Application of halcon in the image analysis of dry cutting gear meshing region

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Abstract

The master-slave bevel gear pair of some automobile rear axle is used to be as the research object, to obtain the image of the gear meshing contact region. Firstly, get the grey image of HSV space from RGB image to HSV space by the pre-processing algorithm; secondly, segment features of image accurately by the adaptive threshold segmentation algorithm; thirdly, fill the holes in the image of meshing region perfectly by proposed holes repair algorithm; fourthly, mark all connected domains of image with 4 -adjacent points domain labelling algorithm; finally, the Marking image area, width and the ratio of width and height features are selected to extract the image of the gear meshing region to obtain the geometry information of the gear meshing region. Research results show: contact centre E/L should be in 45% ~ 50%, and the length of the contact region B/L should be in 45% ~ 55%.

Keywords: HALCON, dry cutting gear, contact region, Image processing

1 Introduction

Dry machining is one of the development trends of metal cutting processing in the future. In recent years, especially the developed industrial country, gave great importance to the dry cutting. The quality of dry gear machining affected the performance of the gear transmission. To analysis the change of the meshing contact region before and after heat treatment, guarantee the system stability of the technological process for the dry cutting gear, the research group used Gleason Phoenix dry cutting machine to the master-slave bevel gear pair of some automobile rear axle, used as the study object.

The gear teeth surface contact region refers to the overlay of the contact lines on the gear meshing tooth's surface. The size, shape and position of the contact region not only reflect the manufacturing precision of a single gear, but also reflect the installation and transmission accuracy of the gear pair [3], which affect the bearing capacity, service life, quality and efficiency of transmission and noise etc. Therefore, scholars both at home and abroad, Litvin studied the dynamic performance of gear transmission for the teeth surface contact region [4], developed the theory of face gear transmission point contact. However, the reports are being rare by image processing technology, to analyse the size, shape and position of the tooth surface contact region.

In this paper, with HALCON image processing software, and through analysis the dry cutting gear meshing teeth surface image of the automobile rear axle, extract the grayscale image of HSV brightness space; use the adaptive threshold segmentation, holes filling algorithm and feature extraction algorithm to get the accurate geometry data of the gear meshing region; obtain the change of contact region before and after heat treatment; give the proportionality range of the required contact region for the final qualified products; and provide the basis of dry cutting gear manufacture.

2 Processing of the contact region image data for dry cutting gear before and after heat treatment

2.1 IMAGE ACQUISITION OF CONTACT REGION

During wet cutting manufacture, because the spiral angle change of big gear is smaller, change of the contact region in the tooth length direction is affected primarily by a small gear, namely, the forward surface turns towards the small end, and the reverse surface to the big end after heat treatment.

In order to get the meshing marks in the contact region of the master-slave bevel gear teeth surfaces, a thin layer of butter smears on the slave bevel gear tooth's surface, some resistance loads on the slave bevel gear to rotate the master gear in the positive and negative two directions, and then the imprinting is observed. Figure 2 shows the meshing contact surfaces image of the big gear tooth's surface before and after heat treatment twice, for the master-slave bevel gear pair of automobile rear axle. This system adopts high resolution digital camera (DH - HV1302UM) to collect images, produced by the Beijing DaHeng Company, a resolution of 1280 x 1024, and which is equipped with the image acquisition card, to

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obtain images. The images of a tooth surface contact region for the gear are shown in figure 1.

(a) When the forward before heat treatment (b) When the reverse before heat treatment

(c) When the forward after heat treatment (d) When the reverse after heat treatment

FIGURE 1 The image of the teeth surface contact zone before and after heat treatment

Seen from Figure 1, there are the fixed contact regions on the tooth's surface for the different gear meshing. Through the information processing of those contact regions, the gear meshing situation can be obtained, thereby the gear machining and assembly process can be improved.

2.2 PROCESSING ALGORITHMS OF CONTACT REGION IMAGE

When measuring the gear contact region, based on the characteristics of the bevel gear meshing, some parameters are designed in this paper: L: the length of teeth, B: the length of contact region, E:, the distance from the centre of the contact region to the gear head, details is shown in figure 2.

