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Identification of Defects in Plastic Gears Using Image Processing and Computer Vision : A Review

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Abstract--In this research paper, we have explored the algorithms/techniques that help in the detection of types of defects (Flash, Warping, Bubbles, Unfilled sections, Sink marks and Ejector marks) that may occur during the manufacturing process of plastic gears. Due to the inherent properties (moisture, absorption, temperature, pressure etc.) of the material (acetal resins such as DELRIN, Duracon M90; nylon resins such as ZYTEL, NYLATRON, MC901 and acetal copolymers such as CELCON.) used in manufacturing of plastic gears, and based on the analysis of previous methods we have drawn some conclusive facts, from which we have proposed image processing andcomputer vision technique which can be implemented for better results in terms of accuracy of such detects.

Keywords-- defect detection; computer vision; image processing.

I.Introduction : Plastic made gears are continuing to displace metal gears in a widening arena of applications these days, due to reasonswhich include cost effectiveness [i] ofthe injection-molding process, elimination of machiningoperations; capability of fabrication with inserts and integral designs. Plastic gears have Low density (i.e.; lightweight, low inertia), Uniformity of parts, Capability to absorbing shocks and vibrations because of elastic compliance. Such gears have the ability to operate with minimum or no lubrication because of inherent lubricity and have optimal coefficient of friction. Some other advantages of plastic gears involve resistance to corrosion which eliminates the cost of protective coatings. In comparison with metal gears; plastic gears are less critical, such gears have excellent consistency with trend to greater use of plastic housings and other components. It is aone step production[ii]; no preliminary or secondary operations.[i ,ii]As the technology progressesthe products are now

extensively made using plastic material especially in robotics[iii] for developing various parts like robotic arm, and most of its moving parts, plastic gears are used in almost all the machineries from small toys to big machines like clocks, printers, lawn sprinklers[4] etc. and most of capital goods. Popular materials used for makingplastic gears are acetal resins such as DELRIN, DuraconM90; nylon resins such as ZYTEL, NYLATRON,MC901 and acetal copolymers such as CELCON.The physical and mechanical properties of these materials vary with regard to strength, rigidity, dimensional stability, lubrication requirements, moisture absorption, etc. [ii].In order to design plastic gears, the effects of heat and moisture must be given careful consideration as it may lead some defects like:

- Backlash**:**Plastic gears have larger coefficients of thermal expansion. Also, they have an affinity to absorb moisture and swell. Good design requires allowance for a greater amount of backlash than for metal gears.Now,due to the thermal expansion of plastic gears, which is significantly greater than that of metal gears, and the effects of tolerances, one should make sure that meshing gears do not bind[i ,ii] during the manufacturing process but if it happens then this will leads to loss of quality and will cause the uneven surface defects like warping, i.e. the deformation occurs when there are differences in the degree of shrinkage of different locations within the molded component[iii].

- Lubrication**:**Most plastic gears do not require lubrication during manufacturing process. However, temperature rise due to meshing may be controlled by the cooling effect of a lubricant as well as by reduction of friction. Often, in the case of high-speed rotational speeds, lubrication is critical. [i]Lubrication of plastic worms is vital, particularly under high load and continuous operation. Depending on the application, plastic gears can operate with continuous lubrication, initial lubrication, or no lubrication. Ample experience and evidence exist substantiating that plastic gears can operate with a metal mate without the need of a lubricant, as long as the stress levels are not exceeded. However, as the stress level is increased, there is a tendency for a localized plastic-to-plastic welding to occur, which increases friction and wears or if sliding speed increased its minimum value. [ii]When a situation of stress level, shock level and sliding speed is uncertain, then this will leads to defects on the gear surface like warping, sink marks (marks or the irregular patches on the surface occurs on the outer surfaces of molded components), bubbles (air bubbles like material trapped inside plastic gears as a defect during its production) and unfilled sections (this defect occurs when injection molding does not reach certain portions of the inner side of the die before solidifying).[iii]

- Plastic gear with metal mate /die tool***:***If one of the gears of a mated pair is metal, there will be a heat sink that combats a high temperature rise. The effectiveness depends upon the particular metal, amount of metal mass and rotational speed.[ii] Improper molding tools and process can produce residual internal stresses at the tooth roots, resulting in over stressing and cause defect on gear surface like ejector marks (Flow marks in which a pattern of the flow tracks of the molten plastic remains on the surface of the molded product.), flash (This defect refers to the excess molding material that penetrates into mold gaps like slide push-out faces, and inserts, etc. in a molten state.)[iii]

- Pressure***:***Pressure angles of 14.5°, 20° and 25° are used in plastic gears. [i]The 20° pressure angle is usually preferred due to its stronger tooth shape and reduced undercutting compared to the 14.5° pressure angle system. The 25° pressure angle has the highest load-carrying ability, but is more sensitive to center distance variation and hence runs less quietly. The choice is dependent on the application. [ii]But if the pressure angle is not proper or the applied pressure is inadequate then this will leads to defects like ejector marks.

