

Development of Improved Method for Magnetically Formed Decorative Painting

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ABSTRACT

Currently, there is a growing demand for application of plastic coverings for motorcycles in the market. Accordingly, decorative features for plastic coverings are increasingly important to enhance the attractiveness of exterior designs of those motorcycles.

Under these circumstances, the magnetically formed decorative painting had been adopted to a mass-production model sold in Thailand in 2008.

Magnetically formed decorative painting is a method in which the design patterns are formed by painting a material that contains flakes movable along with magnetic fields, while applying magnetic sheets in the ornamenting design shapes underneath the part being painted. It offers a three-dimensional appearance even though its surface has no protrusions or indentations.

The degree of three-dimensionality on the paint surface appearance was defined as "plasticity" [1] (a term used in pictorial arts). In our development, a challenge was made to create higher plasticity compared to the painting developed in 2008.

It was understood that the orientations of the flakes had significant influences on the plasticity and our development goal was set to create a method that makes the flakes easily movable and yet discontinues the movements after the flakes settled at the desired orientations.

The controllability of the flakes was realized by using the flakes with high magnetic permeability ([Appendix 5](#)) and by applying high-molecular-weight resin to the paint resin. In addition, by making the optimized selection of the thinner, movements of flakes were controlled during the drying process.

By implementing those measures, high-plasticity design patterns was successfully realized for mass production.

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INTRODUCTION

The market of motorcycles in Southeast Asian Nations is very large and the market size is still growing [2]. Many motorcycle models are marketed in this vigorous market from various manufacturers

There is a significant trend in the designs of motorcycles marketed in these regions. That is to say, the total area of plastic coverings fitted to a vehicle body is increasing. Accordingly, the methodology to create decorative features applied to the plastic coverings is getting increasingly important to enhance the attractiveness of exterior designs of those motorcycles ([Figure 1](#)).

Examples of the methods widely employed for applying decorative features to plastic coverings on motorcycles are regular painting implemented on the surfaces of these body parts and graphical stickers (graphic marks) with symbols or artistic patterns, which are generally affixed above the painted surfaces ([Figure 2](#)).

There are a variety of methods in regular paintings as well and those include the ones using the paint with vivid colors and the ones presenting noticeably high brightness. Graphic marks also have a large variation in their artistic patterns. Both of these decorative methods have a long history in actual

practices as decorating techniques and that long history is making customers' perceptions of these decorations too familiarized and lacking in freshness in the market.



Figure 1. Examples of small motorcycle models

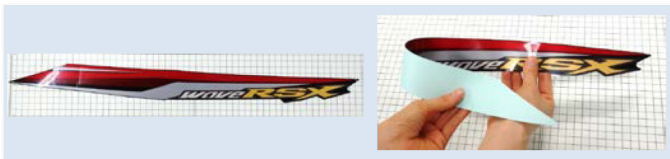


Figure 2. Example of graphic mark

In those circumstances, it has been asked for an innovative decorating method on plastic coverings that can provide a novel feeling through its appearances.

In addition, the graphic marks look the same as commonly available simple adhesive sheets of decorations and are often regarded as non-elaborative decorations without sophistication. That is another reason why a different technique that can provide the appearances evoking customers' perceptions of high-quality has ever been called for [3] [4].

For the markets that have those circumstances, a consideration was started for applying the magnetically formed decorative painting method to enhance attractiveness of the appearances of a motorcycle. As a result, it was successfully carried out to apply that method to a production model in 2008.

Magnetically formed decorative painting is a painting method using a paint material that contains many small thin metal leaves (flakes) with a property of high magnetic permeability. When it is painted, the auxiliary attachments, such as magnets, are applied to the backside of the target parts in order to impose magnetic fields.

By using this method, it is possible to create the design patterns that have almost the same flavor of the drawings manually depicted using an airbrush (Figure 3.)

Moreover, the design patterns created through this painting method can offer three-dimensional appearances to observers even though its paint layer has only a small thickness and the paint surface actually has no protuberances or indentations (Figure 4.)

