# Accurate die-cutting of filmic substrates

## *The point of view of a manufacturer of die-cutting tools*

*Without any doubts filmic labels are the growing trend. Nevertheless, compared with traditional paper labels there are some peculiarities of printing and finishing which must be addressed. In this article Peer Beck, Managing director of Kocher & Beck Rotationsstanztechnik GmbH summarises some practical issues for the die-cutting of filmic labels.*

About 40 years ago pressure-sensitive labels were relatively unknown in Europe. In those days, labels were generally manufactured by either engraving or etching label stamps. At the beginning of the sixties pressure-sensitive labels began to conquer the European market. Paper labels were the main substrate and synthetics were not being used. Little by little the steel-rule die replaced the label stamp because the quality of the steel-rule die had improved significantly. However, for more complex designs e.g. decorative labels this technology was quite limited.

During the mid-sixties, the first rotary die-cutting cylinders appeared. Compared with steel-rules on flat-bed die-cutters, they offered a significant improvement in productivity. By the beginning of the 80's magnetic flexible dies revolutionised the field of rotary die-cutting; paving the way from flat-bed to rotary die-cutting for many label manufacturers.

In Europe, flexible dies long ago outstripped the die-cutting cylinder and in the meantime have become an indispensable tool for current label printing. This is in part due to advances in flexible die manufacture. The obvious trend towards the use of flexible dies is confirmed by the numbers sold by *Kocher & Beck*. For 33 years the company has manufactured all kinds of die-cutting tools and currently almost 30 percent of their total turnover comes from flexible dies and magnetic cylinders. All in all three kinds of tools are of significant importance:

- steel-rule dies,
- solid rotary tools,
- flexible dies.

On the die-cutting cylinder the cutting edge is firmly anchored to the body of the cylinder. The geometrical shape of the cutting edge is processed by CNC milling or spark erosion. Based upon the range of use, different quality die-cutting cylinders are available:

- chrome plated,
- inductive hardened,
- through hardened.

The choice of the most suitable quality is dictated by the particular use and the job run. The single tool types are distinguished by material hardness and cost. For die-cutting filmic labels and medium job runs inductive hardened cylinders are most suitable. If the job is a very long run, for cutting filmic labels or through cutting, *Kocher + Beck* recommends through hardened cylinders. This type of cylinder is vacuum hardened to 62 to 64 Rockwell which considerably increases its lifespan. Chromed cylinders are extremely suitable for manufacturing paper labels but due to the galvanic applied chrome layer they are not recommended for use with filmic materials.

### High flexibility with flexible dies

Flexible dies did not make an immediate impact on the European label industry. They are manufactured of a hardened steel with a strength of about 1850 N/mm$^2$. The cutting relief of a flexible die is not created by milling or eroding but by chemical etching that allows the creation of special shapes.

Advances in flexible die technology by *Kocher + Beck* include determining the worldwide accepted standard die height of 440 microns. This height can be varied according to the thickness of the material being converted. According to the use and design of the magnetic cylinder, flexible dies with an overall height of up to 1500 microns (1.5 mm) can be manufactured. Even different cutting heights on one flexible die is possible, which means that duplex substrates can be processed. Another application for flexible dies is the combination of die-cutting and perforation adding to job quality with better cut registration.

## Easy handling

The handling of flexible dies is very simple. Before the tool is placed on the magnetic cylinder, the surface of the cylinder should be cleaned. This is to ensure that no dirt is trapped between the cylinder and flexible die which could affect the die-cutting performance. As an aid for positioning the flexible die an auxiliary line parallel to the magnetic cylinder axis is engraved. The flexible die is placed along this auxiliary line and then wrapped around the cylinder. Even printers with little experience with flexible dies are able to place them accurately on the magnetic cylinder in a relatively short time.

