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Auto Gear Teeth Burnishing Machine Using Servo Control

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ABSTRACT

A typical vehicle transmission is comprised of between five and six gear sets and a series of gear trains that allows a driver to control how much power is delivered to the vehicle without changing how fast the engine runs. This transmission makes noise due to gear inaccuracies such as burrs, nicks, high points and wrong heat treat scales are the leading causes of noise in power transmission. There are many different causes of gear noise, all of them theoretically preventable. Unfortunately, the prevention methods can be costly, both in equipment and manpower. If the design of the gear and its application are appropriate, in theory all that is necessary is to have a tight control on the process of producing the finished gear. In reality, there are many variables that can cause a process, no matter how well-controlled, to deteriorate, and thus cause errors, some of which will cause a gear to produce unwanted noise when put to use. The effective way to eliminate this noise the process known as "Gear Burnishing". The proposed system uses gear shaving cutter as a master for burnishing or deburring operation of gear teeth with servo mechanism (includes servo motor and servo drivers), Programmable logic controller (PLC), Human machine interface (HMI) to remove gear inaccuracies and so as to reduce or eliminate transmission noise and provide more life and reliability to transmissions in vehicles resulted into noise free vehicles.

Keywords : Gear Burnishing; Programmable logic controller (PLC); Human machine interface (HMI)
Servo Control; Feedback system; Gear box; Maximum accuracy; Programming; Communication.

I. INTRODUCTION

Definitions: Burnishing is a process by which a smooth hard tool (using sufficient pressure) is rubbed on the metal surface. This process flattens the high spots by causing plastic flow of the metal. Burnishing is a surface modification process that produces a very smooth surface finish by the planetary rotation of a tool over a bored or turned surface. The tool may consist of one or more ball or roller. This process does

not involve the removal of material from the work pieces. All machined or other processed metal surfaces consist of a series of peaks and valleys which constitute the surface irregularities. The force applied by the burnishing tool forces the material from the peaks to flow into the valleys. This reduces the height of the peaks and depth of the valleys, thereby reducing the surface roughness.

Burnishing is a super finishing process of obtaining a very fine surface finish having a grain less appearance on metal objects. This process is used on various flat, cylindrical, or conical surfaces. It removes scratches and tool marks on the surface. Burnishing is a versatile process that improves the surface finish and dimensions of the turned parts, without the usage of extensive tooling. Figure 1.1 shows schematic working principle of burnishing process.

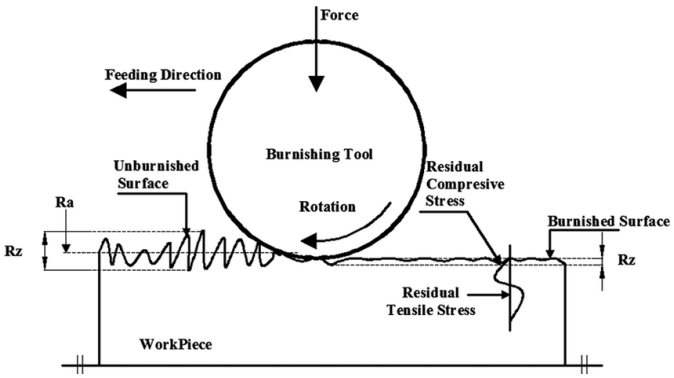

Figure1.1. Schematic working principle of burnishing process

A conventional lathe, on which the workpieces were turned, can be used for burnishing, thereby eliminating the time and effort for remounting the workpiece. The tool used for burnishing consists of one or more ball or roller, held in a casing. This tool can be mounted on the tool post of the lathe. When the tool is made to come in contact with the rotating workpiece, the friction force rotates the balls or rollers of the tool, in a planetary motion. The burnishing process is considered as a cold working process because the surface of the workpiece is subjected to severe stress due to the planetary motion between the tool & workpiece and the pressure applied by the tool. When this stress exceeds the yield strength of the material, it results in the plastic flow of the material from the peaks of the surface irregularities into the valleys, thereby reducing the surface roughness. This also induces thermally stable and long-lasting compressive residual stresses. In this method the machined gear is rolled under pressure with three hardened master gears of high accuracy and finish. The minute irregularities of the machined gear teeth are smeared off by cold plastic flow, which also helps in improving the surface integrity of the desired teeth.

