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Magnetic Particle Inspection of Transmission Shaft using Machine Vision

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Abstract: This paper aims to explain Industrial Process Automation. A system to automate the process of Magnetic Particle Inspection (MPI) has been proposed. This system incorporates Image Processing Techniques to automate the MPI process. The goal is to improve the accuracy of the current manual system and also reduce the falsification of jobs due to manual errors. The time of inspection of this system for one job will be 40 seconds compared to the current system which is approximately 50 seconds. In addition to this, the new system is also economical compared to the conventional system.
Keywords: Industrial Automation, Magnetic Particle Inspection, Camera, UV light.

I. INTRODUCTION

The rapid development of digital computers has led to a vast expansion of applications for computer vision systems. Processes that previously had to be done manually can now be automated using computers and cameras. Computer vision and image analysis have a very high demands for processing power, something that still is a problem for real time applications. While the computers and vision algorithms are getting very advanced, to a level where they supersede human capacity for certain tasks, there are still tasks that have been deemed too difficult.[1] The human visual cortex is a vastly advanced and highly trainable computer that has an amazing ability to analyze images, and the tasks it performs are in many cases difficult, if not impossible, to replicate digitally.[2] It is however limited by a shorter endurance. This is true for most kinds of real-world applications; there is seldom a one best way to solve a computer vision problem, and it is therefore important to be able to quickly draft an algorithm and test its effectiveness.

Transmission shafts are an important part of most of the vehicles. The examination of them plays an important role in traffic safety. Fluorescent Magnetic Particle inspection is a conventional non-destructive evaluation process for detecting surface defects and slightly subsurface discontinuities of ferromagnetic material.[3] If a ferromagnetic material contains discontinuities, after it is magnetized, the magnetic flux near the area of discontinuities will leak. As a result, the magnetic particles applied on the surface will be attracted to the area of leakage, which form indications of discontinuities in the MPI process.[1]

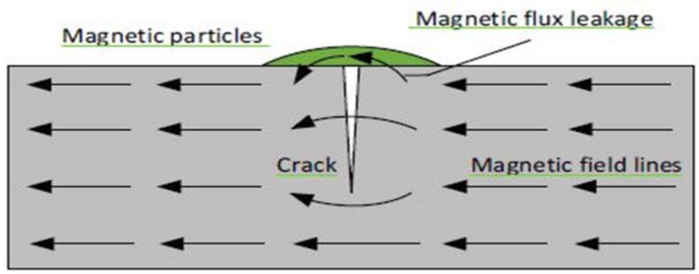

Fig 1: The principle of fluorescent magnetic particle inspection[1]

II. SYSTEM SETUP

In conventional system the shaft is mounted between two magnetic copper coils as shown in the figure and the worker sprays the ferromagnetic solution on it with the help of a pipe. This magnetizes the shaft after which it is sent to the UV light room for inspection. The worker in the UV light room then inspects the job for cracks under UV light. The time required for it is approximately 50 seconds. Now if the worker is working in second or third shift in the industry, the chances of him making manual errors due to fatigue are high and the time of inspection due to fatigue also increases. Hence, to eliminate the manual errors a new automated system has been proposed. In this system, the shaft will be mounted on two roller supports and a stepper motor coupled to it at one end to rotate the shaft. A rack and pinion mechanism will allow the camera to move along the length of the shaft. A DC motor will be coupled to the pinion and the UV will be mounted adjacent to the camera as shown in the figure.

