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The performance of the longbow against plate armour at the Battle of Agincourt

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Abstract

A technical investigation into the Battle of Agincourt, with a focus on the effectiveness of the bodkin arrowhead against French plate armour, was undertaken. The study examines the battle tactics, equipment, and terrain of the French and English forces, identifying competing principal factors that contributed to the outcome.

The report analyses the penetration mechanics of the Needle Bodkin Arrowhead against 3mm plate armour. It evaluates the available literature, numerical analyses, and practical exercises compared to independent penetration calculations.

The findings of this study aim to generate an argument either supporting or opposing the theory that the bodkin arrowhead was the most decisive factor in the Battle of Agincourt.

It was found that the Needle Bodkin Arrowhead could not penetrate French plate armour at 100 meters. Additionally, an argument was established that the bodkin arrowhead was not the most decisive factor; instead, the terrain and poor leadership from the French led to their defeat.

Keywords:

English longbow, Milne-De-Marre, Jowett Equation, French armour, 1400, Penetration mechanics, Bodkin arrow

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1 Introduction

The Battle of Agincourt, which took place on October 25th, 1415, is widely known for the critical role of the longbow in the French forces' defeat. However, there are many conflicting opinions regarding the effectiveness of the longbow in this battle. The use of bodkin arrowheads against French armour has been a subject of debate, both in numerical and practical studies. Therefore, a technical investigation has been conducted to answer whether the Bodkin Arrowhead was the most significant contributing factor to the victory of the English army. This study focused on the following aspects:

- Research into the French and English forces, including their battle tactics, equipment, and terrain, to identify competing principal factors that contributed to the outcome.
- Analysis of the penetration mechanics of the Needle Bodkin Arrowhead against French plate and chainmail armour.
- Evaluation of the available literature, numerical analyses, and practical exercises compared to independent penetration calculations.

In conclusion, based on the above factors, this study aims to generate an argument either supporting or opposing the theory that the bodkin arrowhead was the most decisive factor in the Battle of Agincourt.

2 Background

After the successful siege of Harfleur (18th Aug – 22nd Sep 1415), King Henry the Fifth marched his army north along the French coast to Calais. [1] The French blocked his path at the river Somme, forcing King Henry to find an alternative passage across the river and giving time for the French to rally more men to fight. After weeks of marching, lack of food, and dysentery, King Henry was forced to break the French blockade of Calais by engaging them in battle at Agincourt.

2.1 The Battlefield

The location was a farmer's field, which had recently been ploughed between the village of Agincourt and Tramecourt (Figure. No.1). After days of rain, the mud became soft and unable to support the weight of armoured knights. The English had the advantage of elevation, supporting a defensive battle, and their bows. [1]

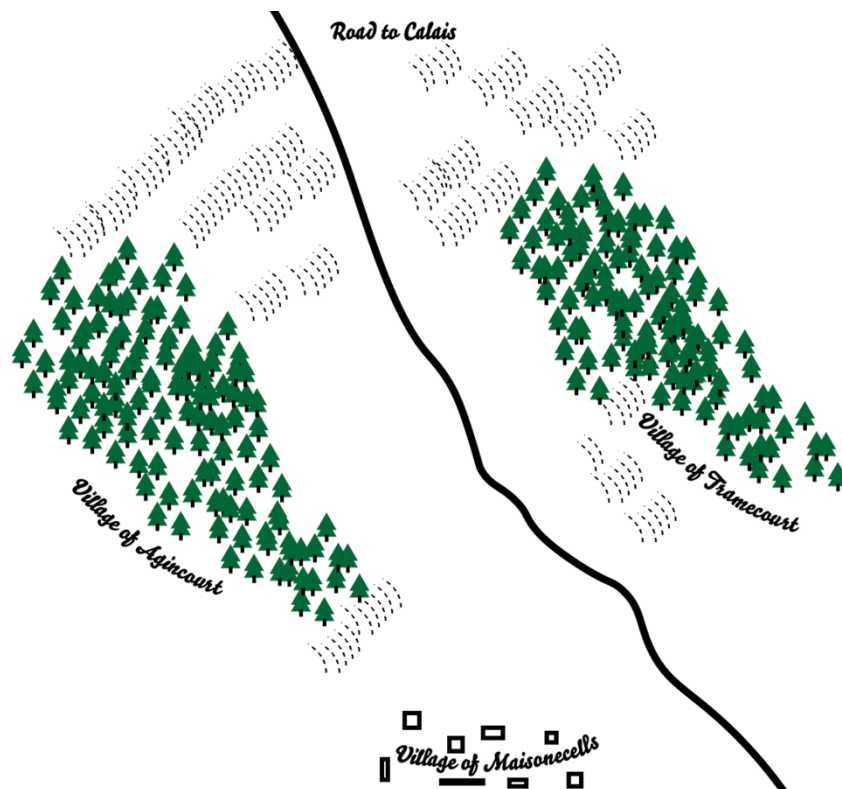


Figure 1 - Agincourt's battlefield

2.2 The belligerents

Kingdom of England	Kingdom of France
Leader: King Henry V	Leader: Charles d'Albret
Men-at-arms: ~ 1000	Men-at-arms: ~ 10000
Knights: 0	Knights: ~ 1200
Longbowmen: ~ 5000	Crossbowmen: ~ 4000
Total combatants: ~ 6000	Total combatants: ~ 15200

Table 1 - English and French forces [2]

