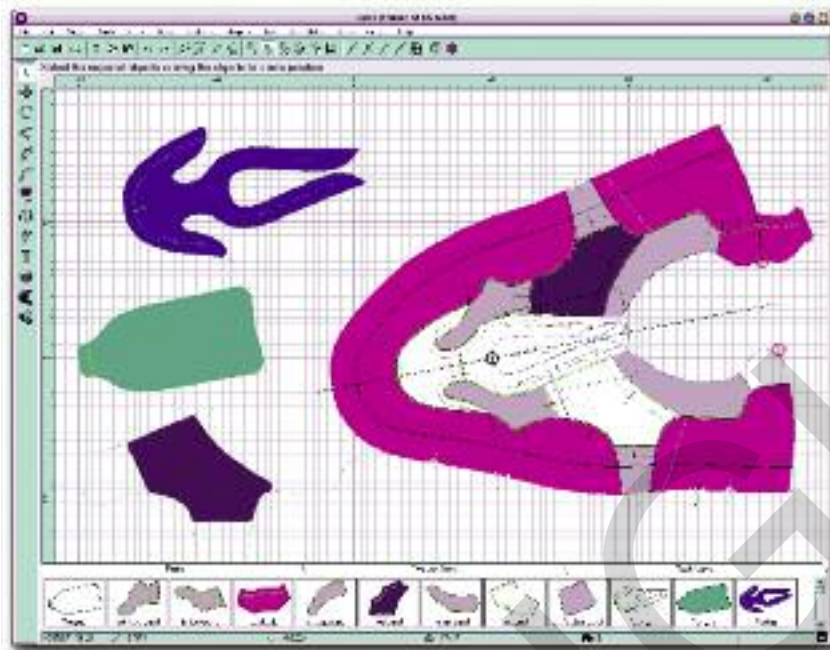




Footwear Fundamentals

PATTERNS VARY IN SIZE

While the function of shoe upper patterns is obvious to all, grading them to achieve all the different sizes required has long been a mystery to most. It could be said, however, that it is arguably the most important aspect of the whole shoemaking process. Without it, it is impossible to produce all the various components needed. Without it they will not fit together accurately to create an upper that both looks in proportion and fits the specific shape and size of last for which it is intended. Indeed, without it, shoemaking as we know it would not be possible.

At one time, pattern cutters were all taught how to grade patterns manually, so that they fully understood the process. Those who went on to specialise in pattern grading would then learn how to operate one of the pantograph-type grading machines that were in wide use. The key thing was that a pattern cutter had some knowledge of grading and a pattern grader had some experience of cutting original patterns.

Today, the whole process from conceptual design through to bulk tooling will normally be carried out using CAD programs and, in some cases, by just one person. While they will be skilled in using the software program, they often lack a full understanding of how the program actually creates all the different shapes and sizes. While it appears to be extremely complex, the basic principles that lie behind upper pattern grading are in fact comparatively straightforward.

SIMILAR TRIANGLES

Modern 3D CAD models are formed from a mass of triangles. One reason is that a triangle is the easiest shape for a computer to recognise. The other is the way a triangle can be manipulated to vary shape and size and this also forms the basis for grading upper patterns as the following explanation will demonstrate.

Triangles having equal corresponding angles are said to be 'similar' as in *Figure 1*, where $A = D$, $B = E$ and $C = F$. While the two triangles may differ in size, they are exactly the same shape. The most important factor however as regards pattern grading is that the sides are proportional, so that if AB is twice DE , then AC will be twice DF and BC twice EF .

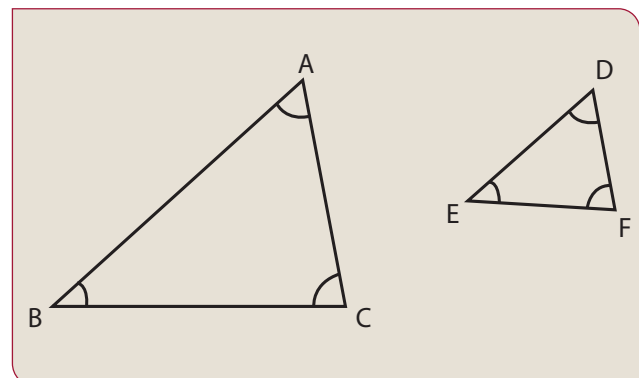


Figure 1 – Similar triangles.