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Fig I.1 Conventional System

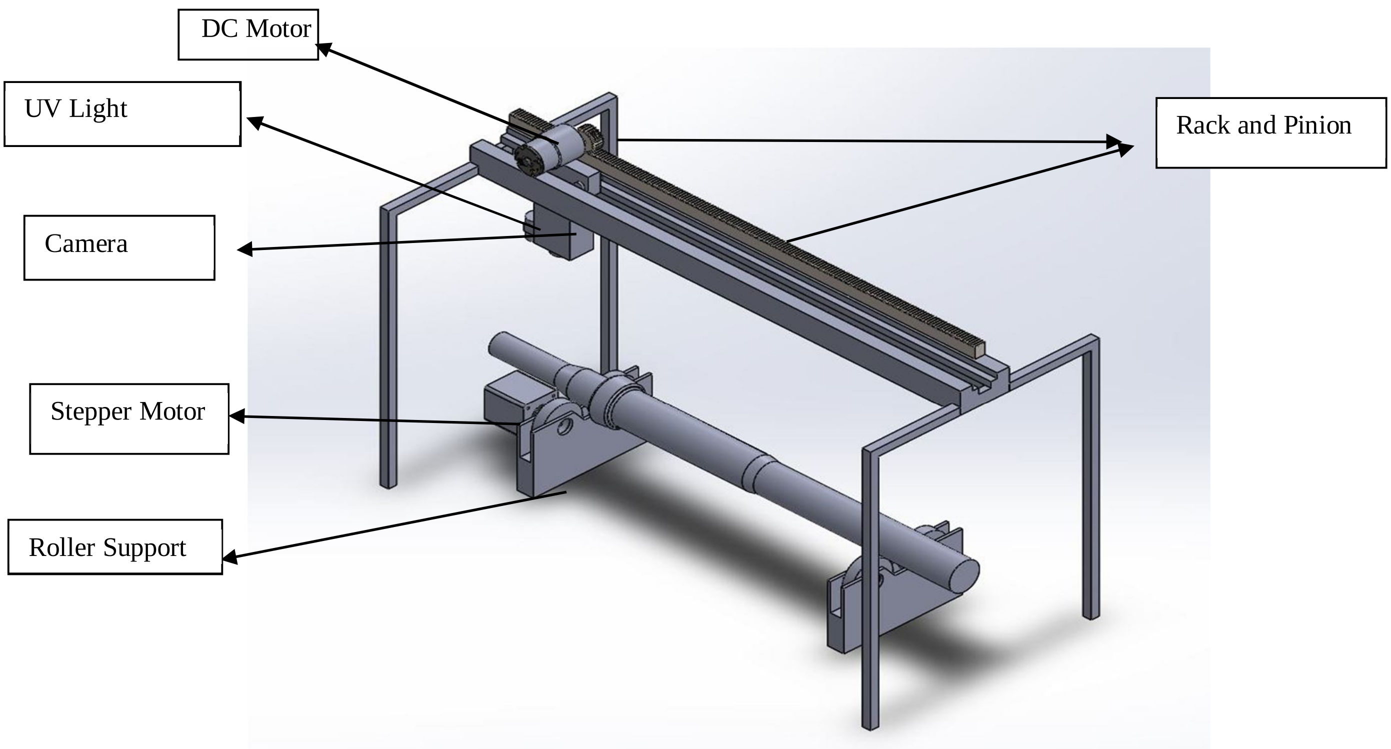

Fig I.2 New System

III. SYSTEM WORKING

A microcontroller will govern the working of stepper motor and DC motor. The camera will stop at 4 different positions along the length of the shaft taking 5 snaps including the snap it will take in its stationary position. A provision for the ferromagnetic solution to be sprayed on the shaft will be made in the system. This solution will be sprayed after each rotation of the shaft. Coils for magnetization will be provided at both ends and at each stop The calculations for the number of shaft rotations required to cover entire area of shaft as are follows:

Shaft length= 570mm

Considering 4 stops for camera & 5 images along the length

570/5= 114mm

i.e. The camera will stop at intervals of 114mm along the shaft during its 4 stops.

