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# Investigation of Aerodynamics Behaviors, Shape of Feathers on Traditional Turkish Archery

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***Abstract* - In traditional Turkish archery, a feather is attached to the back of the arrows to prevent them from changing direction during flight after being shot. While these attached feathers ensure that the arrow flies on a smooth route after being shot, it causes aerodynamic factors that affect the movement of the arrow due to its friction with the air. In the study, the effects of the geometry parameters of the feathers in the traditional Turkish arrow on the aerodynamic factors were comparatively examined. To examine the movements of the arrows in the air, aerodynamic analyzes were carried out by using computational fluid dynamics CFD (Computational Fluid Dynamics) for each arrow type, taking into account the changes in the flow drag force values. By examining the acoustic power level in decibel units, the performance of the arrows from the bow was evaluated in terms of range and sound, and the results obtained through CFD (Computational Fluid Dynamics) were compared.**

***Keywords:*** Bilzek, Traditional Turkish bow, Bowstring, Arrow, Feather, Aredynamics, CFD.

## I. INTRODUCTION

An arrow is a weapon of war that has historically been shot with a sling-like device, and later with a bow, which converts the potential energy accumulated in it into kinetic energy by the tension of the material. Arrows have been used since human existence in the world. The oldest arrowhead found so far in the world dates back to 64,000 years ago (1).

It has been determined from the inscriptions that the first composite bow making dates back to the Assyrians. Scythian bows, which were proven to be composite in the post-Assyrian period, have found a place in the history page. Again, according to historical information, with the Great Hun State, the use of archery and bows became a monopoly of the Turks and they began to be known as an archer society. It can be assumed that world history began to change with the spread of horse archery and the ability of the Turks to shoot arrows on horseback. Although it is known that no historical records were kept by the Turks, it is possible to determine this situation from Chinese sources. Turkish bows are not straight like European bows, they are bows with a twisted tip that give modern Olympic archery its geometric shape [2].

However, it has been revealed in research conducted by the retreat of the glaciers in the Alps that bows and arrows were used in Europe. From the end of the last ice age until the Middle Ages, bows and arrows were the most important weapons used in hunting and warfare. The first confirmed artifacts of archery equipment are arrows from Stellmoor in northern Germany, dating back to 10,000 BC. The oldest bows known to have been used so far are found in Holmegard in Southern Denmark and date back to B.C. 8000 – 6500 BC these are bows made of yew wood in the Neolithic period. Despite their different shapes, all prehistoric bows found in Europe were simple, human-sized bows with an approximately D-shaped cross-section and a flat ventral side, made from a single piece of wood. Arrows were made from split wood or thin saplings and were equipped with different tips made of stone, bone/horn material or wood, depending on the purpose. The production process can be explained by various finds consisting of incomplete arch cavities, such as the Tisenjoch finds. Neolithic arrows were made from hazel, viburnum, or other hardwoods. They are heat-cushioned and are generally longer and thicker than modern sporting arrows for greater weight and punching power. Their three-piece feathers are almost the same as the ones used today. Bow stringss have been rarely encountered in archaeological sites in Europe [3].

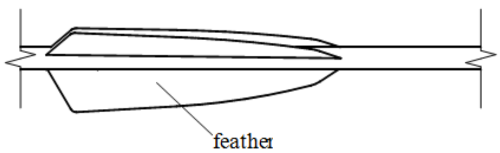


**Figure 1: Feathers attached to the arrow are shown**

Turks draw and throw the arrow using their thumb along with the bow, this shooting style is called latching. They used

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a ring called bilzek, that main purpose was to protect the thumb, but also affected the speed of the arrow. Archery, both on the battlefield and as a sport, became a branch of sport with the establishment of the archers' lodge by Fatih Sultan Mehmet the Conqueror. We can describe this established lodge as the first sports club established in the world. [4] It has become widespread as a sport in the world, especially in the last 4-5 centuries. In fact, today there are competitions in three main branches: Olympic, roller and traditional. The feathershape of arrows shot by recurve and roller bows is almost standardized. In traditional bows, bow forms and technology developed by each society were used, and accordingly, the arrows showed great diversity. The raw material from which it is made, the arrowhead (arrowhead) and the shape of the feather show differences in shape and size. No original feather shape has been found in museums or historical findings. Since the material from which it is made is made of bird feathers, which is a natural and organic material, it has been defeated by time and has not survived to the present day. It has been observed that the temre used as a tip is made of steel and bronze as raw materials. Black pine was generally used as Ulun (shaft) [5].