2.3 The Battle

On the morning of the 25th of October, both forces prepared for battle (Figure No.2). Every English archer, ordered by King Henry V, drove a stake 6 feet tall and 3 inches in diameter in front of their position and waited for the French assault. However, the French were content in waiting for more forces. As such, King Henry abandoned his position and marched forward (Figure No.3). The English secured a new position with archers on the flanks of the men at arms and secured by the treeline and placement of their stakes. The new position allowed the English archers to volley arrows at the French which caused the French to retaliate by beginning their frontal assault (Figure No.4). [2]

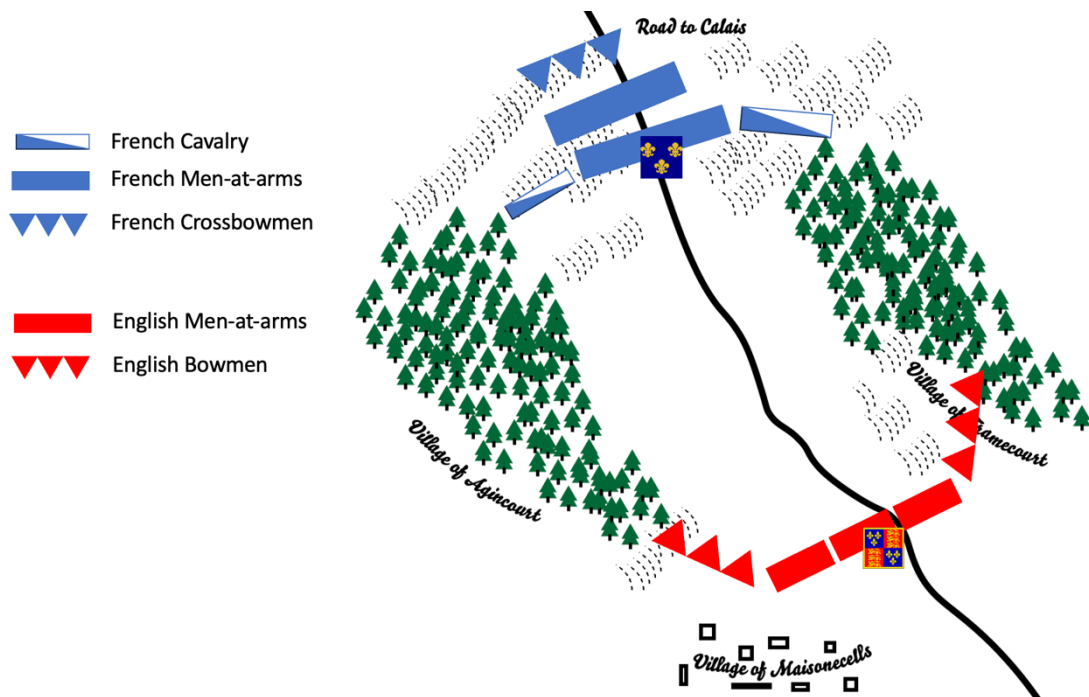


Figure 2 - The fielding of armies

