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Structural Changes to the Floats in the Kakunodate Matsuri: Ingenuity for Winning the Festival Bumping Game

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The Kakunodate Matsuri, held in Akita, Japan, is one of the most game-like festivals in the country in which the festival floats are repeatedly 'bumped' against each other in order to win the right of way. We hypothesised that the accumulation of serious ingenuity by each community that has preserved and operated the floats to win in the 'bumping' might be reflected in the structural form of the floats themselves. To test this hypothesis, we constructed structural models of two floats, one new and one old, and carried out collision simulations. As a result, it was confirmed that the floats, which tended to concentrate the impact force at the front of the structure during a collision, were modified to distribute the impact over the entire structure, preventing axle damage due to stress concentration and at the same time reducing the impact on the musicians on board in the middle of the float.

This result is consistent with folkloric research that has pointed out that improvements have been made to the form, mainly by carpenters in each community managing and operating the floats. Minor changes have been made within the scope of conventional wood construction methods and blacksmith skills, suggesting that these efforts have collective intellectual value. From the structural changes to the floats, it can be confirmed that carpenters gradually improved the structures of the bearers, chassis parts, and musicians' space that protect people to meet site requirements. The existence of moderate skill and technology within everyday life and the continuation of community organizational structure to sustain them are understood as an accumulation of historical knowledge to win this game.

Keywords: festival float; bumping game; structural changes; ingenuity; collective intellect

1 Introduction

The Kakunodate Matsuri, Akita Prefecture, is a very famous traditional Japanese festival in which floats compete by raising their front wheels and repeatedly bumping into each other (Fig.1). This festival has a highly competitive character, in which the "power, strength and pride" of the people operating each float and the people playing the musical accompaniment on board are pitted against each other during the repeated bumping into each other's floats. In order to win this game, the continuous squeezing of wisdom and ingenuity seems to have been accumulated within the very form of the floats. It is essential that the structure is sturdy as the float moves around the town and repeatedly bumps into a competing float. Only then can the best float win following the rules of the game, under the serious involvement of the local area associations (*chonai*) and youth groups (Thompson and Fenton, 1987; Konno,1991; Konishi,2007; Yabe,2011). Some ethnographic researchers have also revealed that the forms of the float have been continuously improved up to now, mainly by the carpenters who lived in each local area. Nakamura (1971) suggested that the elements that make up this festival could be summarised as i) rivalry between townships, ii) pulling of the floats based on tradition, iii) participation of young people, and iv) robustness of the float structures in "Towns and *Matsuri*: The Case of Kakunodate-Matsuri-bayashi in Kakunodate-machi, Akita Prefecture". Moreover, she made quite an interesting observation in the Towns and *Matsuri*, namely that "*Incidentally, Kakunodate's float structure underwent several important improvements only during the Meiji Era (1868-1912). These improvements, however, did not go in the direction of decorating the float with decorative panels, splendid curtains, or mechanical devices, but rather in the direction of building a sturdy and mobile float that could be pulled freely by young men and not be easily broken even when 'butsuke bumping' occurred*".

The floats are inevitably required to be manoeuvrable and tough due to the bumping against each other that takes place. Furthermore, as ethnographic research has revealed, there were carpenters in each *chonai* (a local area smaller than a normal township) where the floats were preserved, developed, and pushed to the festival site every year (Thompson and Fenton, 1987). Moreover, it has been pointed out that these carpenters, who were strongly involved in their respective communities, played a vital role not only for Kakunodate, but also for the Gion Festival in Kyoto and other festivals (Tsubogou, 2008; Yabe,2011).

To the people of each local area, the festival became something akin to an all-out war. The wisdom, ideas, and thoughts of the local community, accumulated through repeated festivals in which the power and pride of each local area was put to the test under a unique set of rules, seem to have come together in the very form of the Kakunodate Matsuri floats. In this paper, an analysis of the form of the floats will reveal how that wisdom and ingenuity have been integrated into the structure to "win" against others.

Figure 1. Butsuke (bumping) of the floats in Kakunodate-Matsuri (Tsubogo,2013)

2 Structure of the float

In this study, twelve floats with representative dimensions (Tab.1) were compared in order to present an overview of the features and the transition in the time axis so that the tendencies of the changes to the structures, in which collective knowledge might be accumulated, could be observed.

2.1 The names of the structural elements comprising the float

The float of Yokomachi (one of the *chonai*), built in 1962, has been considered to be strong in the bumping event. For that reason, it is taken as an example, focusing on the names and dimensions that are representative of its structure, especially those that directly affect the characteristics required in the operation of the float.

Referring to the names in the diagram below (Fig.3,4), the main structure consists of the longitudinal base frame (*tate-dodai*) which corresponds to the chassis of a car, and the transverse base frame (*yoko-dodai*) which connects it to the left and right. This lower level structure, through the vertical timbers (*tsuka*), braces (*sujikai*) and posts (*hashira*), is connected to the middle level structure that is a rectangular frame structure consisting of the front frame (*mae-tage*), the side frame (*yoko-tage*) and rear frame (*ushiro-tage*) on the left and right, which form the horizontal centre of the float. The frame structure in the middle level of the float is used as a stage on which a decorative object like a mountain (*yama*), small room (*mizuya*) in front of the decorated *yama* in which the musicians play musical accompaniments, and the stage for the dancers are placed. In general, *yama* tends to have three meanings. One of them is to denote an object like a rock mountain and another denotes the whole structure of the float. Moreover, *yama* sometimes refers to something like a living organism consisting of the float itself and the people taking part in the festival while pulling the floats (Tsubogo,2013). It may be that, partly because of this, *yama* is gradually changing its meaning.