Based on the historical development of the archery sport given above, it is aimed to evaluate the performance of the arrows used in traditional Turkish archery today. It is envisaged that the output analysis of the simulative environments created with the help of FEA, the data obtained from physical experiments on the speed-dependent performances realized according to the change of the determined parameters, and the changes in the shapes and sizes of the feathers on the arrow pushed by the tensioned bow energy after leaving the bow, will be a reference study in the name of Traditional archery.

### 1.1 Traditional Turkish Bow

Before explaining archery, it is necessary to briefly explain the Traditional Turkish bow from which arrows are shot. The traditional Turkish bow has historically been a composite bow. Historically, maple was used as the body, layers made of buffalo horn to ensure continuous elastic behavior, fiber obtained from the Achilles tendon of the ankles of ox or buffalo, and glue obtained from the mouth of the sturgeon as the adhesive matrix. Nowadays it is called organic bow.

Developing material knowledge and experience have played a role in the production process of these pedestrians by using different materials. Nowadays, many types of wood, carbon or glass fiber have begun to be used as epoxy resin making materials.

Figure 2 shows the bow and its parts used in Turkish archery. Construction and structure of these bows is a very different issue, and especially the organic composite bow needs to be examined separately.

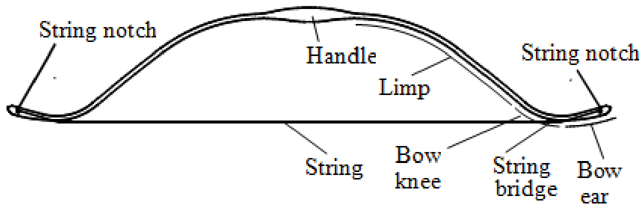


**Figure 2: Parts of the body structure of the traditional Turkish bow [6]**

### 1.2 Bow string

The bowstring in archery is the rigid type on which the bow is held and pulled. The bowstring in Old Turkish is called "skein". It consists of a hard string made of pure silk. The middle of the bowstring is thickened by wrapping a certain amount of thread to hold the arrow. Nowadays, strings made of polyester are used. It is preferred to be light, strong and resistant to abrasion and water.

When artificial materials and silk were not available, stretched and twisted dried sheep intestines were used, protected from moisture [8].

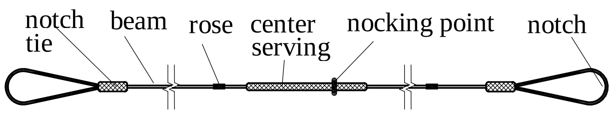


**Figure 3: Bow string and its parts [7]**

### 1.3 Arrow

The arrow is a stick made of reed and wood, 60-80 cm long and weighing 9-50 g. If the arrowhead attached to the arrow's pile is made of metals, temren; if it is made of bone, horn, ivory or fish teeth, its called soya. Rudder feathers on the back of the arrow body, that is, on the head and throat; it is called feather, vest, sometimes sakal, peylek [10] or yün. Figure 4 gives a general picture of the arrow structure.

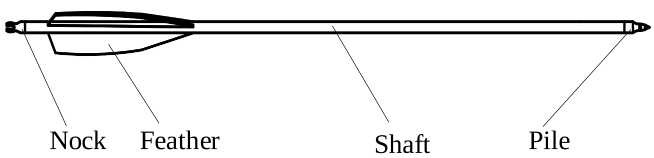


**Figure 4: General structure of the arrow**

Figure 5 shows the arrow and its parts, which are traditionally compared to the human body.