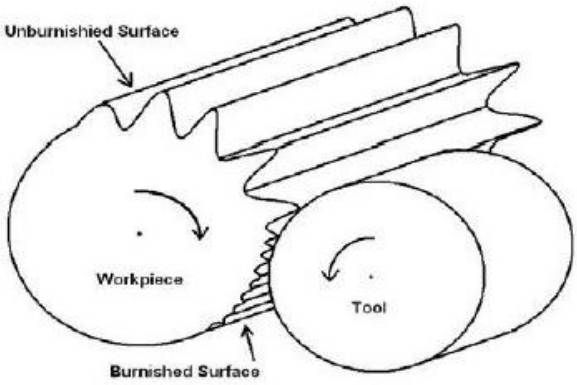

Figure 1.2. Basic operation of Burnishing

The gear to be finished is mounted on a vertical reciprocating shaft and it is kept in mesh with three hardened burnishing compatible gears. The burnishing gears are fed into the cut gear and revalued few revaluations in both the directions. Plastic deformation of irregularities in cold state takes place to give smooth surface of the gear.

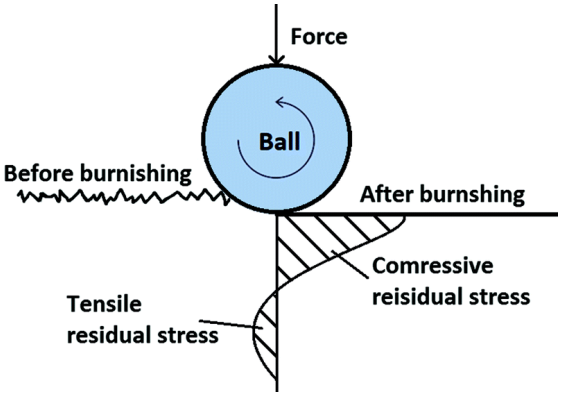

Figure 1.3 Results of Burnishing Process

Proposed system called as "auto gear teeth burnishing machine using servo control" as the name itself indicates this machine is used for automatic gear burnishing using servo mechanism before assembly of gears onto the transmission shaft. Each gear goes through different machining process such as 'roughing' and 'finishing', after going through all these processes gear still has some inaccuracies such as bur, high points and to remove these gear inaccuracies proposed system will work which is nothing but 'burnishing'. After the process of gear burnishing gear is checked with auto DFC (Gear Double Flank Roll tester) checking machine which will check overall geometry, total composite error of gears with bore or between center and tooth to tooth error. If all tested parameters of burnished gear are ok then only it will be assembled on transmission shaft else it will considered as rejected gear.

The project includes the following objectives:

·Comparing the available components from the market which meet the best solution. i.e. (PLCs), Motor controllers, HMIs, Servo motors, Drivers, Encoders etc.
·Designing a layout for the installation of PLC, a Machine and other components together.
·Wiring Design and wiring installation
·Designing and construction of a wiring rail and a servo motor driver support system
·Designing the Machine elements
·Programming
·Testing and Finalizing
·Documenting

Burnishing Machine Elements: We present a taxonomy that will aid in defining the components required for burnishing machine from a high level perspective. Specific taxonomies of each component can be found elsewhere. There are three major components for development of arm are:

a) Hardware - made up of sensors, actuators, PLC, HMI, Servo motors, encoders and embedded communication hardware

b) Software - on demand storage and computing tools for data analytics PLC programming software GX Works 2 is recommended for Programming a FX series PLC.

c) Presentation - novel easy to understand visualization and interpretation tools which can be widely accessed on different platforms and which can be designed for different applications. In this section, we discuss a Human machine Interface (HMI) which is a touch screen display for visualization and to provide output.

II. DESIGN AND DESCRIPTION OF PROTOTYPE

The main objective of this project is to automatic removal of gear accuracies such as burrs, nicks, high point and to make power transmission in vehicles noise free. For this the machine design and sequence of operation is shown in flow chart figure 1.4

- Initially, non-burnished gear is to be picked by the operator and have to put onto the fixture and by confirming machines home position press two hand safety push buttons.
- As push buttons are pressed machine cycle starts and clamping cylinder comes down and clamps the job/gear, by taking confirmation of job clamping via down reed switch sliding cylinder will comes

forward and moves slide forward with clamped job/gear.

