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Design Parameter Structure for Architectural Elements of External Kinetic Facade

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ABSTRACT

Purpose: This paper aims to analyse the composition system of architectural elements including shape, kinetic and material elements of kinetic facades and establish the design parameter system as a common conceptual and practical knowledge sharing platform with mechanical and electrical experts.

Method: This research has been conducted in a three steps. At first, 120 cases of external shading devices are analyzed and their classification criteria have been established. Secondly geometric, kinetic and material elements are categorized in a common kinetic facade coordinates system considering environmental effects and operation method, and the applicability of combination of each element are tested. Lastly core design parameters for each element have been established in a common office building installation coordinate.

Result: Geometry elements are categorized into seven geometric shapes and kinetic elements is categorized into basic linear and rotational motion and combinational folding and rolling motion. The combined set of parameters for three elements composes the whole design parameters for architectural elements of kinetic façade. Design parameters of shape elements are composed of shape, installation and arrangement parameters; design parameters for kinetic elements are composed of axis and range parameters; and design parameters of material elements are composed of thermal, lighting and color parameters.

KEYWORD

kinetic facade
External shading device
geometry parameter
kinetic parameter
material parameter

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1. Introduction

1.1. Background and purpose of study

Boosted by the international interest and the building energy saving innovative measure of government for the energy saving according to the global warming, the countermeasures for energy saving in construction sector have been increasingly required. Especially the increased demand for cooling energy in summer caused from the excessive use of glass in the enclosure of business facility is No. 1 target for energy saving[1-2]. In order to reduce the excessive sunshine heating , the minimization of opened area of external building, the window planning according to direction and shading installation are applied [3]. But the maximization of external opened area and window planning according to directions have no choice but to be restrictively applied. The installation of proper shading to control the sunshine input has the high efficiency and applicability[3-4].

It is a recent trend that the regulation for the installation standards have been enacted and the request for introduction has continuously increased. While it is general to install blinds indoor or to use the fixed type shading outside of building in domestic shading market[5], it is advantageous to install the shading outside of building rather than indoor to save the cooling load caused from sunshine[4], in case of installing a fixed shading, it has the limitation for the seasonal demand, solar trajectory and user's control demand[6].

As a countermeasure to solve this problem, the design technology of kinetic facade, which applied shading to the outside of building, is possible[7]. Kinetic facade refers to the enclosure system moved by the order or external environment, when applying a shading unit to outside of building, opening and closing of shading will be controlled in accordance with weather and temperature, which can compensate the limitation of fixed type shading and the realization of eco-friendly enclosure system [7]. The active study on shading and kinetic facade has been performed earlier oversea, the actual cases in which external typed shading device is applied appear based on this study[*Fig.2*, *3*].

But we have fewer domestic cases as we lack of studies and technology development for kinetic facade. The most representative case includes 'Yeosu Expo theme hall' in which the opening and closing of vertical shading is controlled with a compressive force by using elastic material, the planning case is not expanded. In order to plan the kinetic facade, the integrated linkage by construction, environment and control professionals is

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required during all the process covering plan, construction and operation different from traditional architectural design, the comprehensive study is required for the detailed execution in each stage.

Futhermore, kinetic facade still falls short of the academic base in which we comprehensively understand the kinetic facade to develop and expand through this as the suggestion to emphasize the singularity of operation has been highlighted.

This study aims to provide the cognitive base in which the participants of all the areas can make communication smooth by sharing the initial stage for the kinetic facade design as the first stage of this comprehensive study, it is to establish the integrated plan structure is composed of architectural elements and design parameter of kinetic facade.

1.2. Method and range of study

Study was roughly performed by the process, the first, establishment of classification criteria for Architectural Elements of Kinetic Facade, the second, the establishment of classification and type of architectural element of kinetic facade and feasibility review of new design type, the third, the process of systematization and the establishment of planning elements by architectural elements.

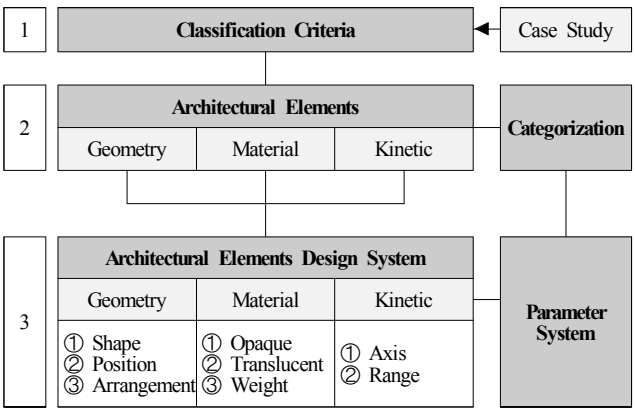


Fig. 1. influx diagram of study

The establishment of classification criteria for elements collected total cases covering the most basic type to modified type of kinetic facade through internet search based on the cases of domestic and international shading and facade books[8-13], set 3 dimensional coordination of x,y,z to objectively understand and compare the Geometric shape and operation type.

For the classification of elements, we categorized the type of shape, kinetic and material which are the cores of architectural elements based on coordination into the basic elements and detailed elements to establish the architectural elements structure of kinetic facade. Based on this, the alternatives with the potentiality of future development were searched by combining the kinetic elements that are applicable by each shape elements and naming as 'geometric elements + kinetic elements'.

Finally, we drew the major design elements by each element, schematized and established systematically so that major architectural elements can apply the integrated plan utilizing parametric design for the future development of kinetic facade. Especially in case of kinetic element, which the close cooperation is required with mechatronics plan and control plan, we searched the possibility which can be utilized as an actual design platform by performing the element analysis of element level.