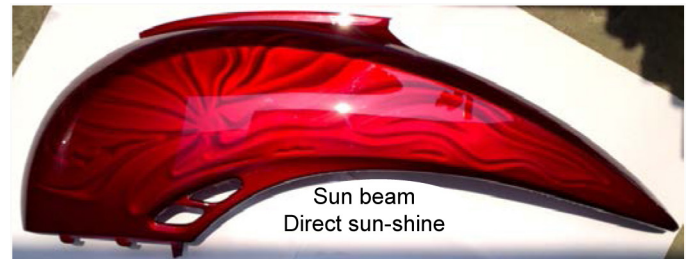


Figure 3. Example of part (trial piece) painted with magnetically formed decorative painting

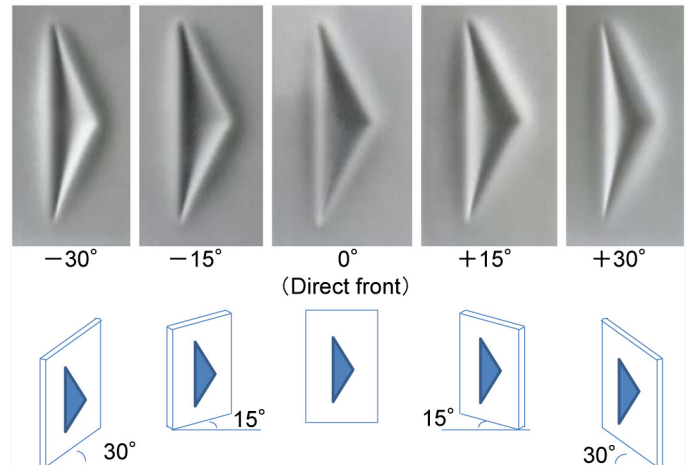


Figure 4. The features providing of having depths created by magnetically formed decorative painting

The technique of magnetically formed decorative painting itself is one of the known methods [5] [6] but it requires many additional measures to cope with restrictions in mass production, including the necessity of applying a magnetic substance before painting. That is why it had not been actually applied to the motorcycles released to the market, before we overcome those difficulties.

The benefits that were expected to be obtained through the outcomes of the development of magnetically formed decorative painting for motorcycles were summarized as follows

- (1). Offering attractive design patterns to observers by an effect of illusory representations, which look virtually three-dimensional while actually not being three-dimensional objects
- (2). Making it possible to provide high quality impressions that cannot be created through graphic marks. It is made possible by establishing design patterns presenting the same features of airbrushed drawings manually painted. It is producible in the equivalent painting processes currently applied for mass productions.

In 2008 in Thailand, the application of this painting method to the mass production was achieved by using a flexible magnet sheet attached to the parts to generate the necessary magnetic fields. Through the application of this painting method, the

representation of three-dimensional patterns and the creation of a high quality customer acceptance were successfully realized but the feature of attracting viewers' attention was fully effective only when the vehicle was in stationary state.

Accordingly, it was decided to make another challenge by doing further development of the magnetically formed decorative painting to realize an enhanced effect of visually observable depth that offers attractiveness while a vehicle is in motion as well.

DEFINITION OF "PLASTICITY"

It was considered that the creation of more conspicuous patterns of decoration compared to the former method was the key to attracting more attention of observers. Accordingly, the required conditions were firstly examined for the manifestation of the conspicuous patterns with sufficient ornamental features created by magnetically formed decorative painting.

Through the representations appeared on the painted surface by the magnetically formed decorative painting, the effect of attracting people's attentions is evoked by a kind of optical illusions in which three-dimensional object is appears as a façade even though any actual solid bodies do not exist. Therefore, it was understood that conspicuousness of the decorative patterns is materialized if this illusive effect is made more enhanced. Here we defined this "illusive effect that induces the artificial appearance of existences of three-dimensional objects" as "plasticity."