2.2 The structure designed to withstand the *butsuke* bumping competition

What is characteristic of the structure of Kakunodate Matsuri floats is that they have been specifically designed to withstand the force of impact during the climax of the festival (namely, the *butsuke* bumping competition) and to protect the musicians, dancers, and the float themselves.

Figure 2. the float of Yokomachi-Wakamono (Tsubogo,2013)

The floats meet each other as they move through the streets of local neighbourhoods (*chonai*). When this happens, if "negotiations" over the right of way break down, the floats that meet each other as they move through the town perform this clash of the floats (*butsuke*), in which the front frames (*mae-tage*) violently collide with each other and push into each other.

According to records, there were cases where a single float was attacked by two floats, one from the front and one from the rear. The impact force applied to the front frame (*mae-tage*) and rear frame (*ushiro-tage*) during this clash would be transmitted to the base frame (*tate-dodai*) via the braces (*sujikai*) and, along with the entire frame structure, would apply a large force to the front and rear axles (*shinbou*). This way of transmitting the impact force would damage the axles, making it impossible to operate the floats, and according to the rules of the festival, the floats would be disqualified, which would have been humiliating for the neighbourhood and the 'young people' (an organization of young people) who owned the floats (Konno,1991).

Furthermore, as each float is only allowed to pass through the same *chonai* once, mobility is required to avoid clashes (*butsuke*) with other floats in order to clear the checkpoints while reading the movements of the other floats. It is easy to predict that this mobility and manoeuvrability could be influenced by the distance between the front and rear wheel axles (*shinbou*). If the distance between the axles is short, the turning capability may be improved at the expense of straightness, and it seems possible to move flexibly at the 'last minute' in the festival.

On the other hand, reducing the distance between the axles (*shinbou*) can also lead to an unstable situation, where the festival float can relatively easily tilt in the pitching direction when forces are applied to the front frame (*mae-tage*), so that forces are transmitted intensively to the rear wheels. It is easily understood that further instability also tends to be induced by the horizontal distance between the front frame and the front wheel axle. If the distance is long, the vehicle may be more stable and the wheels will be less likely to lift off the ground, but turnability will be reduced and manoeuvrability may become a problem. It is also important to reduce the impact on the musicians (*ohayashi*), who continue to perform during the clashes (*butsuke*).

Table 1. Floats dimensions

float's name	a. Axle width	b. Horizontal distance between the front wheel axle centre and the front flame	c. Overall width	d. Total length	e. Vertical distance between the whell axis centre and the side frame	f. Vertical distance between the whel axle centre and the gland line	Remarks
Hokubu	1985	2500	2780	6620	1035	1440	Purchased from the town of Hadaj in 1966 and started to pull. Newly built in 1968.
Chuo-dori	2110	2180	2730	6555	1033		
Nishikatsuraku-machi	1995	2155	2765	6180	1140	1475	
Seibu	1925	2135	2865	6355	1095		Newly built in 1975.
Iwase	1940	2330	2805	6690	1110		The first float was new in 1937 and the second in 1975.
Honmachi-dori	1750	2695	1905	6740	1170		
Eki-dori	2065	2385	2910	6795	1160	1525	
Eki-mae	2215	2210	2780	6400	1170		Newly built in 1964.
Sgasawa	1845	2390	2975	6285	1095		
Toubu	1670	2285	2730	6355	1065	1420	
Kami-shinmachi	1820	2430	2935	6725	1095		
Yokomachi	1855	1950	2845	6415	1090	1435	Newly built in 1962. Second generation newly built in 1992.
						unit: mm	

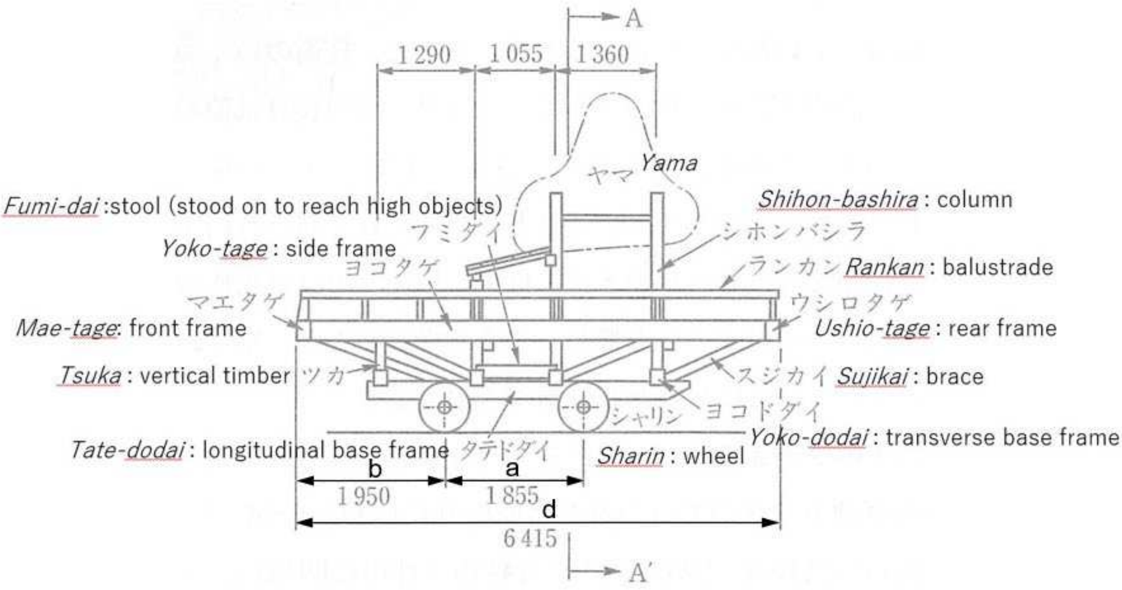


Figure 3 Left-side view of the float (Tsubogo,2013)