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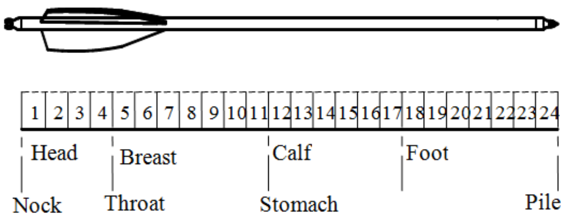


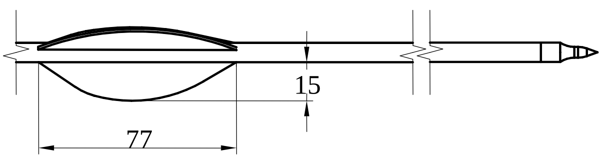

**Figure 5: Parts of the arrow that resemble the human body [7]**

## II. MATERIALS AND METHODS

The shapes and weights of the arrows, bows and arrows of each arrow used within the scope of this study were chosen to be of the same value. The feathers used are made of parabolic, Shield and M1 profiles, which are the most preferred for shooting today, with balance settings of 3, 4 and 5 inches in length. Then, for reverse engineering of the arrows shown in Figure 6, a point cloud was created with a Scantech 775 scanning device, and solid models were obtained for use in the Finite Volumes method by modeling with VisiCAD software.

**Figure 6: General view of the arrows**

Figure 7-9 range gives the measurement details of the arrows used.

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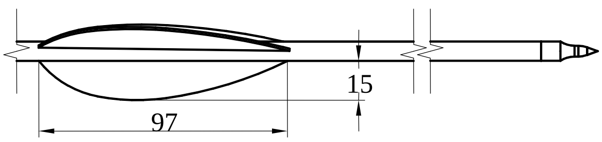


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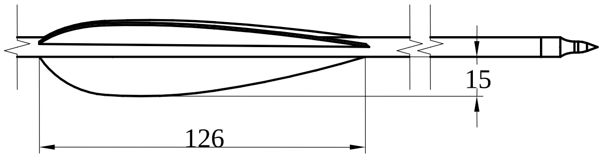
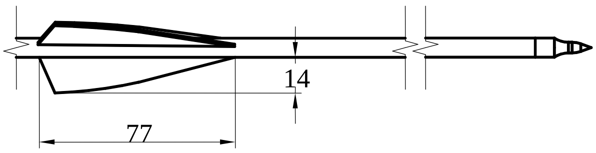



**(c)**

**Figure 7: Dimensional details of the parabolic feathered arrows used in the experiments**
**a) Parabolic 3" Feather**
**b) Parabolic 4" Feather**
**c) Parabolic 5" Feather**

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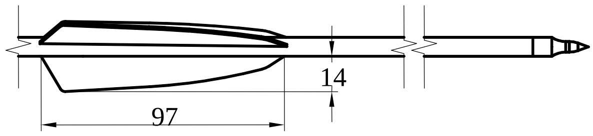


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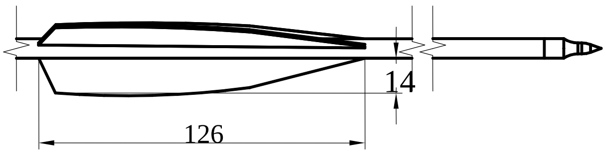
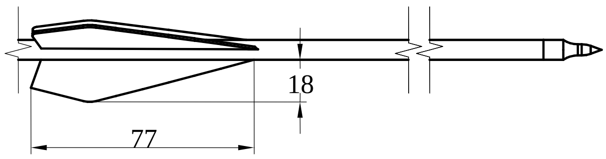



**(c)**

**Figure 8: Dimensional details of Shield feathered arrows used in experiments**
**a) Shield 3" Feather**
**b) Shield 4" Feather**
**c) Shield 5" Feather**

