A Beginning of Fastener Mass Production?

by Peter Standring

Nearly 600 hundred years ago on an August morning, a recently victorious English army consisting of knights, men at arms and longbowmen emerged from the forest which surrounded the French town of Verneuil in Normandy. What astonished them were the sight of two armies drawn up in full battle array (the French and the Scots) with 2000 fully armoured Milanese and Lombard cavalry flanking them. These, dressed as shown in **Figure 1**, were mercenary soldiers sent by the Duke of Milan to fight for the French King.

Figure 1 Armoured Knight of the 15th Century

However, the cause of gravest concern for the English was the fact that the cavalry from Northern Italy wore the latest high tech armour which through both its design and manufacture, made it impervious to the major English weapon of the time, the bodkin tipped longbow arrow. These, much feared missiles, released by 1000 fully trained archers at a rate of one every ten seconds could darken the sky before charging horseman had covered half the distance between the two opposing forces.

And so it was, when the impregnable Italian cavalry charged, the fully armoured horsemen simply rode over the ineffective English archers.

On reading this long forgotten episode in a turbulent history it suggested to the Author an interesting manufacturing problem. By the 15th Century, European plate armour had become the 'must have' attire for every male member of all ranks of nobility. Indeed, those at the very top of society had their armour elaborately decorated and often guilded to create the dramatic effect they desired to impress.

In late Medieval times, all plate armour was beaten by hand or water powered tilt hammers out of iron blooms. The thickest material was up to 3mm in parts of breast plates but drawn down during manufacture to ~1mm thickness which was used for arm and leg pieces and of course hand and foot protection. The use of very clever interlocking and sliding elements together with the personal 'tailoring' of armour meant that a fully trained knight would be capable of fighting on foot with complete mobility for a considerable period of time.

A full set of European plate armour had a mass of around 30kg, less than a modern soldier would have to carry into battle today. Considering the war like nature of most of Europe in the 15th Century, it occurred to the Author that there would have been a demand for the manufacture of around 20,000 full suits of armour every year.

Assuming that the 'yield' of material in manufacture was 50%, then that would require the supply of ~1,200 tonnes of plate iron/steel every year! It should be noted that armour required for Jousting (friendly fighting) was significantly heavier at ~50kg per suit so the figure of material provided above is a conservative estimate.

Armour on an Industrial Scale

A fascinating aspect of the supply of European plate armour in the 15th Century was where it came from; Northern Italy, Southern Germany and Austria being dominant. In these and many other locations, the manufacture of armour was carried out as a family business. Just like Medieval stone masons, each individual manufacturer within a family had their own 'maker's mark'. No trace or evidence of these armour manufacturers remains today. And yet, after losing the battle of Maclodic in 1427 and having 8,000 of his soldiers captured by the army of Venice, the Duke of Milan ordered the workshops of his domain to produce 4,000 suits of cavalry and 2,000 suits of replacement infantry armour in one week! It is the Author's presumption that it was 2,000 of the Milanese Cavalry wearing this same armour who turned up to face the English army outside Verneuil just seven years later. A peace treaty had been concluded with Venice so the Duke of Milan had to recover his costs somehow?

In 1452, The Duke of Milan was informed that three of his armoury workshops could produce 18 full suits of armour per day when working together. To achieve this would have demanded an industrial scale operation with flow lines of production. Labourers and apprentices at the 'goods received' end, would send partly worked stock to lines specialising in breast plates, helmets, leg and arm protection etc. At the end of the lines would be the most skilled craftsmen followed by final inspection not unlike what happens in manufacturing today.

Such an industrial set up would probably have included an international sales team. Their job would be to obtain orders from the rich and powerful who would be present at every important jousting tournament. In addition, it is likely that each major manufacturer would employ a travelling team of service engineers and fitters who could adjust, repair and perhaps part exchange out of date/fashion items.

This, of course, is all the Author's fanciful notion and as two recent PhD studies conclude, no evidence is known to support it (1, 2). However, every engineer will recognise that nothing useful ever gets done without planning and to produce even one hundred full suits of armour would certainly require a highly competent and organised set up.