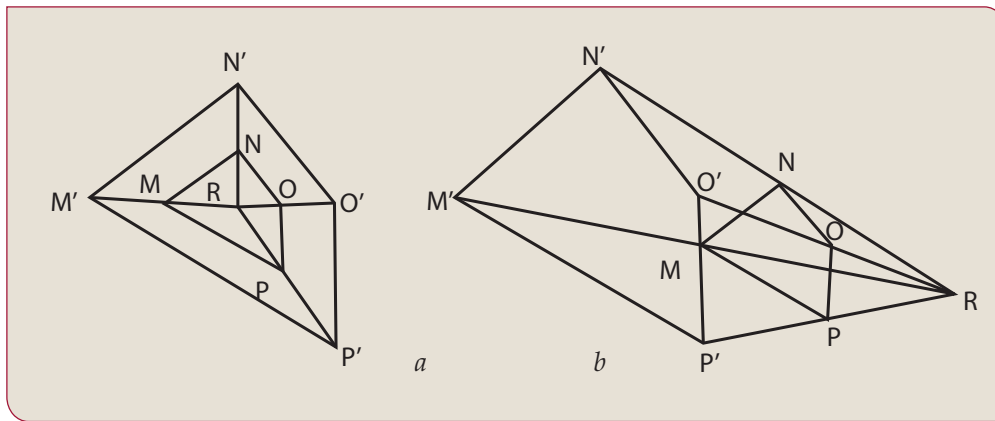


Figure 2a – Radial projection from the inside. Figure 2b – Radial projection from the outside.

This property of similar triangles in turn makes it possible to enlarge other shapes proportionally by means of radial projection. Thus in *Figure 2a*, MNOP is enlarged so that its perimeter is twice as long as before. This is done by drawing lines from a radial centre R which can be inside as here or outside as in *Figure 2b*, through points MNOP. If these radial lines are extended so that $RM' = 2RM$ and $RP' = 2RP$, $M'P'$ will be twice MP since $RM'P'$ and RMP are similar triangles and their corresponding sides are proportional. OP, ON and NM will be altered in exactly the same way.

These two diagrams show that each figure is composed of four pairs of similar triangles. While triangles RMP and $RM'P'$ in *Figure 2a* are different from those in *Figure 2b*, the enlarged figure is actually the same so that $RP' = 2RP$ in each case. This is the basic principle on which the hand grading of all patterns was based in the past.

PANTOGRAPHS

As the footwear industry became increasingly mechanised, ways were sought to grade patterns by machine. The simplest and most effective was to use a pantograph which is most easily explained by referring to *Figure 3*.

This pantograph consists of four arms; FA, AT, CP and BP, joined at points B, A, C and P. Point P is fixed, while F acts as the 'follower' and T as the 'tracer'. BP is equal and parallel to AC, and CP to BA so that no matter how the pantograph is moved, ABPC will always be a parallelogram where $BF = BP = AC$ and $CT = CP = AB$. It can also be shown through similar triangles that FPT will always remain in a straight line.

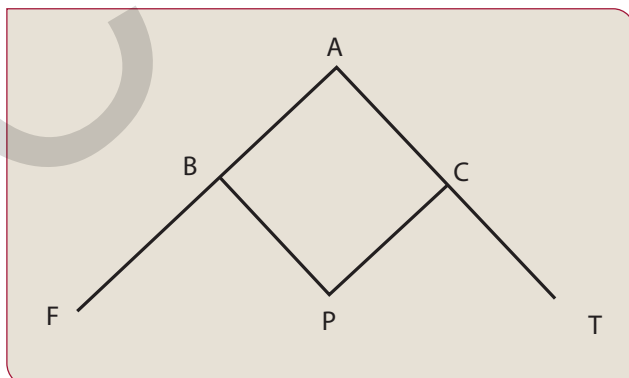
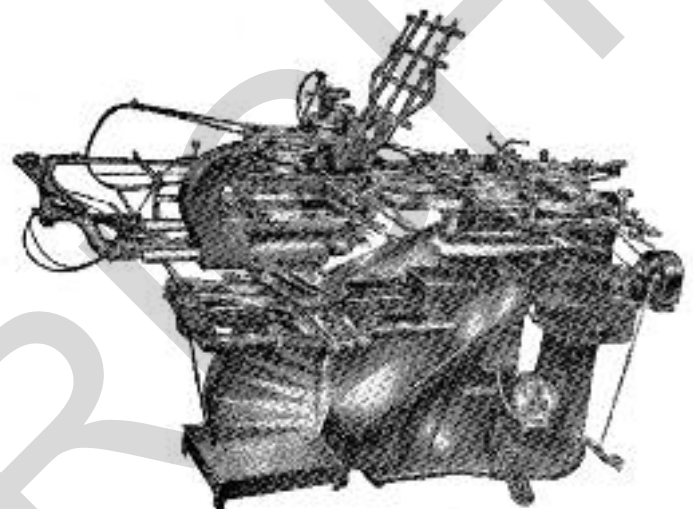