The "plasticity" we have pursued in this particular development is further defined as the pattern representation with the property that the illusive representations range over the entire area of a design pattern surrounded by the perimeter of a decorative figure. For example, the design pattern is formed by a triangular shaped magnetic sheet. The plasticity is redeemed enhanced enough when the design pattern represents the shape of a concaved trigonal pyramid (Figure 5).

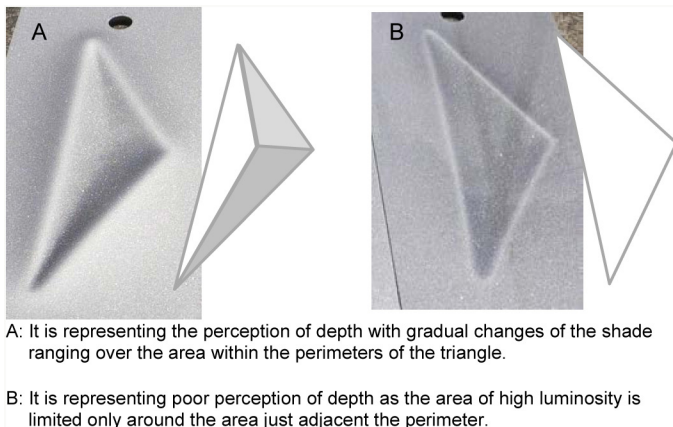


Figure 5. Plasticity defined as development target

The reason why the figurative pattern looks like a concaved trigonal pyramid is that the reflected light intensities within the triangular shaped area vary to a large extent depending on the viewing angles. Moreover, when the area that represents the changes of the light intensity is large, observers can effectively perceive the depth of a design pattern.

PLASTICITY AND VARIATIONS IN LUMINOSITY

In the first step of our analysis, it was tried to make clear the compositional structures of the paint layer to be observed visually three-dimensional. Structural analyses were made on the paint layer reproduced using a pre-existing methodology. They were conducted under various conditions of paint materials.

In a conventional composition of a painting with flakes, the flakes are contained in the base coat layer and a clear top coat layer is painted over it to yield the glossy surface. As Figure 6 shows, the procedures that were applied to our developed painting method adopted the same procedure mentioned above.

Basic Principle of Design Pattern Representation

In Figure 7, you can see the principle of causing the representations of the design patterns. It is presumed that the magnetically permeable flakes in the paint material change their orientations so as to be aligned along the directions of the magnetic fields generated by the magnetic sheet.

It is presumed that the flakes are aligned at the specific angles along the directions of magnetic fields generated by the magnetic sheet. In addition, it was assumed that the entire design pattern is observed virtually three-dimensional because the light intensity from individual regions within a design pattern varies depending on the viewing angles of the pattern.

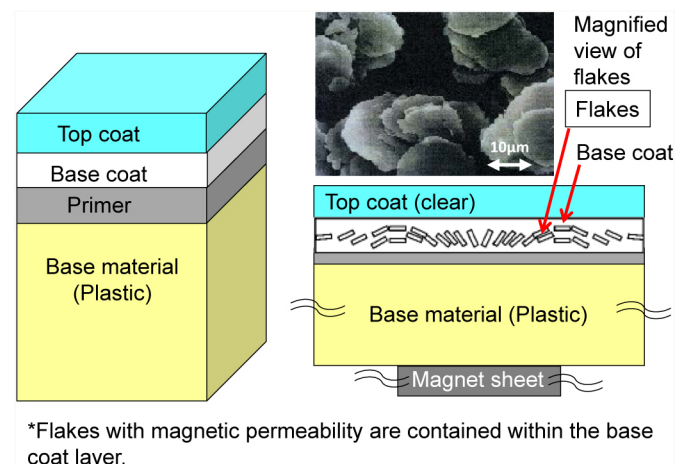
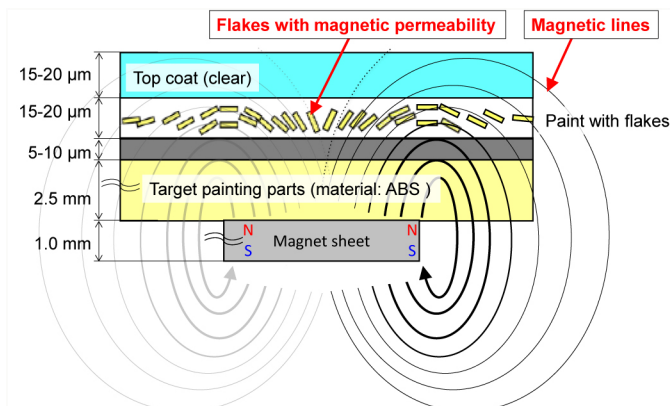