2. Type and combination of shape-kinetic elements

2.1. Classification criteria of shape, kinetic type of Kinetic Facade

To research the classification criteria through cases of kinetic facade that already developed, 'Thyssenkrupp quartier'[*Fig.2*] is designed to compensate the angle in which vertical type shading can't block sunlight by rotating a long shade a full 360degree vertically in accordance with the an incidence angle, 'Kiefer

Fig. 2. ThyssenKrupp Quartier https://www.thyssenkrupp.com/en/presse/bilder.html&photo_id=1126 (accessed on 16 January 2016)

Fig. 3. Kiefer Technic Showroom http://www.archdaily.com/89270 (accessed on 16 January 2016)

Technic Showroom' [*Fig.3*] is planned to compensate the shortcoming of surface typed shading in which it is hard to secure clear view by operating surface type shading parallel with facade surface with folding type.

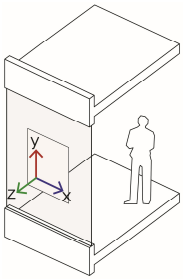
In other words, the planning elements of Kinetic facade include, the first, the shape element that is the target of operation so that it can be operated in accordance with the intended order to make the dynamic change of enclosure, the second, kinetic element that can make the various typed movements automatically in accordance with the user's operation command or intended algorithm not depending on the direct operation of residence, both of them are combined and planned comprehensively.

The shape element generally forms the basic unit which is arrayed to total facade, the basic units are categorized in details in accordance with the shape and the arrangement method. Also the kinetic planning elements that make the unit of Kinetic facade move are composed of a series of structure which includes the central process device equipped with algorithm calculating function to execute based on the movement type, sensor device which collects and send data for calculation and actuator which executes the movement in accordance with the control command[7].

As the terms that call each type of shape element and kinetic element are very various, it is required to arrange and organize the comprehensive criteria the currently and commonly used terms in order to compare and select in the stage of planning. Especially in case of the kinetic element, its various types have been developed but it is needed to systematize the plan of kinetic elements by analyzing them with basic kinetic principle.

Therefore in order to analyze the similarity and difference between shape element and kinetic element and to draw the type, this study set Kinetic facade coordinate system[*Table 1*], compared and analyzed the shape element and kinetic element about 50 fixed type shading devices, 69 variable type shading devices collected from the cases study based on this to draw the type.

Table 1. coordinate system for kinetic facade design elements

Diagram	Precondition
	① Y axis is an direction perpendicular to a horizontal floor, which is a datum line for other axises.
	② X axis is an direction rotated 90° clockwise from Y axis, and composes a facade combined with Y axis.
	③ Z axis is an extrusion axis perpendicular to a X-Y facade.

2.2. Shape element type of Kinetic facade

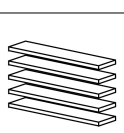
The factor to determine the shape of shading can be categorized into the functional aspect[8] such as sun heat blocking, shading angle control and private life protection and the design function to express the designer's intention and symbolization. The shape elements of functional aspects can be categorized 7 in total. The function of shading is determined in accordance with the geometrical shape first, various types have been developed to compensate this. The geometrical shape of shading can be categorized into the horizontal type which responds to high altitude sun, the vertical type which responds to low altitude sun and surface type which maximizes the feasibility for the environmental control parallel with facade. The grid type in which vertical and horizontal type is combined, the louver type in which the horizontal type inverted to Y-axis, the overlapped type in which surface type is arrayed to Z-axis, the array type arranged on X-Y surface are added for complex utilization so total 7 shapes can be categorized as shape elements.

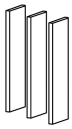
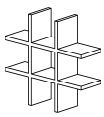
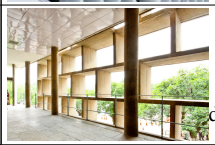
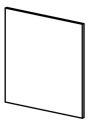
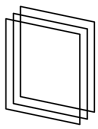
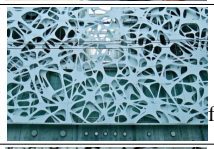
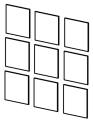
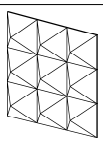
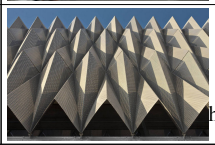
The horizontal type is one of the shading to block the sunlight coming into the close angle with the normal line of high altitude facade, it appears in protruding to the normal line, Z-axis with X-axis variables in coordinating system. The horizontal type is sub-categorized into overhang type and louver type in accordance with the installing type.

Overhang type[*table 2*, ①] can secure the overview as it is visually opened and it can control the direct sunshine as the structural body with individual body is located to the top of facade. Overhang type can't control the glare and influx of solar heat caused from diffused light and reflected light as it has no shading body to block in the glass to secure overview.

Arrayed at regular interval to the height direction in front of facade, Louver type [*table 2*, ②] can control the direct sunshine, diffused light and reflected light more detail than overhang type but it is more difficult to secure overview.