Once , the manufacturing process is complete , it is the time to undergo quality check , which is done by technique called **TQM or Total quality management**.[i]TQM is a comprehensive andstructured approach to organizational management that seeks to improve the quality of products and services through ongoing refinements in response to continuous feedback. Total quality management aims to hold all parties involved in the production process as accountable for the overall quality of the final product or service. Quality check is a necessary step which companies can be done in many ways just as manually, by using image processing, by using video processing and in many ways. **Manually** a company can select its own engineer, an outside consultant or both. If a consultant is called in, this should be done as early in the process as possible. Though similar procedures apply to any failure analysis, the specific approach can vary depending on when and where the inspection is made, the nature of the failure and time constraints.

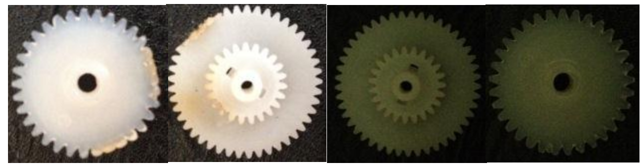

Figure 1:Defective gears(a,b) Non defective gears(c,d)

When and where***:***Ideally, the engineer conducting the analysis should inspect the defectivecomponents as soon as possible. If an early inspection is not possible, someone at the site must preserve the evidence based on instructions from the analyst. If a suitable facility for disassembling and inspecting the gearbox is not available onsite, it may be necessary to find an alternate location or bring the necessary equipment to the site. Nature of defects:The defective conditions can determine when and how to conduct an analysis. For example, if the gears are damaged but still able to function, the company may decide to continue their operation and monitor the rate at which damage progresses. In this case, samples of the lubricant should be collected for analysis, the reservoir drained and flushed and the lubricant replaced. The monitoring phase will consist of periodically checking the gears for damage by visual inspection and by measuring sound and vibration.
Time constraints***:*** In some situations, the high cost of shutting down equipment limits the time available for inspection. Using Image processing for quality check:Surface defects such as holes, dirt and scratches cause major problems for manufacturers,particularly when the production process includes a surface treatment stage. As most products are manually inspected after the process has been completed large quantities of sub-standard product may have to be scrapped.[i ,ii]Manual inspection for surface defects has a number of drawbacks, including subjectivity, varying standards and high costs. Automatic inspection systems using image processing can overcome many of these disadvantages and offer manufacturers an opportunity tosignificantly improve quality and reduce costs.This paper defines a surface defect and reviews image processing algorithms for defect detection, severity measurement and classification. A number of new techniques which have been developed for use on a dedicated machinevision defect detection system are presentedand their applications discussed. [i]This paper is organized as follows: in section II we give an overview of related work done. In section III, we present the methodology. We dedicated Section IV to conclusion where we formulated ideas and present our main research perspectives. In section V we discuss the future scope.

II. Related Work

J. Caron , L. Duvieubourg[v] described the defect detection by using recursive filters in packaging industry. This paper addressed the task of automating the visual inspection of strip of plastic by a vision system based on a line scan camera. The defects on the strip are characterized by a local variation in reflectance properties of the surface to be inspected. There are efficient methods, even with variations in illumination, to highlight the defects. But in the case of poor contrast these methods are inefficient. In this paper they proposed to take advantage of a new method which had been developed in our laboratory and which optimized the edge detection of defect in any case. The performance of this new method is demonstrated with real images and with different kind of defects. This detection method could be of great help, to perform the control of the bags in the packaging industry. The experimental tests were made to verify the performance of the hyperbolic IIR filter among different kind of defects, especially for very noisy images. Since they used the recursive filters for images which was actually the bad idea because it represent image using 256 levels per pixels. Recursive filters work fine in theories but with such type of process it's likely that the coefficient values will blow up as quantization errors creep up. However,**TetsuhiroSumimoto, ToshinoriMaruyamal, YoshihamAmma, Sachiko Goto,MunehiroMondou, Noboru Furukawa and Saburo Okada[vi]** developed image analysis for detection of defects of BGA by using x-ray images.This paper dealt with the development of image analysis for the detection of defects at BGA solder joints in PC boards by using X-ray images. In the conventional IC boards, it was possible to detect defects of solder joints by visual inspection, because the lead of ICpackage is set on its outside. However, they can't detect visually defects at BGA solder joints, because they are hidden under the ICpackage.At the firststep, they attemptedto detect the characteristics of the solder bridges based on an image analysis, and significant results are obtained as follow.To find BGA Bridge, the radius ratio and the roundness of asolder hall is effective.To analyze accurately the radius ratio and the roundness of asolder ball, it is enough to get image data having 20 pixels diameter in each solder ball. To detect defects under the solder ball, it was effective tochange the penetration angle of X-ray. However ,the results of this paper was promising that there accuracy was 100 percent but work was limited due to its complexity which required multi step methodology and therefore this process was very time consuming.