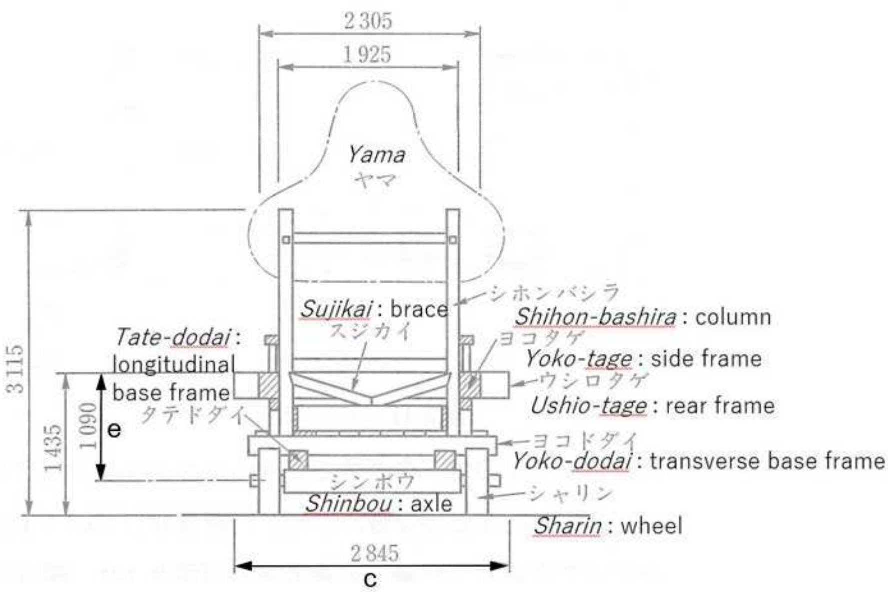


Figure 4 Front-side view of the float (Tsubogo,2013)

According to one of the rules of the festival, if the float can no longer facilitate the playing of the musical accompaniment, it is deemed to have lost the battle. Since the musicians perform in the *mizuya* in front of the area where the *yama* is located on the float, it is necessary to ensure that the impact force is transmitted to the *mizuya* as little as possible during clashes. Several structural strategies can be considered for mitigating the transmission of these impact forces. One of these is local impact force absorption in the front structure from the front frame (*mae-tage*) to the front wheel axle (*shinbou*) area. Another is a method of dispersing the impact forces throughout the entire chassis, consisting of the front frame, both side frames (*yoko-tage*), the rear frame (*ushiro-tage*), the left and right longitudinal base frames (*tate-dodai*) to which the axle is attached and the front and rear transverse base frames (*yoko-dodai*) connecting the longitudinal base frames.

2.3 Classification of the float structures

A principal component analysis was carried out on the 12 floats whose dimensional data had been accurately recorded. Specifically, the following five dimensional items were analyzed: **a**. the axle width, **b**. the horizontal distance between the front wheel axle and front frame, **c**. the total width, **d**. the total length, **e**. the vertical distance between the axles and the side frame in order to classify the structure of the floats in Fig.3,4. These parameters tend to effectively explain the dynamical features of the floats. Moreover, the floats have been mapped with the parameters according to the principal component analysis (Figure 5).