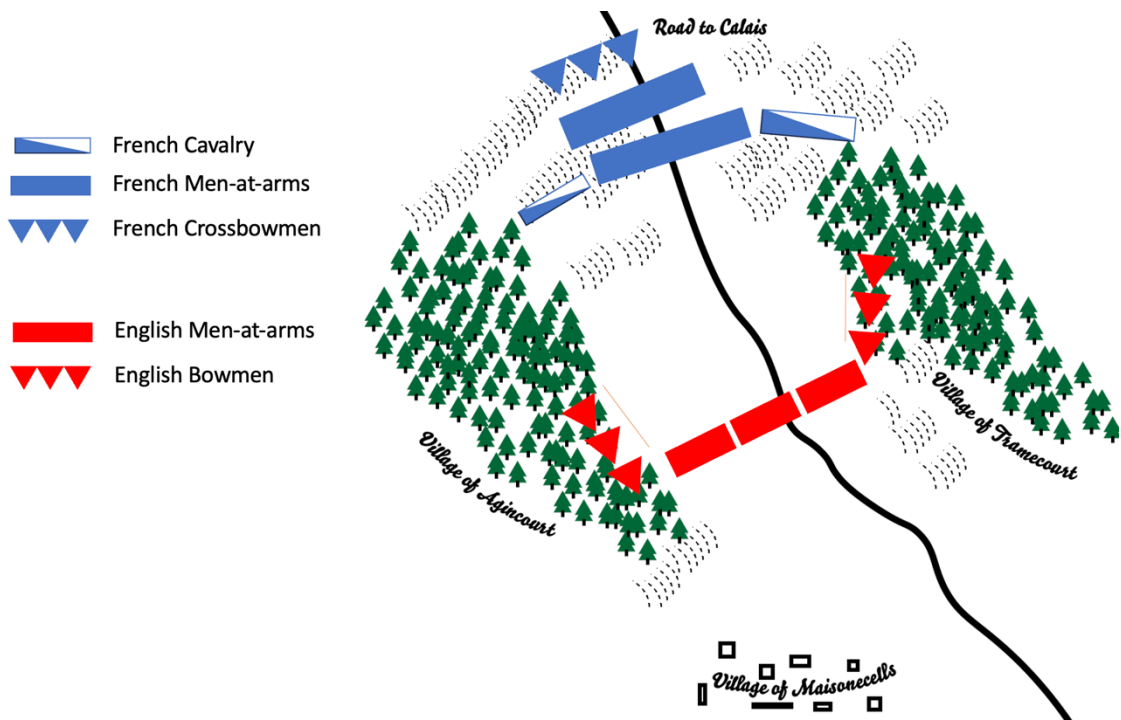


Figure 3 - King Henry's new position

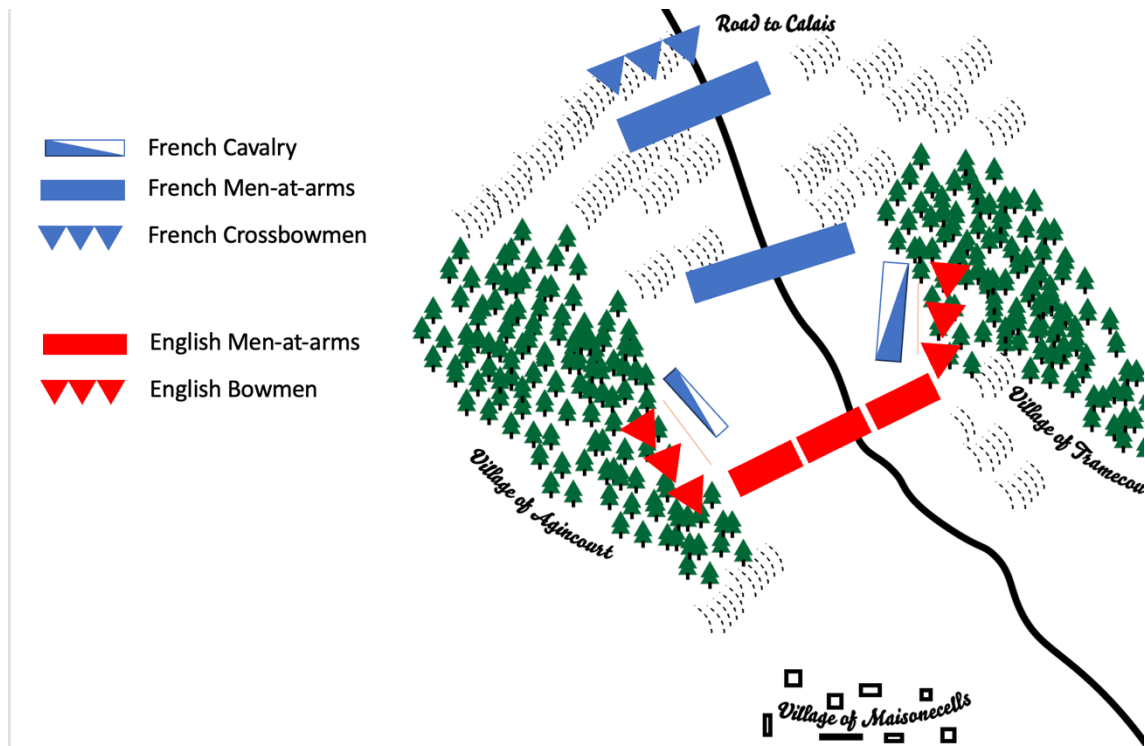


Figure 4 - French cavalry assault

France's strategy was to use knights to disrupt and route the English archers and, using the remaining forces, engulf the English men-at-arms in melee. However, the softness of the mud reduced the speed at which the knights could gallop, as by travelling faster, they risked breaking the horses' legs. The French were also unprepared for the wooden stakes driven into the ground. After a failed charge attempt, the French cavalry retreated in an uncoordinated effort (Figure No.5). The retreat path of the cavalry smashed open rank and file of the French vanguard allowing the English to volley these openings with arrows. [2]

