (ie. food, pharmaceutical, chemical, apparatus industry) have failed to recognise the importance of the packaging position. For years staff was recruited from different disciplinary backgrounds like mechanical engineering, chemical engineering, food technology, physics and even

accounting. Once in the job they were additionally trained by attending the referred short courses and seminars, as well as learning on the job through trial and error.
Exception to this is the situation in the United Slates were since decades the packaging technologist or engineer is recognised as a viable profession in industry, thanks to the efforts of Michigan Stale University and Rochester Institute of Technology through their respective curricula in packaging.

Innovation drivers.
The system of 'educating' packaging people on the job through trial and error and an occasional short course or seminar worked quite well for years. This due lo the fact that for years packaging was not really perceived to be a sophisticated, hi-tech area. To a large extend packaging development was driven by the packaging industry and their achievements in material development and manufacturing technology; driven by their clients wishes lo obtain cheaper, more competitive packaging materials and systems.

However in most recent years developments in packaging technology have been dominantly influenced by a number of developments mostly outside the span of control of the packaging manufacturing industry. In stead of a trend setting industry', driven by innovations in materials and manufacturing technology, the packaging industry has been forced to find technological answers to trends/developments as:

- growing environmental considerations and awareness;
- globalisation of markets with increasing competition on home markets;
- demographic and social developments in consumer markets;
- increasing awareness for save and healthy products;
- emerging new markets (eg. PR of China, Eastern Europe).

These trends urge the packaging industry together with their clients lo become more innovative in developing new packaging technologies. Technologies in which the latest developments in material development, manufacturing technology, preservation technology in combination with distribution and marketing techniques arc sophisticated!)- combined. The product to be market is no longer the originally manufactured product, protected by a container. Increasingly the container (packaging) has become an integral part of the product. The product and its packaging are to an increasing extend playing a subtle combined action in satisfying the needs of all parts of the distribution and marketing chain, including those of the consumer and the environment.

Together with the increasing competition in the global market place, this trend has resulted in an increased pull for innovation in packaging. It appears lo be more and more obvious that innovation in packaging is guided by:

- multi markets;
- multi materials;
- multi functions;
- multi disciplines, and
- multi actors.

A complexity increasing factor lies in the fact that packaging cannot be considered a product on its own. Packaging is a product marketing support element. Like referred before a packaging is becoming more and more an integral part of the product. However at the end of the supply chain it is the content of the packaging which has the consumers' interest and not the container, although the product could not be marketed and often even not used conveniently without the packaging.
This makes packaging a unique issue with many aspects to consider.

In general packaging innovation is driven by demands and opportunities arising from the interaction between consumers, distribution and manufacturers (Figure 1). The consumer (or market) area is to an increasing extend dominating this interaction because of the more severe demands emerging from increasing awareness for healthy and safe products, demographic and social trends and growing environmental considerations and awareness. New materials and technologies arc required to meet these demands, but often also new opportunities arise from these new materials and technologies and with that new consumer demands arc created.