Figure 6. Paint layer composition of magnetically formed decorative painting



The magnetic lines of forces (magnetic fields) originate from the N-pole to the S-pole and travel along circular lines and the magnetically permeable flakes are aligned along those lines.

Tesla is used as the unit for the density of magnetic field (the index for strength of a magnet), where one tesla is ten thousand gauss.

Figure 7. Principle of flake pattern generation in magnetically formed decorative painting

Cross Section of Actual Paint Layer

It was also tried to examine the cross sectional view of the paint layer by cutting the actual layers to verify our assumption. However, it was difficult to identify the direct evidences of the flake orientations corresponding to the light intensity variations that were visually presented to an observer.

When the cross sectional views in Figure 8 are observed, it is noticed that only a fraction of the flakes are representing the different orientations compared to the case of conventional metallic paint layers.

It is understood that the reason why the result had been yielded in this manner is that the orientations of the flakes are not consistently aligned to a single coherent direction. Instead, they have a certain distribution over the range of orientation angles. As a result, various flake angles actually take place. The generated appearance is given only by the average angle of the orientation distribution.

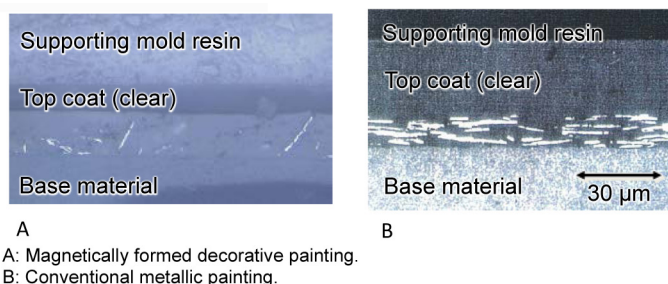


Figure 8. Cross sectional views of painted layers

Accordingly, to clarify the relationship between the direction of the magnetic field and flake angle, the other method was examined. It was considered that the flake movements should

be controlled more forcibly by applying strong magnetic field in a single coherent direction. Applying this method, the intensities of reflected light were able to be investigated and it was identified how they varied depending on the leaning angles of the flakes.

Examining Luminosity Changes to Flake Angles

The leaning angles were controlled by magnetic fields generated by an apparatus specially designed as shown in Figure 9. The apparatus evenly imposes a magnetic field over the entire area of predetermined portion of sample plate, which is coated with a paint layer. The relative direction of the magnetic field is changeable by adjusting the angle of the plate surface to the direction of the magnetic field.

Test pieces containing the magnetically permeable flakes were prepared in the size of 10 by 40 mm. An apparatus was also arranged for applying magnetic fields aligned parallel to a predetermined direction. Test pieces were placed in the designated space in the apparatus.

Apparatus and Test Procedures

The directions of the magnetic field lines were all identical within the space. The flakes were changing their directions to be aligned to the magnetic fields. Therefore, it was assumed that all the flakes situated in the area would change their orientations to be aligned to almost the same direction.

A set of sample pieces were made to investigate the variations of the reflected light luminosities (Appendix 1) from the paint layer. The luminosity depends on the relative angle to the magnetic fields. The direction of the magnetic field in the space was set to the same direction all the time. the test pieces were arranged to be placed within that space at five different angles: 0 degrees, 30 degrees, 45 degrees, 60 degrees and 90 degrees (perpendicular) relative to the direction of the magnetic field.