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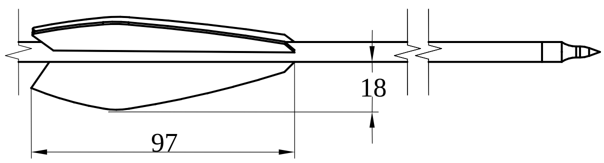


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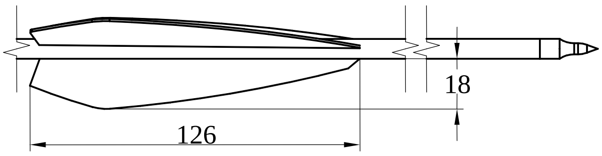



**(c)**

**Figure 9: Dimensional details of the arrows with M1 feathered used in the experiments**
**a) M1 3" Feather**
**b) M1 4" Feather**
**c) M1 5" Feather**

### 2.1 Conducting experiments in a virtual environment using the Finite Volumes method

In this study, FloEFD software was used to implement the Finite Volume Method. In this method used, the boundary layer mesh number was determined as 82326 and the total fluid domain mesh number was determined as 509547. Based on these data, aerodynamic analyzes of each of the arrows used in the experiments were performed and explained in detail below.

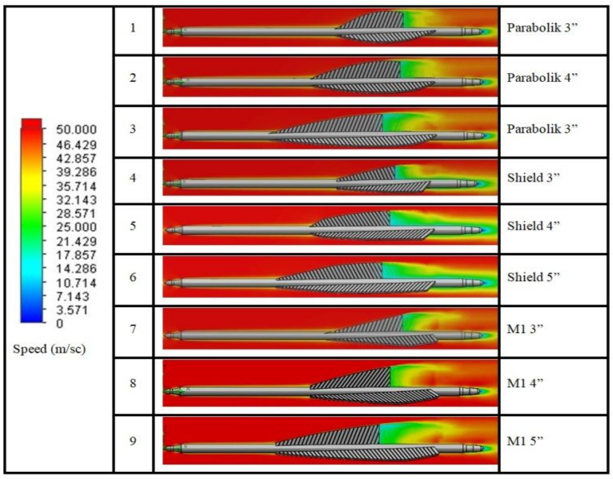



**Figure 10: Drag Speed Analysis Results**

When the feather-on-arrow geometries, which are the subject of experimental studies, are examined aerodynamically, with a total of nine in Figure 10, it has been observed that although long vacuum regions are observed in the traces left behind by the arrows with the Shield series feathershape, arrows with such quills are the most stable feather geometry against friction. In the vacuum region formed here, the friction-induced braking effect on the arrow body has decreased almost to zero, in almost the 1/3 part of the feather geometry towards the back, and again from the 1/3 back part of the feather. This can be easily observed from the scale values on the color scale. In arrows with M1 feathershape, very unbalanced movements were observed in the flow behind the feather. Especially M1 4" feathershape arrows show the most resistance to drift, therefore their speed will decrease during flight and the arrow should be ready for straight flight at the latest. It has been observed that it has a feathershape that will react. According to this result, it can be stated that the flight of M1 4" feathers in the air is the least efficient compared to other shapes. Trajectory stability was observed during the flight of arrows with parabolic feathershape, but it was determined that they were not as efficient as Shield series feathers.

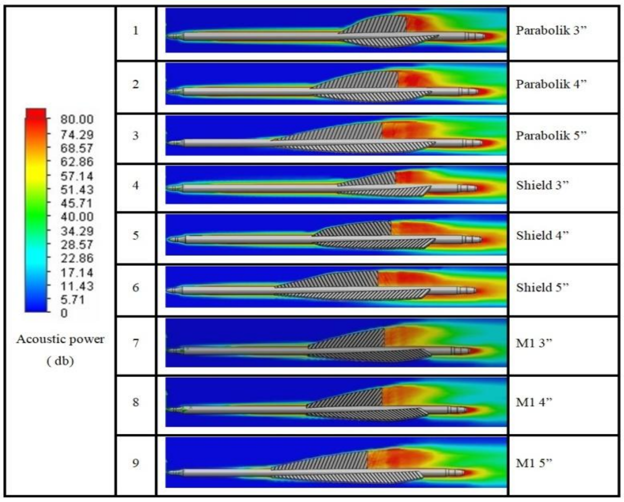
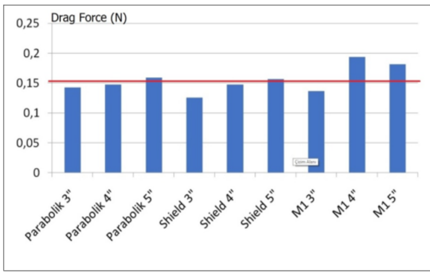



