ASPECTS REGARDING THE TRADITION OF BELL MANUFACTURE AND USE

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ABSTRACT

The paper presents the casting art of bells, their spiritual significance, as well as their evolution over time. The bells may be made of both metallic or and non-metallic materials, of various shapes and sizes. While producing the adequate sounds, bells have found a universal use: they served as musical instruments, sound devices used in religious rituals, for communication and warning signals. In the European world, the progress and the performances regarding of bells development are owed to their use in the Christian Church rituals.

KEYWORDS: art casting, bells, multi-criteria analyses

1. Spiritual significance of bells

It is widely known that the shape of the bell, known today mostly from graphical statistics, is a medieval invention. Before this, the bells used to look like flipped pots, bowls, or bee hives, but never like what we know as being a bell: a carved bowl with an enlarged mouth. This shape was the result of an ultimate rupture with all the previous shapes. The main characteristic of the new shape was the transformation of the neck, barely perceptible at first, from convex to concave; however, the fact that the new shape discovered an unknown potential for the use of bronze became obvious: this alloy endowed the bell with a controlled secondary sound, higher than the percussion note but, surprisingly, creating a particular roar, way lower than the main note, and which is rather felt than heard. By the end of the 13th century, the bells adopted a gradual interior hollow, which strengthens its murmur rumble, its whispered vibration [1].

The bells crown was flatted, its shoulders enlarged, its lateral parts opened until the mouth, and the thickness of the walls was calculated and tuned. Following the differences between working with cast iron and metal, the characteristic sound of each region bells became a familiar element for geography in the late Middle Ages.

Thus, the technologic instrument which incorporated the divine word in a metallic sound, coming from the church steeple, and which dressed each parish in a distinct acoustic mantle, was designed: from the bells swinging and knelling in the North-West, answering to the Flemish beats with the tuned sounds of several bells, to the tempestuous and noisy oscillations from around the Mediterranean.

The Chinese used to ring the bells to announce the meetings of the Imperial Gatherings; they used four different tongues to command the soldiers “to fight, and to dance”. As it seems, the noise making instruments have been widely used, and not only to attract the attention, but also to clean the air of unwanted spirits or to cast away the stormy clouds. According to Josephus, King Solomon suspended a golden bell on the highest beam of the temple to chase away the birds. The Romans used to tie tintinnabula on their shields, to attract the enemy’s attention on the paralyzing face of Medusa, carved on the bronze plate in the middle of the shield. The bells used to open the place for the Bacchante processions. In Astarte’s cult, the priests used to hit a ring that made a sharp sound.

The Greek and Latin authors could not tell the large bell, with the shape of a cup, of the almost enclosed sphere of the spherical bells. Most bells in the Mediterranean Antiquity were small enough to be sewed on the clothes, or held and shaken with one hand. The bigger ones, like gongs or metallic cylinders, were used to announce the fish markets, the baths, and the circus. Plutarch wrote about “bells on nets spread over the river, which rang when people tried to swim, and escape the besieged town Xanthus”.

The dogs, horses, cows, goats, pigs, and sheep were wearing bells on their neck; the skeletons of two horses, each of them wearing three bells, were found in Pompeii. The shepherds wanted to be buried together with the bells they put on their animals’
necks. The ringing kept the vampires and the ghosts away of their goats and cows, and might as well guard their lifeless body of such supernatural beings. A Christian martyr, Sisinnus, was buried wearing a bell on his neck by court order; the Roman magistrate wanted to show, this way, his disregard for the accused, a man that was as irrational as a beast. The Greek night guard was known by the name of codonophor, a bell wearer. The social women in Pompeii used chimes as earrings. In the Middle Ages, the brain-sick, the leprous, the executioners, and the public fools were forcibly sewed bells on their clothes.

After becoming a symbol for the missionary, the molded bells were treated, in the christened Europe, as being some sort of persons. The bells usually had names; the name and the “vocation” of a bell were carved on its crown. These are several typical inscriptions: „Laudo Deum verum [praise the real God] ... plebem congrego [gather the people] ... vivos voco [call the living] ... defunctos ploro [mourn for the dead] ... pestem fugo [banish the plague] ... fulgorem frango [chase away the stormy clouds]“ [2].