Figure 2 shows Maximillian I, the Holy Roman Emperor at his Innsbruck Armoury instructing his top line armourer, Conrad Seusenhofer, how to do his job (3). The wood carving was produced for a book called, Weisz Kunig (white king) which includes Maximillian's ideas on the making of weapons and armour. In the text it states, "Now this young King (Maxillilian I) invented a new art for warrior's armour, so that in his workshops thirty front pieces and thirty back pieces were made at once." This statement certainly implies some method of mechanical production beyond that of one person just hammering metal? (4)

Woodcut by Hans Burgmair 1525 *Bohemian painting on glass*

Figure 2 Workshop of Conrad Seusenhofer (the Author found the painting on glass in an antique shop many years ago)

Joining it all Together

The effectiveness of plate armour lay in the nature of the design curves created to deflect blows. Also in the improved quality of the material and how it was worked and treated. Of equal importance was the design and manufacture of the articulated joints which enabled the wearer to move and fight with freedom for sustained periods.

However, as is always the case, nothing yet made will fly, run on roads or rail, wash clothes or provide our 'cannot live without' personal communicator facilities unless all of its component parts are fastened together.

Much like today's body armour, in ancient times, small overlapping plates were tied, or sown on to clothing to provide protection to the wearer. It was the ability to work iron/steel into larger plates which made the full body armour possible. The big question and limitation then, was how were all the pieces to be held together?

Not perhaps surprising, the primary fastener of choice was the humble rivet. However, what is surprising were the designs, numbers and source from which this ubiquitous item was made and supplied. Today, all outer panels of aircraft are held together using countersunk rivets to aid streamlining and reduce drag. Guess what, many of the medieval suits of armour also used flush rivets where appropriate, to ensure that a weapon striking the surface simply slid off.

Where necessary Medieval, armourers used large headed mushroom and flat rivets to make sure the fastening of leather straps and cloth padding were captured and remained in place, just as we do today.

Button type rivets were used for detachable fastenings with slots in leather like the riveted arrangement of metal fasteners found on the 'jeans' and fashion items today. Tubular eye rivets were also used when a piece of armour was to be fastened using cord or leather thongs. Again, this was for exactly the same reason we use them today on lace up shoes, ruck sacks and tarpaulin sheets.

Some of the show piece rivet heads had intricate designs: blossom, trefoils, cones and square pyramid forms. These were cast in copper or from a copper alloy then polished or guilded to create the required design effect.

Other fastening elements included: spring latches to hold helmet visors open or closed, hinges and hand made screw fasteners which were sometimes used in conjunction with a captured nut not unlike the rivnuts found and used virtually everywhere today.

Perhaps, the most impressive development of fastener technology which the Medieval armourers produced, was the use of the sliding riveted joint. As can be seen in **Figure 3**, these items allowed articulation of the upper arms and elbows and of the lower body. 'Lames', as the moveable pieces were called, allowed a full three degrees of unimpeded physical movement for the upper arms and shoulders of the wearer whilst being so closely interlocked as to prevent penetration by a sword or blade. Add to this the ability to cover the hand and fingers, provide multipiece fully articulated foot protection when fighting dismounted and the Medieval craftsmen's technical achievements become both obvious and significant.