**Figure 11: Acoustic Power Level**

The sound levels created by each feather during shooting are given in Figure 11. Accordingly, it was determined that the arrows with Shield featheredshape had the highest noise according to the dark red color intensity on the back parts. In parallel, shooting stability was observed to be quite high for this type of feather. In general, it has been observed that M1 type and Parabolic feathershape arrows produce lower noise than Shield type feathers, again according to the color scale of the back of the feather. However, instabilities were observed depending on the color scale. According to these results, it has been determined that arrows with M1 and Parabolic feather types will show inconsistent movements during flight.




| Feather Shape | DragForce (N) |
|---|---|
| Parabolik 3" | 0,14279941 |
| Parabolik 4" | 0,147249206 |
| Parabolik 5" | 0,159102699 |
| Shield 3" | 0,125734693 |
| Shield 4" | 0,147187989 |
| Shield 5" | 0,156539655 |
| M1 3" | 0,136637548 |
| M1 4" | 0,19329769 |
| M1 5" | 0,18121741 |

**Figure 12: Drag Speed Analysis Results Graph and Values**

Figure 12 shows the table and values of the drift resistances shown by the arrows in the speed analysis according to the arrow types. According to these values, the

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average drift resistance was calculated as 0.154418477. Figure12. The average value is indicated with a red line.

It has been observed that the drift resistance of arrows with parabolic 3" and parabolic 4" feather shapes is lower than the average level, considering the values, and therefore their speed will be 10% higher. It was observed that arrows with parabolic 5” feather shape were close to the average value. It has been observed that it has approximately an average speed value.

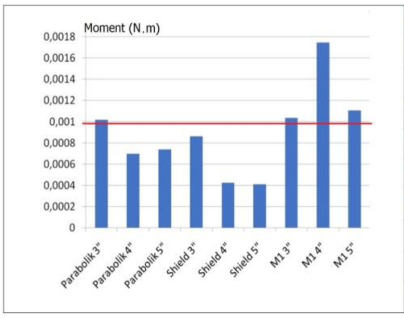
As seen in the drift analysis, arrows with Shield 3” type feather shape were found to be the arrows that showed the least resistance, that is, they flew the fastest in the air and had the longest range. It has been observed that it is approximately 20% faster and the most efficient arrow shape in terms of design.

It has been observed that the speed of arrows with Shield 4” feather shape is below average in terms of drift resistance and will fly in the air at average speed. It has been observed that arrows with Shield 5” feather shape are close to the average speed value and will fly at average speed.

In the speed analysis, arrows with M1 3” feather shape showed resistance below the average, and according to this result, it was observed that they would fly 12% faster.

It has been determined that the most resistance to drift is in the M1 4” feathershape. As a result of the two analyzes we made, when we examined the graphs and compared them with the table, it was stated that the arrow with the M1 4” feather shape behaved unstable in the sound analysis and showed the highest drift resistance. For this reason, it has been observed that arrows have the least efficient shape in terms of speed, range and target consistency. In terms of design, it was seen to be the most unsuccessful arrow shape among the arrows we examined.

