INTERNATIONAL DESIGN CONFERENCE - DESIGN 2002
Dubrovnik, May 14 - 17, 2002.

COLOUR IN TECHNICAL PRESENTATION

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Keywords: Colour, technical, product model, engineering, naval architecture, shipbuilding, technical drawing, design, computer graphics, visual presentation, electronic images, CAD/CAM, standardization

1. Introduction

The paper considers the gap between the classical, standardized single coloured, mainly two-dimensional conventional technical representations in engineering design based on rules of technical drawing [Giesecke et all 1999] and new capabilities of multi-coloured three-dimensional presentations using computers, plotting, printing copying devices, accompanied by adequate CAD/CAM software facilities [Vareško et all 1994]. The use of computerized tools to assist the different activities related to product design and manufacturing, as well as other product life-cycle phases, has pointed out an acute need for a comprehensive, unambiguous, unified digital product model, employing colour on a standardized manner.

Even up to the beginnings of the 20th century technical designs in the field of mechanical engineering and naval architecture were often presented with coloured drawings that were executed with great skill as well as obvious pride of the authors in their art. For that reason many among these drawings, e.g. the 19th century North American fishing schooner "Bluenose" construction drawings, are today considered to have significant value in the field of visual arts. It may be interesting to point out that well beyond the fifties of the past century the use of colour was mandatory in laying down the ship's lines in full size on the wooden lofting floor. This was necessary in order to discern various sets of lines as well as the lines of various ships drawn across one another.

However, the use of colour in presentation of designs in the field of mechanical engineering and naval architecture nowadays seems not to be the subject to the official technical drawing standards. Colour is most often omitted or used deliberately at best. In contrary, the use of colour in presentation of architectural designs is extensive.

It is perhaps in large part due to the masterworks by Michelangelo and other *renaissance* masters that we came under the wrong impression that ancient sculpture or architecture was colourless, since in this sense Michelangelo definitely deviated from the *classical antiquity* while "recapturing its spirit" in his David or Moses. The fact is that almost all architecture and sculpture up to the period of Renaissance was shining with vivid colour. It is true for the Egyptian, the Mesopotamian, the Greek, somewhat more conservative Roman, but even more for the Byzantium, the Gothic and almost all architecture and sculpture of the Asian and American civilizations.

In recent history the fact is overlooked time and time again, that it is the author himself who chooses to use the colour or not and that his work has the right to be presented in full and not reduced by one important dimension such as the colour. In such a case the information is incomplete and therefore definitely false. It should not be allowed to happen in communicating of engineering designs to other people. Hence, the use of colour in technical presentation is a complex and still an unresolved issue.

2. Colour - the important feature of the industrial product and its presentation

The role of colour in human perception is essential - colour is definitely dominant in child's perception. According to Gestalt psychologists, colour is more dominant than the shape in creation of objects [Itten 1970]. Faber Birren even states that the colour is integral with the shape, and he and Piet Mondrian associated various simple shapes (square, circle, triangle etc.) with adequate colours.

It is hard to neglect the colour as an important industrial product's feature, and in the process of designing the colour is nowadays widely employed. It has not so much to do with the *basic, technical* function of the product. The colour is predominantly employed with the purpose of creating purely *visual impression*, *symbolic* or *emotional*, essentially with the intention to optimise the product's *communicational* and *symbolic* function or, in other words, the *syntactic*, *pragmatic*, or *semantic* dimension of the product [Quarante, 1970]. The colour may be used e.g. to focus the attention on a certain object, to worn on a specific property, to unite the particular object with other objects or discern it from them. The colour may be also employed in order to vary shape, proportions or orientation of the object, to enhance its visibility and security, to facilitate identification, compatibility, maintenance etc.

While colour dominates the child's perception, the practice of presenting the mechanical engineering and naval architecture designs with colourless drawings clearly show that the adults are obviously educated to neglect this fact proving, as it seems, the impact of ascetic and profit-oriented Reformation on the Western culture.

But there is no excuse nowadays for omitting the colour in modern mechanical engineering and naval architecture design communication among all participants because of the three essential reasons:

- The necessity to convey the true visual appearance of the product,
- The necessity to allow the clearest possible communication of information by drawing or other type of image,
- Modern computers and accompanied peripherals fully support the abundant use of colour.

The colour standardization will be of even greater importance in technical presentations using animation and virtual reality.