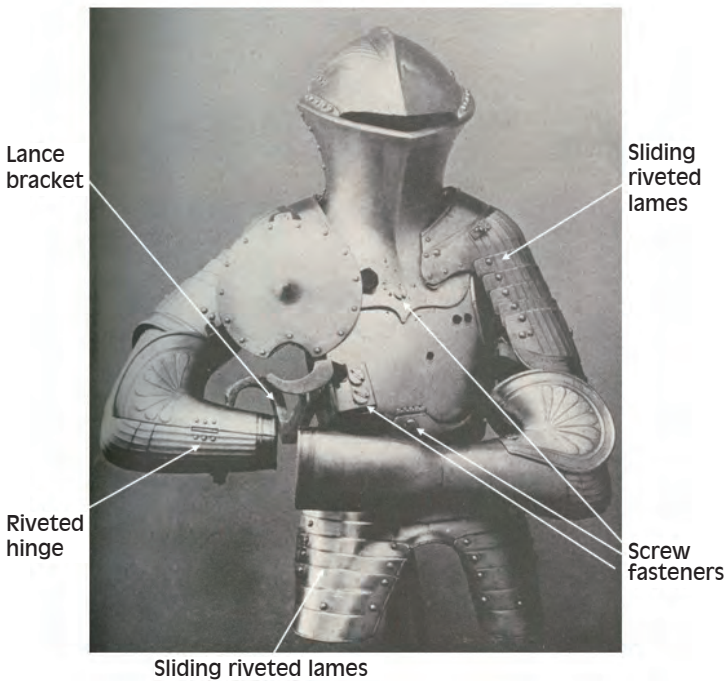

Figure 3 Heavy German Jousting Armour

Figure 3 provides examples of such joint design and illustrates the use of rivets, riveted hinges and hand made screw fasteners.

Supply side issues

From the above, it will be appreciated that behind the historical accounts of the pomp and ceremony surrounding Medieval European chivalric Courts, Tournaments and their almost constant dynastic wars, lay the skill and abilities of the craftsmen who made it all possible.

All landowners from the smallest to those at the very top of society owned castles and employed soldiers to defend their property. In those times, success was counted in land and the more you owned, the more soldiers you needed to defend it (or to gain more!)

With modern vehicle production, units can be shipped from country to country or manufactured where they are sold either by a domestic producer or in transplanted factories. In Medieval Europe, plate armour was made primarily in Northern Italy, Southern Germany and Austria. Unlike car manufacturers today, these Medieval family businesses did not extend their brands outside the country of origin, rather the rich and powerful Monarchs sought to establish their own armouries by employing skilled craftsmen from regions where armour was made. This is indeed quite similar to how the Chinese Government has created its dominance in the automotive market of today! In the early 1500's the English King set up an Armoury capable of rapidly arming thirty to forty thousand soldiers. In State Papers, two English servants to the Monarch describe how they travelled to Innsbruck (Austria) to hire "seven or eight platers, the best that might be found and bring them to England to work in the new Armoury." Writing sometime after the event, the Report goes on to explain. "All the platers formerly brought over are now dead save one, and he is so cunning and obstinate a disposition that he would never teach any Englishmen the true mysteries of plating unto this day." (3) This Author has updated the language used over 500 years ago but the sentiment registered in the Report resonates with any engineer who has spent time on a factory floor. The description of the unknown Austrian craftsman can be used where ever fasteners are produced and perfectly captures the person who knows how to make certain machines work well but will not share that knowledge.

It is as true today as it was in Medieval Europe, that fasteners are ubiquitous and essential for success. Although nothing is known of how rivets were produced, it is likely that the process was similar to nail making. Clearly, every village or small community would have a resident blacksmith who would be capable of making nails or some rivets. But to go to a Tournament or a war would require barrel loads of different rivet types to be readily available 'off the shelf.'

This notion is entirely in keeping with a nailsmith being able to produce 1kg of nails (2000 – 2500) in a 12 hour shift and supports the comment made about, "the massive trade in these tiny products (rivets) put out by the Lombardy (Northern Italy) workshops at extremely competitive prices." (2)

So, the emerging picture is of the Stirya region of Austria providing the 'best' plate material from which the lightest, strongest and most protective armour could be made. This is perhaps no surprise since it is where the Hallstadt Iron Age Culture developed over 2,000 years earlier, based as the name suggests on its iron making technology. The raw material, in the form of blooms or perhaps rough plate, would then be carried by pack animals across the Alps to the major workshops for manufacture. There, specialisation would be the normal practice with craftsmen making helmets, breast/back plates, arm/leg protection etc.. In many Northern Italian family engineering businesses today, the 'cooperative' approach in dealing with large orders which no single Company would be able to handle is still widely practised.