The oldest text preserved, about the special blessing, for the church bells, comes from Spain, a few years before the Muslims conquered the peninsula. The ceremony starts with the solemn exorcizing of the molten metal; the evil, and the unholy spirits which attached to the metal on its birth in the womb of the Earth are cat away from the mass of boiling metal. The priest prays for the bronze to become as pure as the trumpets used by holy orders in Sinai – for God to endow the sound of this bell with the power to clean the laziness and the stupor in the hearts, to extinguish the flames of lust, and to light the weight of the sin, in everyone it touches – for God to give it the power to strengthen the week ones, to comfort the sad ones, and give courage to repent for the sinners.

It is obviously an austere blessing ceremony; in this early text, no words appear about the peculiar rites that treat the bell, a century later, more as a person than an object – and which determined Carol the Great to forbid the bells “baptizing”, in 798: ne cloca baptizent.

On the contrary, with the large acceptance of bells in churches from Western Europe, in the religious area of the Eastern Roman Empire and the Byzantine Empire, they entered later, and with some difficulty. Although the Constantinople had been given a set of bells ever since 886, they were only used to announce the hours, at the Imperial Palace, and the Latin Rite church. The Orthodox Christians in the East were rather used to the sound of an elder instrument – the vesper – the wooden piece that resonates while hit with mallets, and produces various sounds [3].

The museum association of bells and cannons: the conversion of one to the other, bells to cannons, in time of war, and cannons to bells, in time of peace, was a usual behavior for all the peoples, over all times. Such a situation appeared, for the first time, in Russia, in the time of Tsar Peter the First, who, after losing all the Russian artillery in the battle with the Swedish, near Narva, in 1700, ordered all the laic and monastic communities to donate a third of the total bells they had, to recover the artillery. This operation determined the communities to firstly give away the defective bells, which were later replaced by newer ones, more beautiful and durable, and this aspect may be considered as a refreshing moment for the symbolistical patrimony on a national scale.

2. The Evolution history of bells

Ever since the 16th century, a real competition to produce increasingly bigger bells had started. In 1520, in Pskov, the brothers Michael, Onophreus, and Andrew, cast two bells: one weighting 6 tons, and the other, 3.5 tons, the biggest bell ever cast by them having 6.4 tons. In 1533, under Tsar Basil III, a 16 ton is cast, and in 1551, Ivan IV orders the casting of a 35 ton bell, which, owing to its exceptional ringing, was named “The Swan”.

The 17th century comes with the triumph of the bell casting art in Russia and strengthens the position of the Russian manufacturers on the European bell market, successfully competing with the German or Polish foundries. The customs were equally impressive: it was already traditional in Moscow, for the exact midnight of Easter’s Eve, the first and the only bell which shared the news of Jesus Revival, to be the big bell in the Kremlin Tower; after that, sounds of over 3500 bells burst over the giant city. These bells used to ring for a whole week. In this week, after the Easter, the local rites permitted to any citizen to ring the bells of any church, if he wanted, this being also a good occasion of “live” practice for the aspirants on the sexton job.

The transformation of bells in cannons determined the adjustment of the foundries and, consequently, the regress of bell casting, but the stagnation period was short. For example, the statistics show 13 foundries in the area of the new Capital St. Petersburg that cast, in 1811, 4220 bells and some other tens of thousands of sleigh bells. The famous Russian sleigh bells of the horses carrying troikas have a history close to the times of the first Slavic migration and their settling on the territory which will later become Russia. The most famous chimes and sleigh bells are the “Valday Chimes”, often sung by the Russian classics and quasi-present in the folklore and cult literature. The numeric increase of bells and chimes was favored by the
Russian territorial expansion in the depths of Asia, where the conquered peoples tried to oppose the occupation, cut could not oppose the adoption of some objects (sleigh bells) or some habits (Christianity), together with the use of bells, imposed by the Russian church, which was also trying to expand. This tendency was even found in Alaska and the Aleutian Islands, where the first missionaries, in the 18th century, installed the first bells, for the Orthodox Christian missions created here [4].