E. Deutschl, C. Gasser, A. Niel, J. Werschonig [vii] proposed an approach to Defect Detection on Rail Surfaces by a Computer Vision based System. A new vision based inspection technique for rail surface defects is presented. It replaced visual checks with an automatic inspection system. Color line-scan cameras and a special image acquisition method - the so called Spectral Image Differencing Procedure (SIDP) –allow the automatic detection of defects on rail surfaces, likeflakes, cracks, grooves or break-offs by means of image processing. The presented vision based system is suitable for railsurface inspection. It used an image acquisition andprocessing technique which is fast and able to detect 3Ddefects.Using this system, humans have to examine only 5% of arail (automatically presented) which is a speedup oftwenty times compared to the old method. Due to Spectral Image Differencing Procedure (SIDP) they have processed additional data, the required computation time and memory increased significantly.

Qingxiang Wang1,2 , Di Li1 , Wujie Zhang1[viii] used OptimalGabor Filters for Detecting Defects in Golden Surfaces of Flexible Printed CircuitsThis paper studied the application of advancedcomputer image processing techniques for solving theproblem of automated defect detection for golden surfacesof flexible printed circuits (FPC). A special defectdetection scheme based on semi-supervised mechanism isproposed, which consists of an optimal Gabor filter and asmoothing filter. The aim was to automatically discriminatebetween "known" non-defective background textures and"unknown" defective textures of golden surfaces of FPC.The performance of the proposed defectdetection scheme is evaluated off-line by using a set ofgolden images acquired from CCD. The results exhibitedaccurate defect detection with low false alarms, thusshowing the effectiveness and robustness of the proposedscheme. In this paper, a semi-supervised defect detectionscheme for golden surfaces has been proposed, which was constructed based on optimal Gabor filters. The geneticalgorithm was utilized as the major technique to obtain theparameters of an optimal Gabor filter which was consistentwith basic texture features of the studied golden surfaceimages, and the Fisher criterion was applied to designfitness function for genetic algorithm. The performance ofthe scheme has been extensively evaluated by using anoffline test images, which consists of a variety of goldendefects differing in defect type, size and shape, and imageresolution. The test results obtained have shown that thescheme is simple, effective and robust. In short, theyobtained good detection results confirm the efficiency androbustness of the detection scheme. However, the Gabor filters used here was computationally expensive. The overall process wastime consuming and costly and there is possibility of improvement.

Alisha Tremaine et.al [ix] were able to understand how mould and die when not working properly, might give rise to the surface defects in plastic product. This paper basically discuss defects developed due to shrinkage, due to overheating and

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variation in temperature. To identify these kinds of defects, this paper suggests using SEM (Scanning Electron Microscope) technique. This algorithm was running on the surface as well as the cross-sections of the plastic products. The main objective of this paper was to perform a systematic study of several types of internal defects that can be occasionally found in forged products and identify the defect surface prior to and after high temperature heat treatment.

S. Kamaruddin et.al. [x] paper presented a study in which an attempt has been made to improve the quality characteristic (shrinkage) of an injection molding product (plastic tray) made from blends plastic (75% polypropylene (PP) and 25% low density polyethylene (LDPE)) by optimizing the injection molding parameters using the Taguchi method. This paper had made an attempt to described the defects occurs during the manufacturing process and optimization of the injection molding process parameters for optimum shrinkage performance of a plastic tray which is made from polymer blends or polyblends.The performance of the plastic trays was evaluated in terms of its shrinkage behavior. The analysis of the results shows that the gears are prone to different kind of defects like backlash, flash, warping, ejector marks, bubbles etc.and optimal combinations for low shrinkage are low melting temperature, high injection pressure, low holding pressure, long holding time and long cooling time. Using Taguchi method for design of experiment (DOE), other significant effects such as interaction among injection moldingparameters were also investigated.