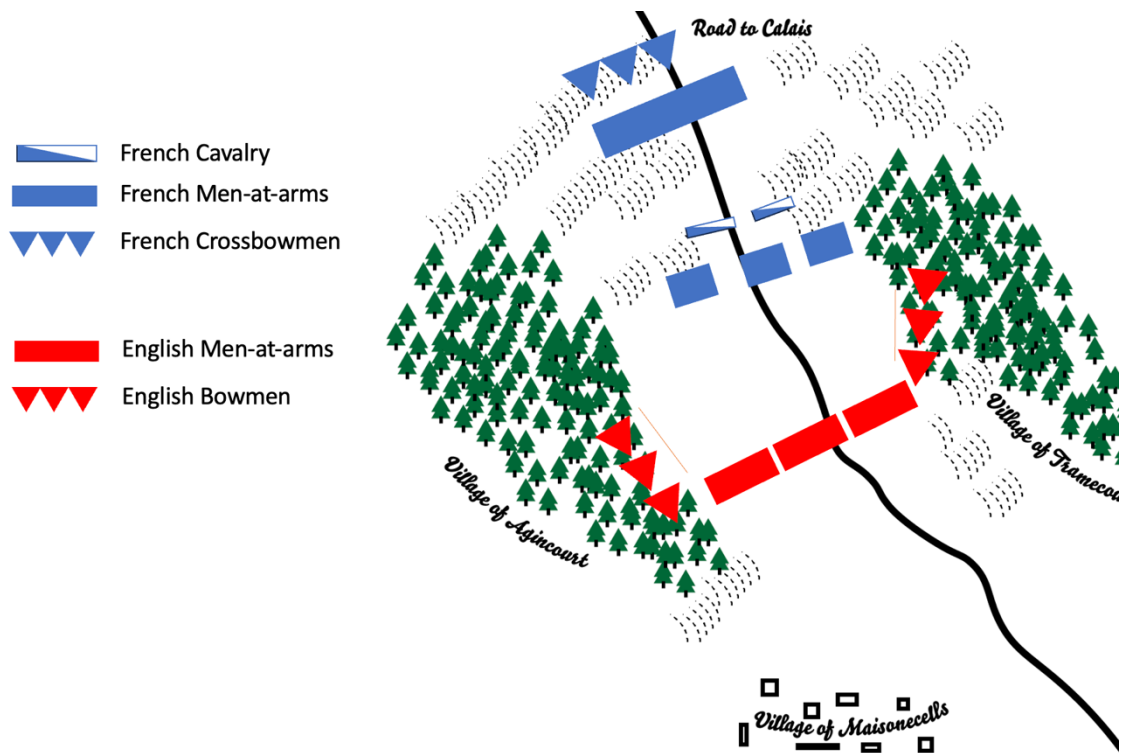


Figure 5 - French cavalry retreat

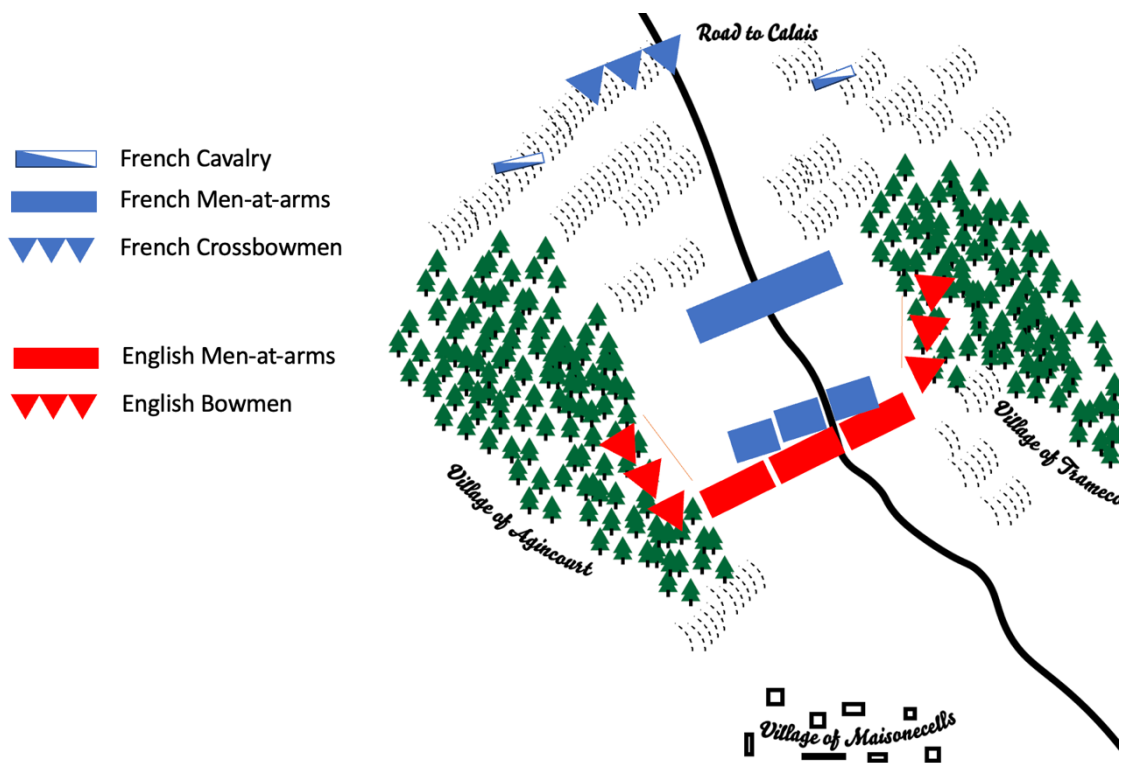


Figure 6 - French vanguard assault

The French vanguard met the English men-at-arms and melee pursued (Figure No.6). A second reinforcing line marched up the hill to support the vanguard. Eyewitness accounts reported that by the time the French met the English, their troops were exhausted from fighting the mud. Additionally, the French forces became so dense in numbers that they could not raise their weapons to fight. A push of a knight from the rear would cause another in the front to fall and die. Either from the weight of others falling upon them or drowning in the mud as they were too exhausted to raise themselves. [2]