The basic prerequisite for problem-free running of flexible dies is a precisely manufactured magnetic cylinder. The two most important parameters for magnetic cylinder precision are the air-gap and the concentricity of the cylinder. To achieve the tightest tolerances (below 3 microns) great efforts are made during manufacturing of the magnetic cylinders. This is especially important during grinding so as to ensure true concentric running. Sometimes these cylinders take over 20 hours to produce. When selecting a magnetic cylinder, keep this fact at hand higher cost cylinders are justified as the quality of die-cutting depends on the optimum interaction of magnetic cylinder, anvil roller and flexible die. The result is only as good as the weakest link in the chain, and accurate magnetic cylinders are an important part of the system.

## Magnetic cylinders need maintenance

As far as the magnetic strength is concerned, the lifespan of a magnetic cylinder is almost unlimited. Experience has shown that after five years the magnetic strength only reduces by about 5 percent. A bigger issue is wear of the bearer rings. Depending on how often the magnetic cylinder is used and how much working pressure is used, determines the amount of wear to the bearer rings. This kind of wear is very problematic as it directly affects the air-gap. To keep this wear as low as possible it is important to perform routine comprehensive maintenance of the bearer rings. Unfortunately experience has shown that this is not always done in practice. There are magnetic cylinders which have never even seen the slightest drop of oil which is exactly opposite to conventional die-cutting cylinders that are taken out of service after a period of time because minimum maintenance is strictly necessary.

Sometimes magnetic cylinders with very small diameters are ordered. The manufacture of such cylinders is not a problem but the problems for the user are predetermined because smaller diameter cylinders are prone to axial deflection. This the »flexing« of the cylinder is one of the most frequent reasons for faulty die-cutting. This problem inevitably occurs if the cylinder diameter is too small. The first problems appear with the horizontal cutting lines (the cross cutting tool) as this is where the highest cutting pressure occurs. During cross cutting the long cutting edges penetrate into the substrate. With the longitudinal cutting there are only a few contact points requiring a considerably lower cutting strength.

***Figure 1:***
***For many label manufacturers the magnetic cylinder die-cutting technology paved the way from flat-bed to rotary die-cutting.***

This problem also occurs with magnetic cylinders of reasonable dimensions if the impression pressure is reduced to a minimum. On the die-cut product it is easy to see that the longitudinal cutting is perfect. However, the cross cutting section supports the face stock so that the bearer rings of the magnetic cylinder are raised away from the anvil roller.

## The importance of proper tolerances

To minimise the dynamics of die-cutting problems, *Kocher + Beck* recommends that the ratio

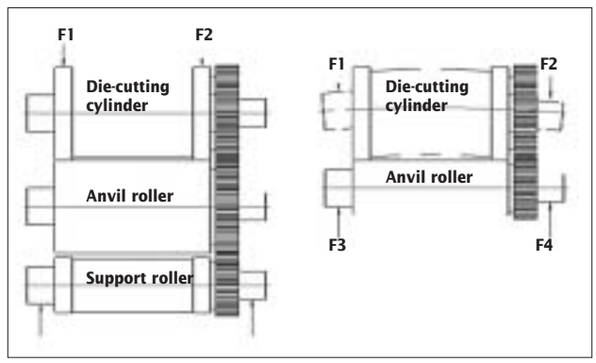



***Figure 2:***
***The impression pressure altered by the adjustment screw should be transmitted to the bearer rings. If the pressure acts on the journals the cylinders tend to sag due to the higher leverages.***

of cylinder circumference to die-cutting working width should be no less than 1:1. As this is not always possible, there are other ways to counteract the flexing of the magnetic cylinder (within certain limits). However, this is not always without compromise. For example die-cutting pressure can be reduced if an optimised cutting edge is implemented, especially on the cross cut. However, this method is limited to changing the cutting edge angle. To reduce the cutting pressure, the angle must be steeper which means that with such die-cutters, the bearings in the machine frame are too highly loaded. This may cause premature wear which is often not recognised in time. In any case for prevention purposes it is useful to check the die-cutter, the impression pressure transfer and the anvil rollers regularly and to exchange worn components.