TABLE 1: COMPARISON TABLE

III. Methodology

S.no.	Previous research	Algorithm used	Machine learning	Features used
1.	J. Caron , L. Duvieubourg	Recursive filters	Artificial Visual inspection by image processing	Edge detection
2.	Tetsuhiro Sumimoto, Toshinori Maruyamal, Yoshiham Amma, Sachiko Goto,Munehiro Mondou, Noboru Furukawa and Saburo Okada	Image analysis algorithm	Machine learning is not used	x-ray images, thresholding, perimeter, Radius ratio.
3.	E. Deutschl, C. Gasser, A. Niel, J. Werschonig	Spectral Image Differencing Procedure (SIDP), 2D histogram	Computer vision /machine learning is used	optical inspection systems, texture features, eddy currents
4.	Qingxiang Wang1,2 , Di Li1 , Wujie Zhang1	Advanced computer image processing technique, optimal gabor and smoothening filter, genetic algorithm	Semi supervised mechanism, machine learning is used	Texture feature, segmentation
5.	Alisha Tremaine et.al	SEM (Scanning Electron Microscope) technique	Computer vision or machine learning is not used	Surface features
6.	S. Kamaruddin et.al.	Taguchi method	Computer vision or machine learning is not used	Injection moulding parameters

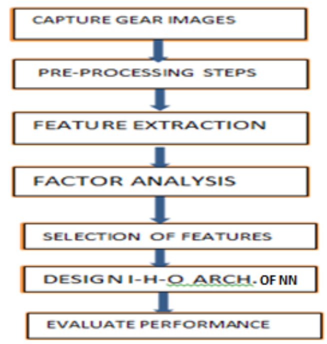

Figure 2: Block schematic of the defect detection

After conducting a systematic review and after reading all other possible resources we are proposing a methodology that covers up the limitation of previous work done and it can be summarized intothe following steps:

(1) Capturing of gear images***:*** Images of the object under study are to be captured using a digital camera. These captured images are then being processed for the detection of plastic gear surface defects.

(2) Pre-processing steps:Since, the images are exposed to multiple kind of noise and other interferences during image acquisition phase. The images may require some pre-processing steps for it to work with the algorithm and results in good level of accuracy. Pre-processing involves the following:**Resizing**means change the size of the image or to make the image size more appropriate for faster processing. The gear images captured from the camera are very big in size i.e., about 5MB. Since we have to process lots of gear images in faster speed, the size of images should be compressed. Sometimes, when we capture these images from the camera, **noise** encounter the gear images. The noise in images is because of variation of brightness or color information in images, unwanted signals, electrical fluctuations etc. during acquisition various types of noises may arise including Gaussian noise caused by poor illumination or high temperature during capturing, salt and pepper noise occurs because of analog to digital converter errors and bit errors in transmission, film grain is usually regarded as a nearly isotropic noise source. Its effect is made worse by the distribution of silver halide grains in the film also being random. Anisotropic noise occurs when the image sensors subject to row noise or column noise. In order to make the gear image smoother or to suppress the noise **blurring** is applied on the images. Sometimes **flash** is used during image capturing which is the instantaneous illumination of bright light but this intensity of light may cause problems in images like some portion of image illuminate with light intensity is not clearly visible hence, cannot be observed properly. Sometimes, because of noise and flash either a part of gear image is destroyed or whole part is eliminated or only half part of the gear image is captured. Therefore, keeping in mind all these steps we have to consider only those gear images which represent whole part of gear.Finally we go for the **Contrast enhancement**that helpsin improving the perceptibility of gears in the seen by enhancing the brightness difference between gears and their backgrounds.

(3) Feature selection and extraction**:** When the input data to an algorithm is too large to be processed and it is suspected to be redundant then the input data will be transformed into a reduced representation set of features (also named features vector). Transforming the input data into the set of features is called feature extraction.[xi] Therefore, multiple features are then extracted on the basis of descriptive statistics of coherence and spectral density of the gear image signals. **Coherence:**The spectral coherence is then used to examine the relation between two signals or data sets and is commonly used to estimate the power transfer between input and output.The **coherence** (sometimes called **magnitude-squared coherence**) between two signals x(t) and y(t) is a real-valued function that is defined as:

$$C_{xy} = \frac{|G_{xy}|^2}{G_{xx}G_{yy}} \qquad \ldots\ldots\ldots\ldots(1)$$

Where, G_{xy} is the cross-spectral density between x and y, and G_{xx} and G_{yy} the auto spectral density of x and y respectively. The magnitude of the spectral density is denoted as |G|. Values of coherence will always satisfy.[xii]**Spectral Density:**In statistical signal processing, statistics, and physics the spectrum of a time-series or signal is a positive real function of a frequency variable associated with a stationary stochastic process, or a deterministic function of time, which has dimensions of power per hertz (Hz), or energy per hertz. The spectrum decomposes the content of a stochastic process into different frequencies present in the process, and helps identify periodicities. The spectral density of 'f(t)' and the autocorrelation of 'f(t)' form a Fourier transformpair.Descriptive statistics measures the following: Mean, Variance, Standard Deviation, Minimum and maximum etc.