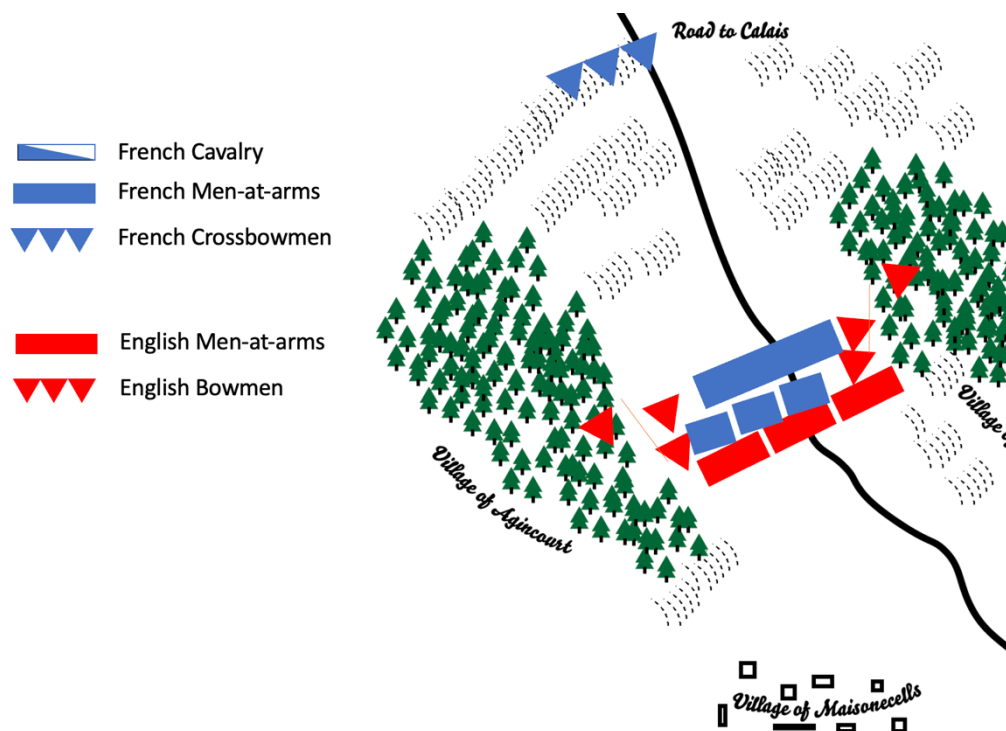


Figure 7 - English archers charge the flanks.

During the assault of both waves, the French were under fire from English archers. Some of them could leave their positions and fire point blank at French men-at-arms due to the threat of cavalry being neutralised. After their ammunition depleted, they picked up weapons and flanked the French men-at-arms in melee (Figure No.7). French men-at-arms began to surrender, however, in fear of being surrounded from an attack on his baggage train and the rally of a third wave, King Henry ordered the execution of French prisoners. The remaining French soldiers retreated from the battle, and King Henry claimed victory.

2.4 Summary Remarks

In summary, the competing decisive factors from the Battle of Agincourt are:

ID	Factor for the French's defeat.
1	The weight of French armour and the terrain of Agincourt.
2	France's poor leadership and battle tactics.
3	The crushing phenomenon within the French ranks during the melee.
4	English adoption of the wooden stake to repel cavalry.
5	The longbow's range and penetrative power.

Table 2 - Decisive factors

3 Methodology

Table No. 1 provides a breakdown of five significant factors that influenced the outcome of the Battle of Agincourt. While four of these factors are based on qualitative data from eyewitness accounts, the range and penetration power of the longbow can be represented using quantitative data. This can be achieved by utilizing penetration mechanics to determine whether a bodkin arrow could penetrate French armour.

To determine whether the bodkin arrowhead was the most decisive factor in the battle, a methodology is proposed that involves several steps. Firstly, an independent penetration calculation of a bodkin arrow against French armour will be conducted using both the Milne-De-Marre Formula and Jowett Equation (1986). The figures and results will then be compared against literature and practical experiments.

Using the five factors in Table No. 1, a matrix will be created using logical reasoning, historical accounts, and eyewitness accounts to determine the impact each factor had on the other. This will help in generating a parameter comparison.

Overall, this proposed methodology will allow determining the effectiveness of the longbow against French armour. An argument will also be formed based on a parameter comparison of the five factors, detailing if they positively affect or negatively affect competing factors.

4 Results

4.1 Penetrator Data

Type of Ordnance	Bodkin Arrow
Diameter of arrow shaft	11.11mm (assume same diameter for bodkin)
Mass of Arrow	Arrow 0.116kg (1800 grains)
Thickness of Plate Armour	2.5mm – 4mm
Yield Stress of Armour	350-600 MPa (variation between foot soldier armour and that of a king)
Velocity of system at impact (100m)	Arrow 53.34ms ⁻¹ Knight on horseback (8.95ms ⁻¹) Foot soldier (0.9ms ⁻¹)

Table 3 - Longbow performance data (provided)