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Total area along shaft surface= $A = \pi dl$

$= \pi * 53 * 570 = 94907.51\ mm^2$

Area(rectangular) from top plane as viewed from the camera
= Snap 1 + Snap 2 + Snap 3 + Snap 4 + Snap 5
= 37*114 + 37*114 + 37*114 + 53*114 + 26*114 (37, 53, 26 are diameters of shaft at different positions in mm)
= 21660 mm^2

Calculation for no. of shaft rotations for clicking images:
= 94907.51 / 21660
= 4.38 ≈ 5
Degree of rotation = 360/5= 72 degree
Thus, the shaft will rotate 72 degrees 5 times for the camera to cover its entire area.
The snaps taken by the camera get stored in the local memory of the microcontroller. The microcontroller will then send these snaps to the host device for image processing. The program for image processing is written using Canny Edge Detector Algorithm in Python. The program is written in such a way that if there is even 1 crack on the job, it will show the message “job rejected” and if there are no cracks on the job, it will show the message “job accepted.” So in this way, after the job is mounted, the entire process is automated and it will simplify the inspection process as a result of which the manual errors will be eliminated.

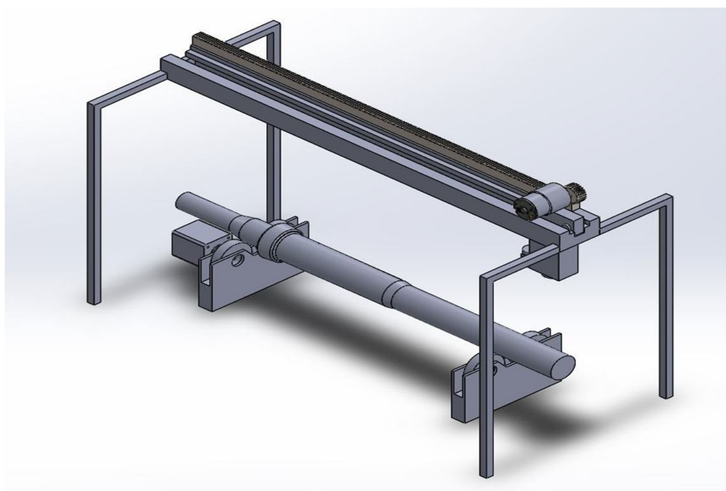

Fig II.1 Camera position 1

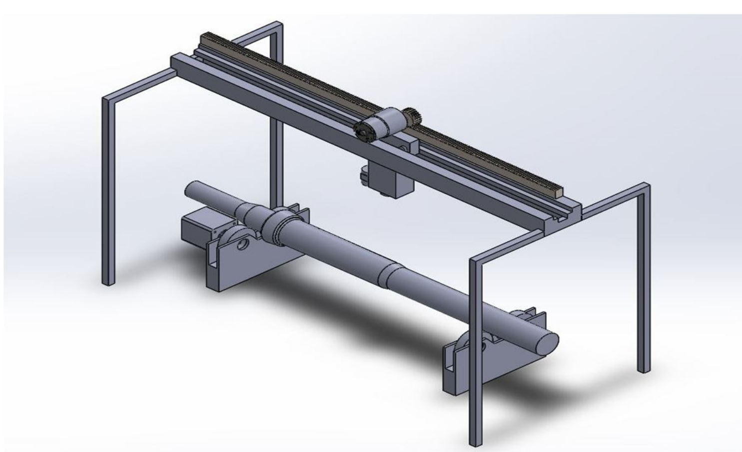

Fig II.2 Camera position 2

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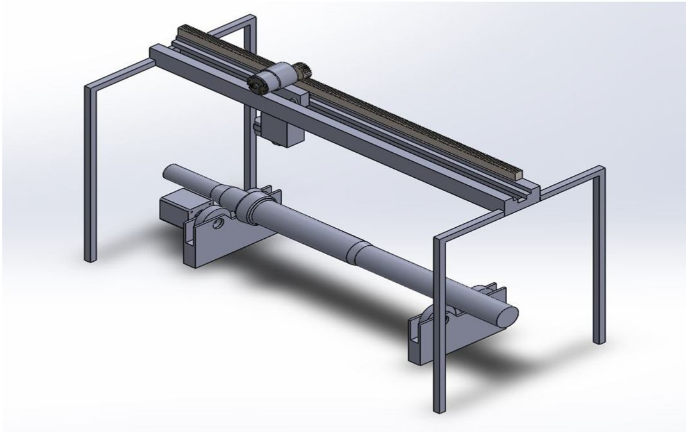