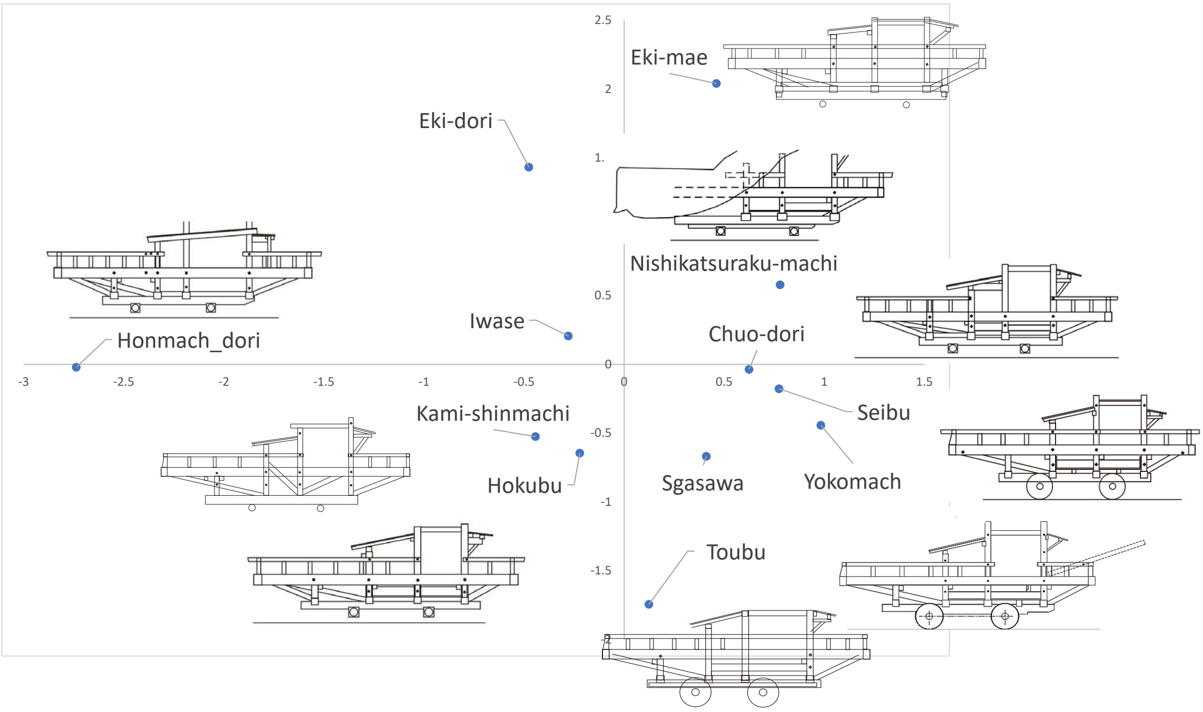


Figure 5 Floats mapped according to the principal component analysis

Table 2. The principal factors of the floats' dimensions

	1sr factor	2nf factor	3rd factor	4th factor	5th factor
distance between the front axis and rear one	0.167	0.685	0.353	-0.695	0.457
horizontal distance between the the front frame and the front axis	-0.409	-0.075	0.211	0.176	1.395
overall width	0.367	0.01	0.402	1.095	0.388
overall length	-0.319	0.125	0.674	0.241	-1.02
vertical distance between the the side frame and the front axis	-0.182	0.597	-0.526	0.751	-0.143

It can be seen from the table that the Honmachi-dori float is relatively longer than the other floats and is also characteristically positioned in the principal component analysis, being located on the left side of the 1st principal axis. It is interesting to note that the Yokomachi float, which is considered to be the strongest in the bumping, is positioned opposite the Honmachi-dori one. In checking the meaning of the horizontal and vertical axes of this scatter diagram, it can be seen that the floats positioned on the right side are more strongly influenced by the overall width according to the principal component scoring coefficients in Table 2, while the horizontal distance from the front axis to the front frame tends to be longer in the floats positioned on the left side, and the overall length tends to increase as well.

This geometrical tendency is confirmed by the distance from the front wheel axis to the front frame and the overall length divided respectively by the overall width of each float (Fig.6). The results show that the Honmachi-dori float, which has a large aspect ratio, is markedly longitudinal. Although there are no notable differences in the aspect ratios of the other floats, it can be seen that the front structures of the Yokomachi and Seibu floats, i.e. the structure from the front frame to the front axle, seem to be more horizontally spread than the other floats. However, this structural characteristic has yet to be reconciled with the reasons why the Yokomachi float is considered the strongest. It may be one of the interesting tendencies of the float.

Similarly, checking the values of the second principal component shows that the arrangement of the floats along the vertical axis in the figure 5 scatter diagram seems to correspond to the size of the area multiplied by the distance between the front axis and the rear one [a] and the distance from the axis centre to the top of the side frame [e] shown in the Figure 7.