Figure 3 – Pantograph.



Universal Grading Machine by BUSMC. Grading machines of this type were in general use up until CAD software programs became widely available. This one featured two pantographs that could be set to grade either proportionally or length and width independently so that a full range of sizes and fittings could be cut from one model to produce either hand cutting patterns or press knives.

If P is fixed to a flat surface and F drawn round a given shape, T will trace out a similar shape. If sections FB, BA, BP, PC, AC and CT are all equal, it will also be exactly the same. If, however, CT, CP and AB are longer than FB, BP and AC, the tracing will be correspondingly larger than the original in the same ratio as BA to FB on that arm of the pantograph. Any size of pattern can therefore be produced from a sample size merely by altering the lengths of the pantograph's arms in the required ratio.

RESTRICTIONS

In practice, the ratio or increase or decrease from the model size (usually as close to mid size range as possible) is seldom directly proportional. If it was, smaller or shorter upper sections would become distorted. While the actual method of grading the different sizes remains the same, it is modified or 'restricted' to prevent this and provide the correct required increase or decrease in size.

In addition, features such as lasting margins and seam underlays must also be restricted to the same width regardless of size. It is therefore easy to see why pattern

Tables of underlays.

Margins / Offsets - Mens		Margins / Offsets - Mens	
Feature	mm	Feature	mm
Bagged seam	3	Close-seam: medium	1.5
Close-seam: medium	1.5	Close-seam: heavy	2
Close-seam: heavy	2	Gimping	2
Folded edge	5	Bagged seam	3
Gimping	2	U-edge trim	3
Lap-seam U-lay	10	Folded edge	5
ditto: with spaced rows	12.5	Trim-off - lining U-lay	8
ditto: with 2-and-1 punch	15	Lap-seam U-lay	10
U-edge trim	3	ditto: with spaced rows	12.5
Trim-off - lining U-lay	8	ditto: with 2-and-1 punch	15

1. Lifted by feature.

2. Lifted by measurement.



Example of grading input on a CAD system.

grading was traditionally such a highly skilled and specialist area of shoemaking. Today, it is far easier as CAD grading programs have all these factors built in as 'wizards' whereby the operator merely has to select the appropriate restriction from a table. The computer then automatically applies this to the pattern being graded.

GROUP GRADING

The principle of restricting certain aspects of the grading of upper sections has been further extended over the years to cope with situations where fixed-size components such as buckles are involved or the cost of tooling needs to be controlled.

Buckle straps – in the style shown in Figure 4, the strap of the inside quarter passes through a buckle attached to the outside one. The buckle is available in only one size, so the width grade of the strap must be modified such that it remains the same as that of the model irrespective of shoe size. This ensures the strap fits the buckle closely on every size.

Other components with fixed dimensions include zippers and hook-&-loop fastenings and the metal D-rings they are looped through. These and similar components that are only made and/or bought in one size will require upper pattern grading to be modified in some way. The reason they are 'one size only' is cost and manufacturing practicality. The supplier would face huge increases in manufacturing and handling costs (think of the mould costs for a range of buckles graded in width), while the shoemaker would find it took far too long ensuring each

size of component was identified and used in the correct size of upper.