- On the other side of slide shaving cutter/master/burnishing tool is mounted through servo mechanism (includes servo motor and gear box). If the gear teeth and master/cutter teeth are matched, confirmation is takin by teeth matching sensor which is inductive type proximity sensor, then servo motor will rotate in clockwise direction for set no of rotations.
- Reduction gear box is used with servo motor for higher torque. After getting rotation completion confirmation by servo encoder servo motor will rotate in anticlockwise direction with the set number of rotations.
- Anticlockwise rotation confirmation is given by servo encoder to PLC and now sliding cylinder moves slide reverse and position is confirmed by reverse reed switch of sliding cylinder.
- Now clamping cylinder is reverse/up to its home position and job/gear is de-clamped and cycle completed with incremented job counter.
- In another case if gear teeth and master/cutter teeth are not meshed/matched and teeth matching sensor remains off then, sliding cylinder is getting back/reverse and servo motor will index half pitch angle of gear so as to match master and cutter teeth.
- After indexing of servo is complete PLC gets its feedback from servo encoder and now sliding cylinder is again forward and slide with clamped gear moves towards master/cutter.
- Now again gear and cutter teeth matching is checked via teeth matching sensor and if teeth are matched then burnishing cycle is repeated if not then again sliding cylinder is reverse and cycle continues.
- Once a burnishing cycle of a gear is complete machine counter is incremented, this is provided to keep production track.
- This way all gear inaccuracies such as burrs, nicks, wrong heat treat scales, high points are removed and it will be checked on gear roll tester/ auto DFC Checking machine. If all parameters such as tooth to tooth error, gear geometry, number of teeth are ok then that gear is taken for assembly in engine transmission.
- Here in this machine for operator safety complete work area is covered under the safety light curtains (works on optical principle). If in between machine cycle if operator tries to put hand in working area or any obstacle comes in working area then machine is stopped at its current position and manual intervention alarm is generated and displayed on HMI screen with buzzer and red light and after removing hand/object/obstacle from machine working area by pressing reset button machine goes to its home position and is ready for next cycle.

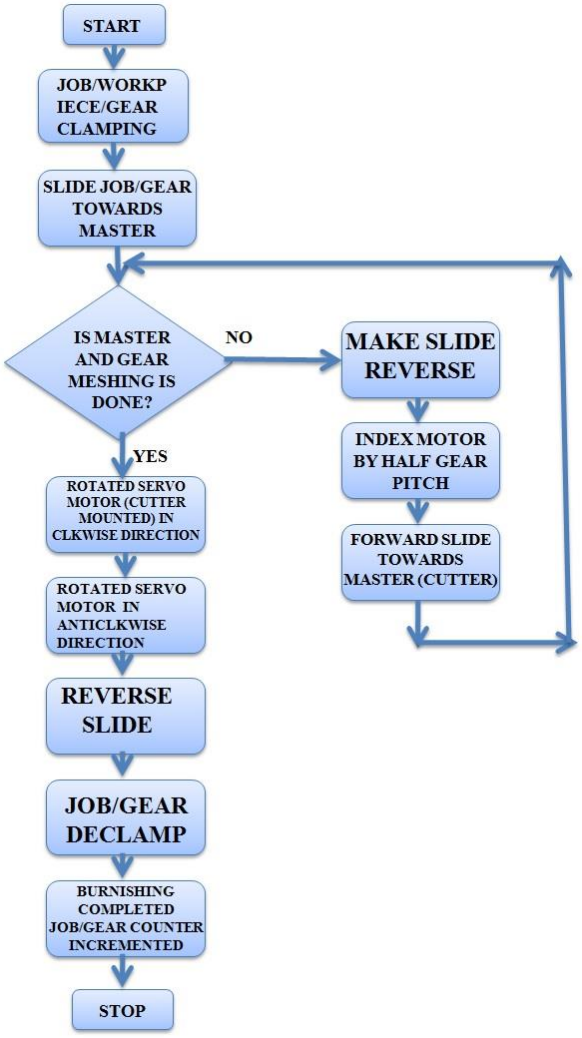

Figure 1.4. Machine Flow Chart

Hardware and Software Requirements: For this project, we require different hardware component and different software. So that this project is a combination which full fill the definition of both robotics and automation This is a list of all the hardware components that will be used in this guide:

- Programmable logic controller (PLC)
- Human machine interface (HMI)
- Stepper motors with drivers and encoders
- Pneumatic cylinder
- Inductive proximity sensors
- Safety light curtains
- Relay board
- Contactor
- Power supply
- Miniature circuit breaker (MCB)
- Wires with dia 0.5sq.mm, 1sq.mm