With the die-cutting of very expensive and technically demanding filmic substrates significant savings can be achieved by producing the magnetic cylinder to the correct dimensions and optimum maintenance of the die-cutter and the die-cutting module components.

## A number of factors affecting quality

There are many factors that affect die-cutting quality that have already been discussed, but they bear repeating. The flexible strength of the die-cutting station which includes its construction, the proportion of cylinder diameter to working width of the printing press, the concentricity and accuracy of the magnetic cylinder, as well as the condition of the anvil roller. Other factors include the tolerances of the cutting edge height of the flexible dies.

Also of significant importance is the physical character of the substrate In this case the adjustment of both, the geometrical shape of the cutting edge as well as the cutting edge height to match the substrate are two of the most important issues. In this connection the experience of the tool manufacturer is very important.

Following are some recommendations to improve the partnership between the tool supplier and the label manufacturer. By following the recommendations a producer of labels can ease the pressure of ever shortening delivery times.

- One of the most important rules is thoroughly cleaning the flexible dies, the magnetic cylinder and anvil roller with the proper and recommended detergents before running. Incorrect detergents may cause bleeding of the adhesive or corrosion of the die-cutting tools.
- The regular maintenance of all movable components of the die-cutting station should be carried out daily.
- The use of a cutting die control sheet for the tools is recommended. The running time, the frequency of make-readies, as well as their condition after the job is finished should be entered.
- The use of pressure gauges on the die-cutters have proved to be useful for determinining the current die-cutting pressure. Furthermore, these pressure gauges are perfectly suitable for obtaining the proper adjustment and production of even die-cutting pressure as well as capable of detecting the increase in pressure caused by decreased cutting ability. This data should also be included on the cutting tool control sheet.
- It has always been proven useful for additional accuracy to check the die-cutting tools with actual substrate samples of the current production run. By sending these substrate samples to the tool supplier, greater accuracy is ensured.
- Since there is no standardized PE substrate the die-cutting properties may change with different deliveries from the suppliers of these materials. Although this generally does not cause problems, the die-cutting quality can be increased by supplying the current material samples to the tooling supplier.
- The label press personell should advise the supplier of the slit dimension of the magnetic cylinder and the type of machine being used.

***Figure 3:***
***These three variations are of limited use for faultless die-cutting. Left: a manually sharpened profile with visible weaknesses at the different angles. Middle: Etched profile partly manually equalised. Right: Mechanically sharpened cutting edge of earlier days.***

## A trend toward filmic substrates

The present trend in pressure-sensitive label production is moving more and more towards synthetic substrates. The output of filmic labels of some printers in Germany being as high as 80%. Such substrates create higher demands on the capacity of flexible dies. To process substrates like PP, PE or PET, new technologies had to be developed.

One thing learned after years of successful flexible die production is that in order to

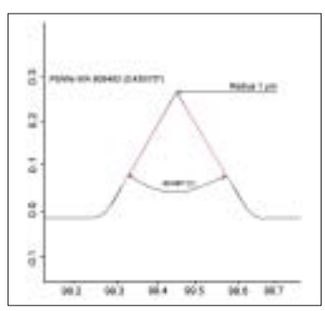


***Figure 4:***
***Standard cutting edge geometry for filmic applications.***

achieve successful, consistent die-cutting, the geometry of the cutting edge needs to be adapted to each pressure-sensitive substrate. For these technical reasons *Kocher + Beck* discontinued manual processing of the cutting edges (something that is still necessary for the manufacture of conventional die-cutting cylinders). Instead of manually sharpening the cutting edges, *Kocher + Beck* use their self-developed CNC machine systems. With this forward-looking process, cutting edge geometries between 25° and 100° are completely sharpened, automatically. Attention is mostly directed at keeping the cutting edge angle, the radius of the cutting edge point and the surface of the cutting edge shoulders correct. *Figure 3* shows different cutting edge profiles created with a checking device orginated and used at *Kocher + Beck* for quality control and training.