Fig II.3 Camera position 3

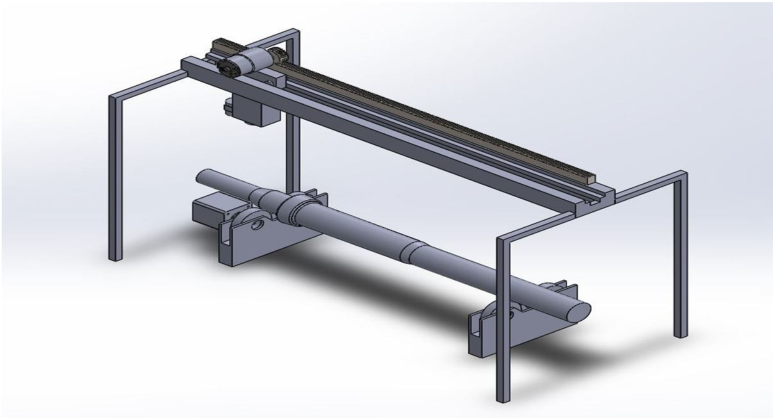

Fig II.4 Camera position 4

Fig II. 5 Crack detected under UV Light

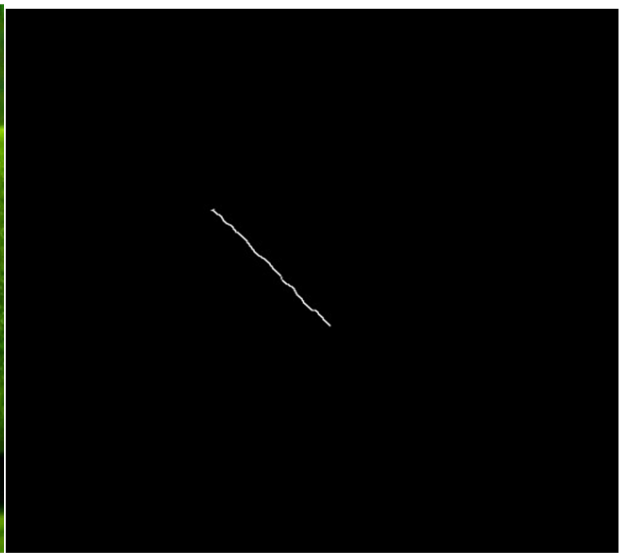

Fig II.6 Crack after image processing

As shown in Fig II.6, the crack is seen in the processed image and thus this job will be rejected according to the program written. Similarly, snap taken of every job at different positions will be processed and a decision about its acceptance or rejection will be taken.

IV. COST ANALYSIS

Sr No.	COMPONENT NAME	COST (Rs) (New system)	COST(Rs) (Conventional System)
1.	UV Light	22000	
2.	Rack & Pinion (S45C &SCM440) 1m length	2900	
3.	Stepper Motor(0.52 Nm torque)	5000	
4.	DC Motor	1500	
5.	Fixture x 2	5000	
6.	Roller Bearings x 4	3200	
7.	Camera (5MP)	37000	
8.	Support Structure	10,000	
9.	Monitor	22,500	
10.	Microcontroller(Rasberry Pi)	7000	
11.	Miscellaneous Costs	15000	
12.	Electromagnet	8500	
13.	Ferromagnetic Solution(1 litre)	38,400	
	Total	1,78000	4,15000

V. CONCLUSION

The proposed system will save 8 seconds of inspection time per job. Thus considering 1000 jobs, it will save 2.22 hours of inspection time. From the table presented above, it is seen that the new system is significantly cheaper than the conventional system and gives better accuracy at the same time. In addition to that, the new system will eliminate acceptance of jobs with cracks and rejection of jobs without cracks which takes place in case of manual inspection. Hence, this system is a step forward towards industry 4.0 and Industrial process automation.