Of the most important donations of bells, from the Russian tsars for the North American communities, we can mention those made by Emperor Alexander III – to the Holy Trinity Cathedral in San Francisco, and the Orthodox Church of the American Western Diocese, or the one made by the Martyr Tsar – Nicholas II to the Bridgeport Church, in 1894, to celebrate his coronation.

The great trial for the Russian Church comes with the beginning of the revolution, in 1917, and lasts for all the functioning period of the soviet and communist regime.

In 1941, out of over 60,000 churches and 1000 monasteries and abbeys, there were only about 500 churches still functioning, and just a few of them kept their bells; however, the use of bells was prohibited by a “directive” in 1935, and, as a result, only one set of bells from Kremlin was allowed to ring, as horologe, but with the imposition of a new melody, on a new rhythm.

A set of bells which remained untouched is the three bell set in Rostov; for unknown reasons, these were protected for unknown reasons by the Ministry of Culture, in the regime of Stalin. Later, after the Cuban missile crisis in 1962, the Russian Government disposed an extremely unusual measure: the reposition of these bells as “cultural artifacts” and, even more surprisingly, the recording of an LP called “The Bells of Rostov”, but the text accompanying the recording made no reference to religion.

The faith retaliates now: the old armament factories, with insufficient commands, now switched to bell casting, an activity that proves to be profitable, on a continuously growing and long term secure market. If the 20th century was one of competition with all the other bells in Moscow, drawn simultaneously. The experiment succeeded, and the arbitrators noted that the sound of the Great Bell dominated, being heard on a 40 km distance, covering
Bells like “Saint Peter” have been heard in Europe in an era in which the sense of the place suffered an extraordinary transformation. The technology, stimulated by horses, permitted the people to live together, to move from hamlets to real villages. The urbanization supported the regular gatherings in rural markets. The church created parishes with resident clerics and established a new set of regulations to control the marriages and the communal life. The Central Europe establishment processes populations have earned, during Early Middle Ages, lots of characteristics that were kept up until the 19th century. The communities were spread as far as the bells were heard, mixing up in a new manner.

The use of the tower building to spread a religious sound was an invention born in the Early Middle Ages, taking the form of the bell tower and the minaret.

Starting in the 5th century, the churches started to build towers for bells. San Apollinare Nuovo and San Apollinare in Classe in Ravenna have round towers. A mosaic in Santa Maria Maggiore in Rome, created in the time of Sixtus III (432-440), shows a church with two such round towers.

The wish to hang the bell in a high place precedes the existence of those very powerful and heavy bells; hence a special building was needed to shelter them. In 752, Pope Steven III built a steeple for three church bells in Rome, at Saint Peter. The weight of the tintinnabuli and the wish to make it heard contributed to ordering this special architectural piece of work. In the 11th century, the steeple’s tower became a common image, and in the 13th Century, it already became a part of any parochial church or cathedral. Gradually, it started to be also used in the Orthodox Church. Around the year 865, the Doge Orso sent twelve bells from Venice to the Emperor Michael III, known by the name of “The Drunk”. These bells have been installed in the magnificent steeple near Saint Sophia and, in less than a century, the bells could be heard in the neighboring Lavra, and then on Mount Athos; however, the bell did not compete with the simandrum as a convocation instrument. There is no doubt that the affirmation that the bell is an accidental invention and that the Orthodox Church had not used it before the 11th century is an exaggeration. Anyway, it is a sure thing that the most prevalent instrument used to summon the believers to the ministry was the “holy wood”.