With current technology, cutting edges with sharpness tolerances below 3 µm can be manufactured. This enables substrates to be processed which were previously hard to handle, if not impossible to handle.

## The life of flexible dies

If the life of flexible dies and die-cutting cylinders are compared it must be considered that there are different qualities with different running performances associated with several different factors. However, in general the life of a universal flexible die compares to a Chrome plated solid rotary die.

If synthetic substrates are processed, the running per-formance of flexible dies can be even longer than with solid die-cutting cylinders, provided that the cutting edge geometry is accurately defined. The fully automat-ed manufacturing of flexible dies allows a precision that can not be achieved with conventional die-cutt-ing cylinders. For the manufacturing of labels for office products, applications like computer labels, and A4 or 8-1/2" x 11" sheets, flexible dies are generally used. Some leading label printers with long production runs and standard formats no longer use conventional solid rotary tooling.

## Advantages of flexible dies

Some of the most important advantages of flexible dies are:

- low purchasing costs (about 40 percent of the cost of a conventional solid rotary tool);
- fast delivery times (1 to 2 days) with reproducible cutting edge parameters;
- complex edge shapes are easily manufactured;
- smaller storage space requirements;
- reduced transportation costs and less logistical effort due to lower weight of the tool.

The development of flexible dies is not haphazard. *Kocher + Beck* constantly work to achieve better running performances and improved working life. Standard processes used for producing conventional die-cutting cylinders were rejected after several trials. Coatings such as chrome,

can crack along the cutting edges and can not ensure 100% cutting height tolerance precision. Hardening processes like inductive hardening, cause the tools to become very hard but entirely too brittle. Coatings like TiN or TiCn are extremely expensive and such coatings are difficult to control. In light of this, *Kocher + Beck*, in cooperation with various professional insti-tutes, developed a process to harden the point of the cutting edge with an extremely accurate and focussed laser beam.

The upper area of the cutting edge is post-hardened exactly where it comes in contact with the pressure sensitive substrate. As only the point of the cutting edge is extremely hard the flexibility of the flexible die is fully maintained and it can be placed on the magnetic cylinder without cracking or affecting cutting performance. This tool quality is offered under the name *3L Long Life Laser*.

In practical, long term trials the *Long Life Laser* quality gave 2 to 3 times longer running life for all kinds of substrates. *Figure 6* shows the results for Polyester, Polypropylene and Polyethylene films as well as for paper substrates. Compared with non-laser hardened tools, the *3L* flexible dies can give the label printer an extension of the working life between 200 to 300 percent.

## Wear with abrasive substrates

The substrate has a significant effect on the working life of the die-cutting tool. Wear diagrams show the extent to which the cutting edge geometry is affected. These wear diagrams are created from the use of a checking device originated and used at *Kocher + Beck* for quality control and training.

Typical wear which occurs after a long run using either flexible dies or die-cutting cylinders can be seen in *figure 7*. The cutting profile shows an increased flattening of the originally manufactured 60° cutting angle. This flattening to 110° is particularly evident in the areas where the cutting edge – penetrates the substrate. It also shows unevenness in the cutting die height. This change of the original cutting angle is caused by the abrasive action of the penetration of the cutting edge into the substrate. The shoulders of the cutting edge are literally eroded.

*Figure 8* shows the wear of a flexible die after processing a very abrasive $SiO_x$ coated film. A high reduction of angle as well as a narrowed angle can be seen.

In this case laser hardened flexible dies have significant advantages. In addition to improved hardness of 62 to 67 HRC (on the upper part of the cutting edge) there is also a very even transition from the hardened portion of the die into the relatively softer area. With the use of laser hardened die-cutting tools there are no changes to the cutting edge geometry like unevenness or enlargement of the cutting edge surface. Changes to the cutting geometry can occur with non-laser hardened dies due to increased wear of the cutting flanks. The shoulders of the cutting edge have a very smooth surface since there is no layered structure as with coated tools, like TiN or Chrome. In addition the hardening process can be reproduced at any time and the flexibility of the flexible die is almost fully maintained. Also the environmental friendliness of laser hardening is evident because this process does not require chemical substances or heavy metals, as with coatings. Some users state that hardened tools are much less sensitive to damage compared to standard tools.