It has been observed that arrows with M1 5” feather shape have high resistance to drifting, have an inefficient shape and are unsuccessful in design.




| Feather shape | Moment (Nm) |
|---|---|
| Parabolik 3" | 0,001020185 |
| Parabolik 4" | 0,000698617 |
| Parabolik 5" | 0,000740929 |
| Shield 3" | 0,000863012 |
| Shield 4" | 0,000425928 |
| Shield 5" | 0,000411526 |
| M1 3" | 0,00103547 |
| M1 4" | 0,001746028 |
| M1 5" | 0,001107937 |

**Figure 13: Graph and Values of Arrows' Desire to Rotate Around Their Own Axis**

When the arrow is shot from the bow, it shows a bending movement in the direction from which it was shot from the bow handle (right-left). If the desire to rotate around its own axis is too high, it will reach the target with an unstable and inconsistent route during the flight. Speed is the most important factor that directly affects the distance and target consistency. In this table, the average value is calculated as approximately 0.000894403. In Figure 13, it is indicated by the red line.

It has been observed that arrows with a parabolic 3” feathershape have low resistance to rotation. Considering the drag resistance and acoustic power level, and considering that the arrow with the feather type has the smallest surface area, it has been determined that there are arrows with high target inconsistency and an inefficient feathershape in design.

It has been observed that the drift resistance of the arrows with a parabolic 4” feathershape is at an average level, in the acoustic velocity analysis, they produce irregular sound, and the desire to spin is approximately at an average level. It has been determined that the range distance of arrows with this feathershape is average but the target is inconsistent. It can be said that there are arrow types that are not ideal in terms of design.

It has been observed that the drag resistance for arrows with the parabolic 5” feather type is higher than average, and although the friction is low in acoustic sound analysis, it has an unstable movement. Since the desire to rotate around their own axis is below average, they can be considered to be arrows with an average efficient feathershape.

According to the acoustic sound analysis, it has been observed that the friction in Shield 3" arrows with a feathershape is balanced, and that they are arrows with an efficient feathershape, considering the drift and the desire to rotate on their own axis.

It has been observed that Shield 4" and Shield 5" arrows with a feathershape are the arrows that rotate the least on their own axis during flight. Considering the acoustic sound analysis and speed analysis, it was determined that the arrows with the most efficient feathershape were the arrows with the Shield 4" shape.

It has been observed that arrows with M1 3” feathershape show resistance below average in speed analysis, produce low sound in sound analysis and their desire to rotate around their own axis is above average. When the comments were combined, it was seen that there were arrows with an inefficient feathershape.

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It was concluded from the analysis that arrows with M1 4” feathershape were the most inefficient arrow structure.

It has been determined that the drag and rotation values of arrows with M1 5” feather shape are above average and according to the acoustic sound analysis results, they have unbalanced movement and therefore they are arrows with inefficient feather shape.

## III. CONCLUSION AND RECOMMENDATIONS

The results obtained based on the aerodynamic and acoustic analyzes of the data obtained in this study are listed below.

It has been concluded that the aerodynamic form of the arrow group with the shild feather shape is the most optimum form in terms of range. It is the most stable feather group. In particular, Shield 4" has been determined to be the most efficient and most successful arrow structure among the nine feather shapes we examined.

It has been observed that the arrow group with M1 feather shape has a high desire to rotate. According to this result, it has been observed that the M1 group arrows with a feather shape are a group of arrows with an inefficient feather shape, both in terms of range and target consistency. As a result of the analysis, it has been determined that arrows with M1 4” feather shape are the arrows with the least efficient feather shape in terms of distance and target consistency. The reason is; In its design, as shown in Figure 14, the gap resulting from the absence of feathers at the junction of the feather and arrow body can be shown.

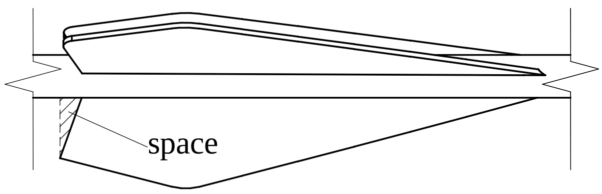


**Figure 14**

Analyzes can be repeated in subsequent studies, taking into account different feather parameters. Additionally, studies on the flight stability and distances of arrows can be carried out by analyzing the speed changes that will occur using different bow types.

## ACKNOWLEDGEMENT

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