4.2 Penetration Equations

4.2.1 Kinetic Energy Equation and Calculation

$$K_e = \frac{1}{2}mV^2 \quad (4-1)$$

$$\frac{1}{2} * 0.116 * 53^2 = 230 \text{ J} \quad (4-2)$$

4.2.2 Milne-de-Marre graph, equation, and calculations

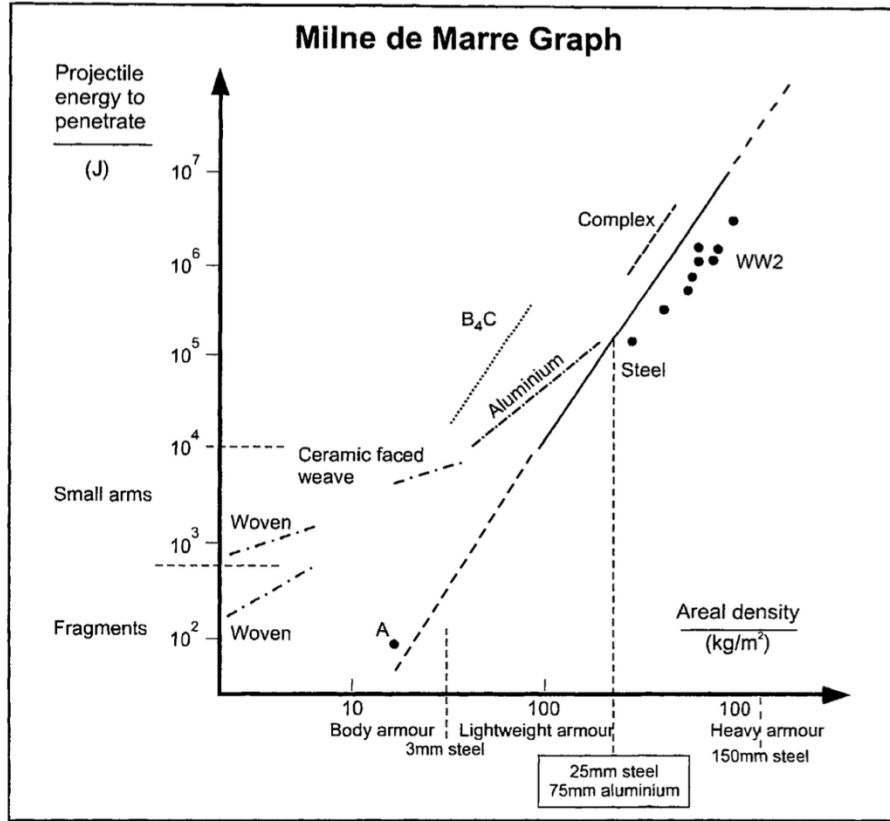


Figure 8 - Milne De Marre graph [3]

$$E_c = aD^{1.5}h_o^{1.5} \quad (4-3) \quad [4]$$

$$\frac{500}{0.011^{1.5} * 0.003^{1.5}} = 2.64 * 10^9 \quad (4-4)$$

$$\frac{E_c}{\sigma_u D^3} = \frac{a}{\sigma_u h_o^{-0.1}} \left(\frac{h_o}{D} \right)^{1.5} \quad (4-5) \quad [4]$$

$$\left(\frac{2.64 * 10^9}{500 * 10^6 * 0.003^{-0.1}} \left(\frac{0.003}{0.011} \right)^{1.5} \right) (500 * 10^6 * 0.011^3) = 279 J \quad (4-6)$$

4.2.3 Jowett Equations (1986) and calculations

$$\frac{E_c}{\sigma_u D^e} = 0.38 \left(\frac{h_o}{D} \right)^{0.84} \left(\frac{W}{D} \right)^{0.61} \quad (4-7) [4]$$

$$\left(0.38 \left(\frac{0.003}{0.011} \right)^{0.84} \left(\frac{0.116}{0.011} \right)^{0.61} \right) (500 * 10^6 * 0.011^3) = 361 J \quad (4-8)$$

		1	2	3	4	5	Calc		Calc
	Pairwise comparison of decisive factors 1 = No Preference, Reciprocal = 1 2 = Slight Preference, Reciprocal = 0.5 5 = Preference, Reciprocal = 0.2 9 = Strong preference = 0.11	Weight of French Armour and Terrain	France's poor leadership and battletactics	Crushing Phenomenon	Wooden Stakes	Longbow range and penetration power	Row Product	nth root of row product	Total Normalised
1	Weight of French Armour and Terrain	1	0.1	9	9	9	72.9	1.3	26
2	France's poor leadership and battletactics	9	1	9	0.1	9	72.9	1.3	26
3	Crushing Phenomenon	0.1	0.1	1	9	9	0.81	1	19
4	Wooden Stakes	0.1	9	0.1	1	9	0.81	1	19
5	Longbow range and penetration power	0.1	0.1	0.1	0.1	1	0	0.5	10
							0	5.175	100
							147.42		