Table 2. classification of shape elements

Geometry	Type	Example	
Horizontal	① Overhang		 a)
	② Louver		 b)

Vertical	③ Fin		 c)
Grid	④ Grid		 d)
Plane	⑤ Basic		 e)
	⑥ Overlap		 f)
	⑦ Array		 g)
Cubic	⑧ Cubic		 h)

a) *http://www.rdsherrill.com/work/5/spring_mountain_1 (accessed on 16 January 2016)*
b) *http://www.solaripedia.com/13/92/783/devonshire_building_louvers_(uk).html (accessed on 16 January 2016)*
c) *http://www.acca.it/euleb/en/p19/index.html (accessed on 16 January 2016)*
d) *https://www.flickr.com/photos/scottnorsworthy/albums/72157624641131396 (accesed on 16 January 2016)*
e) *http://www.solashade.com.au/blog/how-to-choose-the-best-outd oor-blinds-in-perth (accesed on 16 January 2016)*
f) *http://faulders-studio.com/AIRSPACE-TOKYO (accesed on 16 January 2016)*
g) *http://www.seangodsell.com/rmit-design-hub (accesed on 16 January 2016)*
h) *http://www.archdaily.com/229821/cib-vaillo-irigaray-galar (accesed on 16 January 2016)*

Vertical type[*table 2*, ③] is applied when it is required to secure the view of certain level by blocking the sun light coming from a far angle with the normal line of facade at the low altitude, it appears in the shape having Y-axis displacement in coordination system and protruding to normal line Z-axis. The vertical type directly control the direct light, diffused light and reflected light of sun as it is arrayed at the regular interval to the length direction of facade. The view securing is the similar with Louver type.

As the vertical type and horizontal type has a contrast shape, its function is opposite, the grid type compensated this contrast function.

The horizontal type Louver and the vertical type Fin were used together in latticework , The grid type[*table 2*, ④] appears in the shape in which the displacement value of X-axis protruded to Z-axis and Y-axis displacement value regulate the size of grid. Regardless the height of sun and the incident angle with normal line, the grid type is applied when controlling the amount of sunshine and securing the view of certain level at the same time, it is arrayed and used on the front of facade with regular sized grid shape.

The surface type is applied when controlling the amount of sunshine regardless of height of sun and incident angle, and blocking the eyes of outside to protect the private life at the same time, it is formed with surface type on XY-axis parallel with facade without the displacement of Z-axis in the coordination system. The surface type is sub-categorized into basic type, overlapped type and array type in accordance with the installing method.

As it is hard to control the sunshine transmission rate other than perforating rate owned by shading material, a basic type[*table 2*, ⑤] can block the view because the structure having the individual body is installed with the size of glass of facade front. It is mainly applied for the sunshine blocking and private life protection at the same time.

Overlapped type [*table 2*, ⑥] sub-categorizes and controls the number of overlapped surface by forming basic type with multi layers, the transmission rate of visible ray with the perforating rate of each surface and density of color, it is applied to control the density of visible ray influx.

Array type[*table 2*, ⑦] controls the amount of sunshine in accordance with the array interval and the number of array by arranging several basic types in parallel, it is mainly used when the design effect is required by regularly changing the shape and size of surface type.

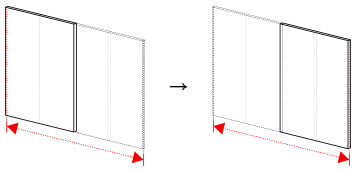
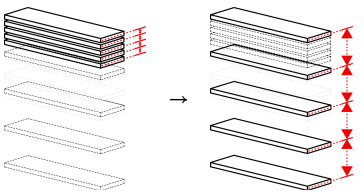
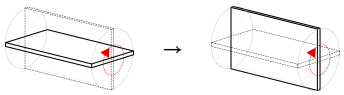
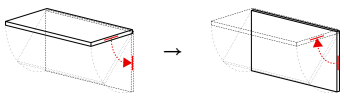
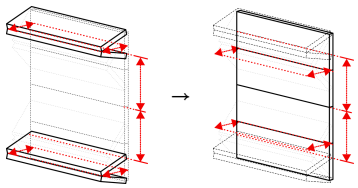
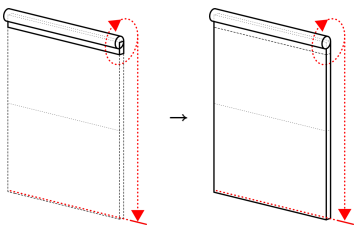
Other than above types, the 3 dimensional type[*table 2*, ⑧] which is not the basic shape but it is hard to define as a special type. As it acts as an important factor that the length value of Z-axis from facade determines the shape of shading, it mainly appears in the type to change the position value to the Z-axis direction according to the incidence angle of sun and design intention. The 3 dimensional type is used when expressing the atmosphere of building with regular pattern and plastic design rather than the purpose of sunshine blocking.

2.3. Type of kinetic element of Kinetic facade

The kinetic element of Kinetic facade can be comprehensively used as a concept which includes the deformation by occupation, position change, shape change and material change[14], considering that it is used changing the shape of shading by operating actuator with electric power resource[7], we analyzed based on the type of transit and deformation of facade in

accordance with the mechanism of actuator and joint supplementary material.

Table 3. classification of kinetic elements

Mechanism	Type	Example
Linear Motion	ⓐ Sliding	
	ⓑ Retract	
Rotational Motion	ⓒ Rotate	
	ⓓ Tilt	
Linear + Rotational Combination motion	ⓔ Folding	
	ⓕ Roll	

The changing patterns of visible shape of Kinetic facade are very various, the basic principle is composed of straight line movement and rotation movement[15], the movement type with complex mechanism is composed of the repeat and the combination of straight line movement and rotation movement. Therefore the kinetic element of Kinetic facade is categorized into straight line movement type, rotation movement type and combination type movement first, the straight line movement type is sub-categorized into location change type(sliding) and interval change type(retract) in accordance the realization type of energy and sunshine control type related to the placement of window and door. The rotation type can be sub-categorized into rotation type and tilt type, the combination movement type into the folding, roll type which are the combination of straight line + rotation.

Straight line movement type can be categorized into the position change type to move the position of shading, the interval change type to change the interval of shading.

Position change type[*table 3*, ⓐ] is mainly applied to surface type, it has the most basic mechanism in which the opening and closing of total shading is controlled by moving in the surface coordination system like sliding type. the position change type has the property that it is hard to control sunshine influx in detail as the movement direction is stiffened.

