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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 fouls 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 cloccas 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 specific market. If the 20th century was one of atheism in the USSR, the 21st - the first of the Second Millennium of the Russian Orthodox Church and the third of the mankind will be a profoundly religious one, or will not be at all.

Other famous bells are those from the Danilov Monastery, of which the biggest, cast in 1654, weighed 131 tons, and its sound could be heard on a distance of over 17 km, and many times, dialogue, were carried between the bell towers of Kremlin and Danilov. It seems that the exuberance manifested by the Danilov Monastery sexton, during such a dialog, produced major damage to the big bell, which had to be restored. The bells in here were reserved an unfair faith, but better than other bells in the Tzarist Russia. When the Soviet Government decided the destruction of these bells in 1930, they had the chance to be redeemed by the American industrialist Charles Crane, which paid for their disassembly and transfer to the USA. Even today, they still resound at Harvard University, although the Russian officials started the redeeming approaches in the 90s, in order to bring them back to their rightful place before 2003 – the Anniversary for 700 years since the Monastery foundation, so they would be the same rang bells which Gogol heard and evoked.

This was not possible due to the very high costs of such an operation, even though the initiative was personally sustained by President Ronald Reagan; this way, the Danilov Monastery had to celebrate the century-old anniversary with the bells cast in 1988, the year when Mikhail Gorbachev considerably lowered the religious persecution imposed for several decades by the soviet regime, and permitted the organization of the manifestations related to the Anniversary of 1000 years of Orthodox Christianity in Russia [5].

The 17th century was marked by the realization of The Grand Bell – TSAR KOLOKOL, but also the set of three big bells in Rostov, of 8, 16, and 32 tons respectively, which can be heard on a distance of over 30 km.

The Tsar of Bells was made and it existed up until now, but the divine grace punished a wish of greatness, maybe unjustified, and the great bell sits unused in the Red Square, in Moscow, close to another vainglory monument: "The Tsar of Cannons" – another dream of greatness, also never utilized, thankfully, this time. The two symbols have been, and still are, just tourist attractions.

The biggest bell ever cast – The Tsar of Bells – was, in fact, realized at the end of a series of four tries, during almost 150 years. Other three bells which preceded this one have previously wore this name. Here is their brief history:

- the first one was cast in 1599, during the regime of Boris Godunov, by the master caster Andrei Chohov: it weighted 35 tons, and ended in the fire in Moscow, in the 17th century;

- the metal from the first bell was melted and used to cast the second Tsar Kolokol: this one was released in 1654, under Tsar Alexei Mikhailovich, by the metallurgical master Emilian Danilov, weighing 128 tons, and being cast in the premise of Kremlin. Satisfied with this result, the Tsar ordered it to be lifted on an improvised stand, and ringed in 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

all the others; however, the ardor of the 25 soldiers that made it ring, moving its heavy tongue, possibly combined with a casting imperfection, makes that after only one hour, the bell gives an unnatural sound, and then falls down in pieces. Disappointed, the Tsar ordered the immediate remake of the bell.

- the third Tsar Bell was cast the next year, in the same place, and the honor to coordinate the work was given to a 20 year old master – Alexander Grigoriev. This bell had 160 tons of incorporated metal and was called "The Bell of the Great Dormition", after the Cathedral of the Dormition in Kremlin. Ten years had to pass until it could be provisionally set in a wooden tower, and another 10 years until the definitive settlement in the tower called "Ivan the Great". This one could only be used occasionally, and this only after all Moscow has been previously warned, as its sound would produce such an intense vibration, that it felt similar to a small earthquake. This one resisted until 1701, when a fire in Kremlin leads to its falling and breaking [6]:

- in 1730, Tsarina Anna Ioannovna commanded the collection of the broken bell's remains and the casting of a new one, with the addition of approximately 35 tons of bronze. The task was taken by the master Ivan Motorin who, for 5 years, tried countless solutions, and even a casting – which was a failure, and led to its death, due to fatigue and sadness. His work was continued by his son, Mikhail Motorin, who perfectly organized the whole process and managed to cast the bell from the first try, in 1735. The history recorded this fact as a true performance, the whole quantity of molten metal, 196.556 kg, being cast in the matrix in only 36 minutes; and this really is a performance, as to cast 6 tons of metal per minute is not easy, even now.

Unfortunately, not even this last Tsar Bell was made to ring. As long as it was still on the place where it was cast, and the metal was not cold yet, an unexpected fire started and collapsed the wooden scaffold over the bell. The workers, with a good intention to save it, but unskilled, poured water that made it crack, and a piece of 11 tones disengaged. This way, the Great Bell lay down for almost 100 years, until the 19th century, when its move on an especially built pedestal was commanded, so the greatness and richness of its decorations can be admired. The experts of the time and the ones after consider that, if that bell could ring, it would have become a real danger for all the constructions around it, for an area of a few kilometers, as its vibrations would have collapsed everything, including Kremlin, the palaces and cathedrals around, and everyone in the surrounding area would have become death at the first ring. The bell named "Saint Peter", the largest bell on the Rin, is 3 meters high, weights 24 ton, and its sound is heard over more than 30 kilometers.

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 occidental 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 rang 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).

Fig. 1. *Core bell*

"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.

Fig. 2. *Fake bell*

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.