Even more remarkable than the ecumenical acceptance of the bell in the Eastern and Western Churches is the recognition of the important civic role of the bell along the 19th century. During the liberal anti-ecclesial waves in the South-European countries, the “right for the bell” became a major litigation reason between the catholic bishop and the civil
authorities. Why would the prefect have the right to silence the bells after 7 in the evening? Or to order the bells to be rung to announce a fire, or to announce the passing of an important person through the city? If this was the case, should not the municipality pay the bell ringer? Does the municipality have the right to forbid the ringing of the “death bell” in case of a pestilence, to avoid general panic? From a survey on the Court Orders and the decisions of the Supreme Court in France, the fact that, until the beginning of the 20th century the sound of bells establishes, in a powerful manner, the sovereignty on the space that it fills, becomes very clear.

3. Bell manufacturing techniques

The bell has its own structure, and for a best functioning, it must be put in an optimal relationship with the mechanism that engages it to make the sound [7].

The first step in the manufacture of a bell is the creation of the core. This one is manufactured the first, in a brute form, close to the final one, from bricks, and then it is finished by adding the formation mixture.

The core is covered with a dust (a layer of grease, in other situations), so the core would not adhere to the surface of the fake bell – the one made of ceramic (or wax, as it was used in older times).

“The fake bell”, or the one made of ceramic, is covered with a thin layer of wax which - at the moment when the superior part of the casting matrix becomes dry - melts and permits its separation of the fake bell. Before covering the fake bell with a new layer of a clay (which will become the superior part of the casting matrix), this will be decorated with wax ornaments.

A very fine formation mixture, that should take all its details, is applied in thin layers over the wax surface that covers the fake bell.

A metallic carcass is put around this ensemble, and the free space between them is filled with formation powder.

The ensemble is warmed up in order to dry up the superior part of the matrix, while the thin wax layer melts down; after that, the matrix is lifted to clean the interior of the rests of unmolded wax and other potential impurities [8].

After these operations are over, the fake bell is removed, and the space it used to occupy is filled with molten bronze. This one is poured in the final matrix, at 1050-1100°C. The pouring must be continuous, and under qualified personnel supervision, so no impurities interfere during the cast. The cooling is made very slowly and, for this reason, the casting and the cooling processes are made with the casting matrix on the ground. After the cooling, the formation mixture is removed, and the bell’s sound adjustment is made.
4. Modeling elements in bells execution

4.1. General

Advanced multi-criteria analysis is a general method to compare products, services or activities that has proven effective.

This chapter aims to analyze various materials used for casting bells. Analysis consists in a performance coefficient derived from calculations for ranking the analyzed products [9].

4.2. Analyses establishing alternatives

In this analysis materials used for casting bells were compared. These materials are presented in Table 1.

Table 1. Materials and symbols used in the analysis

<table>
<thead>
<tr>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>M6</th>
<th>M7</th>
<th>M8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special Bronze (20-22% Sn)</td>
<td>Industrial Bronze (6-14% Sn)</td>
<td>Special Brass</td>
<td>Alloyed Iron</td>
<td>Alloyed Stell</td>
<td>Al Alloys</td>
<td>Crystal</td>
<td>Ceramic</td>
</tr>
</tbody>
</table>

4.3. Advanced multi-criteria analysis of variants selected for comparison

To make a comparative analysis in terms of performance following ten criteria were established:

- C1 - bell sound amplitude vibrations;
- C2 - time maintaining vibration in the ear;
- C3 - Specific musicality;
- C4 - aesthetics exposed surfaces;
- C5 - technological properties of molding;
- C6 - technological properties of casting;
- C7 - surface processing capacity;
- C8 - mechanical resistance characteristics;
- C9 - resistance to corrosion;
- C10 - manufacturing costs.
Table 2. Comparing for individual criteria results

<table>
<thead>
<tr>
<th>Ci</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
<th>C10</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>C2</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
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<tr>
<td>C3</td>
<td>0</td>
<td>0</td>
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<td>0.5</td>
<td>0.5</td>
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<td>2</td>
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<td>C4</td>
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<td>C5</td>
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<td>C6</td>
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<td>C7</td>
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<td>0</td>
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<td>2</td>
<td>2</td>
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<tr>
<td>C8</td>
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<td>0.5</td>
<td>0.5</td>
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<td>1</td>
<td>0.5</td>
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<td>1</td>
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<td>0.5</td>
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</tr>
<tr>
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<td>0.5</td>
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<td>0.5</td>
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</tbody>
</table>