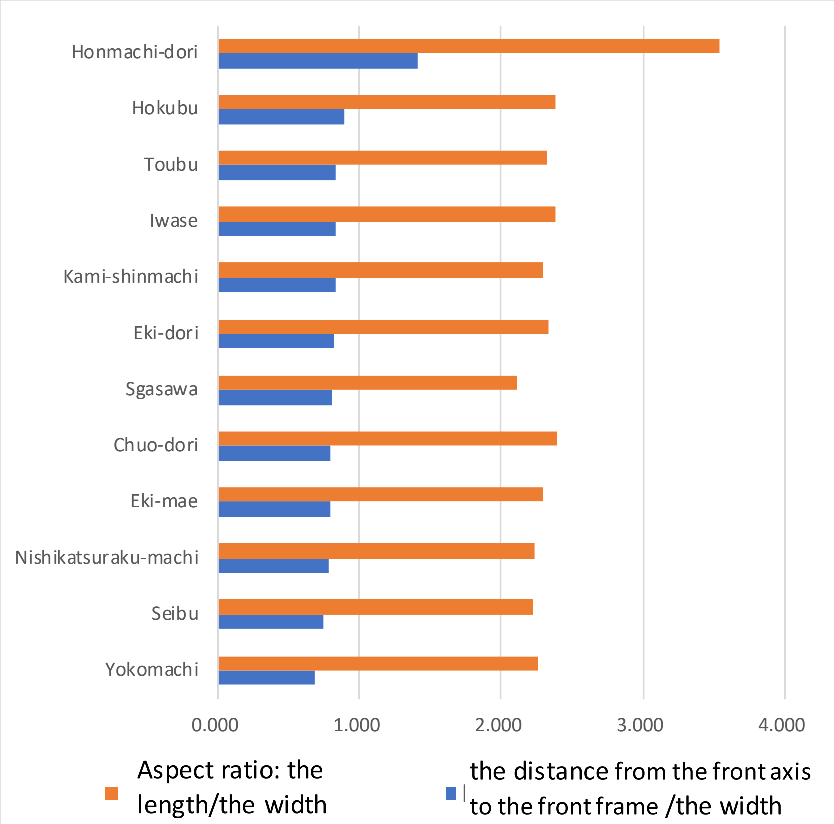


Figure 6 Aspect ratio and the distance from the front axis to the front frame

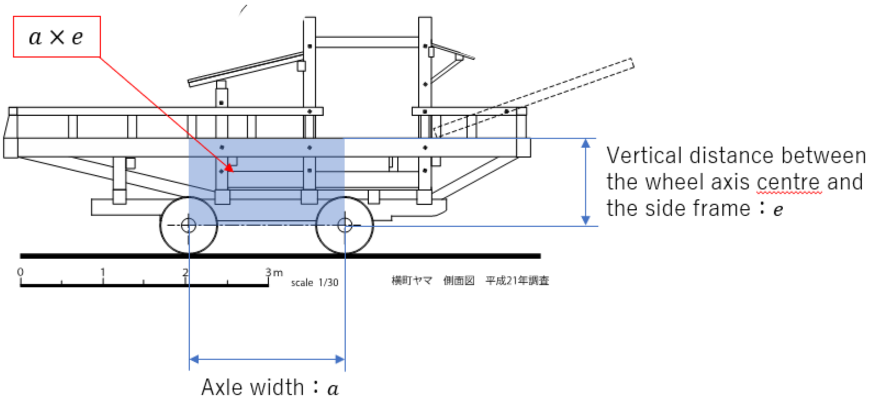


Figure 7 The $a \times e$ to the 2nd principal component analysis

The values a × e in table 3 are expressed as a ratio of the maximum area of the float called Eki-mae (meaning 'in front of the station'). It can be confirmed that the larger this area ratio is, the higher the area is placed on the upper part of the vertical axis of the principal component analysis, clearly indicating the differences in the characteristics of the mountain structure centre. It seems that the possibility of improving mobility and strength by reducing the area here cannot be ruled out. Moreover, the tendencies of the structural changes have affected the tactics of *butsuke* and the traditional bumping style (Fig.1), in which raising the fronts of the floats and bumping into each other. has been realized.

Table 3. The comparison of the $a \times e$

float's name	a. Axle width	e. Vertical distance between the whell axis centre and the side frame	a×e	standartized a×e
Eki-mae	2215	1170	2.592E+06	1.000E+00
Eki-dori	2065	1160	2.395E+06	9.243E-01
Nishikatsuraku-machi	1995	1140	2.274E+06	8.776E-01
Chuo-dori	2110	1033	2.180E+06	8.411E-01
Iwase	1940	1110	2.153E+06	8.309E-01
Seibu	1925	1095	2.108E+06	8.134E-01
Hokubu	1985	1035	2.054E+06	7.928E-01
Honmachi-dori	1750	1170	2.048E+06	7.901E-01
Yokomachi	1855	1090	2.022E+06	7.802E-01
Sgasawa	1845	1095	2.020E+06	7.796E-01
Kami-shinmachi	1820	1095	1.993E+06	7.690E-01
Toubu	1670	1065	1.779E+06	6.863E-01

2.4 Structural comparison between the floats of Yokomachi and Kami-shinmachi

The comparison of dimensions in the previous section shows that the distance from the front frame to the front wheel axle centre is only 50 cm longer in the Kami-shinmachi float than in the Yokomachi float, but the overall dimensions are similar (Fig.8). There are traces of consideration for the increased strength of the structure by placing the brace (coloured yellow) in the lower centre of the Kami-shinmachi float, but the horizontally placed boards surrounding the lower centre of the Yokomachi float appear to be more effective in increasing the strength of the structure. In addition, the brace extending into the front frame appears to be more elongated in the Kami-shinmachi float and, moreover, the angle from the horizontal appears to be shallower. The shallower angle is more direct in receiving horizontal impact forces from the front frame, but the slender and longer construction means that buckling is more likely to occur, and when comparing the Yokomachi and Kami-shinmachi floats, the front structure of the Kami-shinmachi float seems to be slightly weaker.

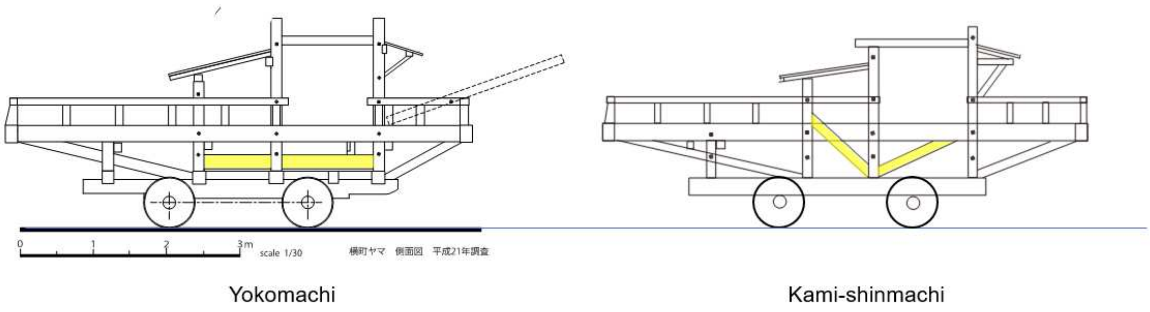


Figure 8 Yokomachi and Kami-shinmachi

2.5 Structural comparison between the floats of Yokomachi and Honmachi-dori

The central lower part of the slim Honmachi-dori float, which has the largest aspect ratio (Fig.6), is a frame structure without long braces or side-plates. The two braces extending from the front wheel axle to the front frame appear to take the force of any impact on the front frame. If most of the impact is not properly transmitted to the longitudinal base frames, the central lower part of this structure, which is neither a truss nor a rigid frame (rahmen), is likely to be insufficiently strong. It is not expected to function structurally in such a way that the whole structure of the float, as seen in the Yokomachi design, could be subjected to the impact. With the structure of the Honmachi-dori float, the impact forces in the event of a bump are likely to be concentrated in the front part of the structure.