3. Employing colour in modern technical presentations – reasons and obstacles

In the modern society, due to the accelerated development of the computer technology, standard technical drawings are quickly becoming obsolete as means of presentation of designs, yielding to electronic images. After all the same is true with all printed matter. In early seventies of the 20th century, digital computers accompanied by printing, plotting and copying peripheral devices, also employing the CAD/CAM software, provided some new practical capabilities beyond the mere application of conventional engineering presentations. For example, geometric information is stored in 2D or 3D, a wire frame or a solid model, using or not using colour. A solid model can be represented by the boundary representation method or by the constructive solid geometry model. However, maturing of standards did not adequately follow the fast hardware development and software implementation into engineering practice. The modern dichotomy in technical presentations origins from the methods of preparation and viewing the same object on the screen of a computer monitor and its electronic image presented on a hard copy on a paper. The present use of CAD/CAM software supports presentations in different layers for specific conceptual, logical, technical or formal components of the object under study. To each of the layers adequate colours can be assigned, irrespective of the final preparation of the output of the drafting process. Hence, the view on the computer's monitor is not necessarily identical to the hard copy of the object's final presentation. The absurd is even greater in the cases when the complex, user oriented and adapted view, which is created in colours on a monitor by using the state of the art facilities, is to be converted to a single coloured paper output in order to comply with the traditional conventions and standard requirements.

Graphic colour presentations of the results of numerical analysis, as it is the case of various diagrams and charts of longitudinal strength or hydrostatic calculations or in finite element method applications for levels of stresses, safety factors etc., are already in wide use.

The final classification and fabrication drawings in shipbuilding do not employ colours, although in

their preparation by CAD/CAM tools colours are frequently used in different subdivision and sub structuring of an object. The reason is that original drawings (earlier usually pencil or Indian ink on a tracing paper) are kept in the design offices, only copies are issued to the workshops. These were made as blueprints (white lines on blue background, developed in water) or positive prints (red lines on white background, developed by ammonia vapour) – not allowing colour reproduction.
In general, the colours may be assigned to versatile technical subsystems, like piping, ventilation, electricity, ship's hull structure etc. In ship structures for example, the logical usage of colour may be related to longitudinal and transverse hull structure components, to different substructures, to specific frames or grillages, panels and girders, or to groups of components of related properties. From the formal standpoint, different colours can be used for external contours, internal contours, axes, dimensions, cross-hatching etc. The 3D presentation, particularly in colour, is not yet in wide use in shipbuilding industry, at least in the classification and fabrication documentation, although there is suitable software providing versatile capabilities with or without hidden lines, rendering and shading. However, the modern approach by Det Norske Veritas to new Class Service Concept in shipbuilding design, fabrication, operation and maintenance, denoted Nauticus, applies 3D ship information model of the hull geometry and scantlings in various, but not standardized colours [Andresen 2000].
Product data representation and exchange is a subject of international effort resulting in an already large and still growing collection of technical documents under informal name STEP (STandard for Exchange of Product model data) for international standard ISO-10303 [Gu and Chan 1995]. Today's reality is a network-aided collaborating global design teams with distributed responsibilities of a complex technical design problem. The information interchange of a variety of technical data presentation such as text, sketches, drawings, pictures and articles of mixed contents in different colours, makes an additional problem. The goal of a remote cooperation in construction is to eliminate the paper drawings. However, the fabrication documentation still has to be prepared on paper and it appears at present that there is no adequate electronic replacement for traditional presentation methods [Žiha et all 1998].

3.1 Conveying the true visual appearance of the product in modern technical presentations

Visual presentation has no alternative in communication of information on the product's design between the design authors and their customers - the manufacturers, the users or the general public. The designers have to define to the last detail and consequently to convey, predominantly by drawings or other technical images, the information on the *structure* of the product, as well as the *shape*, the *dimensions*, the *material* and the *surface* of each structural element of the product. To fully complete the information, the one on the *surface* includes not only the definition of the machining quality of various element surfaces but also

- the information on the colour coding of particular elements (e.g. safety buttons, electrical equipment, dangerous rotating parts etc.)
- the definition of the colour of the paint used.

The complete information of the product's appearance must include the product's colour too.