The interval change type[*table 3*, ⓑ] controls opening and closing by widening and narrowing the interval of multiple shading to the direction of normal line of shading surface based on a fixed axis. Mainly, it controls the array interval by applying to shape element in which the shading is arrayed with regular interval like Louver type and Fin type. It has the advantage which can actively control the sunshine influx of window, it can be combined and used mainly with rotation type in order to actively control. The rotation movement type has the different actuator and hinge in accordance with the range of rotation movement, it is categorized into rotation type and tilt type.

Rotation type[*table 3*, ⓒ] is the movement type to control opening and closing by rotating the standard of shading more than 90 degree, it can actively control the facade blocking area by rotation shading so that it can have the normal line displacement with facade. When the surface of shading is consistent with the normal line direction from facade, it blocks the influx of direct light and reflected light but it blocks even diffused light at the angle parallel with facade as the shading is rotated. The shading interval of rotation type should be controlled considering the turning radius.

Tilt type[*table 3*, ⓓ] controls closing and opening by rotating the standard axis of shading less than 90 degree. Tilt type performs the same rotation movement with rotation type, while the rotation type directly rotates the rotation axis, tilt type often converts the straight line movement into rotating movement using attached arm, many cases of actuator and joint supplementary material show the difference with roll type, it is judged to categorize into separate type by considering the linkage with movement design for the future.

Based on the basic movement type, the combination movement type can be categorized into the roll type and folding type to combine the straight line movement type and rotation movement type. In case of the folding type [*table 3*, ⓔ], the rotation movement of folded column is determined by the linear movement of movement column which moves parallel with completely folded surface of shading based on the totally motionless fixed axis, in case of the roll type [*table 3*, ⓕ], the linear movement of surface is determined by the rotation of rotation axis, the nature of movement

is totally different. The design of movement can be clarified by clearly analyzing the movement of combined movement type, it is judged that it can enhance the possibility of future cooperation by disassembling the movement based on the basic movement type when considering the cooperation with other fields and supplementary material plan which makes motion available.

In the most universal case of the moving heat of folding type, the wheel moves according to guide rail to make the shading move, the folded column accepts the free round movement by using hinge. When the shading is folded, the unfolded surface is minimized to actively control the sunshine influx, it has the advantage which can be used as a separate shading device to suppress the influx of sunshine at other angle as it forms the shading of normal line direction and folded surface.

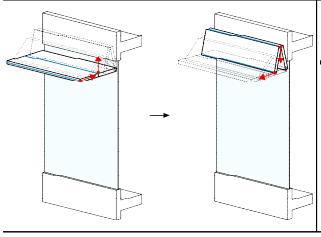
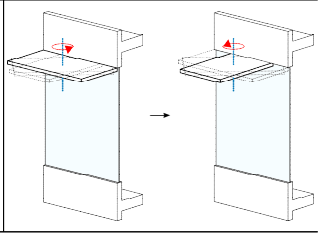
The roll type is categorized into the system in which the surface playing the role of shading is wound in and out around axis based on the power of the rotation movement of shaft playing the role of roller. It is mainly applied and utilized as the system to block the influx of sunshine by comprehensively controlling the blocking function of material and the blocking area of surface.

Recently the movement mechanism of new type which changes the properties of material and changes the shape by pressing and heating has been emerged. Because the movement type using the properties of material directly deforms the material not using the joint supplementary material, each material has the different factors to be considered. Therefore it is hard to categorized into specific factor the operating type using the properties of material and the mechanism of movement requires the delicate technology, the cases were excluded because we fall short of the cases of realization.

2.4. Type and applicability of shape-kinetic combination

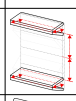
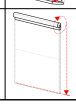
The development of shape-kinetic element type is for the various Kinetic facade plan, this study reviewed the possibility of new type development through two type specific combinations. For example, if the kinetic element of folding type which is operated to X-axis direction to the overhang type of shape element like awning which can be commonly found, it can be the useful combination in which the control of influx of sunshine in accordance with the necessity[Refer to *table 4*, available case], so it is judged that it can be the meaningless combination as the function before and after operation has no difference as well as the realization of operation is impossible as the turning radius of shading doesn't come out.

Table 4. Shape & kinetic elements combination cases

Available Case	Unavailable Case
Overhang + X axis_folding	Overhang + Y axis_Rotate
	

Concretely, the combination of shape-kinetic element, the first, the proper shape element was selected by considering directions, the second, it was performed to draw the kinetic element which can compensate the limitation of fixed type, the combination of shape-kinetic element was categorized by naming 'shape element+kinetic element'.

Table 5. Shape & kinetic elements combination examples

			Geometry Elements						
	Type		①	②	③	④	⑤	⑥	⑦
	Axis								
Kinetic Elements	ⓐ 	X	X	X	X	△	○	○	△
		Y	X	X	X	△	○	○	△
		Z	X	X	X	X	X	X	X
		XZ	X	X	△	X	○	△	X
		YZ	X	△	X	X	○	△	X
	ⓑ 	X	X	X	○	△	X	X	○
		Y	X	○	X	△	X	X	○
		Z	X	X	X	X	X	X	X
	ⓒ 	X	○	○	X	X	X	X	△
		Y	X	○	○	X	X	X	△
		Z	X	X	X	X	X	X	X
	ⓓ 	X	○	○	X	X	X	X	△
		Y	X	X	○	X	X	X	△
		Z	X	X	X	X	X	X	X
	ⓔ 	X	X	X	X	X	○	△	△
		Y	X	X	X	X	○	△	△
		Z	○	X	X	X	X	X	X
	ⓕ 	X	X	X	X	X	○	△	△
		Y	X	X	X	X	○	△	△

* ○ : Existed Cases △ : Applicable Cases X : Unapplicable Cases

To review the already developed products, it shows the combination type of shape-kinetic factor is limited due to the kinds of limited actuator and the limitation of joint supplementary material which supports the weight of shading body, the new typed shape-kinetic factor combination with useful functions is expected if putting the kinetic factor type with the available operational direction by kinetic factor type.