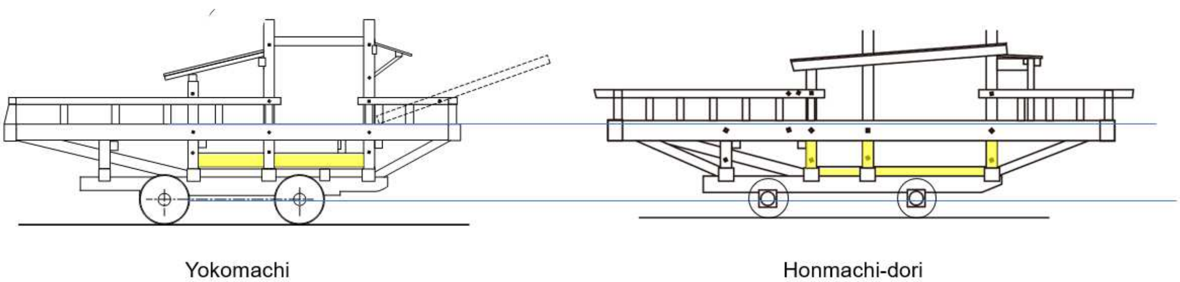


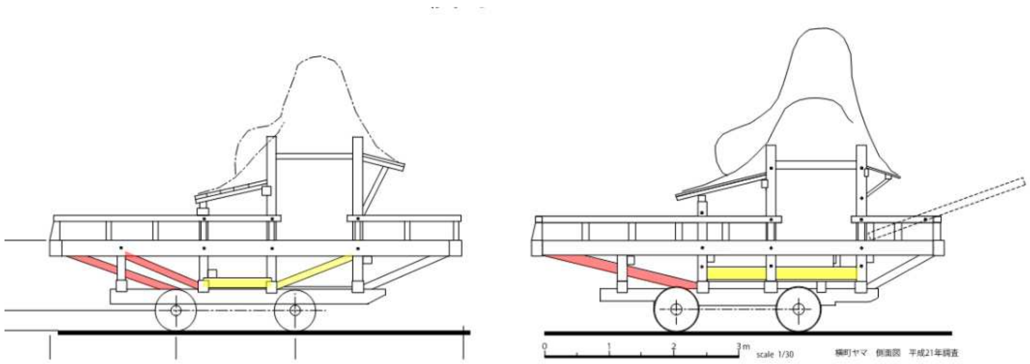
Figure 9 Yokomachi and Honmachi-dori

3 Changes in the float – the structural changes in the two floats of Yokomachi-Wakamono *yama*

The Yokomachi-Wakamono *yama* that has been constructed and improved continuously in the Yokomachi local area (*chonai*) has had the reputation of being one of the strongest *yama* in the game (Konno, 1991). A structural comparison has been made between the float built in 1962 and the float that continues to be used to the present day (Tsubogo,2013) in order to observe the transition of the float. In this comparison, an attempt has been made to explore the engineering meaning of the changes in the structure of the float through physical simulation in a 3D CAD model reproduced from drawings, rather than merely through a simple consideration and comparison based on side views as in our previous investigations.

However, at first, from the lateral view (Fig.10), some striking differences between the float of the 1989 survey on the left and the float of the 2009 survey on the right can be seen in the braces (highlighted in red) connecting the front frame to the base frame and the central transverse plate (highlighted in yellow) set out in the figures. In the float of the 1989 survey, there are two braces (one on each side) which are relatively short and thin in the front part of the float. In contrast, the brace of the float of the 2009 survey is long and thick. The central part of the 2009 float appears to be composed of a single high horizontal board (highlighted in yellow, right), whereas the central and rear parts in 1989 are composed of shorter horizontal beams and braces (highlighted in yellow, left).

The structural differences between the two float structures, which can be clearly seen from this side view, are that the structural elements (or structural members), such as braces and beams or plates, of the 2009 float tend to be longer in the front-back direction than those of the 1989 float, and the entire structure of the 2009 float is composed more continuously and simply.



the 1989 survey
(Built in 1962)

the 2009 survey

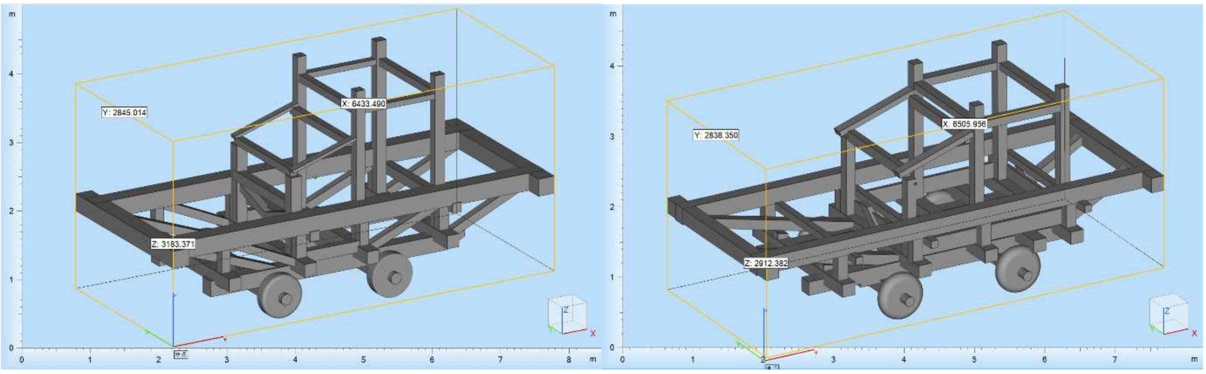
Figure 10 the two floats of Yokomachi (Tsubogo,2013)