Results

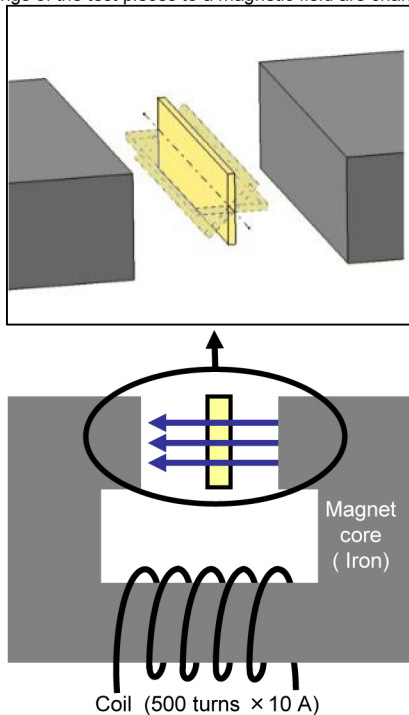
The results were shown in Figure 10. Through the figure, you can see the luminosity is the strongest when the paint layer plane is set parallel to the magnetic field.

When the magnetic field was set perpendicular to the layer, the primer layer underneath the base coat layer was left uncovered. It was because almost all the flakes in the base coat were perpendicularly erected to the paint layer.

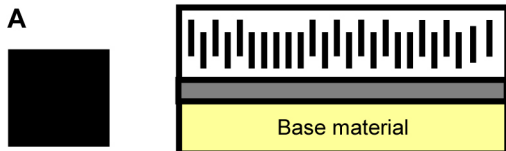
Consequently, there was a very large difference shown in the luminosities of the test pieces between the case with parallel set arrangement and that with perpendicularly set

arrangement. In the cases with the angles in between, the luminosity represents gradual changes according to the relative angles to the direction of the magnetic field.

The angle settings of the test pieces to a magnetic field are changeable.

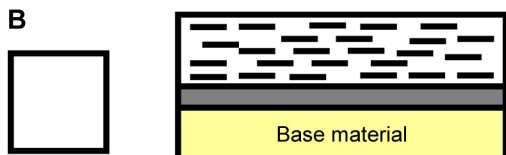


A: When the test piece is placed with its paint layer plane perpendicularly arranged to the magnetic fields:



Presumption; In this case, all the flakes are aligned perpendicularly to the paint layer resulting in almost no reflections of light from the flakes showing a dark appearance.

B: When the test piece is placed with its paint layer plane arranged parallel to the magnetic fields:



Presumption; In this case, all the flakes will be aligned parallel to the paint layer resulting in strong reflections of light from the flakes showing a bright appearance.

Figure 9. Schematic drawings of tests using magnetic fields generator

These gradational luminosity changes were presented in the same fashion as the luminosity changes observed in the design pattern area with magnetically formed decorative painting. It was reasonably concluded that the luminosity variations were caused by tilted arrangement of the flakes aligned with the direction of the magnetic field.

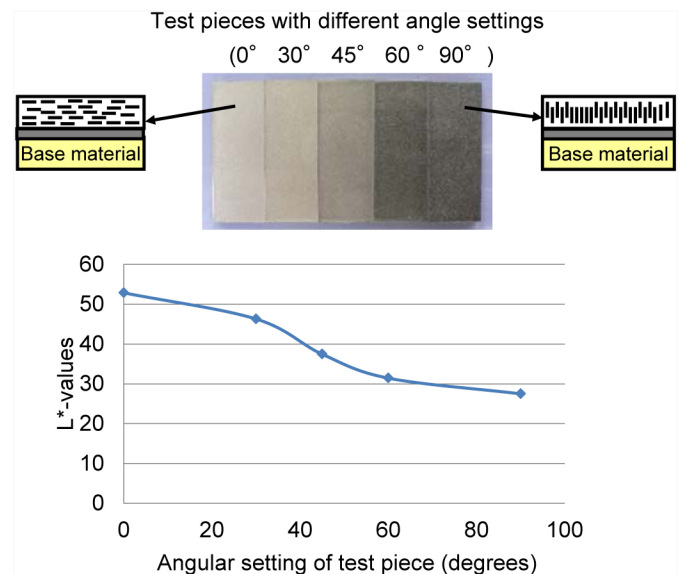


Figure 10. Luminosity changes (measured in L*-values) of test pieces when varying setting angles to magnetic field

