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ON-LINE RED-SCALE MEASUREMENT SYSTEM FOR WIRE ROD COIL

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Abstract: This article deals with a red-scale measurement system which can be applied to Wire Rod Production Line in POSCO (Pohang Iron and Steel Company). A red-scale is a type of oxidized Fe coated on the surface of wire rod and as the name means it has red color. The main cause of red-scale is an improper control of cooling process after final milling stage. To control the cooling process we need to measure the amount of red-scale on the surface of wire rod and to feedback the information of red-scale to control unit. We developed a red-scale measurement system in which we used a color camera to get the information of the amount of red-scale on the whole of wire rod surface instead very limited spot information when we employ commercial colorimeter. This paper will explain the details of the structure of red-scale measurement system and its red-scale estimation algorithm Copyright © 2008 IFAC

1. INTRODUCTION

There are two points to evaluate the quality of wire rod product. The first, we can rate a surface quality in the defect point of view. Secondly, a color of wire rod surface is a key quality criterion because customers easily conjecture the quality of wire rod at first glance of the exterior part of wire rod product. Generally, the normal color quality of wire rod is shinny black grey. Otherwise, if there is oxidized Fe layer on the wire rod surface, we can recognize there is red color. We call the oxidized Fe as red-scale.

1.1 Properties of red-scale

The source of red-scale is whisker generated after cooling process as shown fig. 1.

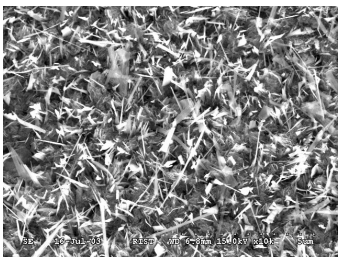

Fig. 1. Photo of whisker shape of red-scale

The powdered scale (FeO, Fe_3O_4), which does not display red color but dark grey color, turned into red color as powdered scale is oxidized by cooling water.

1.2 Measuring red-scale

A main purpose of measuring red-scale is to control cooling process not to have red-scale on the surface of wire rod. Basically, there are two methods to measure red-scale on wire rod products. The one is to rely on human inspectors who are very prone to tiredness. The other is to employ colorimeter or spectrometer which has very limited target area and small lift-off. To overcome those drawbacks we proposed a new type red-scale measurement system using color CCD(Charge Coupled Device) camera and Xenon strobe illumination.

2. COLOR SPACE

2.1 RGB color model of Color camera

Color disply of digital camera or television system is done by the combination of three basic color components, that is red, green and blue as shown in fig. 2. The color of snow mountains in fig. 2. is white and three color sensors have high value for snow mountains. If we want to extract red color component (log house in fig. 2) from Color image we need to employ three sensors' output to find out component from the color image in fig. 2.

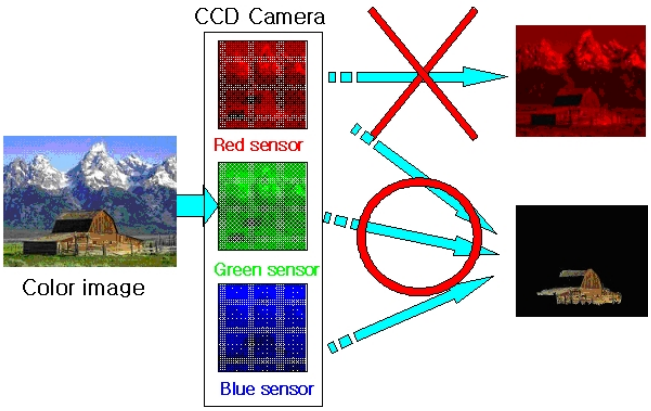

Fig. 2. Red color extraction from color image.

2.2 Color space conversion

To evaluate the amount of red-scale on the wire rod surface we adapted color CCD camera. There are several types of color spaces such as Munsell, XYZ, L*a*b*, HSL color space. In this paper HSL color space is used to describe color of red-scale. HSL color space model is very similar to human's color presentation. Here HSL denotes Hue, Saturation and Luminance respectively as shown in fig. 3.