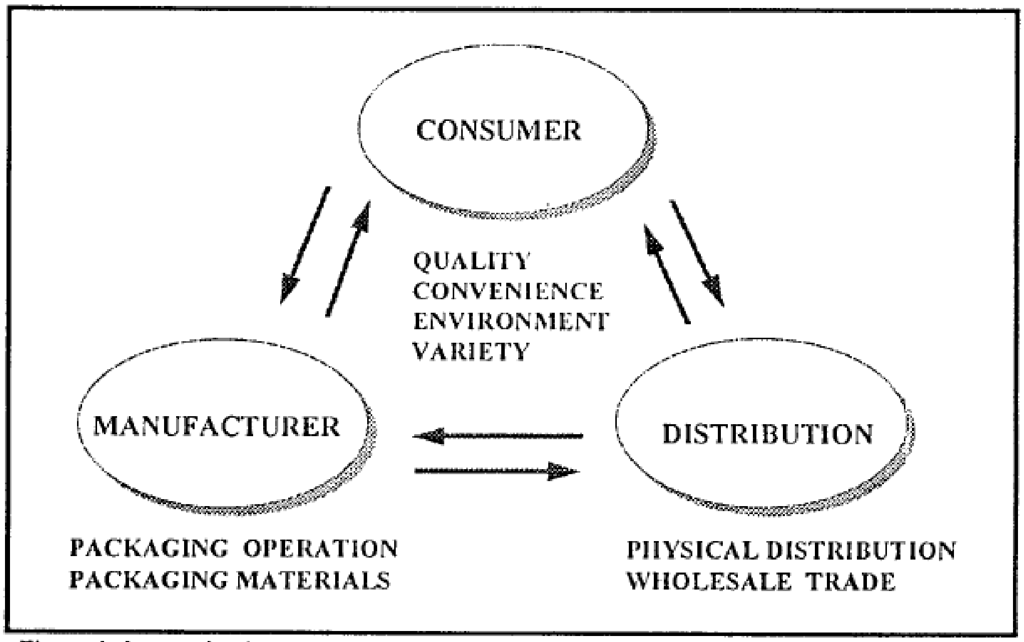

Figure 1: Interaction between consumer, manufacturer and distribution in respect to demands for packaging development.

The manufacturer (product as well as packaging manufacturer) can and has to apply the latest advances in materials, process and packaging operations and will have to offer them to the product user (consumer).
For example, new technologies to extend the shelf life of fresh produce will enable consumers to buy products less frequently. However, it also offers an opportunity for the manufacturer to distribute his products over a larger geographical area and with that reaching new markets.
Another challenge for the manufacturing industry is the need for flexibility. With an increasing variety in product packaging combinations, the manufacturing process must be able to change quickly between relatively small production runs without losing efficiency. Automation and robotisation are very important in this area.

Need for Education in Packaging

The wide variety of trends and developments in the market place arc constantly confronting the product supply chain with new demands for packaging systems. Demands which mostly indicate a need to change. Il is very important to approach this need to change a packaging material or concept as an opportunity to improve the technical and commercial performance of a product packaging combination (Figure 2). This need to change has driven the development of many new materials and systems.

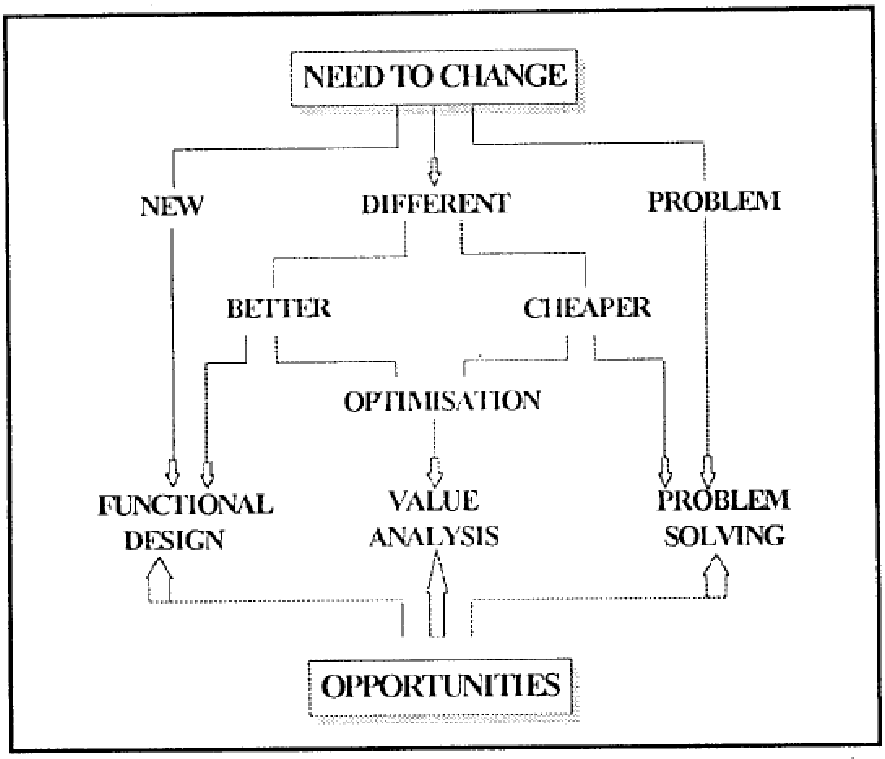

Figure 2: Need to change can be approached as opportunity to enhance packaging performance.