Cross Sections of Test Pieces

The cross sections of the paint layers of these test pieces were observed microscopically. As shown in Figure 11, it was confirmed that the orientations of the flakes were almost completely aligned to the direction of the magnetic fields. Consequently, it was verified that the gradation in luminosity appeared in the area of design pattern was generated by the changes of the orientations of the flakes.

Examining Luminosity Changes to Viewing Angles

Furthermore, the changes in the intensities of the reflected light associated with the variations in viewing angles were verified by using variable-angular photometer.

Apparatus and Test Procedures

This measurement equipment is capable of measuring light intensity while varying the directivity of the measurement angle. (The values measured in this experiment are indicated in the unit of "light intensity." Both "light intensity" and "luminosity" are used in this paper and further descriptions are given in Appendix 1.)

A magnetic sheet in the shape of an isosceles triangle, which has a 100 mm base and base angles of 30 degrees, was used to be affixed behind a part to be painted. Then, the magnetically formed decorative paint was applied. The generated shape of decorative pattern was used as the reference shape for the measurements (Figure 12). Hereafter, this shape is used as the normative shape for the measurements.

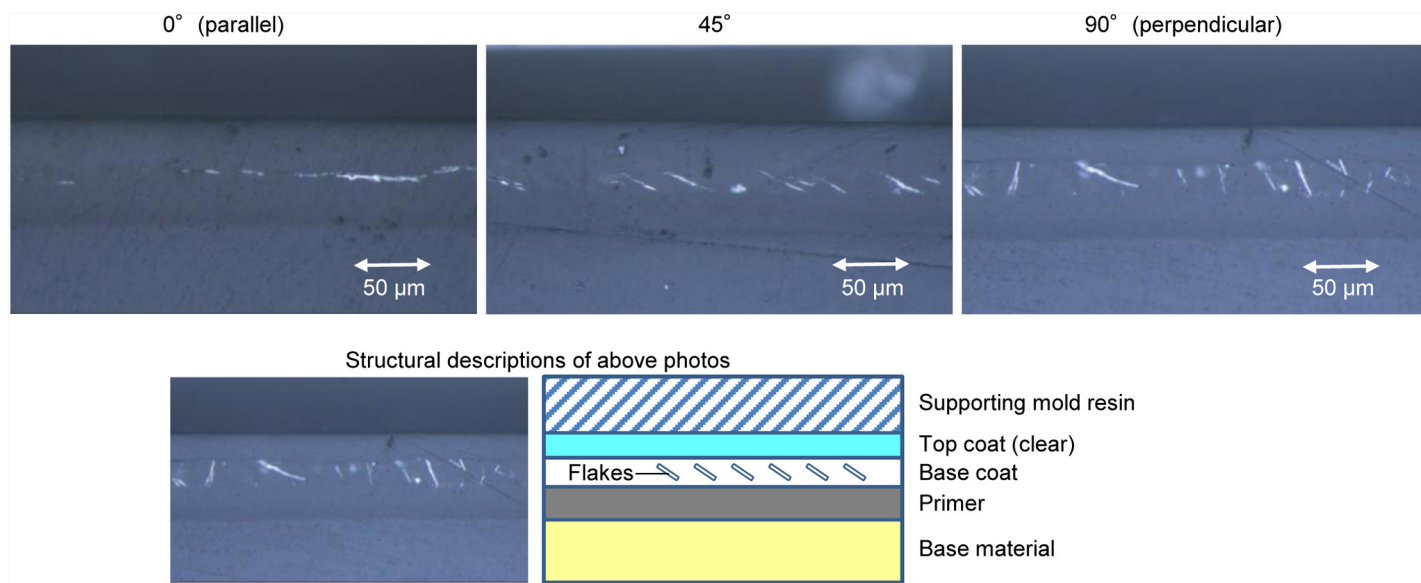


Figure 11. Cross sectional views of painted layers of sample pieces

The measurement method is described in schematic drawings in Figure 13. The intensity of the light reflected from the area, indicated as a hatched circle in Figure 13, was measured using the test piece. The test piece was painted with the magnetic sheet of above-mentioned shape attached behind a plate. The plate was made from acrylonitrile-butadiene-styrene resin and its thickness was 3 mm.