[*Table 5*] is the example of process to draw the combination of new shape-kinetic elements by applying shape element + kinetic element, it lists the shape elements to the horizontal row of table,

the type of kinetic element and the operating direction to the vertical low, check ○ for the type which is already developed like the roll blind which is regulated as 'surface type+roll type', check △ for the type with effective environmental control ability even if it has no developed case and check × for the type in which the environmental control function is not arranged at all, very little or the combination itself is not possible, it determined and organized the type of applicability caused from the combination of 'shape element + kinetic element'. Therefore it is judged that the development of new shape-kinetic elements type will be available based on △ type.

3. Design parameter and system by architectural elements type

The movement of kinetic facade has the availability for integrated plan including shape, environmental function, construct ability utilizing the parametric design. For this, the process to make the elements to be considered in the process of parametric design is required. Under the condition in which international standard for shading including kinetic facade is not established, ISO 15099 that established the calculation standard for environmental function of shading regulates the shape of shading as the core element of shading, the position of each slat in total shading set, the physical function of material as the core elements to regulate the optical and thermal properties[16].

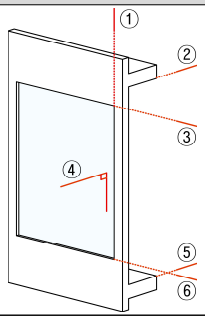
This section drew the design parameter required by ISO standard by shape element and kinetic elements type established in section 2, categorized them into shape parameter, kinetic parameter and material parameter and parameterized them based on the coordination system regulated in 2.1 section. Parametrization analyzed and visualized[2] the element affecting to the environmental function and plan mainly with core parameter which can be universally used in various plans.

3.1. Reference system for the establishment of design parameter

To regulate and schematize the standard design parameter, when the parameters are determined using the major parts of building, the basic architecture system was set by considering the installation of kinetic facade based on the common reference required to parameter setting. The major parts of building are the elements to categorize the glazing part of facade part closely related to shading setting and body part, it is the standard to regulate the exterior, position, moving distance and angle of shading.

First, the bottom of body part excluding the finishing of vertical structure dividing floors is ceiling surface(②), the top is the floor surface (⑤) which regulates the vertical distance. The lintel surface(③) refers to the point in which the glass part of facade opening and the material to support the weight of opaque structure of top opening meet. On the contrary, the baseboard surface(⑥) refers to the point in which the glass part of facade opening meets with the padded supplementary material to support the loading of glass to the opaque structure of bottom opening. Doorpost surface (①) refers to the point in which the supplementary material to connect the lintel surface(③) and baseboard surface(⑥) meet with the glass part of facade opening. The direction which is right angled with vertical structure regulating external and internal part is the direction of normal line(④), it is the standard to regulate the angle, curvature of shading unit.

Table 4. references of parameters

Diagram	Reference factors
	① Vertical rough opening
	② Ceiling
	③ Lintel
	④ Perpendicular
	⑤ Floor
	⑥ Sill

3.2. System of design parameter of shape elements

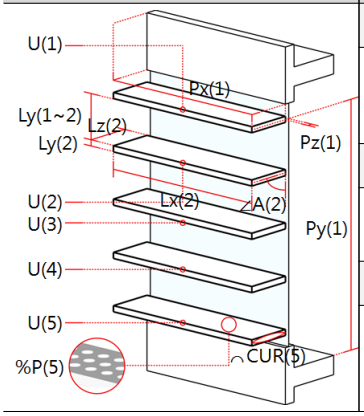
The design parameter of shape elements are composed of Shape parameter which forms the formative principle of shading and the material parameter which is related to the physical function of material, it influences to the shape complexly.

1) Shape parameter

Shape parameter draws and organizes the major consideration which determine the shading type, the major consideration can be regulated through shape elements which regulate the shape of individual unit of shading, the distribution elements which regulate the angle and the distance of outer wall of shading, the array elements which regulate the array relation of each unit in case of various unit formation. To draw the major design parameter by each element again, we have following data.

2) For the visualization, we symbolized the parameters, expressed shape element and kinetic element into diagram on which parameters are marked as sign. The symbolization was performed in the order of 'abbreviation, axis, number'(ex. Lx(1), dY(2)), for the abbreviation we marked the initial of word meaning the relevant parameter or sign, marked X, Y, Z axis on coordination system, marked integer from 1 in the parentheses from the first installed unit by turn. To confusion between parameter, we marked the abbreviation of shape parameter with small letter, axis with capital letter, on the contrary, marked the word, kinetic parameter in capital, axis with small letter.

Table 5. shape parameters of louvre type

Example	Shape parameters
	1. Shape Factors Length : Lx(N), Ly(N), Lz(N) Curvature : ⌒CUR(N) Perforated rate : %P(N) 2. Placement Factors Position : Px(N), Py(N), Pz(N) Angle : ∠A(N) 3. Arrangement Factors Unit : U(N) Interval distance : Ix(N~N+1), Iy(N~N+1)

The shape elements comprehensively plans controling of sunshine by regulating the size of surface of individual unit first, it searches the detailed qualitative change by giving the change of perforating rate or the curvature type of surface. The shape elements can be formed with length, curvature and perforating rate by reflecting this. The length parameter refers to the parameter to determine the size of shading, the distance between the most outer line of shading can be regulated as the length(signal Lx(N), Ly(N), Lz(N)) that corresponds to horizontal (X-axis direction), vertical (Y-axis direction), thickness (Z-axis direction) of shading.