The change from technology push from the packaging industry towards technology (innovation) pull from the market requires an adequate answer from companies in the supply chain in order to stay in business. Collaboration and cooperation will have to be a major part of the answer. Effective collaboration between product manufacturers, packaging suppliers, distribution industry, research providers and educators is essential to be able to develop adequate, economic, environmental sound and acceptable product packaging combinations.

In this process the role of packaging has gained importance. Subsequently packaging development and management is getting more attention and industry, packaging industry as well as packaging using industry, starts lo realise that the packaging issue requires qualified staff to handle the complex and multi-disciplinary area. Not only because of the multi-functionality of packaging and the multi-actors involved in the supply chain, the complexity is also apparent in the packaging operation in the manufacturers environment as can be demonstrated from table 1.

Table I: Company sections involved in the packaging operation

Production	Warehousing and distribution
Production panning	Accounting
Intellectual property control	Product research and development
Technical services	Packaging procurement
Strategic planning	Market research
Marketing	Advertising
Packaging research	Packaging development

It is obvious that Packaging procurement. Packaging research and Packaging development arc the primary sections regarding the packaging operation. Packaging development is considered the most important of

the three. It includes a central position in the interaction between product management, packaging research, packaging procurement, packaging operations, distribution and marketing.
The complexity of the packaging development complex is illustrated in figure 3.

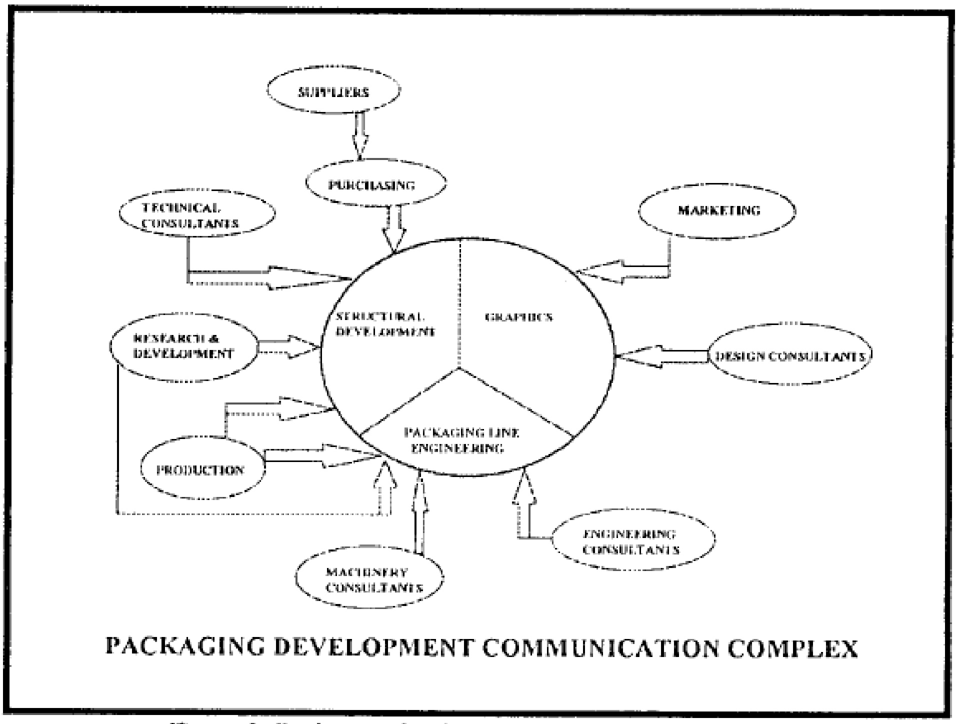

Figure 3: Packaging development communication complex

The increasing complexity of the packaging operation urges industries in the supply chain to hire qualified packaging personnel. In particular over recent times a need for qualified people lo manage the packaging operation in the company has emerged. It also is noticed that the need for qualified packaging managers, technologists or engineers has moved from the packaging supplying to the packaging using and distribution industry. This complies with the earlier statement that the driving force for new packaging technology is moving from packaging supplier lo the product market.
Packaging management in packaging using and distribution industry requires close collaboration with many different disciplines from the commercial, legal, scientific and technical areas. This collaboration is not limited to the product manufacturing company itself(sec figure 3) but includes collaboration and cooperation with external relations as well. Upstream as well as down stream the supply chain a packaging manager has lo maintain good relations in order to be able to select the optimum packaging solution (sec figure 4).