(4) Factor analysis***:***Here we have to find out the features which are more significant that than the other analysis. i.e., we choose different factors which then help to select the best feature out of no. of features. Therefore, for this we employed step up/grow up method.

(5) Selection of features: We have selected spectrogram of the image signal and the coherence and finally calculate their descriptive statistics. We are then trying to analyze the statistic features which are more significant for identification of defect and non-defect. We can view feature selection as a method for replacing a complex classifier (using all features) with a simpler one (using a subset of the features).[xiii]

(6) Design I- H- O architecture**:**The real challenge in designing a neural network based solution is to design the I-H-O architecture. The idea is to build an learning classifier that can adapt, as well as remain stable for large data set variations with lowest possible computational overhead. We need to find the best possible combination of input features which can yield the most significant factors from which defects can be identified mathematically in easiest possible way. The number of hidden layers must be optimal so that large memory and computational resources are not wasted. In hidden layer there has to be some correlation between the input and output layer. Therefore, it is always suggested to design multiple I-H-O architecture and out of these we have to find out the most optimal one.

(7) Evaluate performance:After processing the data on the neural network we will then evaluate performance of the system. i.e., how accurately the system is operating.

IV. Conclusion

The technique used here in this research work is better in accuracy, cost and time consumption. In this paper we are using the advantages of neural networks/machine learning that other researchers did not used. We are using the spectrogram and checking the coherence of the ideal and the new image and calculate the performance of the system.

V. Future Scope

For future work, we suggested that a network of IP based infrared cameras (wireless)may be used for capturing images of defects/defective gears during manufacturing process. Therefore, even the defects due to air or holes that are not visible may be traced using image processing.

VI. Reference

i. Marks' Standard Handbook for Mechanical Engineers

ii. Elements of metric gear technology, section 18 design of plastic gear

iii. AmandeepMavi, MandeepKaur proposed "Identify defects in Plastic (gears) using Digital image processing -A Review "and is published in IRACST - International Journal of Computer Science andInformation Technology & Security (IJCSITS), ISSN: 2249-9555 Vol. 2, No.2, April 2012

iv. *Zan Smith and Andy Ulrich, " Exploiting the potential of plastic gears"*

v. *J. Caron , l. Duvieubourg proposed" Defect detection by recursive filters in packaging Industry" andpublished in international conference on Information, communications and signal processingICICS Singapore, 9-12 September 1997.*

vi. *TetsuhiroSumimoto, ToshinoriMaruyamal, YoshihamAmma, Sachiko Goto, MunehiroMondou, NoboruFurukawa and Saburo Okada3 proposed"Development of Image Analysis for Detection of Defects ofBGA by Using X-Ray Images'' and published in IMTC 2003 ~ InstrumentationandMeasurementTechnology Conference 2Vail, CO, USA, 20-22 May 2003*

vii. *E. Deutschl, C. Gasser, A. Niel J. Werschonig proposed"Defect Detection on Rail Surfaces by a Vision based System''and published in 2004 IEEE Intelligent Vehicles Symposium University of Parma Parma,Italy June 14-17,2004*

viii. *Qingxiang Wang1,2 , Di Li1 , Wujie Zhang1proposed " Detecting Defects in Golden Surfaces of FlexiblePrinted Circuits Using Optimal Gabor Filters" and is published in Second International Symposium onIntelligent Information Technology Application.*

ix. *Alisha Tremaine (2005), "Characterization of Internal Defects in Open Die Forgings" FIERF Grant Projectfor Undergraduate Research November 17, 2005*

x. *S. Kamaruddin, Zahid A. Khan and S. H. Foong(2010) " Application of Taguchi Method in theOptimization of Injection Moulding Parameters for Manufacturing Products from Plastic Blend " IACSIT International Journal of Engineering and Technology, Vol.2, No.6, December 2010 ISSN: 1793-8236.*

xi. *http://en.wikipedia.org/wiki/feature_extracti on*

xii. *http://en.wikipedia.org/wiki/coherence_(signal_processing)*

xiii. *nlp.stanford.edu/IRbook/html/htmledition/feature-selection-1.html*