Fig. 3. *The biggest bell in Russia and the whole world is the "Tsar's Bell" or "The Empress' Bell", kept in Kremlin. It is put on a pedestal at the base of "Ivan the Great" steeple's tower. Its dimensions and art are still unequaled in the world*

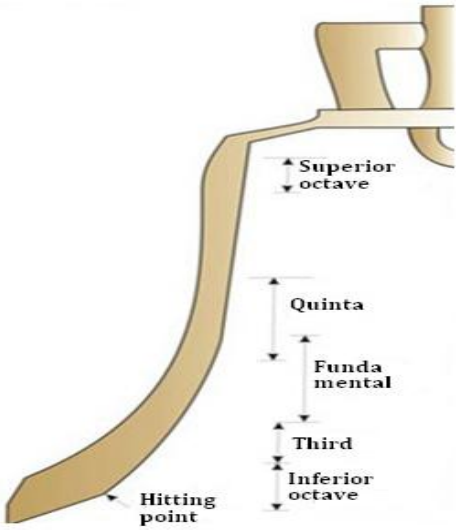

Fig. 4. *Musical tones of the bell*

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 analyse 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*

M1	*M2*	*M3*	*M4*	*M5*	*M6*	*M7*	*M8*
Special Bronze (20-22% Sn)	Industrial Bronze (6-14% Sn)	Special Brass	Alloyed Iron	Alloyed Stell	Al Alloys	Crystal	Ceramic

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*

Ci	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*p*
C1	0.5	0.5	1	1	1	1	1	0.5	0.5	0.5	7.5
C2	0.5	0.5	0.5	1	1	1	1	0.5	0.5	0.5	7
C3	0	0.5	0.5	1	1	1	1	0.5	0.5	0.5	6.5
C4	0	0	0	0.5	0.5	0.5	0.5	0	0	0	2
C5	0	0	0	0.5	0.5	0.5	0.5	0	0	0	2
C6	0	0	0	0.5	0.5	0.5	0.5	0	0	0	2
C7	0	0	0	0.5	0.5	0.5	0.5	0	0	0	2
C8	0.5	0.5	0.5	1	1	1	1	0.5	0.5	0.5	7
C9	0.5	0.5	0.5	1	1	1	1	0.5	0.5	0.5	7
C10	0.5	0.5	0.5	1	1	1	1	0.5	0.5	0.5	7

Weighing coefficients "Y_i" are calculated with Frisco:

$$Y_i = \frac{p + |\Delta p| + m + 0.5}{\frac{N_{CRT}}{2} + |\Delta p'|} \quad (1)$$

where: p - the amount on line points for each criterion;

Δp - difference between the criterion score and the score criterion taken from the last level;

m - number outclassed criteria;

N_{CRT} - total number of criteria;

Δp' - difference between the criterion score and the score criterion taken from the first level.

For each material were granted N_{ji} 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*

Ci	*p*	*level*	*Δp*	*m*	*N_{CRT}*	*Δp'*	*Y_i*
C1	7.5	1	5.5	9	10	0	4.5
C2	7	3.5	5	5	10	-0.5	4
C3	6.5	6	4.5	4	10	-1	2.666
C4	2	8.5	0	0	10	-5.5	0.238
C5	2	8.5	0	0	10	-5.5	0.238
C6	2	8.5	0	0	10	-5.5	0.238
C7	2	8.5	0	0	10	-5.5	0.238
C8	7	3.5	5	5	10	-0.5	4
C9	7	3.5	5	5	10	-0.5	4
C10	7	3.5	5	5	10	-0.5	4

Table 4. *Grades given according to performance criteria for the analysed materials*

Material symbol	*Grades given according to performance criteria*									
	C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*
M1	10	10	10	10	8	7	9	6	9	1
M2	7	7	5	10	8	7	9	9	8	2
M3	8	8	7	10	9	7	9	7	8	4
M4	5	5	5	7	8	4	8	5	1	8
M5	5	5	5	6	7	2	5	10	1	7
M6	5	5	5	9	10	10	9	8	9	8
M7	7	8	9	10	5	5	8	5	10	6
M8	5	5	4	8	3	3	10	1	9	10

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

$$F_{ji} = Y_i \cdot N_{ji} \quad (2)$$

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

$$FV_j = \sum_{i=1}^{i=10} F_{ji} \quad (3)$$

Table 5. *Calculation results of partial and total value coefficients and total value of analysed materials*

M	***Partial value coefficients, F_{ji}***										***FV_j***
	C1	***C2***	***C3***	***C4***	***C5***	***C6***	***C7***	***C8***	***C9***	***C10***	
M1	45	40	26.66	2.38	1.904	1.666	2.142	24	36	4	183.752
M2	31.5	28	13.33	2.38	1.904	1.666	2.142	56	32	8	176.922
M3	36	32	18.662	2.38	2.142	1.666	2.142	28	32	16	170.992
M4	22.5	20	13.33	1.666	1.904	0.952	1.904	20	4	32	118.256
M5	22.5	20	13.33	1.428	1.666	0.476	1.19	40	4	28	132.59
M6	22.5	20	13.33	2.142	2.38	2.38	2.142	32	36	32	164.874
M7	31.5	32	23.994	2.38	1.19	1.19	1.904	20	40	24	178.158
M8	22.5	20	10.664	1.904	0.714	0.714	2.38	4	36	40	138.876

Table 6. *Ranking of the materials used for casting bells according to the total calculated coefficient of performance*

Place	***Material symbol***	***Material description***	***FV_j***
1	M1	Special Bronze (20-22% Sn)	183.752
2	M7	Crystal	178.158
3	M2	Industrial Bronze (6-14% Sn)	176.922
4	M3	Special Brass	170.992
5	M6	Al alloys	164.874
6	M8	Ceramic	138.876
7	M5	Alloyed Steell	132.59
8	M4	Alloyed Iron	118.256

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.

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