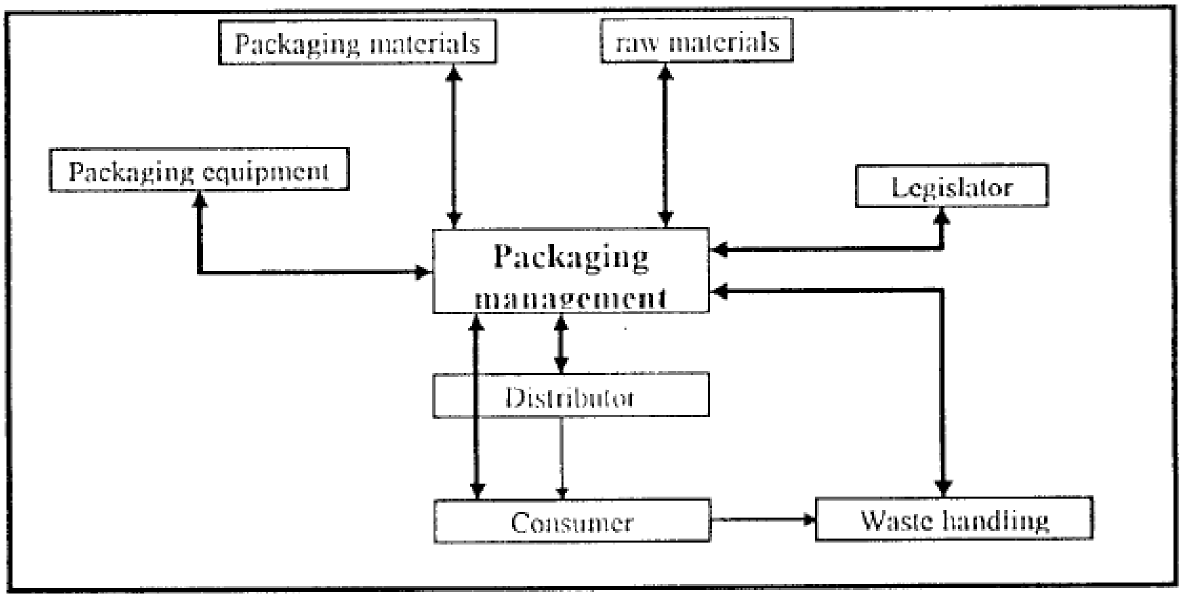

Figure 4: Packaging management communication complex

Packaging education in Australia

These changes in the tasks and responsibilities of the packaging operation requires qualified and adequate management. Consequently industry now starts to recognise the importance of adequate training in the packaging area. Due to this development in Australia there is an increasing interest for training in the packaging area. The majority of this interest is coming from people already employed in industry. Those people experience a lack of adequate knowledge and arc looking for ways to upgrade their knowledge in combination with their work commitments.

In anticipation to this need, a number of initiatives have emerged in Australia. In addition to an increasing number of undergraduate students in 'design' focussed tertiary education programs at several universities, three institutions are now offering education programs in packaging science and education.

Australian Institute of Packaging (AIP)

Since 1979 AIP is offering the 'Diploma in Packaging Technology'- course on behalf of the UK based Institute of Packaging (IoP), which offered the course for the first time in 1955. On behalf of IoP AIP is managing the presentation of the course and the administration of students in Australia and the Pacific Rim. The course, which is considered a basic training in packaging technology, is offered by distance learning only and provides an opportunity for industry people to gain a professional qualification without the need to physically attend classes at sonic place. The course is recognised by WPO and as an entry level by two universities in the UK. It has some disadvantages like the 'European Flavour' and the limited possibilities for students to interact with tutors. In the near future it is planned to move to a new, three part structure which will allow students to study for and gain a Certificate in Packaging Technology (Part I). To go on and study for two more written examinations (Part II) and then to complete the requirements for (lie Diploma by submitting an extensive dissertation (Part III).