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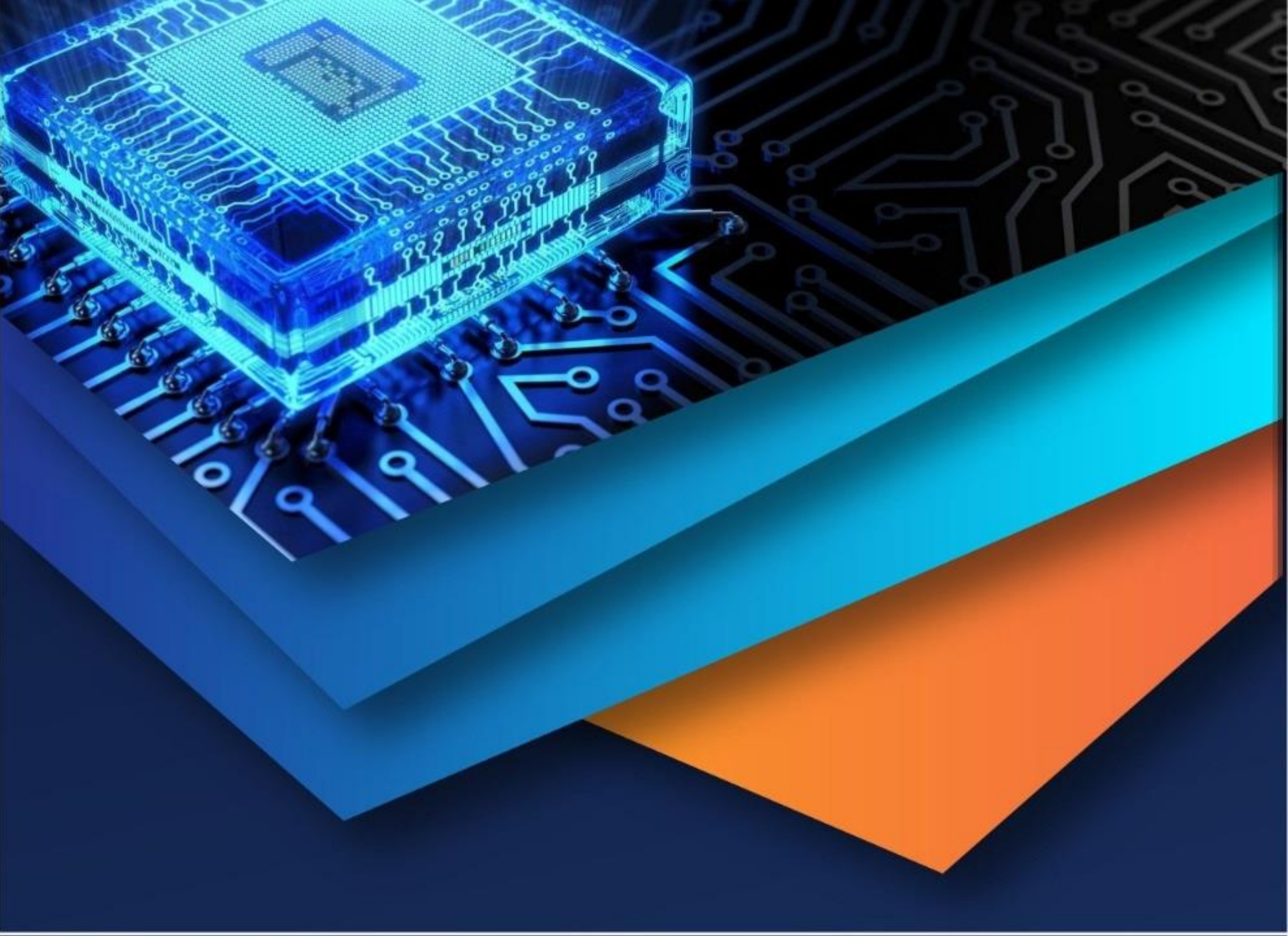

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