Three different types of software are required for controlling the major three devices which are PLC, HMI, and motor driver. Software used in this project are listed below:

- PLC programming software GX Works 2[8]
- HMI Programming software GT designer 3
- Servo motor driver software

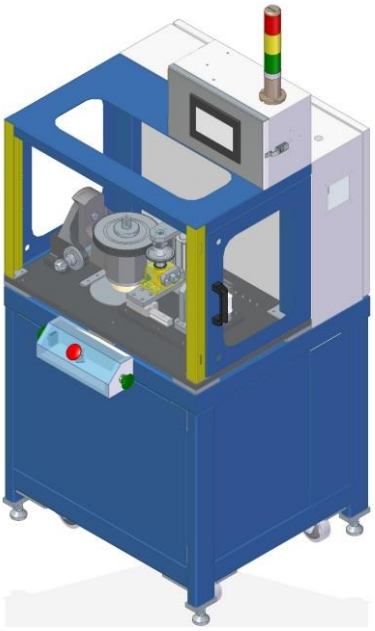

Figure 1.5. Machine 3D View

Hardware Configuration:

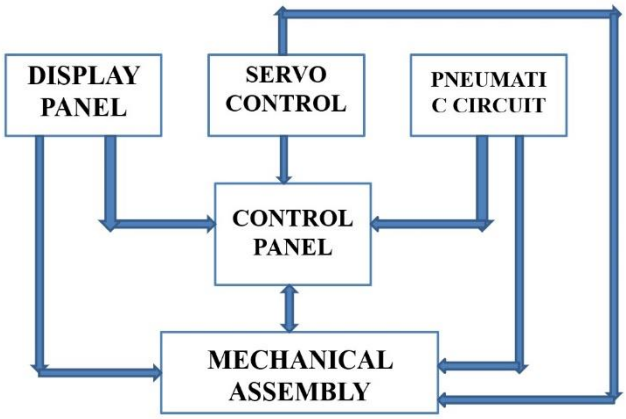

Figure 1.6. Main Block Diagram

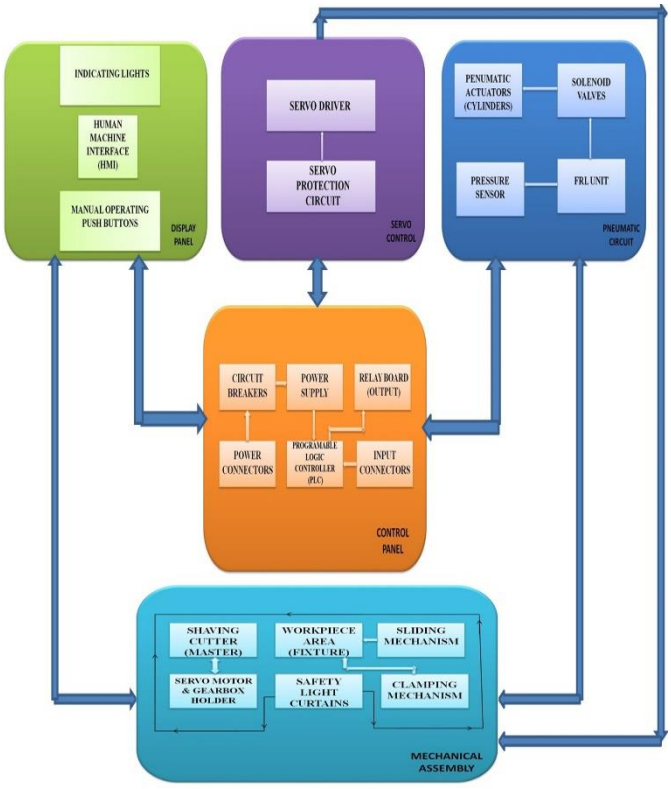

Figure 1.7. Machine Block Diagram

Basic building blocks of auto gear teeth burnishing machine are control panel, servo control, mechanical assembly, display panel and pneumatic circuit as shown in figure 1.6. Detail block diagram of machine is shown in figure 1.7 We are now going to see major block/parts of machine in detail

- Programmable Logic Controller: A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. A PLC is an example of a hard real time system since output result must be produced in response to input conditions within a limited time, otherwise unintended operation will result[8]

Figure1.8. PLC FX Series (FX3U)