Centre for Packaging, Transportation and Storage, Victoria University of Technology (CPTS)

CPTS started packaging education in 1990 with offering a Mastercourse in Applied Science in Packaging Technology. Additionally the Centre offers postgraduate education in packaging by research. Over the past seven years a limited number of students have completed Masters as well as PhD degrees by research on packaging subjects.

The Mastercourse however suffered from lack of students due lo the fact that:
- the content did no longer nice! (changing) industry needs (to much engineering focussed), and
- potential students do not have the time available to physically conic lo the university.

In view of the already referred increasing interest from industry people to enrol in a postgraduate education in packaging technology, it was recently decided lo re-develop the Course. This re-development concerns the course program as well as the way it will be offered.
The re-developed course will follow the model used by Brunell University in the UK. Its objectives arc to:
- develop a sound theoretical knowledge and application ability of appropriate scientific, engineering and computing techniques as they relate to the study of modern packaging technology;
- encourage direct application of advanced techniques to innovate the design, manufacturing and evaluation of commercial packaging;
- enable graduates of the course to support the packaging industry and packaging using industry by developing high level research and management skills.

The course will contain a range of modules, covering general subjects ranging from Packaging Manufacture, Packaging materials. Marketing and Financial Management, Legislation and Standards, Packaging Machinery and Operations through Physical Distribution and Marketing. Additionally elective modules on specific topics like Food Packaging, Packaging Design, Environmental aspects of Packaging, Packaging of Dangerous Goods and Pharmaceuticals, and Packaging Research will be offered to meet specific interests of the students.
The modules will be offered over a two year period as a combination of residential and distance learning modules. This model his the advantage that only three or four times a year the students have to come to the university for a limited period of 3-4 days only. In between two residential modules the students have to study a distance learning module which can include an assignment or an assessment (test) upon return for the next residential module.
After successful completion of the modules students will be required to successfully complete a minor thesis (in the third year) in order to be awarded the Master Degree. The topic of the minor thesis can be an (industry related) research subject or, alternatively, the development of a full packaging system.

Additionally CPTS still offers students the possibility lo obtain a postgraduate degree (Masters or PhD) in Engineering or Science by research on a packaging related topic.

CRC for International Food Manufacture and Packaging Science
The objective of this Cooperative Research Centre (CRC) is lo raise the competitive ability of the Australian Food and Packaging industry by creating effective cooperation and collaboration between industry, research providers and government, and providing relevant education and training.
In addition to training of existing personnel on relevant scientific and technical topics, this training also includes personal skills development and training of commercial and marketing skills.

A major objective of the CRC's education program is to provide the food and packaging industry' with future leaders. To accomplish this, the CRC is running a PhD scholarship program for which the brightest, young graduates arc selected. The topic of their PhD is strongly related to one of the topics of the CRC's research program. However, in addition to the 'normal' research training the PhD student is trained in the development of commercial, presentation and leadership skills. Furthermore the program includes a half year work experience program in industry in order to familiarise the student with industry practices. The core objective of the work experience program is to have the student manage a project under the supervision of an industry mentor.

Future developments
Structured packaging education in Australia has, like in most countries around the world, only recently got more attention from industry. Qualified packaging professionals arc more and more recognised as value adding to the business operation. Manufacturing and distribution industry in particular arc emerging

as the drivers for this recognition. This results in a need for initial education and training in the packaging area. However due to the fact that packaging science and technology is a very dynamic field, an increasing need for continuous education will emerge as well. Continuous education in respect to new emerging technologies, new materials, standards and legislation eteetera. The latter need can be delivered through a range of facilities like short courses, seminars, workshops and conferences.

