

# A Concept for Shoe Last Manufacturing in Mass Customisation

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## Abstract

This paper presents a process chain development for the production of shoe lasts for mass customised shoes. Shoe lasts are moulds that manufacturers use for stretching the shoe leather and applying the sole. The authors propose the complete manufacturing of shoe lasts in only one machine with two clamping systems. During a first phase the shoe last is clamped conventionally – between centres. In a second phase the last is clamped in the top region and the clamping dogs that remain from the first phase can be removed. This new approach reduces the number of process steps, is customised and reduces the immense content of manual work. Although the single process steps are carried out slower than in conventional shoe last industries the complete manufacturing in one machine reduces the total production time of one pair of shoe lasts and permits the economic production of single pairs of lasts for mass customised shoes.

## Keywords:

Customisation, Flexible manufacturing system (FMS), Automation

## 1 INTRODUCTION

Often, shoes that fit don't please customers and the ones they like might not fit. Hand made shoes offer a way out of this dilemma but are out of reach for most of the customers because of their high price. So, the majority wear mass produced shoes. Individual shapes of feet or even aesthetic wishes of customers in terms of design, material or colour will not be considered. A potential necessity for customised shoes, however, always existed. Liu and Rottman [1] wrote in 1986 that approximately 87% of the US American population have foot problems of some kind with women having four times as many foot trouble as men. Today, new developments in production engineering shall foster the personalisation in shoe manufacturing. If shoes do not fit, this is usually due to the shape of the shoe lasts (Figure 1). The shoe lasts do not only determine the shape of the shoes. They are also used to produce parts of the shoe like insoles and parts of the shoe production tooling like injection moulds for soles.

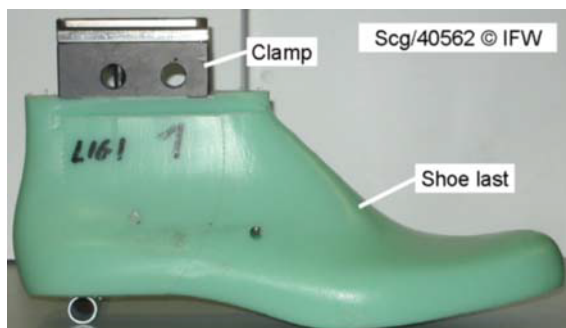


Figure 1: Shoe last with clamp for handling.

## 2 CONVENTIONAL PROCESS CHAIN

While in former times shoe lasts for industrial shoe production consisted of wood, today these production shoe lasts mainly consist of polyethylene (PE). The manufacturing process chain itself starts with a PE-blank that undergoes a roughing process. The roughing machine is a three axes lathe where the shoe last is clamped between centres. After the roughing process the hinge, a joint that is necessary to open the last and extract it from the shoe, is mounted. The c-cut hinge (Figure 2) is the type that is mostly used.

Next, the roughed blanks are finished. Once again the work piece is clamped between centres in a 3-axes lathe and processed by a driven toroidal finishing tool. Modern finishing machines can process two or three pairs of shoe lasts simultaneously. After the finishing operation the

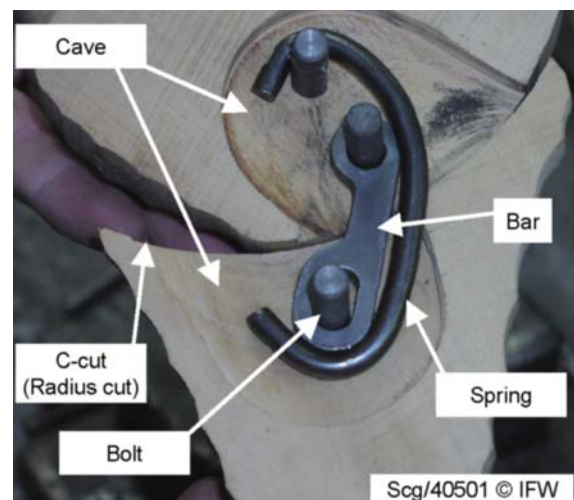


Figure 2: C-cut hinge.

clamping dogs in the heel and toe regions remain. This material is removed manually. The accuracy of the manual rework of heel and toe regions is very important especially for lasts that are used for the production of direct injected soles. The manual rework can take about 5 to 8 minutes per pair depending on the type of last.

Finally, the top surface of the last is processed. First, the top part is cut off. Shoe lasts for automated shoe production need several bore holes with different diameters and depths in the top plane in order to mount a clamp for automated handling and transport.

### Main problems

Today, the set up for all machines in the process chain is determined by producing test pieces. From the perspective of full customised shoes this means that for one single customised pair of lasts several pairs of test lasts would have to be produced and measured in advance to find the correct set-ups. Due to the connected expenses, this is unacceptable.

Furthermore manual rework is necessary for removing the remaining material from the toe and heel region. Efforts on automation in order to avoid this expensive manual rework are difficult because of the free form surface of the last.

New machines with different clamping mechanisms and different process strategies are available or have been patented (for instance [2], [3], [4]). Almost all of them try to automate the processing of the toe and heel regions. But processing the shoe last from a blank still requires several machines and the economic batch size one seems half to reach, mainly due to set-up operations.

### 3 COMPLETE MACHINING PROCESS

#### 3.1 Machine specifications

To overcome the bottlenecks of conventional last manufacturing and to reduce the costs of customised lasts the roughing and the finishing operations, as well as the processing of toe and heel regions, have been integrated into one machine. Moreover, the top surface is processed in the same machine. So, the functionality of five machines and one critical manual operation have been integrated.