It was checked that curvature parameter is utilized for the role to control the influx of reflected light by controling the refraction angle of reflected light in Louver type and Fin type, and the role which lower the wind pressure that is loaded to unit by controling the wind influx speed bumped to unit, it can be regulated as the curvature(signal ⌒CUR(N)) which is the angle between thickness center line with the linked line when connecting the most thick point and the most thin point from the thickness center line of slit. The perforating type for opaque shading is founded in many cases, it is applied in order to control the amount of environmental control determined by length parameter in the qualitative type, the perforating rate(signal(%P(N)) is regulated as perforating area rate from the total area by assuming the perforating type of even pattern in the stage of plan design.

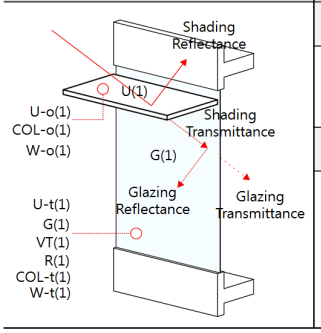
While planning outer shape element, the type to install the unit of shading is planned based on facade at the same time, the installing position (signal Px(N), Py(N), Pz(N))and installing angle(signal ∠A(N)) of shading are the major design elements. The installing position of each shading unit can be determined by horizontal(X axis) direction, vertical(Y-axis) direction, facade surface and the distance with shading, the objective installation position can be clearly determined by regulating Px(N) parameter(refer to Px(1)) and Py(N) parameter(Refer to Py(1)), Pz(N) parameter(Refer to Pz(1)) as the distance from the floor surface[*table 4*, ⑤] to the Y axis direction distance, the normal line[*table 4*, ④] from the outer glass surface of facade to the outer line of the closest shading, and the X-axis direction distance from the doorpost[*table 4*, ①] in which opening part starts. It is judged that Dz(N) valued can be expressed and utilized by 0 or − value when the shading is installed indoor or the intermediate space is installed in thermopane.

The installation type forming shading unit at the different shape angle with external wall surface has been founded in many cases, the installation angle parameter(refer to ∠A(2)) can be regulated as the angle from facade outer glass surface to the shading center line for this. The parameter to regulate the type forming one set shading with multiple units like Louver type and Fin type is categorized into array elements. To regulate the interval between unit and the number of total unit is the design element for the array plan, the number of unit (signal U(N)) and the array interval (signal Ix(N~N+1), Iy(N~N+1)) between unit was drawn as the major parameters, the array interval parameter can be regulated as the distance between the center line of 2 consecutive shading like Iy(1~2).

3.3. Design parameter system of material properties

Various material shadings not existed opaque shading have been developed recently, many light weighted materials with the operation availability have been adopted to kinetic facade, selecting of shading material has been highlighted as a major design element. Especially it is required to clearly regulate details as the properties of material can result the change of transmittance and reflection rate of solar energy. As the material parameter starts with the classification and the designation of opaque material and transparent material primarily, it was analyzed that the establishment of detailed parameter by each type is required, and each type-specific detailed parameter is essential to include the weight affecting to the kinetic element with the thermal, visual properties.

Table 6. material parameters of overhang type

Example	Material Parameters
	1. Shading Factors Thermal Transmittance : U-s(N) Color : COL-s(N) 2. Glazing Factors Thermal Transmittance : U-g(N) g-value : G(N) Visible Transmittance : VT(N) Reflectance : R(N) Color : COL-g(N)

Sun light is not transmitted in the opaque element basically, the

color(signal COL(N)) of material to determine the reflection rate and absorption rates are the major determinations it was analyzed that it can include heat transmission coefficient (signal U-s (N)) by considering the case that the judgement and decision for thermal function is required for the special case such as double enclosure.

When determining the transmission elements, the decision for thermal and visual elements of material is accompanied, the heat transmission coefficient(signal U-g(N)), solar energy transmittance (g-value, signal G(N)), visible light transmission(visible transmittance, signal VT(N)), reflection rate(signal R(N)) and glass color(COL-g(N)) can be formed as the major parameters.

3.4. Design parameter system by kinetic element type

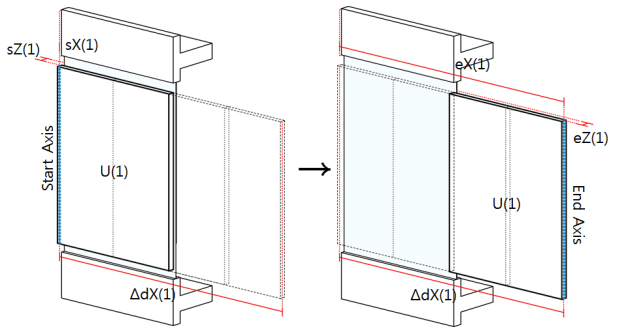
Kinetic element of Kinetic facade is the core to control solar heat and light actively different from fixed type shading, it defines the movement based on starting point, displacement type, displaced amount and finishing point, draws and establishes the plan parameter suitable to each type with vector method so that it can express the situation in which movement starts and finishes to regulate the element of major movement. Therefore the major decision elements of design are drawn into standard line in which the movement starts or it is the fixed point during rotation movement, standard axis and displacement amount. Because kinetic parameters are not regulated as the parameter that is commonly applied to kinetic element different from shape and material parameter, It needs to be specified as a separate type.