However, numbers of students will still be limited and they require flexible ways of delivery because they have limited possibilities to attend training sessions. In increased use of distance learning methods will be the answer. The classical method of supplying distance learning, however is not very feasible because of a lot of practical problems like the higher costs of preparing learning materials, difficulties in motivating students, and lack of interaction between students and teacher and between students.
With the development of modern communication technology however there arc a range of possibilities emerging to overcome these problems. Application of tele-conferencing systems for example offers the potential to interactively communicate between students and teacher, to use the same materials as in normal class contact teaching and even make use of teachers based in other parts of the world (without having them physically to travel to the deliver)' location). Other possibilities arc the use of the World Wide Web and CD-Rom facilities. An big advantage of such systems arc the savings of travel costs for the students, in particular in a remote country like Australia. It also opens up possibilities to deliver education and training to students in foreign countries as it offers opportunities for packaging educators around the world to collaborate and cooperate in delivering training programs.

Conclusion

Emerging needs for education and training in packaging focuses on full-time employed people for initial training and continuous education. The change from manufacturing technology push towards market driven technology pull is resulting in an increasing need for initial and continuous education in the packaging area. Innovation in packaging requires qualified staff, able to communicate on a multi-disciplinary basis up and downstream the supply chain. The classical way of training people through seminars and conferences only appears no longer adequate.
However, time and location constraints appeared to be dominant impediments for students. Distance learning offers considerable opportunities for those students. With the development of multimedia communication technology an important step in the evolution of distance learning methodologies is envisaged. Australia has a long experience record in delivering education programs through distance learning and with the assistance of modern technologies a lot of the disadvantages could be transferred to the passed to the benefit of the modern packaging professional.

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日本包装学会ミニ・インターナショナル・セミナー　要旨

Packaging Education in Korea
Especially at the junior college

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KOREA

1. Introduction

No goods are sold without packaging.
Without packaging , the product would never have survived during its distribution from manufacturer to final user. Rapidly changing society makes life-cycle of the product shorter and shorter.

Consequently, new packages for new products should be designed and developed within very short interval. Despite the significant role of packaging to the society, people who have few understanding to the packaging regard it simply as an unnecessary cost and/or a contributor to the solid waste. This attitude has flowed through to the extent where those who design packaging systems and develop more efficient packages are not regarded as professionals.

As a consequence, any colleges/ universities have to develop degree courses in packaging and have ignored the size and importance of the packaging industry.

In the year 1993, packaging department was established in Tong Kuk College (2-year course) for the first time in Korea. Comparing with the other countries, 40 colleges/universities which offer the packaging major in America, and a few colleges/universities in Australia, New Zealand, and Thailand have the packaging major. Packaging as one of the sciences is not popular but in the beginning state. We, Korea, have only two junior colleges which offer the packaging major up to now.

This paper will discuss the present situation of packaging education in Korea, especially at the junior college. Careers of graduates and curriculum guide of the packaging department, Tong kuk College will be included.

2. Development of Packaging Department

2. 1. Professionals in packaging industries

KIDP(Korea Institute of Industrial Design Promotions) had made the study on "Research on the actual condition of packaging management" for 75 large companies in Korea during the year '93 and '94. As the result, top managers in 53 (70.6%) companies showed very high interest in packaging and its management. However, only 21 (28%) companies had the independent department responsible to the packaging development and management. And 60 (80%) companies response that they were experiencing the difficulties in carrying out the packaging operation because of lack of packaging professionals. This result shows that there are plenty of rooms for packaging professionals.

About half of those companies were operating self educational program to train packaging professionals, and 92% of companies predicted that there must be some packaging professionals in their companies in the near future

At present, we have only 2 junior colleges which offer packaging major, however, we have large possibility to have packaging department in university level (4-year degree course), since the career opportunity of packaging graduates is very widely opened.

One national university located in the eastern part of Korea is hopefully expected to launch the packaging department from next year.

2.2. Establishment of Packaging Department in College

In 1987, professionals from the fields of governmental organizations, industrials, educational institutions and research institutes insist loudly on necessity of cultivating the packaging professionals at "Technical Committee on Packaging Policy" meeting sponsored by the Ministry of Trade and Industry. In the same year, KIDP asserted necessity of4-ycar university grade packaging education through the report, "Packaging Education System for the Future". However, before 1993, no positive movement was made to establish the packaging department in the college or university.