The area in perimeters surrounding the triangular shape was presenting high light intensities in all the conditions. It was considered that this area was inappropriate for the evaluations of varying light intensities in our study. Consequently, this area was not included in our target measurement areas.

The light source was set right upward to the measurement base plane. The measuring plate was placed on the base plane so as to be kept slanted by 5 degrees against the base plane. In this configuration, the direction of slope slanting was oriented perpendicularly to the scanning directional plane of the photometer.

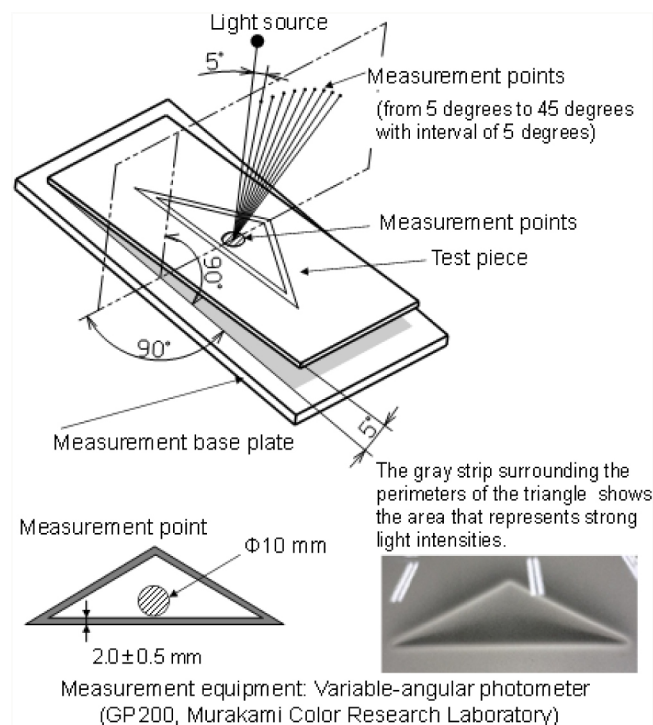


Figure 13. Methodological configuration of measurement using variable-angular photometer

If it were the conventional metallic painting under the same measurement conditions, the light intensity goes down significantly when the detection angle is slightly shifted from the position perpendicularly located.

This is because the flakes in the paint layer are aligned mostly parallel to the paint layer plane. In this case, most of the irradiated light is reflected perpendicularly to the painted surface and the reflected light intensity decreases significantly when the detecting angle is deviated from this particular angle.

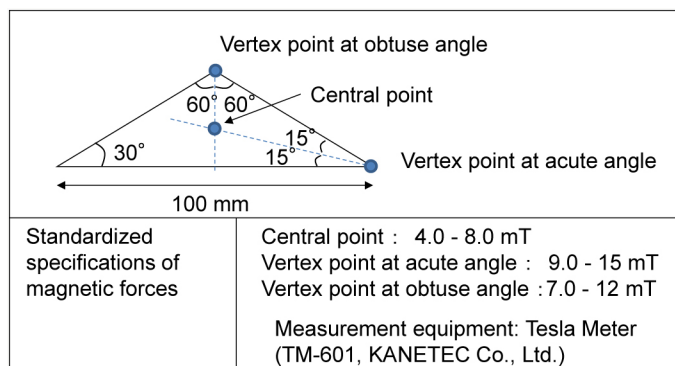


Figure 12. Standardized specifications of magnetic sheet