Figure 9 - Factor matrix

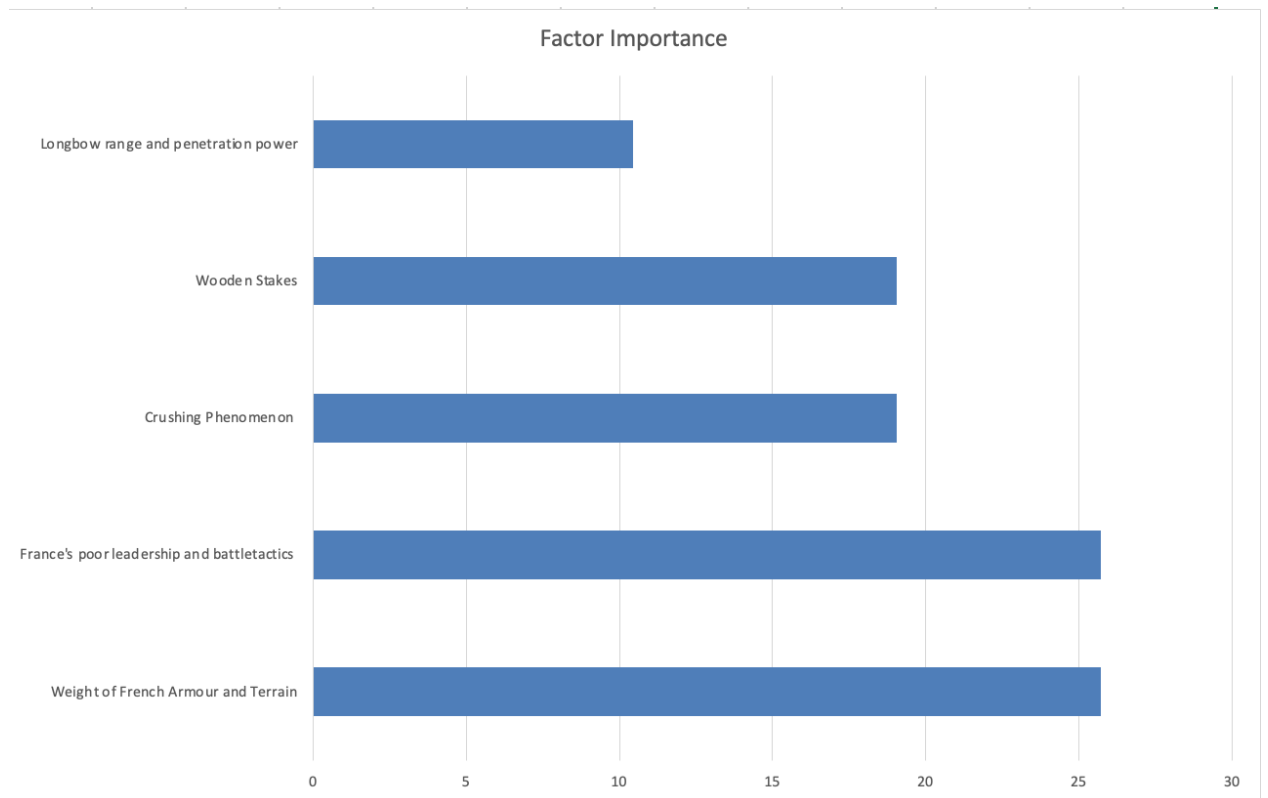


Figure 10 - Factor importance based on matrix

4.2.4 Literature review of the bodkin arrow penetration against various target materials

Reference	Title	Summary	Concluding Remarks
[5]	English Longbow Testing	Practical experiment conducted. Using a 110 lbs longbow, and long no.7 bodkin arrowhead different armour types were tested at a range of 9 m normal to the surface. Plate armour, of 1.2mm thickness was used. Material type not defined.	Two tests were conducted. Both penetrated 0.5 inches.
[6]	Evaluation of Mail Horse Armour	Practical experiment conducted. Bodkin arrows were fired from 9 m into varying layers of mail armour and linen. The draw weight of the bow was 72 lbs, and the arrowheads were coated in wax.	Paper determined bodkin arrows could penetrate 20 mm up to 80 mm of chain mail and 8 layers of linen.
[7]	Experimental tests of arrows against mail and padding	Practical experiment conducted. Using 64 lbs and 72 lbs bows bodkin arrowheads were fired at targets consisting of: mail and linen; mail, linen, and cotton; from 9 m normal to the surface.	The bodkin arrow could penetrate both combinations of armour. The average depth of penetration was 40mm and 30mm respectively.
[8]	Numerical analysis of English bows used in battle of Crecy.	Using Autodyne the researchers conducted experiments of the needle bodkin arrows, and warhead bodkin arrow against 2mm cast iron plate armour considering varying distances, and penetration angle. The researchers arrow mass, and velocity were less than the values in Table No.2. Additionally, the research paper considered deformation of the arrowhead.	They found penetration was only possible with the heavy warhead bodkin arrow and could be achieved up to 250m.
[9]	Medieval Armour Tested! – Arrows Vs Armour Part 2	Practical experiment conducted. French armour, arrows, and bows replicas built as close to historic design and accounts. Using a 160 lbs bow, shooting at distances of 25 m at a plate target of 2.5 mm 0.6% carbon steel.	No penetration of plate armour. Suspected penetration of thing plate armour. Majority of shots ricochet.

Table 4 - Comparison of practical and numerical calculations

5 Discussion

5.1 Longbow Effectiveness

5.1.1 Practical experiments against calculations

The data in Table No.2 suggests that an arrowhead could not penetrate 3mm plate armour at 100 meters, using the Milne-de-Marre formula and Jowett equations for calculations.

However, practical experiments [5,10] reviewed plate armour with thicknesses of 1.2mm and 2.5mm, respectively. The former did not describe the material type, but the latter used 0.6% carbon steel, which was representative of the armour used by nobleman in the 1400s. The practical experiments did not show continuity, as penetration was achieved with a weaker bow (50 lbs difference) at shorter distances (16m difference), but the armour was thinner (1.3mm thinner). A 160 lbs bow at twice the difference could not penetrate the armour.

Compared to the practical experiments, the numbers used to calculate penetration are favourable for the penetrator. In Table No.3, the impact velocities are greater, as the velocity of the arrowhead and velocity of the target have been considered, compared to the practical experiments which remained stationary. Additionally, resources have referenced the arrowhead to be less than 96 grams. In the calculations, a mass of 116g was used, resulting in a greater kinetic energy being achieved compared to practical experiments.

The challenges with the armour calculations are that they do not consider the arrowhead deformation. As the arrowhead collides with the armour, because the velocity of impact is within the sub-ordnance range, the materials behave as solids. Greater velocities would result in a greater stress/strain rate and therefore materials would act like fluids. However, because the strain rate is less due to

lower velocities, the physical mechanical properties of materials can be considered. Therefore, during impact, the arrowhead conducts work on the armour.

5.1.2 Numerical Calculations

The theory mentioned above faces only one challenge, which is the numerical analysis that considered the deformation of the arrowhead and used values lower than the ones we used in Table No.3. However, the Ultimate Tensile Stress (UTS) used for their materials was 300 MPa, whereas 500 MPa was used in Jowett, and Milne-De-Marre equations.