Of course, public organizations such as KIDP and Korea Corrugated Packaging Case Industry Association have been operating the packaging education program in short period, and many companies have been training their packaging related employee through their own packaging job training courses.

As the packaging department was established at long Kuk College in 1993 and at Shin Sung College in 1995, wide opportunity was opened to the people who wanted to have packaging education and to make a career in packaging.

3. Curriculum of the Packaging Department

3.1. Scope of packaging science

Well-known business magazine "Forbes" has been publishing the statistics of the American packaging industries annually from 1989. It means that packaging is already classified as an independent industry such as foods, Pharmaceuticals, automobiles, etc. in the industrialized countries.

Before any discussion of the scope of packaging science, the functions of packaging must be clearly understood. For an objective assessment of packaging, cognizance must be taken of the many functions which packaging performs. These can be described under six headings : containment, protection, convenience, unification, apportionment, and communication.

Consideration of the packaging functions and the environments in which the packaging must perform to provide a valuable starting point for what fields should be included in the scope of packaging. Clearly there must be consideration in design, materials, technology, and machinery as well as some social sciences such as economics and marketing. However, unlike many other technological disciplines, packaging must perform in the human environment. Therefore, some understanding of consumers and their needs must be included. An attempt which must be avoided is to focus on the manufacturing of packaging materials rather than on their use and application in packaging. Many engineering and technology degree courses already provide excellent programs in material production. Modern concept of packaging science must include the following fields, which are composed of not only social sciences but also natural sciences. And "package design", "distribution system", and "communication" could be included, too.

Sociology	Economics	Environment
Marketing	Product Science	Packaging Materials
Material Converting	Packaging Technique	Packaging Machinery
Physical Distribution	Test & Evaluation	

3.2. Progress in packaging development

In the beginning, packaging was utilized only to contain and to protect products during distribution channel. Early 1900s, production of goods increased to such a level that it outstripped demand. The consumer now had a choice among competitive products. Thus, what is now known as the marketing function was developed simultaneously with the development of mass production and distribution of goods. Although packaging was used in this new function, it was not accepted as an integral member of the sales and marketing department until the late 1 930s. One of the first innovations of the marketing function was the combined introduction of the unit package, brand identification, and advertising. The unit package carried the identification and provided better quality and convenience.

During the depression years, management discovered, however, that the package could do an excellent job of advertising its contents. The era of use of styling and design in packaging to motivate purchase had begun. With the advent of the self-service store which minimized or eliminated the sales clerk, it became imperative that the package serve as a silent salesman. During the following decades it became apparent that the package could also apply functional conveniences for both the consumer and to wholesalers. Marketing people discovered that in an affluent society customers buy on impulse the products they don't really need. Customer motivation at point of purchase became an important function of the package as a marketing tool.

Both theory and practice of protective packaging developed remarkably during the World War II, since every war supplies which included not only general munitions also foods were distributed throughout worldwide from Africa to South-East Asia. A war of attrition made logistics and packaging skills for the munitions far developed. America was the head quarter of the logistic strategy, and they made approach to develop efficient packaging scientifically and enthusiastically. After the war, that experiences, which would be transplanted to the commercial products, made America packaging leader in the world.

Development of protective packaging in America, which influenced related industries of Europe and Japan, initiated the research and study on protective packaging practically. Now, we have objective and scientific criteria for the protective and cushioning packaging.

3.3. Curriculum of packaging department at junior College

Packaging oriented to marketing and to protection has been the two main stream in packaging development flows. Although unexpected factors such as product liability law, rising of consumer power, and environmental aspects has appeared, those two main stream would not change their directions.

In November 1994, Dr. B. Marie, director of the School of Packaging, Michigan State University, agreed to author's opinion on those viewpoints and said "Now, packaging science is fixing its position as one of the natural science, and it could be divided to two courses, one is food packaging focusing to the flexible packaging, especially plastics, the other is protective packaging emphasizing on the analysis of shock and vibration and cushioning materials.