Punched caps – a ladies court shoe with a punched wing-cap requires a modification to the 'normal' grading for quite a different reason. The punching is often done with a single die that cuts out all the punch-holes simultaneously. These dies are expensive. If each cap line is graded 'normally', the size and shape of this line will be different for every size and half-size, and a punch-die will be needed for each one. Group grading reduces the number of dies required without compromising the accuracy of the relationship between the edge of the graded caps and the punching alongside it (Figure 5).

The front edge of the vamp, to which the cap is stitched, will be similarly graded to match the restricted cap line. The rest of the pattern—especially overall length and width—will still be graded uniformly to fit every size of last.

Back heights – an important quality issue during manufacture is ensuring the height of the back of a shoe is consistent between shoes of the same size and, especially, between the left and right foot of a pair. If back-part moulding is used to shape the back of the upper before

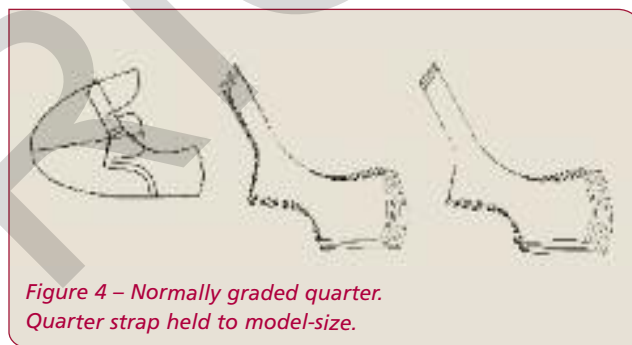


Figure 4 – Normally graded quarter.
Quarter strap held to model-size.



Figure 5 – Normally graded cap line.
Cap line restricted to three sizes.

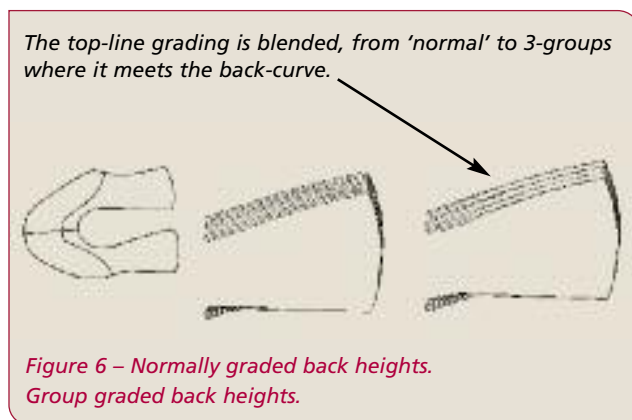


Figure 6 – Normally graded back heights.
Group graded back heights.

lasting, fitting height gauges to the moulds minimises the time and skill needed to achieve the specified back-heights. When this is done, the back of the upper pattern is usually group graded according to the size grouping for each back-part mould (Figure 6).

Group-grading the back of an upper may also be carried out for a totally different reason. The stiffener inserted between the outside of the upper and the lining is often made in a limited size range: typically small, medium and large. Some manufacturers choose to have their uppers group graded at the back to match the stiffener size range. Using a limited range of stiffener sizes also controls the cost of this item and simplifies handling in production.

Tongues – in large-scale production of low price shoes where costs are critical and simple manufacturing essential, a very different motivation for modifying the ‘normal’ grade applies. Group-grading the tongue on a men’s shoe into three sizes only (Figure 7), offers a modest reduction in press-knife costs but a major change in the way the components are cut and handled. Bulk quantities in the three sizes can be cut separately from the rest of the upper, from cheaper material, and in probably just two or three colours. This stock is held in the closing room and then used on the appropriate size uppers.

The tongue and eyelet stay of a sports shoe present a further opportunity for group grading. The facing may have the lace holes cut at the same time as the outline of the component, so group grading reduces the number of press knives or dies required. Knives with punch tubes are much more expensive than plain ones, so the saving in cost is useful (Figure 8). The alternative manufacturing method where lace-holes are punched as a separate operation subsequent to cutting would also benefit, as a reduced number of gauges and dies will be required for the punching operation. Having group-graded the eyelet stay, it is natural to take any benefit that derives from group grading the tongue as in the case of the previous men’s dress shoe tongue.