3.1 3D models according to side and cross-sectional views of the floats

The basic structure of the float is symmetrical with respect to a vertical plane that includes the long axis that passes backwards and forwards through the centre of the structure. The float structure is basically a simple frame structure, consisting of truss, rahmen structures and a flat plate structure, using transverse plates. The structural elements that make up each local structure are basically only rectangular cross sectional square timbers and flat plates, except for the axles and wheels, so the 3D model can be easily reproduced from drawings of left-hand side view and cross-sectional view(Fig.3,4).

First, the side view is traced in a drawing tool or CAD and, using the cross-sectional view as a reference, the 2D drawing of each structural element is thickened and defined as a solid model using the extrusion function of the CAD. As the elements are symmetrical, most elements are created as either left or right parts and 'duplicated' and 'moved' according to the cross-sectional view to easily construct the 3D structure of the float (Fig.11). A 3D model was constructed in which consistency between the side view and the cross-sectional view was ensured. The floats of the Yokomachi-Wakamono model which were surveyed in 1989 and 2009 are shown in Figure 11. Through this 3D modelling, it is possible to check the dimensions of each part, the state of arrangement of each structural element, and the way the elements are connected. In addition, other structural features can be grasped concretely. In particular, it is easy to identify the structure of the rectangular-shaped frame in the middle of the chassis between the front and rear wheels. The specific three-dimensional structure of this part is difficult to grasp from the given side view and cross-sectional view alone, but by making it 3D, the features of the structure become clearer.

The Yokomachi float surveyed in 2009 was similarly modelled to check the structure from a free viewpoint in a 3D-CAD system and the model was adjusted so that a 'bumping' collision simulation could be carried out.



the 1989 survey the 2009 survey

Figure 11. 3DCAD-model of the YOKOMACHI float

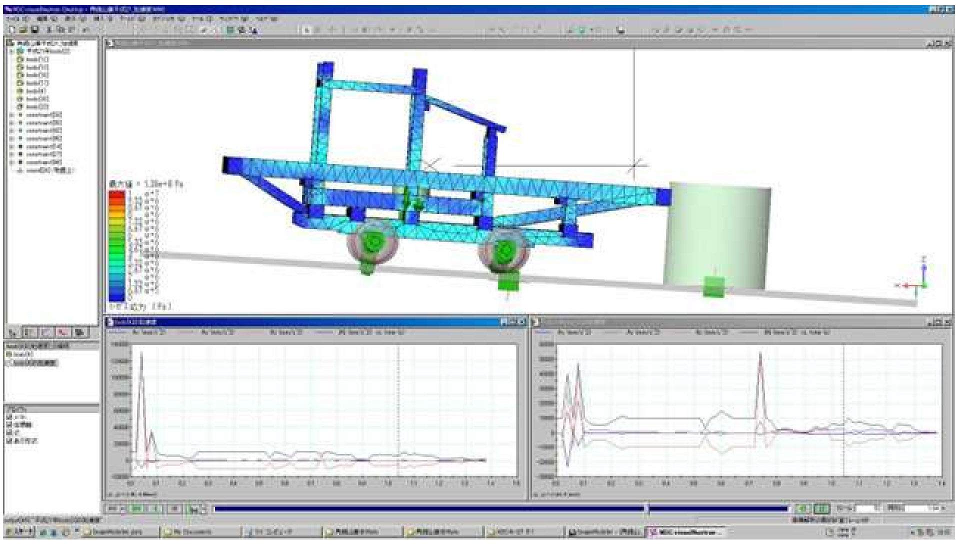
3.2 **Crash simulation of the float CAD model**

SAT data (one of the neutral files of 3D feature data) of the 3D models of the floats, created according to the side and cross-sectional views, was imported into SimWise4D (one of the mechanical and structural simulation applications) and a dynamical simulation was carried out under a condition of collision. The frames of the 3D model float imported into SimWise4D were converted into a physical simulation model according to the finite element method, where the properties of the materials (elastic modulus, Poisson's ratio, etc.) comprising each frame are given virtually in addition to shape information. The finite element method, briefly explained here, divides a structure of an arbitrary form into small elements (called finite elements because their size is finite rather than infinite) including information on physical properties represented by the material properties. It then mathematically models the structural properties of each small element, and finally constructs a mathematical model of the entire structure according to the positional relationships between the small elements.