1) Linear position change type

Many linear position change type normally move to the direction parallel with shading formed surface, it is found that a few cases move to the vertical direction with shading formed surface. In case of parallel transit, the movement is regulated by the area change overlapped with external window and doors in accordance with the displacement, in case of vertical transit, the movement is regulated into the type in which the variable control of sunshine amount is available in accordance with the change of gap caused from the changed interval with outer wall surface. Therefore, the position and displacement size of starting point, finishing point can be drawn as major design parameters for the design of position change type.

Concretely when each unit is positioned to the point where each guide starts and finished, displacement amount(signal ⊿dX(N), ⊿dY(N), ⊿dZ(N)) can be regulated as a lineal distance from the starting point to finishing point of the same point of shading in accordance with the position of starting point (signal iX(N), iY(N), iZ(N))and finishing point(signal eX(N), eY(N), eZ(N)).

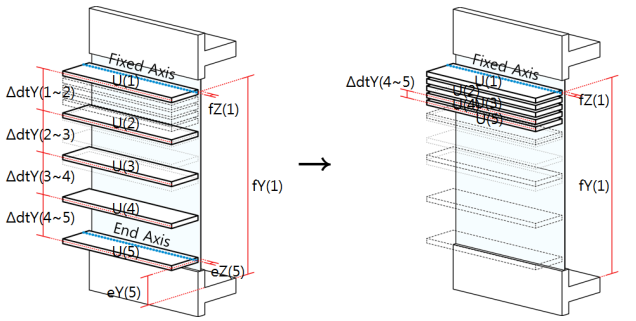
Table 7. kinetic parameters of sliding type

Example	
	
Kinetic parameters	
1. Initial-End point	Initial point : iX(N), iY(N), iZ(N) End point : eX(N), eY(N), sZ(N)
2. Kinetic Range factors	Displacement : ΔdX(N), ΔdY(N), ΔdZ(N)

2) Linear interval change type

Interval change type plans the displacement amount not to have influx of sunshine when the interval of unit increased evenly as wide as possible around the fixed standard axis in the part in which the glass begins considering the incident angle of sun. Therefore the interval of unit, finishing axis and the fixed axis when the interval between shading gets the most wide is drawn as the major parameter in the interval change type.

Table 8. kinetic parameters of retract type

Diagram	
	
Kinetic parameters	
1. Axis factors	Fixed Axis : fX(N), fY(N), fZ(N) End Axis : eX(N), eY(N), eZ(N)
2. Distance factors	Distance : ΔdtX(N~N+1), ΔdtY(N~N+1)

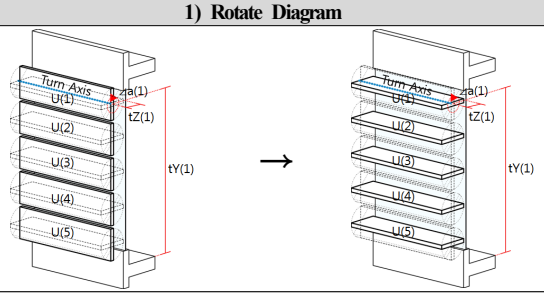
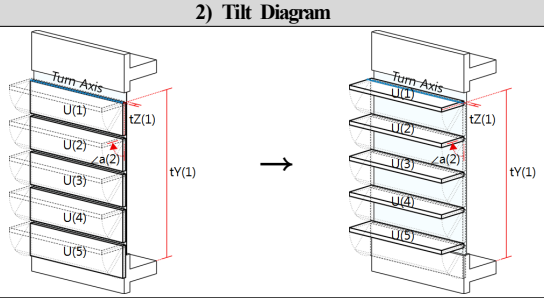
The fixed axis parameter(signal fX(N), fY(N), fZ(N)) of standard axis element can be regulated as a standard axis in which the position value is unchanged when the interval of shading unit is controlled, the finishing axis parameter (signal eX(N), eY(N), eZ(N)) can be regulated as a position value of final shading unit when the interval of shading unit gets increased as wide as possible, the interval between two can regulate the total blocking area of shading set.

The number of overall unit and the interval between unit is linked and determined with total blocking area, if regulating the shortest straight distance between center line of 2 consecutive units when the interval get increase as wide as possible, the numbers of linked unit can be automatically determined. For example, when the shape element is the horizontal Louver type, the kinetic element is interval change type to the Y-axis direction[*Table 8*], if supposing the slat installed from top section to U(1), U(2), U(3), U(4), U(5), it is possible to express the interval between each unit that is the major design parameter such as ⊿dtX(N~N+1), ⊿dtY(N~N+1) in accordance with the moving direction.

3) Rotation type and tilt type

Rotation type and tilt type perform rotation movement around the rotation axis, its area to block external wall changes in accordance with the rotation angle. To design two motions, it is required to determine the position of standard axis(signal tX(N), tY(N), tZ(N))and rotation range (signal ∠a(N)), it was drawn as a major parameter. But even if two motions are the same geometry expressions, the actual motion inducing type is a little different, while rotation type uses the direct rotation of axis shaft as driving energy, the straight line movement generated from arm type actuator that perform the straight line movement in the specific point of unit is expressed into the rotation movement finally, they have big difference, it is judged that such a difference will result the big difference in the type which forms driving energy and driving system for the future cooperation plan.