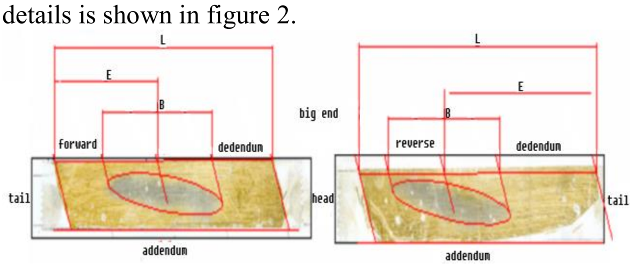


FIGURE 2 The measured data of the contact region

2.2.1 Image transformation from RGB to HSV

Seen from the image of the gear meshing contact region, the boundary is fuzzy between the contact region and the contact region. It is difficult to identify the edge of the contact region accurately with the image segmentation algorithm. Even the owe or excessive segmentation problems may be lead [1]. The grey value of the contact region image and the background is close, when the colour image of the gear meshing contact region is transformed into the grey image. For this phenomenon, the grey value segmentation method is not good. According to the characteristics of the gear meshing contact region image, this article proposed algorithm based on HSV space V component to segment the gear meshing contact region image, and obtain the geometry information of the contact region.

The colour image segmentation algorithm based on HSV space in this paper, is aimed at the existing problem of RGB colour image segmentation, and combined with the three components in HSV colour space, which have nothing to do with the brightness. RGB colour space is converted to HSV space, there are:

$$\begin{cases} 0^\circ & \max = \min \\ 60^\circ \times \dfrac{g-b}{\max-\min} + 0^\circ & \max = r, g \ge b \\ 60^\circ \times \dfrac{g-b}{\max-\min} + 360^\circ & \max = r, g < b \\ 60^\circ \times \dfrac{b-r}{\max-\min} + 120^\circ & \max = g \\ 60^\circ \times \dfrac{r-g}{\max-\min} + 240^\circ & \max = b \end{cases} , \quad (1)$$

$$s = \begin{cases} 0 & \max = 0 \\ \dfrac{\max-\min}{\max} & otherwise \end{cases} , \quad (2)$$

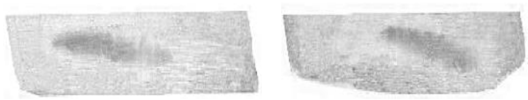
$$v = \max . \quad (3)$$

The following is the programs from RGB to HSV, the transformed images are shown in figure 3:

min = min(R,G,B)
max = max(R,G,B)
V = max
if (max == min)
S = 0
H = 0
else
S = (max - min) / max
if (R == max)
*H = ((G - B) / (max - min)) * 60*
elif (G == max)
*H = (2 + (B - R) / (max - min)) * 60*
elif (B == max)
*H = (4 + (R - G) / (max - min)) * 60*
fi
fi

Range of values: H = [0;2pi], S = [0;1], V = [0;1].

(a) When the forward before heat treatment (b) When the reverse before heat treatment

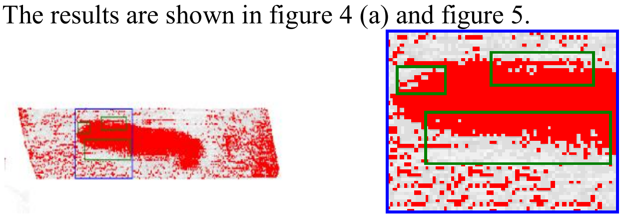


(c) When the forward after heat treatment (d) When the reverse after heat treatment

FIGURE 3 the bright image of HSV

2.2.2 The adaptive threshold segmentation

In figure 3, the bright image of the gear meshing contact region is obtained after transformation, which is already a pair of grey image. To extract the information of the contact region, the binarization processing of the image should be done, which is the key is to choose a suitable threshold. Such as Otus, the image segmentation algorithm can be used to get the better threshold with the least squares principle value [2]. In figure 3, the boundary is not obvious between the contact region and the contact region. When the change of grey value is the smallest, the effects of image segmentation are not ideal. Its main reason is that every pixel point in the image segmentation process all adopted the same threshold. So this paper introduced the adaptive threshold segmentation algorithm, its basic idea is that the image are divided into several sub images; for the neighbourhood window which is determined by the centre of each pixel itself, the average value of all the pixels in the window is used as a threshold value [3]. If the pixel of this point is less than the threshold, then this point is set to 0, otherwise it is set to 255.So the threshold of the whole image is not fixed, but adaptive. In this way, the part is segmented completely. To get ideal segmentation results, the key is the select the smoothing filter size and threshold [4-6]. The results are shown in figure 4 (a) and figure 5.