3.2 Colouring with the purpose of clearer communication and features of modern computers

Since visual communication via technical images is the most important means of communication in engineering and naval architecture, it is compulsory that this communication is made unambiguous and as clear and flawless as possible. The modern computers opulent drawing possibilities allow the designers in the field of mechanical engineering and naval architecture to design using a variety of colours in order to discern the particularities of their designs. The standard features of the drawing software include the use of a variety of colours allowing the choice and the control of the main parameters of the particular colour i.e. the *hue*, the *saturation* and the *brilliance*, up to the CMYK rendering for offset or digital printing.
Due to the fact that the colour definitely creates a whole new dimension facilitating communication with the technical image, there should be no reason not to use these computer and printer features accordingly.

3.3 Consideration of possible disadvantages and obstacles in employing colour in technical presentations

Up to the present one of the main disadvantages in employing colour in technical presentations was the increase of cost of executing and copying/printing the colour drawings (copying technologies that do not allow multiplying colour drawings are presently becoming obsolete). In our fiercely profit-oriented civilization this fact presented the most serious obstacle in presenting the technical designs with colour drawings. However, perhaps the careful consideration of the benefits of presenting in colour against its disadvantages, expressed in economic terms, would confirm the advantages of using colour in presentations of the designs. E.g. it has been found that if shaded/coloured exploded-view production illustrations are used the initial assembly of parts into a machine or device is three or four times faster than if a conventional assembly drawing is used [McGraw-Hill Encyclopedia,1960]. This is particularly important keeping in mind that drawings are slowly but inevitably giving way to other means of communication, predominantly the electronic images.

Another possible obstacle in communicating via coloured technical presentations is the fact that a certain percent of the population is colour blind. However, since this percentage is as small as 8% of male population and only 0.5% of female population [Encyclopaedia Britannica], it can not be regarded as an argument for excluding colour in technical presentations.

4. Employing colour in drawings

In the field of mechanical engineering and naval architecture the technical image is constructed of lines, surfaces and solids. To create desired effects various colour contrasts can be applied to lines, surfaces and solids as the elements constituting the technical image with greater of lesser efficiency.

According to Johannes Itten, surveying the characteristics of the colour effects, there are seven different kind of colour contrasts: the contrast of *hue*, the *light-dark* contrast, the *cold-warm* contrast, the *complementary* contrast, the *simultaneous* contrast, the contrast of *saturation* and the contrast of *extension*. The vast experience of experimenting with the colour contrasts in the history of art can be employed in mechanical engineering and naval architecture design whether to optimise the *syntactic*, *pragmatic*, or *semantic* dimension of the product, its *communicational* and the *symbolic* function or, on the other hand, to improve the communication by the technical image based on the twelve-part colour circle, Fig. 1.

This paper considers some of the examples that are expected to have the greatest effect.

The contrast of hue, the simplest of seven, is illustrated by the undiluted colours in their most intensive luminosity. It is found e.g. in ancient sculpture and architecture, in illuminated manuscripts or in folk art of peoples everywhere, especially in gay embroidery, costume or pottery.

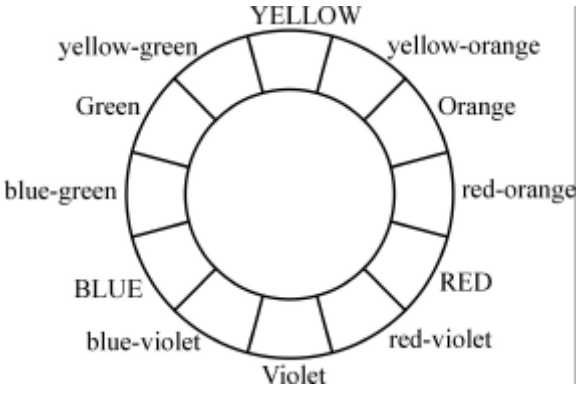

Figure 1. The twelve-part colour circle

The colour can be employed to the lines in the technical image with the purpose of discerning various formal sets of lines. Employing the contrast of hue, among the obvious combinations are yellow/red/blue, red/blue/green, blue/yellow/violet, yellow green/violet/red etc.

It must be noted that the intensity of contrast diminishes with the distance of the hues employed from the three primaries in the colour circle, Fig 1. It is therefore most probably that the colours of the twelve-part colour circle at most should be used, which would be sufficient in most drawings.

The light-dark contrast is in the foundation of much European and Asian art, with the outstanding examples in Chinese and Japanese ink drawing. Here the effect of polarity, which has the fundamental significance in human life and experience, the effect of day and night, light, and dark is explored. While the application of the light-dark contrast to the lines in the technical image does not seem to offer a variety of satisfactory effects, the surfaces yield interesting possibilities.