Weighing coefficients “Y_i” are calculated with Frisco:

\[ Y_i = \frac{p + |\Delta p| + m + 0.5}{\frac{N_{CRT}}{2} + |\Delta p'|} \]  

where: p - the amount on line points for each criterion;
\( \Delta p \) - difference between the criterion score and the score criterion taken from the last level;
\( m \) - number outclassed criteria;
\( N_{CRT} \) - total number of criteria;
\( \Delta p' \) - difference between the criterion score and the score criterion taken from the first level.

For each material were granted \( N_j \) notes to the way they satisfy each criterion of comparison.
The notes represent an integer from 1 to 10.

Table 3. “Y_i” weighing coefficients calculation results for each criterion

<table>
<thead>
<tr>
<th>Ci</th>
<th>p</th>
<th>level</th>
<th>( \Delta p )</th>
<th>m</th>
<th>( N_{CRT} )</th>
<th>( \Delta p' )</th>
<th>Yi</th>
</tr>
</thead>
<tbody>
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<td>5</td>
<td>10</td>
<td>-0.5</td>
<td>4</td>
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<td>8.5</td>
<td>0</td>
<td>10</td>
<td>-5.5</td>
<td>0.238</td>
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<td>0.238</td>
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Table 4. Grades given according to performance criteria for the analysed materials

<table>
<thead>
<tr>
<th>Material symbol</th>
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<th>M4</th>
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<tbody>
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</table>

Based on Table 4 for each material were calculated partial coefficients \( F_{ji} \) value in relation to each criterion as:

\[ F_{ji} = Y_i \cdot N_{ji} \]  

Then for each material the sum of these factors was calculated:

\[ FV_j = \sum_{i=1}^{10} F_{ji} \]
Table 5. Calculation results of partial and total value coefficients and total value of analysed materials

<table>
<thead>
<tr>
<th>M</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
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<th>C10</th>
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<td>1.666</td>
<td>2.142</td>
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<td>36</td>
<td>4</td>
<td>183.752</td>
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Table 6. Ranking of the materials used for casting bells according to the total calculated coefficient of performance

<table>
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<th>Place</th>
<th>Material symbol</th>
<th>Material description</th>
<th>FV j</th>
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</thead>
<tbody>
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<td>M1</td>
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<td>183.752</td>
</tr>
<tr>
<td>2</td>
<td>M7</td>
<td>Crystal</td>
<td>178.158</td>
</tr>
<tr>
<td>3</td>
<td>M2</td>
<td>Industrial Bronze (6-14% Sn)</td>
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</tr>
<tr>
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<td>M3</td>
<td>Special Brass</td>
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</tr>
<tr>
<td>5</td>
<td>M6</td>
<td>Al alloys</td>
<td>164.874</td>
</tr>
<tr>
<td>6</td>
<td>M8</td>
<td>Ceramic</td>
<td>138.876</td>
</tr>
<tr>
<td>7</td>
<td>M5</td>
<td>Alloyed Steel</td>
<td>132.59</td>
</tr>
<tr>
<td>8</td>
<td>M4</td>
<td>Alloyed Iron</td>
<td>118.256</td>
</tr>
</tbody>
</table>

5. Conclusions

The results and rankings in Table 6 show that the first material for casting bells is special bronze with a performance coefficient value of $FV_j = 183.752$. For industrial bronze the performance coefficient value is $FV_j = 176.922$.

On this score industrial bronze is ranked third in the classification of materials used for casting bells. Even if some estimates may lead to some error margin, of error, the results reveal that bronze occupies a special place in the materials used for obtaining and casting bells.

On the other hand, the research carried out and the results show that the use of the multi-criteria method can be successfully extended in every industry, including the casting alloys.

References