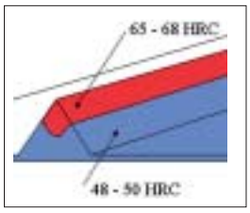



***Figure 5:***
***Selective post hardening of the cutting edge with the 3L technology.***

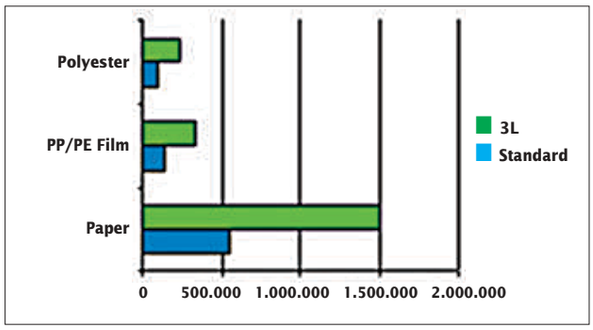
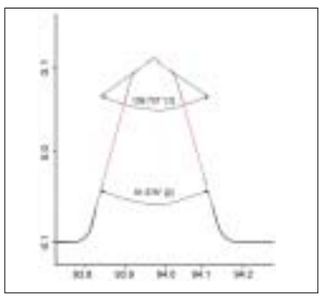



***Figure 6:***
***Comparison between the operating performance of standard die-cutting tools and the Laser-Long-Life quality.***

*Figure 9* shows the different wear characteristics of hardened tools and standard tools. The heavy wear of the standard tools from first use is evident. During the first 15,000 to 20,000 die-cuts a loss of die height of about 3.5 microns occurs. This is especially evident when processing filmic substrates and has a distinct disadvantage as it results in higher working pressure.

## Differences between die-cutting of filmics and papers

In general there are differences in the die-cutting of paper and



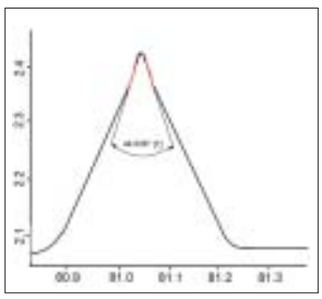


***Figure 7:***
***Wear diagram of a flexible die used for processing PET film.***

***Figure 8:***
***Analysis of a flexible die profile used for $SiO_x$ coated film.***

filmic labels. This is because flat-bed die-cutting and rotary die-cutting is not a simple cutting process but rather a combination of cutting and bursting. Therefore it is easy to understand why films have poorer bursting characteristics than paper.

*Figure 10* shows that for paper substrates penetration of the cutting edge of two thirds is sufficient to break the remaining third without further cutting.

With films, the cutting edge must penetrate four fifths or more into the substrate in order to cut the face material. This significantly reduces the required tolerances for the die-cutting process. As a general rule it can be said that the softer the face stock the deeper the cutting edge has to penetrate. However, it has to be mentioned that some films, filmic compounds or laminates cause more blunt cutting edges than paper substrates do.

The liner material is also of significant importance for die-cutting. The deformation of the liner material, which occurs with every die-cutting process is not shown in *figures 10* and *11*. The combination of a soft face stock and a hard liner paper is most suitable. Difficulties often occur with thin or soft base liners as they are compressed by the die-cutting process. This alters the correct cutting point. If the dimensions of the tool are adjusted to the substrate thickness, proper cutting of the face stock is still not guaranteed. In the worst scenario, the base paper *(liner)* bursts and the face stock remains untouched.

Due to the manufacturing processes associated with producing substrate materialsit has to be considered that for films the interior strength of the substrate is different in the longitudinal direction than in the axial direction.