One obvious effect is organizing the drawing in planes to create the desired depth effect. Controlling of perspective with successive shading is particularly effective in orthogonal plans.

The cold-warm colour contrast is definitely important in solving the problem of the *communicational* and *symbolic* function of the product itself. It has been experimentally demonstrated that the sensation of temperature, the subjective feeling of heat or cold, can be identified with the visual realm of colour sensation. Human or animal experiments have discovered that e.g. blue-green slows down the blood circulation and the red-orange stimulates it. However, considering the problem of communication with the technical image, the cold-warm contrast does not to seem to be particularly interesting to employ.

The complementary contrast is based on colours that are the opposite ones in the colour circle. Their pigments if mixed together yield neutral grey, while the light of the two such colours, mixed together, yields white. Nature displays a multitude of mixing such colours in stems, leaves and flowers. Again, this effect is not so effective and interesting to employ in technical images as in designing the product.

The simultaneous contrast results from the fact that for any given colour the eye simultaneously requires its complementary colour, generating it spontaneously if it is not present. This effect is more important for the *communicational* function, and not so much for consideration the technical image.

The contrast of saturation is the contrast between the pure, intense colours and the dull ones, which are diluted with white, black, grey, or with the mixture of the complementary colours. The contrast of saturation can be employed in the technical image in the similar manner as the light-dark contrast.

The contrast of extension involves the relative areas of the two or more colour patches. It is the contrast between large and small, much and little.

The force of the pure colour is determined by its light value (brilliance) and its extent. To set the quantitative proportion between areas of two or more colours yielding the balance, Johann Wolfgang Goethe set up simple numerical ratios of the light values for various hues (yellow: orange: red: violet: blue: green = 9: 8: 6: 3: 4: 6). The knowledge of the effect of contrast of extension is very much applicable in performing the technical drawing as well as in designing the product itself, in order to achieve the desired balance between the two or more colours.

5. Conclusion

Along the harmoniously colour-balanced product, the nice balanced technical image is not necessarily a completely unimportant issue. Moreover, the usage of colours in design and technical drawings are subjects to intellectual property protection.

Technical presentations in engineering were a matter of technical drawing for a long while, and the subject of conventions, as well as of national and international standards, e.g. ANSI Drafting Manual Y14, in order to provide most comprehensive, unambiguous and efficient presentations for competent participants in product design, fabrication and maintenance processes.

Standards required clarity, order, composition, a number of views and sections, including in details the formats, type and thickness of lines, fonts, hatch-patterns etc. Colour was hardly ever the issue in standardization, so it was understood that drawings have to be in a single colour.

Not a comprehensive study but rather a number of the examples given in this paper and also found elsewhere, illustrating the benefits of optional employment of colour in modern presentations of mechanical engineering and shipbuilding products, suggest the need for more intensive usage of colour and implementation of amendments to standards relating the usage of colour.

Following the logical, technical and formal levels of abstraction, it would e.g. be possible to set

- The standards for employing the colours for lines, surfaces or solids (6 part colour circle at most),

- The choice of colours for static or moving parts (colour) - casing (grey),
- The colours for standard machine elements, etc.

Naturally, it would be wise to set the standards for the use of colours in such a manner that would allow significant creative freedom in their utilization, the personal choice of colours, as is the case with other standards e.g. for various types of lines, surfaces or bodies.

It is true that any job can be performed as a mere routine or with creativity. Due to the importance of visual communication in the field of mechanical engineering and naval architecture a person dealing with presentation of designs should be adequately educated -along with the technical knowledge the person presenting the designs should also acquire adequate education in art.

Perhaps a new specialized draftsman/woman profession is not necessarily required because it appears appropriate that the designer himself, even in the field of mechanical engineering or naval architecture, should also be the person presenting his own designs. He or she needs the adequate knowledge and experience in art in order to be able to competently solve his own product's communicational and symbolic function anyway. The same knowledge and experience of visual communication is needed to put to full use the possibilities offered by computers and to allow better communication of his design.

The improvement in the future designer's education should therefore include a bit more intensive and broader humanistic educational programme, particularly the domain of art, in his informative as well as his formative education. Since in utilizing the colour mechanical engineers and naval architects display reluctance caused by their relative visual art illiteracy, the emphasis should be put on proper education in colour theory. By learning through his informative education the designer would thus acquire the informative knowledge on art that would, merged with his cognitive knowledge acquired through his formative education and developed during his professional activity, provide the required and desired designer's experience.

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