A commercially available turning machine has been chosen as the basis of this new shoe last manufacturing machine. Its tool turret can host up to twelve tools which can be driven at a rate of 4,500 revs/min. For the critical (in terms of material removal rate) roughing operation a tool holder with a gear-ratio of four is used. With up to 16,000 revs/min the material removal rates are the same compared to conventional milling. Additionally, a gripper is mounted to the tool turret. In contrast to the three axes (z-, x-, c-axis) that are known in conventional shoe last manufacturing machines there is a fourth y-axis necessary in this machine for off-centre processing of the top plane and milling of toe and heel regions. The machine's main

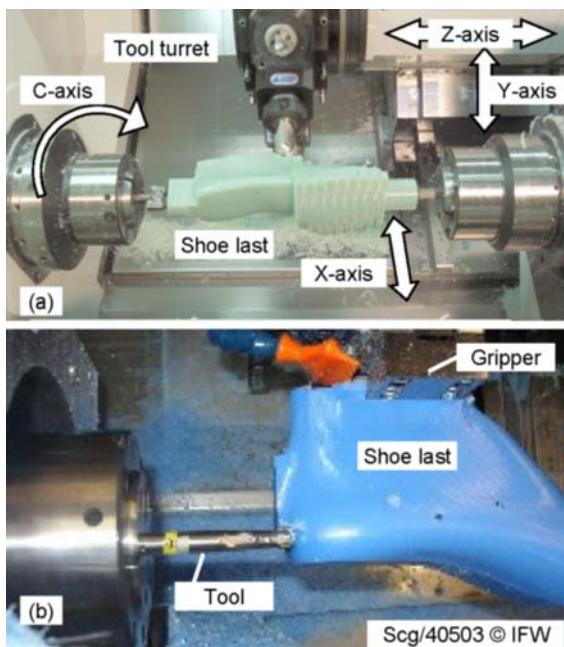


Figure 3: Two manufacturing phases.

and counter spindles can be operated as interpolating axes as well as tool spindles. Both spindles are equipped with a pull back chuck with a fixed stop.

The manufacturing process is divided into two phases. In the first phase the work piece is clamped between two clamping pins, see Figure 3a. The outer shape of the last is worked out as well as the top plane with the functional surfaces. In the second phase the shoe last is grasped at its top by means of a gripper. The toe and heel regions are

now accessible. Two ball head milling tools are automatically changed to the pull back chucks in order to machine the toe and heel regions, see Figure 3b. The chatter and vibration problems when milling the toe region are reduced to a minimum because only very little material at a reduced feed rate has to be removed during this second phase.

#### 3.2 Process steps and parameters

In contrast to the conventional process chain the steps roughing and hinge integration have been swapped so that in the new machine a hinged blank is clamped between centres during the first manufacturing phase.

##### *Roughing*

At first the top plane is roughed. If this step is not performed at first a collision between the tool holder and the work piece can occur. Next, the complete shoe last is roughed and the functional surfaces on the top are created. For roughing, a combined shaft and plane milling tool with a diameter of 14 mm and a cutting length of 25 mm that can mill in all directions is used. The maximum diameter is limited by the driven tool holder. The

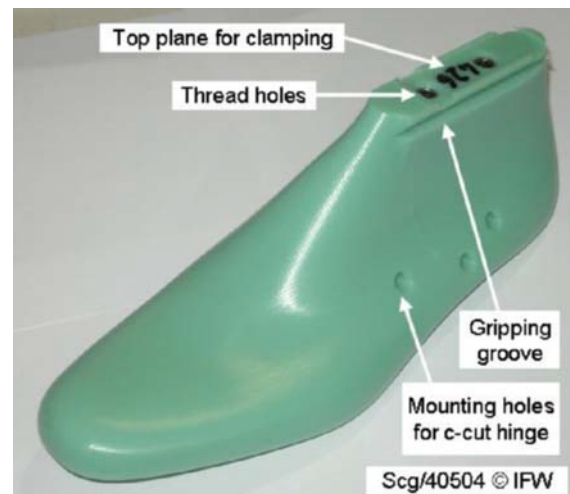


Figure 4: Complete shoe last.

tool has 3 cutting edges and is designed for cutting materials like aluminium or plastics. At present, the process parameters for roughing are  $f=10,000$  mm/min,  $a_p=15$  mm,  $a_e=7$  mm and  $v_c=615$  m/min,  $n=14,000$  revs/min.

##### *Finishing*

While conventional shoe last milling machines use toroidal milling tools, this new machine uses ball head milling tools with a maximum diameter of 30 mm for finishing. A problem, however, is the fact that the cutting speed of ball head milling tools decreases from the outer edge towards the tool centre, being zero in the centre. Because of the free form surface of the shoe last there are only a few situations where the work piece gets in contact with the tool's centre. The surface quality in these regions is not as good as in the other regions. In order to improve the surface quality the feed rate could be reduced in the regions of low cutting speeds or the lasts could be reworked with polishing brushes. The actual process parameters for finishing are  $f=12,000$  mm/min,  $a_p=4$  mm,  $a_e=1$  mm and  $v_c=316$  m/min,  $n=4,500$  revs/min.

##### *Gripping*

The last process step of this first manufacturing phase is the milling of two parallel triangle grooves in the sides of the last's top. The profiled gripper chucks then grasp into

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