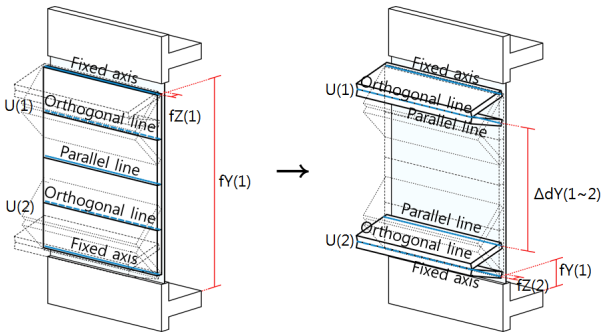
Table 9. kinetic parameters of rotate & tilt type

1) Rotate Diagram	
	
2) Tilt Diagram	
	
Kinetic parameters	
1. Axis factors	Turn Axis : tY(N), tZ(N)
2. Kinetic Range Factor	Turn angle : ∠a(N)

4) Folding type

Folding type has a rather complex mechanism in which shading surface is divided into more than two surfaces, divided shading surfaces are rotated and folded to the opposite direction using hinge junction in the joint part. But to determine the area to block external wall is the most important element when it is unfolded basically in the design of folding type, afterward, it is followed by the process to determine the number of folded surface considering the length of protruded part of Z-axis of exterior wall and weight of unit surface. Therefore if regulating the design parameter of fixed axis (signal fX(N), fY(N), fZ(N)) to regulate the start and direction of transit first, the transit can be regulated to be proceeded to the vertical direction. The final displacement can be regulated as displacement amount (signal ⊿dX(N), ⊿dY(N)) same as other type.

Table 10. kinetic parameters of folding type

Example	
	
Kinetic parameters	
1. Fixed Axis factors	Fixed Axis : fX(N), fY(N), fZ(N)
2. Kinetic Range Factor	Displacement : ΔdX(N), ΔdY(N)

But it is required to subdivide and regulate the transit more by considering the components plan required to operation of folding type. While the fixed axis is generated one by one in each shading surface, the rotation axis and mobile axis are designed in turn repeatedly by considering the loading, it is judged to be used to the plan of components required to transit by defining and regulating repeated rotational line and parallel line into 'N_n', each repeated rotational line as rl(N_n), each repeated parallel line pl(N_n).

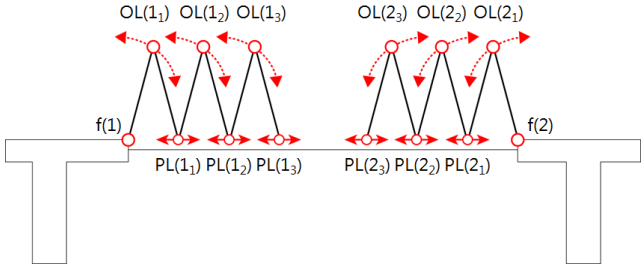
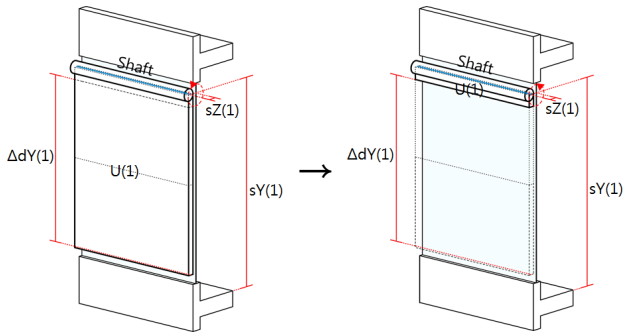


Fig. 4. folding plan diagram

5) Roll type

Roll type is divided into the part leading the motion similar with folding type, the part in which the motion is restrictively performed by the motion. Driving shaft part of Roller type should secure the structural stability as well as the power of motion started at the place, it can determine the position of driving shaft (signal sX(N), sY(N), sZ(N)) and the final displacement(signal ⊿dX(N), ⊿dY(N) as important design parameter.

Table 11. kinetic parameters of roll type

Example	
	
Kinetic parameters	
1. Shaft Axis factors	Shaft : sX(N), sY(N), sZ(N)
2. Kinetic Range Factor	Displacement : ΔdX(N), ΔdY(N)

4. Conclusion

This study is conducted in order to subdivide, stereotype the architectural element of kinetic facade in accordance with the necessity of establishment of common platform shared by professional of various field in the stage of plan design considering the complex properties of kinetic facade which requires the plan through cooperation architecture, environment, mechatronics and control field, and to draw and systematize the major design parameter by each type.

Through the cases analysis for many existing fixed type shading and kinetic facade, the architectural elements of kinetic facade thatis major target of design in the architectural filed are composed of shape, material and kinetic elements, each type can be sub-categorized into basic type based on geometry shape different from complex aspect and detailed type in accordance with sunshine influx control type and energy realization type.

The shape elements are categorized into horizontal type, vertical type, grid type, surface type and 3 dimensional type basically, the horizontal type is sub-categorized into overhang type and Louver type, the surface type is sub-categorized into basic type, overlapped type and array type and planned in accordance with the kind and direction of sunshine. Exceptionally, the 3 dimensional type is freely designed in accordance with the intention of designer when planning shading as a design element to express the dynamic elevation of building rather than the function of sunshine control.

The kinetic elements are categorized into straight line motion type, rotational motion type basically, sub-categorized into the position change type by the shading unit direction transit, and the interval change type to move vertically with the shading unit direction, the rotational motion type can be sub-categorized into axis rotation centered rotational type and the tilt type which is the rotational convert type of shaft straight line motion, the combined type of straight line and rotation can be categorized into the folding type in which hinge rotational movement is subordinated from the position change type as an energy source, and the roll type in which the straight line motion of surface is subordinated by the axis centered rotation, they should be designed considering the shape elements. To control more actively, the kinetic element is complexly planned considering actuator and joint supplementary material for the motion realization, sunshine angle which can't be blocked in the shape element.

We expect that establishing major design parameters and forming overall parameter system can not only strengthen the cooperation with professional of other field but also it can be utilized to the development of new type by reviewing the possibility of type combination. It is judged that environmental goal setting of kinetic facade composed of shape, material and kinetic elements, mechatronics design and verification should be conducted based on this study for the future.

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