(a)The adaptive threshold image. (b)Image of the enlarged hole region.
FIGURE 4 The adaptive threshold segmentation image and local enlarged image

(a) When the forward before heat treatment. (b) When the reverse before heat treatment.

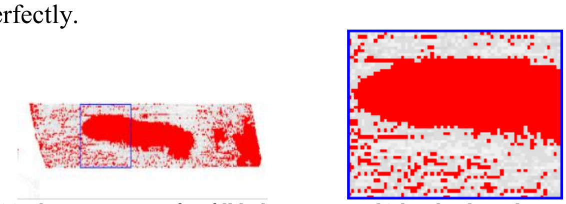
(c) When the forward after heat treatment. (d) When the reverse after heat treatment.
FIGURE 5 The image of the adaptive threshold segmentation

2.2.3 Feature repairing: holes filling in a region

In region filling algorithm, in addition to the traditional scanning algorithm, Suzuki [7] proposed a method, which marks images and updates the array through the forward and backward scanning to decrease the scanning numbers of image greatly. Wu [8] during the linear scanning process, took into consideration the target pixel neighbourhood judging priority order, based on the different images which reduce the visits numbers neighbourhood and improve the scanning efficiency. He and others based on single linear sweep [9] and double linear sweep [10] of pixel neighbourhood characteristics, further development of this type of scan filling algorithm.

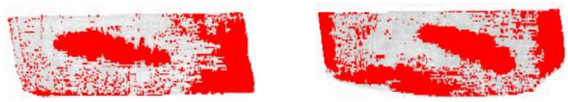
In region filling algorithm, in addition to the traditional scanning algorithm, Suzuki, [7] proposed a method, which marks images and updates the array through the forward and backward scan to decrease the scan numbers of the image greatly. Him and others, based on pixel neighbourhood features of single linear sweep [9] and double linear sweep [10], further developed the scanning filling algorithm.

In this paper, seen from the figure 4 (b), there region lots of holes and dispersed regions in the tooth's surface meshing region. These are adverse to extract the meshing region area information. So, firstly, holes need to be filled to maintain the integrity of the characters. The optimal neighbourhood region filling algorithm is adopted [11], and its calculation results are shown in figure 6 (a) and figure 7. Contrast the same region filling effect of figure 4 (b) and figure 6 (b), it can be seen that the algorithm not only ensure the accuracy of the gear meshing region edge image, but also fill holes in the meshing region image perfectly.



(a) The gear image after fill holes. (b) local enlarged image.
FIGURE 6. The gear image after fill holes and its local enlarged image.

(a) When the forward before heat treatment. (b) When the reverse before heat treatment.

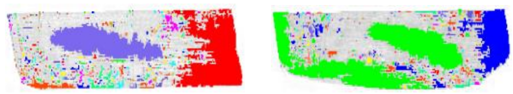


(c) When the forward after heat treatment. (d) When the reverse after heat treatment.
FIGURE 7 The gear meshing region edge image after fill holes

2.2.4 Mark connects demean each other

In figure 7, after filling holes, the contact un-contact regions (in the middle of the image) of the gear meshing are separated clearly, but there are many noise spot images at the un-contact region of the image, which are not benefit to extract image information of the contact area image. To distinguish the contact and un-contact region, so all connected domains are marked in the image with different colours, as shown in figure 8.

(a) When the forward before heat treatment. (b) When the reverse before heat treatment.



(c) When the forward after heat treatment. (d) When the reverse after heat treatment.
FIGURE 8 the gear meshing region image of mark connects domain

In this paper, 4-adjacent point region labelling algorithm is adopted, the steps are as follows:

1) Scanning image line by line, when the unmarked pixel point P is found, whose pixels value is 255, this point is set to a new ID.

2) Checking 4 -adjacent points of P, assign adjacent points to the same ID with P, whose pixels value is 255.

3) According to the step (2), check all adjacent points of marking pixels, and assign the same ID.

4) The repeating steps (3) do not be stop until all interconnection pixel points are marked.

5) Return to step (1), find untagged pixel points again, if found, then repeat the previous step (2) - (4), otherwise, the marking process is over.