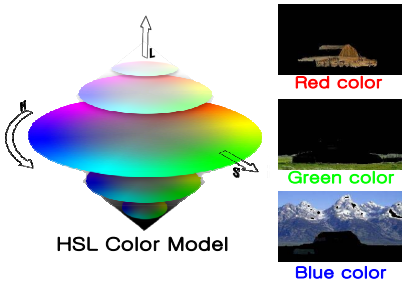

Fig. 3. HSL color space model and extracted color components from the image using HSL model.

There is standard color space conversion formula from RGB color space model to HSL color space as shown in fig. 4.

```
var_R = ( R / 255 )                  //Where RGB values = 0 ÷ 255
var_G = ( G / 255 )
var_B = ( B / 255 )

var_Min = min( var_R, var_G, var_B )   //Min. value of RGB
var_Max = max( var_R, var_G, var_B )   //Max. value of RGB
del_Max = var_Max - var_Min            //Delta RGB value

L = ( var_Max + var_Min ) / 2

if ( del_Max == 0 )                    //This is a gray, no chroma...
{
  H = 0                                //HSL results = 0 ÷ 1
  S = 0
}
else                                   //Chromatic data...
{
  if ( L < 0.5 ) S = del_Max / ( var_Max + var_Min )
  else           S = del_Max / ( 2 - var_Max - var_Min )

  del_R = ( ( ( var_Max - var_R ) / 6 ) + ( del_Max / 2 ) ) / del_Max
  del_G = ( ( ( var_Max - var_G ) / 6 ) + ( del_Max / 2 ) ) / del_Max
  del_B = ( ( ( var_Max - var_B ) / 6 ) + ( del_Max / 2 ) ) / del_Max

  if ( var_R == var_Max ) H = del_B - del_G
  else if ( var_G == var_Max ) H = ( 1 / 3 ) + del_R - del_B
  else if ( var_B == var_Max ) H = ( 2 / 3 ) + del_G - del_R

  if ( H < 0 ) ; H += 1
  if ( H > 1 ) ; H -= 1
}
```

Fig. 4. Color space conversion formula from RGB space to HSL space.

3. EVALUATION OF RED-SCALE

3.1 Hardware system for red-scale measurement

The red-scale measurement consists of color CCD camera unit, Xenon strobe illumination unit, signal processing unit and interface unit with cooling control system. The environmental conditions for red-scale measurement are very hostile to the measurement system to be being operated stably. The temperature of wire rod coil is up to 300℃ and wire rod coil is swinging at the moment of taking red-scale image. Therefore, we applied Xenon strobe illumination to reduce the coil swinging effects on image and implemented exact triggering system with CCD camera unit.

3.2 Evaluation algorithm for red-scale

At the beginning step, we extract red, green and blue pixel value from color CCD camera output. At the next step, we convert red, green and blue pixel value into HSL space value such as Hue, Saturation and Luminance with conversion formula shown in fig. 4. At the final step to extract red color level of every pixel in the image, we applied our own red color level evaluation formula for every pixel level shown in fig. 5.

```
if(L > 0.5)
Red_value_of_Pixel = (-L/(LU-0.5) +
LU/(LU-0.5))*S*cos(3.141592*(H-
theta)/180.0);
else
Red_value_of_Pixel = (L/(0.5-LL) -
LL/(0.5-LL))*S*cos(3.141592*(H-
theta)/180.0);
```

Fig. 5. The evaluation formula for red color level of every pixel in the image.

From now on, we need to evaluate the level of red-scale on the whole surface of wire rod coil. Human inspectors consider the peak red color level of whole coil surface and the average red color level together to evaluate the level of red-scale. We used four variables to emulate human inspector's red-scale evaluation method. We made a regression equation to emulate human inspectors' red-scale evaluation method using pre-defined four variables.

4. EXPERIMENTAL RESULTS

HSL color space performs well to estimate red-scale level. We tested 42 coils and the developed system can hit the red-scale level of 39 coils. This means red-scale evaluation accuracy rate of 93%.

5. CONCLUSIONS

This paper deals with a red-scale measurement system to control cooling process of wire rod mill at POSCO. To evaluate the level of red-scale on the surface of wire rod coil we adapted color CCD camera technique to overcome the drawbacks of commercial colorimeter or spectrometer.

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