3.3 **Comparison of the structural properties of two floats**

The physical simulation visualizes dynamic changes in the distribution of the internal forces/stresses (Mises stress: a measure of the average magnitude of stress due to axial and shear stress) transmitting through the elements comprising the float as it descends a slope from left to right and strikes a cylinder fixed to the slope(Fig.12). Intuitively, the closer to red in the stress gradient, the higher the stress, and the closer to blue, the lower the stress.

the 1989 survey



the 2009 survey

Figure 12. Crash simulation

Simulations have been carried out for each of the floats from the 1989 survey and the 2009 survey, both in Yokomachi, to compare the distribution of stress during the collision. This comparison reveals force transfers in the collisions which are markedly different in the case of two braces or one brace extending from the front centre of the chassis to the front frame which are the characteristic structural elements observed from the sides of the floats. In the float surveyed in 1989, a remarkable concentration of stress can be seen in the front frame and the braces extending from it (red-coloured part in Fig.10). In addition, the yellow-coloured part that follows the red part is also distributed from the front frame to the lower centre along the longitudinal axis of the braces, and it is easy to imagine that the strength of an impact may be directly transmitted to the part in which the musicians are performing. In contrast, the float surveyed in 2009 clearly differs from the 1989 float in that there is no concentration of stress. Stress of similar magnitude seems to be evenly distributed as the entire structure of the float tends to be pale coloured, comparatively. This indicates that the impact at the time of the collision is not concentrated in the front part, but distributed over the entire structure in the 2009 float. The stresses around the horizontal plates to the centre are particularly low (the 2009 survey in Fig.12). It suggests that there may be little impact on the musical accompaniment. Since one of the rules of the festival is that the music should not be interrupted during the 'bumping', the low impact on the central part must be one of the most important points of the float design, on the same level as avoiding the inability to operate the float due to local damage caused by stress concentration.

In conclusion, it could be confirmed that the differences in the arrangement of the braces and the structure of the central part, which receives the force transmitted from the braces, have a significant effect on the differences in the structural characteristics of the whole float, and that these differences in the characteristics work effectively in the 'win or lose' drama of the festival.

4 Discussion

In this report, we analyzed how the structures of the floats, which seem to be strongly affected by the changes in the tactics of the game known as *butsuke*, have been changed or improved. We carried out this analysis by means of a numerical collision simulation of a CAD model of the float as well as through interviews with stakeholders of the Kakunodate Matsuri and reviews of relevant valuable documents written by researchers, organizers, and players. From the results of the structural analysis of the floats presented in previous sections and the results of the crash simulation, what can be learned about the changes in the form of the floats is as follows:-

1) The braces have been changed from short, thin squared timbers to long, thick ones. The change has reduced the number of parts, simplified the structural form, and improved the structural efficiency. The braces are parts that support the framework of each float, and their shapes, way of placement, and number are closely related to the structural characteristics of the float. The long, thick braces show an anticipation that the structure will have the effect of dispersing impact force so the float could receive the impact force not partially but entirely. According to an ethnographic assessment of the float structure, it could be suggested that the structural changes were an inevitable improvement aimed at new tactics to win the game when transitioning from bumping with all four wheels on the ground to colliding and competing with the front wheels lifted (Fig.1). Moreover, it has been more necessary to reinforce the structure of the float in order to avoid the rear wheel axle in particular being broken in the *butsuke*.

2) The structural changes have affected the centre of gravity and stability of the floats in accordance with a change in tactics regarding the *butsuke*. When all four wheels were on the ground in the bumping game, the centre of gravity of the float was low and the stability was high, but after the tactics changed and it became the norm for the front wheels to be lifted up, the centre of gravity tended to rise, and the stability also seemed to decrease. At same time, the movability of the floats was improved and the bumping game seemed to become more attractive for the players and the visitors to the Kakunodate *Matsuri*.

3) When the tactic changed from keeping all four wheels on the ground to lifting up the front wheels, the structures of the floats tended to converge on the same material (shifting from cedar to zelkova), and a pretty similar simplified structure. This phenomenon could be called 'form integration in a process of optimization'. The form integration has the effect of improving balance and operability by standardizing weight and shape. From these observations, it can be seen that the change in tactics has had a great impact on the structural changes to the floats.

Finally, it could be suggested that the change in tactics caused problems related to the centre of gravity and stability of the floats. To cope with these, the floats were reinforced, simplified, and improved in terms of efficiency, and they converged on similar designs. These structural changes have enhanced the functionality and durability of the floats and also seem to have expressed a kind of structural beauty and individuality in the game.

5 Conclusion

From a folkloristic survey of the Kakunodate Matsuri, it has been pointed out that there is ingenuity in the way in which the town's professional workers/carpenters who have traditional woodworking techniques and ironworks technology have been continuously acting as leaders, sharing their structural knowledge and making minor changes to the shape of the floats in conjunction with the inhabitants who are the actual participants of the festival. This study examined whether the aforementioned ingenuity has structural significance or not and whether that ingenuity, which is a collective wisdom within the community that does not rely on expert knowledge, is rational or not.

Specifically, the structures of the floats were modelled using CAD and collision simulations were performed. As a result, it was confirmed that the ingenious design dissipates the impact force concentrated on the front frame of the float throughout the entire structure, thereby reducing the impact on the chassis and axles while avoiding transmission of impact force to the *mizuya* area around the centre of the float. It was suggested that this "historical accumulation of wisdom," which is motivated by a desire to "win at the festival," may lead to optimization of the float structures.

Finally, we would like to stress that the Kakunodate festival floats are a cultural totality, influenced not only by their history and cultural background, but by their need to be created, improved, and sustained by the people in the chonai for winning the festival butsuke game. For this game, which is one of the most important element*s* of the festival, the structures of the floats must have evolved in order to increase the strength, stability and manoeuvrability required to win the game, as that evolution could be confirmed objectively by using the collision simulation with 3D-model.

Furthermore, the evolution also seems to serve as a means of expressing the beauty and individuality of each float. The structural changes are not limited to their form and materials, but also include the feelings, awareness, wisdom, techniques and ideas of the people involved in their production and operation. The festival, with the float at its centre, should be closely related to people's lives, culture and society. The structure of the float seems to have expressed people's creativity, cooperation, enjoyment and pride experienced in their daily lives.

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