Safety Light Curtains: Light curtains are opto-electronic devices that are used to safeguard personnel in the vicinity of moving machinery with the potential to cause harm such as presses, winders and palletisers. Light curtains can be used as an alternative to mechanical barriers and other forms of traditional machine guarding. By reducing the need for physical guards and barriers, light curtains can increase the maintainability of the equipment they are guarding. The operability and efficiency of machinery can also be improved by the use of light curtains by, for example, allowing easier access for semi-automatic procedures. Light curtains fall into a category of equipment known as presence detection devices. Other common presence detection devices are pressure-sensitive safety mats and laser scanners (often used on Remotely Operated Vehicles (ROV) when in industrial settings). Most important applications of safety relays are in automation industries dealing with robotic cell setup. Light curtains are supplied as a pair with a transmitter and receiver. The transmitter projects an array of parallel infrared light beams to the receiver which consists of a number of photoelectric cells. When an object breaks one or more of the beams a stop signal is sent to the guarded equipment machine. The light beams emitted from the transmitter are sequenced, one after the other, and pulsed at a specific frequency. The receiver is designed to only accept the specific pulse and frequency from its dedicated transmitter. This enables the rejection of spurious infrared light and thus enhances their suitability as components within a safety system. Typically, light curtains are connected to a safety relay which will remove motive power from the hazard in the event that an object is detected. Safety relays can be provided with muting functionality which enables the temporary disabling of the safety function to allow objects to pass through the light curtains without tripping the safety relay. This is particularly useful for machinery which has some semi-automatic procedures.

Figure 1.9. Safety Light Curtains

Servo motor and driver : A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. A servomotor is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is a signal (either analogue or digital) representing the position commanded for the output shaft. The motor is paired with some type of encoder to provide position and speed feedback. In the simplest case, only the position is measured. The measured position of the output is compared to the command position, the external input to the controller. If the output position differs from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the positions approach, the error signal reduces to zero and the motor stops.

Figure 1.10. Servo motor and driver

Human machine interface (HMI): An acronym for Human Machine Interface. An HMI is a software application that presents information to an operator or user about the state of a process, and to accept and implement the operators control instructions. Typically information is displayed in a graphic format (Graphical User Interface or GUI). Here in this project I used Mitshubhishi GS series HMI and GT designer 3 is the software used for programming of it. Basic use of HMI is for providing input to the arm with the help of touch screen display and for displaying output

Figure 1.11. HMI GS series

Mechanical Assembly: Machine assembly is nothing but the complete integrated view of different parts for specific task which is to be performed. Here in this project task is to heck crankshaft oil holes presence and this is done by actual machine assembly which is nothing but integration of sensors, actuators through fixtures and mechanical parts made up of different engineering materials such as table structure is made up of mild steel (MS), some parts are of EN31, Where there is sliding or moving parts in between part harden material is used (by changing material property through heat treatment). Control panel is mounted on below side of the machine table and display panel is on front top side of the machine table.

Proximity Sensor: A proximity sensor is a non-contact sensor that detects the presence of an object (often referred to as the "target") when the target enters the

sensor's field. Depending on the type of proximity sensor, sound, light, infrared radiation (IR), or electromagnetic fields may be utilized by the sensor to detect a target. Here M8 PNP NO non flash inductive type proximity sensor is used as shown in Figure1.12

Figure 1.12. Proximity Sensor

III.CONCLUSION

This paper, presents what Auto Gear Teeth Burnishing Machine using Servo Control is, which components are necessary to make a burnishing machine Thus at the end auto gear burnishing machine works in any environment with same accuracy and precision for long time and removes all gear accuracies and eliminate vehicle noise. This is one of the low cost solution among all other machines available in market. Also the following objectives of dissertation are accomplished:

- Comparing the available components from the market which meet the best solution. i.e. (PLCs), Motor controllers, Servo motors etc.
- Designing a layout for the installation of PLC, a servo control and other components together.
- Wiring Design and wiring installation
- Designing and construction of a wiring rail and a Servo motor driver support system
- Designing of machine
- Programming
- Testing and Finalizing
- Documenting

This Application notes detailed how to design and install Auto Gear Teeth Burnishing Machine using Servo Control and testing them This arm can be used many of the industries not only for the purpose of a specific industry following are Some of the applications where this type of machine with slight design changes

1. Defense Applications
2. Medical Applications
3. Pharmaceutical Industries
4. Automobile Industries
5. Process industries

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