In terms of fasteners, the likelihood is that these specialised items would be produced in bulk by other workers leaving the better paid armourers to do their job. If this scenario is true, it suggests a very interesting line of further speculation; namely, were fasteners made to 'standard' sizes? If as quoted above, there was indeed, "a massive trade in these tiny products", then to satisfy that demand particularly when working 'collectively', the products supplied must have been produced to standard forms and dimensions?

What now becomes very intriguing is the business side of how such a transaction might take place. This was the time when the Italian Renaissance families, having become fabulously wealthy from their banking activities, achieved 'Princely' status. Since such monetary transactions were standard practice across

Medieval Europe, why should the same method of operation not also have been available to the armourers who provided the 'Lords' they served with the means to protect their own wealth? It was reported that the Missaglia Family of Armourers based in Milan were once owed 100,000 Lira by the Duke. At this time, a very top person in Government would only be paid between 160 – 300 Lira per year! This suggests that as dealers in commodities, the Missaglia business, along with other armourers, could have been making and distributing barrels of fasteners all over Europe?

And if they did, how might the transaction take place? Would they have agents in various countries seeking orders and feeding them back to Head Office? Might there have been a Parts Catalogue listing the 'standard' types and sizes of fasteners requested? Perhaps they employed their own 'travelling salesmen' calling on their existing customer armoury workshops in the various castles they visited and maybe cold calling new ones in search of possible business and enhanced sales bonuses?

Conclusions

The extemporaneous thoughts about Medieval armour which gave rise to this article has led the Author down a rich vein of interest. The result is the inevitable conclusion that folks who were busy making the 'must have' fashion items of the rich and famous in European society many hundreds of years ago were no different than we are today. In short, the manufacturers were making the highly desirable products which most people could never own. Commercial viability is an absolute requirement to ensure a business is successful but when that success becomes overwhelming (as in the demand for 6,000 full suits of armour within one week) then to remain in business requires the introduction of new technologies and working practices.

For this reason, it seems to the Author, that the 'golden age' of European manufacture of plate armour operated at the cusp of mass production. The stated estimation of 20,000 suits of armour per year would be a significant output and if we assume an average of 500 fasteners per suit, that would require the manufacture of 10 million items each year. Also, like the current automotive industry, the aftermarket will be as large, over the lifetime of a vehicle, as the new build one. It is clear with Medieval armour that the maintenance and repair side of plate armour would at least double the need for fastener output which could push the manufacture to well over 20 million pieces a year. If we take the output of a nailmaster over a 12 hour day as stated above, this would require between 8 to 10 thousand people across Europe making only fasteners for armour. Impressive?

It would perhaps be an interesting exercise for someone to study the use and manufacture of fasteners for other large scale military purposes of the past? The two subjects which come to mind from both the East and West are those of the Emperor Qin Shi Huang's terracotta army and the Roman army? Since these are contemporary and I believe, having no known contact between them, a comparison of their respective designs for and use of fasteners would make fascinating reading.

Oh and by the way, if you are wondering what happened after the Milanese cavalry charged down the English archers at the battle of Verneuil; they rode off to loot the English baggage train. Mercenary soldiers do that sort of thing. The rest of the English army then beat the French and Scots using the standard tactics of the time making the success of the unstoppable Milanese, meaningless. Which in summary shows, it's not the tools or the fasteners which matter but how and where you use them that counts!

References

1. Nickolas Dupras, "Armourers and their Workshops. The Tools and Techniques of Late Medieval Armour Production." PhD Thesis. University of Leeds, UK, 2012.

2. Matthias Goll, "Interdisciplinary studies on the technology of late medieval European armour production between 1350 and 1500." PhD Thesis. University of Heidelberg, Germany, 2013.

3. Charles Ffoulkes, "The Armourer and his Craft." London: Methuen, 1912, reprinted Toronto: Dover, 1988.

4. Charles Ffoulkes, "A craft-picture by Jan Brueghel." Burlington Magazine for Connoisseurs, 19 (1911), 41 – 48.