INVESTIGATION OF MACHINE VISION BASED SYSTEM FOR SURFACE HEALTH MONITORING OF CLEATED CONVEYOR BELTS

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ABSTRACT

A non-intrusive system for surface health assessment technique of a cleated conveyor belt is an intriguing research issue which has been investigated in this study. The problem is important as intrusive systems are costly and difficult to maintain, nonetheless surface health assessment is necessary to reduce down time and production losses in conveyor systems by initiating timely action. To address the health assess problem, a machine vision based automatic optical inspection (AOI) system has been designed and its efficacy is examined through a laboratory based study. The laboratory based prototype of AOI model is equipped with a light source, a camera and a laser line projection device mounted on a movable platform which is allowed to capture the belt surface data when a belt is kept underneath the inspection assembly. Prior to implementation of the above system for belt surface health status assessment, several parameters associated with belt scanning process are set. In this connection, the influences of a series of parameters, like imaging distance, illumination, inspection speed, camera frame rate and field of view, on the accuracy of dimension measurements by the system have been studied through a mixed level full-factorial design of experiment approach. The study results for this part of investigation reveal that all the above parameters along with ID * FOV (II level) interaction effect influence significantly towards the accuracy of dimension measurement by the AOI system. It also appears that setting the parameter values at imaging distance of 60 cm, field of view of 75^{o}, illumination of 0 lux, belt speed of 9 cm/s and frames rate at 75/s, the optimum response in terms of minimum percentage error for dimension measurements are obtained. Further, in pursuit to improving the accuracy of the depth (thickness) estimation by the AOI system, the laser light sectioning process of the setup has also been calibrated using a stepper caliber based device.

Upon completion of AOI system design, the same is implemented for capturing belt surface data of four stages of cleated conveyor belt segments collected from Rungta mines as a part of heath condition assessment of the above belts. These four stages of belt segments represent three different time of usage of the belts such as six months, eight

months and twelve months old used in an actual iron ore conveying process including an unused fresh belt segment.

The AOI system is made to capture line scan (depth) and areal scan (color) image data of the belt surfaces for the four different stages which are then analysed for belt surface defect detections, and surface width wear and thickness wear assessments.

Prior to this, the belt surface is partitioned into five different regions across the width of the belt, viz., belt left edge region, belt left cleat / chevron region, belt middle region, belt right cleat / chevron region, and belt right edge region. This is for the interest of assessing differential surface wear as manifested over belt surfaces even through visual observations.

For surface defect analysis, the defects are segmented from the belt images using Otsu's thresholding based segmentation algorithm. These segmented defects are then processed for feature extraction which in turn are used for designing an automatic defect classifier, which would classify the defects into any of eight different classes. These defect classes are defined as RIP_1, RIP_2, GOUGE_1, GOUGE_2, TEAR_1, TEAR_2, ABRASION_1 and ABRASION_2 in consultation with field experts of Rungta mines and clues from literature review.

A SVM based classifier model has been examined which is trained with a bootstrap sampling based approach. The validation of the model on the defect dataset suggests that 91.3% classification accuracy could be achieved by this model.

On a subsequent analysis, the model is trained with two synthetic data set generated by data warping and SMOTE to overcome class imbalance (disproportionate number of class instances present in the dataset) problem. The model trained separately with 3000 synthetic samples across each class of defects generated by data warping and SMOTE independently, is found to achieve classification accuracy up to 96.8% and 92.3% respectively. Hence, it is recommended that data warping based SVM should be used for defect classification for further applications.

In continuation of the study, surface width and thickness assessment has also been done by the AOI system. It has been observed that belt surface has suffered differential wear for

different regions in the following pattern, which is also supported by visual observations. The thickness of the left edge region has worn more than that of the right region by 9.7%. The left cleat arms has experienced higher (18.7%) wear in thickness than the right cleat arm. Amongst the five designated belt regions, the maximum wear in thickness has been observed for the left cleat arms (59.4%). The lowest thickness wear is witnessed over right belt region (17%). With respect to belt surface width wear, it has been noticed that the left cleat arms have suffered the largest extent of wear (34.5%) compared to any other belt regions. In contrary, the middle belt region has witnessed negligible width wear (0.01% only).

In reference with belt used in the current study, the belt has suffered 41.2% and 0.8% overall thickness wear and width wear respectively for a period of twelve months of belt operation.

A validation exercise has also been carried out to determine the error associated with the estimation of belt thickness and belt width by the process, which would place confidence in the estimated values. In this pursuit, few physically measurable spots on the belt surface have been marked (20 in number) randomly using a marker. These marked spots are physically measured for their dimensions using screw gauge for thickness and Vernier calipers for width. The corresponding spots are then segmented from the line scan images to estimate their respective dimension for thickness and width values. This validation exercise suggests that the mean absolute percentage error for the thickness and width estimations is found to be 0.52% and 0.05%, respectively.

Keywords: Conveyor Belt Health Assessment; Cleated Conveyor Belt; Automatic Optical Inspection; Laser Light Sectioning; Design of Experiments; Support Vector Machines; Class Imbalance