Boots – these often feature modified grading for more than one reason. Take zippers, for instance, where the length and width of the slot must be controlled. Think of the product labelling, which frequently refers to a specific height of leg. This is not size dependant; a 15-inch leg boot has a 15-inch leg whatever the foot size. When grading, the leg height must be controlled to model-size, as shown on the right (Figure 9).

Some boots may have a further modification applied to the width of the leg. Without any special control the width of the leg will be graded (increased or decreased) in proportion to the length grade of the foot part of the pattern, which may not be appropriate. In riding boots, for example, the width of the leg may be graded to give a fixed increase or decrease per size, which is again not in proportion to the length grading of the foot part of the pattern.

Grading upper patterns is clearly a complex and extremely important aspect of the tooling process in footwear production. It directly affects the appearance of a

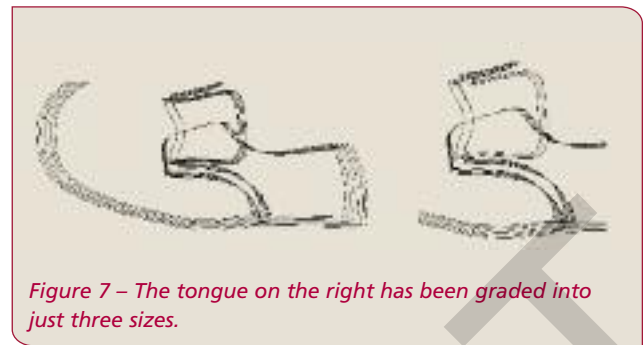


Figure 7 – The tongue on the right has been graded into just three sizes.

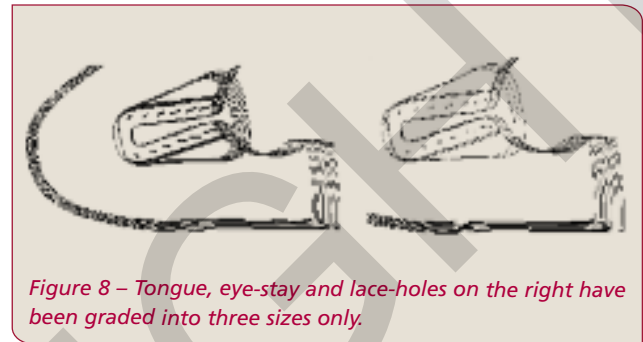


Figure 8 – Tongue, eye-stay and lace-holes on the right have been graded into three sizes only.

There is an analogy here with lasts for ladies footwear. If a court shoe has a 2-inch heel, then the retailer expects this to be true for all sizes. The last-maker, when grading ladies lasts, makes adjustments to ensure a fixed heel height.

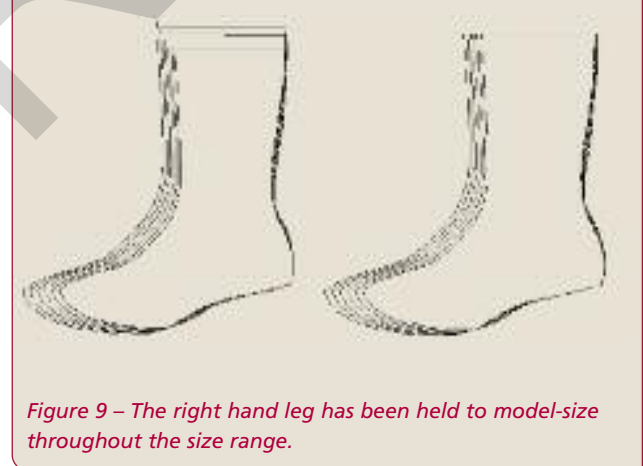


Figure 9 – The right hand leg has been held to model-size throughout the size range.

style throughout the range of sizes in which it is to be produced and how the shoe or boot will fit the wearer. Correctly done, with all the appropriate restrictions, it also helps to ensure trouble-free manufacture. And, finally, it can have a distinct bearing on the cost of the tooling and processing involved.

The future will further influence the application of special grading techniques. A numerically controlled machine, for instance, can work just as easily when every size is slightly different. Die-less cutting systems in manufacturing can sometimes make group grading unnecessary, while the continuing trend to shorter runs of a specific style will focus even more attention on tooling-up costs. Special grading techniques are likely to be with us for a long time yet. 🍷