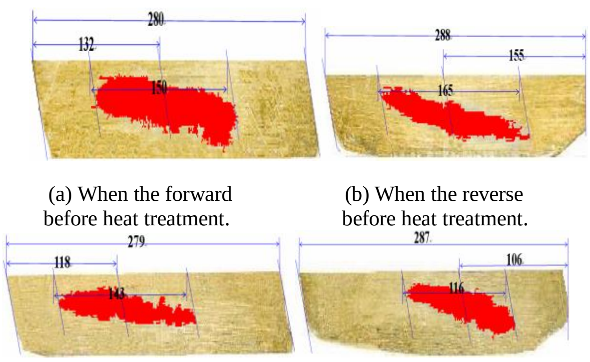
2.2.5 Feature selection and extraction

After the pixel connected domain, all obvious features (see figure 9) are connected into one region. Many connected regions are obtained. But only one is the desirable contact region image of the gear meshing. The image data of few larger regions in figure 9 and data analysis results are shown in table 1.

TABLE 1 Feature regional information and analysis

No.	Region	Width	Height	Width/ Height	Contact?
a	3046	150	41	3.7	Y
	1306	70	42	1.7	N
b	2376	165	36	4.6	Y
	2478	153	54	2.8	N
c	2060	143	27	5.3	Y
	2848	90	55	1.6	N
d	1837	116	36	3.2	Y
	2329	193	53	3.6	N

$$\begin{cases} 1500 < area < 3500 \\ 100 < width < 180 \\ 3.0 < \dfrac{width}{height} < 6 \end{cases} . \quad (4)$$



(a) When the forward before heat treatment. (b) When the reverse before heat treatment.

(c) When the forward after heat treatment. (d) When the reverse after heat treatment.

FIGURE 9 The final meshing region image and the analysis of Geometry data

3 The analysis and conclusions of experimental data

3.1 DATA ANALYSIS

Through the image processing of the gear tooth's surface before and after heat treatment, analysis results of geometry data information can be obtained and shown in table 2.

TABLE 2 Geometric data information analysis results of the gear meshing region image

	forward		reverse	
Design B/L	30%		30%	
	before the heat treatment	after the heat treatment	before the heat treatment	after the heat treatment
B/L	53.6%	51.3%	57.3%	40.4%
E/L	47.1%	42.3%	53.8%	36.9%

Data analysis shows:

1) The length of the actual contact region is longer than theoretical contact region;

2) After the heat treatment, the contact region is changed to the more narrow and shorter; as shown in figure 10, the forward surface is shorten about 3mm (7 pixels), and the reverse side is shorten the 20mm (47 pixels);

3) The forward and reverse surfaces are both moving towards the smaller end, where moving distance of the reverse surface is longer; as shown in figure 10, the forward surface is moving about 6mm (14 pixels), and the reverse side is moving the 21mm (49 pixels);

Through the above experiments, considering the change of the contact region in the meshing process, and the shape and position of the contact region of the final product, the general requirements of ensuring the contact region shall be as follows:

1) The forward surface: the contact region is above in the middle position of the tooth length and tooth root:

Contact centre E/L = 45% ~ 50%.

Length of contact region B/L is, generally in 45%~ 55%.

2) The reverse side: the contact region is slightly smaller than the end tip, and length slightly shorter:

Contact centre E/L = 40% ~ 45%.

Length of contact region B/L is about in 40%~ 45%.

3.2 CONCLUSIONS

In this paper, the meshing region image of the dry cutting gear for the automobile rear axle is studied by image processing technology. When the boundary is found to be the more vague between the tooth surface contact and un-contact regions, the preprocess algorithm is proposed to obtain the grey image in HSV space brightness; but the change of image grey difference is very small, the effect of the ordinary image segmentation is poor. In this paper, the adaptive threshold segmentation is used to segment features of the image; after image segmentation, there are lots of holes in the image, which are not benefit to extract the area information of the meshing region. Holes must be filled. So the holes repairing algorithm are put forward to fill the holes in the meshing region image; all connected domains of image are marked with 4-adjacent points domain labelling algorithm; the marking image area, width and the ratio of width and height features are determined by the geometry information of every the connected domain; the final accurate image of the gear meshing region is obtained by three features.

According to the geometry data of the gear meshing region, the contact region change of dry cutting gear is obtained in the meshing process before and after heat treatment, and the required proportion range of the contact region shape and position is given to guarantee the qualified products, to provide the basis for dry cutting gear manufacture.

Acknowledgments

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