Throughout the papers, it was noted that there were no standardized bodkin arrowheads. The brief requires a long-head bodkin arrow for penetrating armour. However, references six and seven detail these arrowheads as best for penetrating chainmail, due to the size of the arrowheads that can penetrate through the rings. A heavy-war-bodkin arrow, which consists of a wider and, therefore, denser point, is used for plate armour. Therefore, for the Jowett and Milne-De-Marre formula, a different mass should be used. The diameter could remain constant as the arrow shaft was used.

5.1.3 Milne-De-Marre Calculations

Challenges with the Milne-de-Marre formula are to determine the constant alpha, practical experiments need to be conducted. Additionally, the equation is non dimensionally homogenous. Meaning that the units are not even on each side. Therefore, using the factors of penetration being weight, length, diameter, UTS, and material thickness a dimension analysis was applied to the equation to produce (4-5) [4].

The Milne-de-Marre graph was used to estimate the kinetic energy to penetrate 3mm of steel (500 J). Hence 3 mm was selected as this was an appropriate value within the brief. However, during research it was determined French armour had an average thickness of 2.5mm. Using this alpha could be determined. This was then used for the dimensionally balanced Milne-de-Marre equation.

Point A on the Milne-de-Marre graph represents the energy required to penetrate chain mail armour (100 J). The kinetic energy calculated exceeds this value, and the practical experiments conducted in references six and seven collaborate with the kinetic energy calculated. Against knights, and foot soldiers the longbow would have been effective. The horses would have been targeted instead of the knights, especially due to a larger mass allowing an easier target.

5.1.4 Jowett equation calculations

During research, sources stated the Milne-de-Marre equation was accurate for velocities greater than 200 m/s but less than 1000 m/s. The Jowett Equation was identified which was listed as a suitable equation for projectiles in the sub-ordnance range and were a flat nose projectile. The benefit of the Jowett equation is that no constants are required, and therefore can be calculated using no experimental data.

From the calculations, the Jowett equation shows the longbow at 100 meters could not penetrate plate armour. This aligns with practical experiments and the calculations carried out using Milne-De-Marre. However, further research is required to understand the limitation of the Jowett equation, as such the Jowett equation was used as guide to compare values against the Milne-de-Marre formula.

5.1.5 Summary of the Longbows effectiveness

Based on the research conducted, it has been concluded that the longbow was not capable of penetrating plate armour. However, the longbow and arrowhead mentioned in the brief were able to penetrate chainmail with linen but only at point-blank ranges (9m). Unfortunately, the armour worn by French men-at-arms was plate armour and helmets based on eye-witness accounts. Therefore, it can be argued the longbow effectiveness was reduced based on the practical exercises conducted.

5.2 Factor Matrix

Figure No.9 displays a matrix with the selected factors along both the files and rows. Values were assigned to each product, valuing which factor was more decisive. A 9 above the black line meant the factor in the row was more decisive than the factor in the column. Meanwhile, a 0.1 represented the factor in the row, which was more decisive than the column. Below the diagonal black line, the opposite is true.

Using the products, per cent average, and normalised values of the rows were generated. This graphically represents (Figure No.10) which factors were considered decisive. The disadvantage of this method is the values of the factors are based on the author's knowledge and therefore could contain bias.

However, combined with the knowledge of the penetration power of longbows the following arguments could base against the longbow:

1. France's battle tactics and leadership were inadequate for the battlefield. France, knowing the direction the English Forces were retreating could have split forces, and fell back to more favourably ground. Allowing the knights ground to travel, and men-at-arms to outmanoeuvre the smaller forces. Historians stated they did not want to fight a defensive English battle yet engaged.

2. Additionally, the mentality of adopting wave tactics in a compressed lane (Similar to that in the battle of Thermopylae) show no decisive leadership.
3. The stakes were a new battle tactics adopted by the English and so the French cavalry was not prepared. However, without the stake and tree line it could be argued the stakes prevented skirmishes and cavalry from disrupting the archers from firing. Therefore, without the stakes the archers could have been overrun.
4. Men-at-arm chain mail could be penetrated while plate could not. Therefore, the majority of armour was effective against English arrows. As such the defeat mechanism was the limits of the French soldier. Becoming too exhausted to move, and fight. Granted there were areas of weakness and with enough arrows they would be pierced. Although with exhaustion. The archers could continually out-manoeuvre and therefore repeatedly test the weaker spots.
5. Finally, crushing was another defeat mechanism of the armour. The mud, combined with a push of a soldier would have allow weaker joints to be exposed. Due to the density of soldiers a push would transfer through rank and file and created pockets in which men would fall and asphyxiate. As seen in stadiums, but with the weight of armour (35Kg) and softness of the mud drowning would have been more common.

6 Conclusion

It was determined at 100 meters the bodkin arrow could not penetrate 3 mm plate armour; however, it could penetrate chainmail and other light armours. Circumstances which include thinner plate mail, and shorter distance could result in greater penetration. As suggested from the practical exercises.

Using the findings from the report, an argument can be established that the longbow was not the most decisive factor at the battle of Agincourt. This is due to the review of several other decisive factors (Terrain and crushing) which lowered the difficulty to defeat French armour. However, the sheer volume of arrows, although not effective, some would have found weak points in French armour. Additionally, the longbow did force the French to engage enabling the English to fight a favourable defensive battle.

Ultimately, France should have chosen a more favourable battleground by retreating allowing more forces to rally and weakening the English forces further through hunger and dysentery.

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