For easier processing of films *Kocher + Beck* has a practical recommendation: PE films are easier to die-cut when they are varnished in advance. This improves the die-cutting quality and allows for increases in production speed.

## Waste removal as part of the die-cutting process

Technical aspects of waste removal are also important for die-cutting. There are different options for the removal of the waste as these can affect the conversation.

When using an idler roller for waste removal, it is recommended to position the idler roller straight after the die-cutter (*figure 12/1*). If it is placed some distance from the die-cutter the adhesive may join back together. This inevitably results in bleeding of the adhesive which may cause removal of the already die-cut label into the waste matrix. It is also an advantage to use a small diameter idler roller.

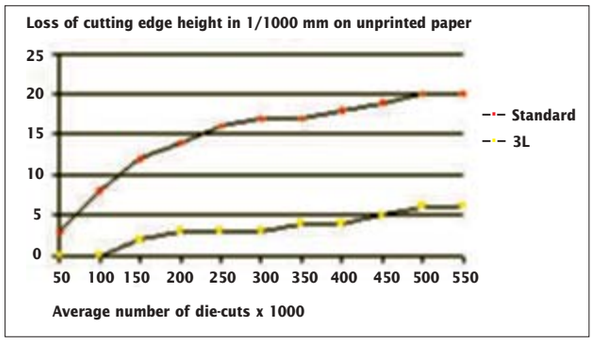



***Figure 9: Comparison of cutting edge wear of different die-cutting tools.***

As an alternative the waste can be removed with a knife (*figure 12/2*). However, with this method, the matrix is exposed to a very high load as there is a negative removal angle to the web. This method is advantageous when converting extremely aggressive or fluid adhesives.

With difficult substrate compounds it is an advantage to remove the waste directly above the magnetic cylinder (*figure 12/3*). The disadvantage is a slightly reduced production speed. The waste matrix passes around the magnetic cylinder or the die-cutting cylinder at an angle of between 10 and 40°. If machines are used with such facilities, changes to stripping angles can be performed more easily.

Label production requirements are constantly increasing and changing. In any event, it is more important now than ever before, that all participants in the label production process, including suppliers of substrates and die-cutting tools work closely together for the benefit of everyone. ■

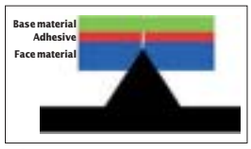



***Figure 10: Diagram of the die-cutting of paper labels.***

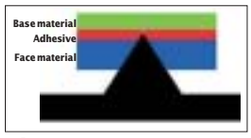
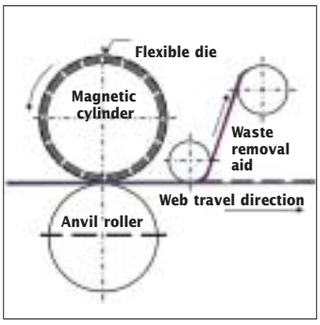
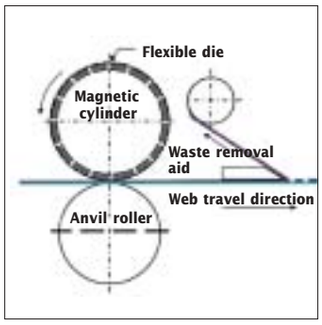



***Figure 11: Diagram of the die-cutting of filmic labels.***



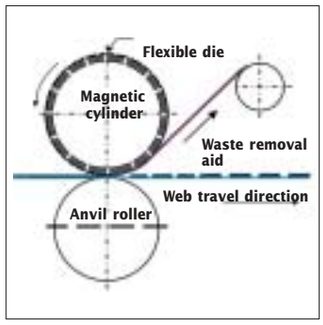




***Figure 12: Three different ways of waste removal: 1. Waste removal with an idler roller. 2. Waste removal with a knife. 3. Waste removal with a cylinder.***