As shown in Table 1, careers of graduates from the packaging department of Tong Kuk college arc divided into two main streams almost half and half. That is, 23 students to food and flexible packaging industries and 28 students to appliance, automobile, cushioning industries. Curriculum of the packaging department at Tong Kuk College was decided by reflecting the trend of packaging development as a science. (Refer to appendix)

1) As the packaging core, "Intro-packaging", "packaging materials", and "packaging tectonics" arc adopted. As the food packaging and protective packaging will be the two main stream of packaging science, "food packaging I" and "packaging dynamics" are selected as core course, too. Also, "packaging lab I" and "field study" are selected, since we, junior colleges, usually focus on training technician.

2) Considering the functions of packaging and the environments in which the packaging must perform, "Advertising", "Trading", "packaging design", "Intro-marketing", "packaging and environment" arc selected as packaging electives.

3) To enhance the food packaging course, "Food preservation" and "food packaging II" arc added. For the protective packaging course, "packaging and cushioning" and "packaging and physical distribution" were enhanced as packaging electives.

4) To enforce the adaptability as a technician to the field, "Quality Control" and "packaging lab II" arc added to the packaging electives.

<Table 1> Careers of graduates from the packaging department, Tong Kuk College

classification	department	persons
Appliance, Electronics	Research Lab	10
Flexible Packaging	Q.C.	15
Foods	Packaging Development	5
Cosmetics, Toiletries	\\	1
Paperboard	Q.C.	10
Cushioning, paper	Development	4
Automobile, Parts	K.D.	3
Furniture	Development	1
Research Institute	Researcher	1
Trading	Trading	I
Magazine	Reporter	1
Machinery	Development	2
Printing	Development	1
Study, overseas	China, U.S.A.	4
Total		59

4.Conclusion

The definition "Packaging is the custom-made to the product" has already become traditional and classical definition. liven today, most packages arc designed and developed by that manner. However, complicated consumer requirements and so many packaging related regulations and laws influence not only the products but also the packages. It has been very difficult tasks for packaging professionals to develop the efficient, marketable, environmental packaging.

Packaging must be independent and integrated natural science and be studied by the packaging professionals. If the image of the industry and those who work in it lo change, then there needs to be professional education available.

Packaging is one of the largest industries in the world. Without packaging, international trade could not be materialized. Countries in the Asia/Pacific region need creative, innovative, and professionally educated man powers to ensure that (heir products have the efficient packaging to compete on world markets.

In the near future, Korea will extend the packaging degree course up to the university level. Korea Society of Packaging Science and Technology(KOPAST) has a aim to set up packaging departments at the universities at least 2 in the capital city area and 2 in the provincial area.

Appendix : Curriculum of the packaging department, Tong Kuk College & Shin Sung College

	Tong Kuk	Shin Sung
College requirements	Occupational Ethics Intro Computer Chinese Characters English Conversation Oral Communication Korean History Bible Study	Joint Seminar with industry Living English Intro Computer Occupational Ethics Chinese Conversation Industrial Physics
Packaging Core Courses	Intro Packaging Intro Packaging Technics Paper & Board Packaging Glass & Metal Packaging Plastic Packaging Packaging Dynamics Food Packaging I Packaging Lab. I Field Study	Chemistry Industrial Packaging Packaging materials & Lab. Quality Control Package Design &Lab. Plastic Packaging Packaging Evaluation & Lab 1,ll Packaging Machinery Glass & Metal Packaging Packaging Technology & Lab. Food Packaging & Lab. Paper & Wooden Packaging & Lab. Field Training
Packaging Electives	Food Chemistry Chemistry Intro Marketing Advertising Trading Food Preservation Package Design Quality Control Packaging and Physical Distribution Package Printing CAD Flexible Packaging Package Development Packaging and Environment Cushioning in Packaging Food Packaging II Packaging Lab II	Food Distribution & Sanitary Science Packaging Specification & Regulations Packaging Materials Processing & Lab. Distribution Engineering Cushioning Packaging & Lab. Packaging & Printing Packaging Process Control Marketing Packaging & Environment Packaging Design & Development