Design & Development of Low Cost Automation System for Loading & Unloading of Steam Turbine Blades on Vertical Milling Machine

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Abstract— The major concern in machining steam turbine blades lies in loading and unloading of the component, which is been currently done manually. Since this loading and unloading operation considerably incurs some cost affecting areas like manufacturing lead time, decrease in productivity and loading and unloading time directly or indirectly, there is a need to implement an automated method of actuating these sequences significantly. Low cost automation principle is best approach to perform loading and unloading of work piece to machine that permits enhancing the performance of existing facilities by incorporating simple mechanical, pneumatic, hydraulic or electrical systems and devices with low investments. The present Project work is concerns with design and development of low cost Automation System For Loading & Unloading of Steam Turbine Blades on Vertical Milling Machine, which will remove the human interference in repetitive working environment and increases the productivity by reducing the manufacturing lead time.

Key words: Low Cost Automation, CNC machine, Steam turbine blade, Fixture

I. INTRODUCTION

Industrial automation is very popular in now day's modern factory, it can perform jobs that people are not willing or able to perform, it can repeat the same work at the exactly same way, resulting a higher productivity and quality of production. Low cost automation is an approach that permits enhancing the performance of existing facilities by incorporating simple mechanical, pneumatic, hydraulic or electrical systems and devices with low investments. The term "Low Cost" is a relative quantification of cost incurred on renovation project. Appropriate systems can be devised for parts handling automation on process machines or between operations for achieving smooth production flow, reducing manpower requirements, more consistent performance, reduced labour cost, achieving higher productivity and so on.

Automation is a higher degree mechanization in which human participation is replaced by mechanical, electrical, fluid power technologies capable of doing physical and even mental work as in the case of CNC machines. In some situations automation also demands accurate sensing, recall, memory storage, physical efforts or movements requires special sensors for controlling the technological processes. The combination of losses resulting from conversion, idle time and high technical maintenance costs quickly negated the expected economic benefits. Today at many locations highly automated production facilities are making way for systems with significantly lower degrees of automation. Exaggerated automation was found just as often at small enterprises as it was at larger companies. It appears that short innovation cycles define the limits of economical automation. An industrial automation can increase the productivity of industry to great extent rather they can reduce human interference within the production. Cost is the dominating reason for its not being favored much. However, for situations where production rate is high (low cycle time) and the operation is largely pick & place type, use of simple robot is suggested for low weight components.

II. DESIGN OF PICK AND PLACE AUTOMATION

A pick and place mechanism is a part of a larger production process which performs loading and unloading operation of blade component to a production process for further manufacturing and modification of a product to be carried out.

The pneumatic pick and place unit has a gravity feeding mechanism which works on earth's gravity for the movement of blades so that the blade is moved one by one and is picked by an end effector of the robot. Since the mechanism proved quite cheaper and simple further design developments were undertaken to build an overall simple mechanism for the loading and unloading of blades. Along with the Gravity feeder mechanism we also needed a robotic arm carrying an end effector with it. Therefore, over a period of time and process study we have come with the new concept which includes robotic arm, feeder mechanism and the blade collecting mechanism thereby completing the total functional automation setup. Design and development of these mechanisms and the simulation were carried out in CATIA V5 R18. Assembled 3D CAD model of the automation setup is as shown below.

Fig. 1.shows the isometric view of the automation setup. The main objective behind developing this mechanism is it should be as simple as possible and should be less costly.

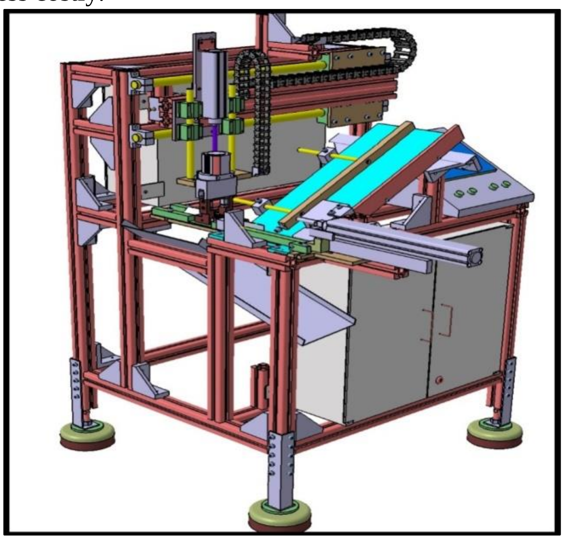

Fig. 1: Assembled CAD model of the Automation Setup

To build this mechanism we have utilized maximum number of things that was available in the scrap yard in-house, hence theoretically proved the mechanism less costly.

The stroke length of various cylinders is as given below:
X Axis Cylinder
Stroke = 280mm
Y Axis Cylinder
Stroke = 570mm
Z Axis Cylinder
Stroke = 100mm
Door Cylinder
Stroke = 360mm

A. Robotic Arm

Robotic arm performs the actual work of picking and placing. The arm slides on the aluminium structure (Aluminium Extruded Channel) with the help of bearings. The aluminium is fixed to a steel table on which the linear motion roller bearings are housed on the other side. These bearing slides in the direction of guide rods attached to the structure (Table). The other end of the arm consists of end effector which in turn houses gripper and Z-axis pneumatic cylinder.

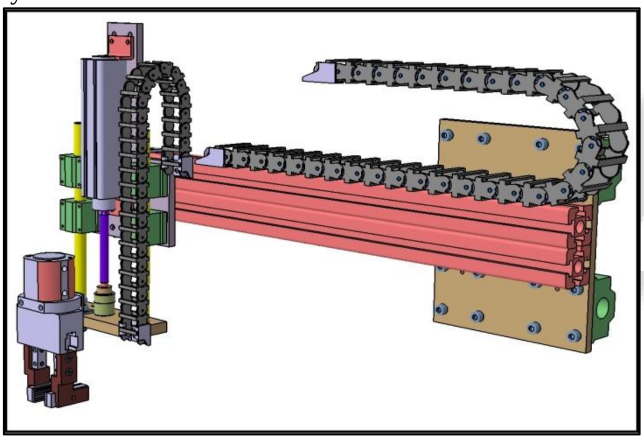

Fig. 2: Assembled CAD Model of Robotic arm

The gripper is clamped to a support table. The support table also holds a pair of guide rods which helps the gripper to move up and down in Z direction. The end effector is just a T-shaped aluminium table which keeps in holding the cylinder and two pairs of small sized linear motion roller bearing which guides the gripper smoothly without a glitch. Large and small sized flexible cable trays are employed in order to carry the required cables and pneumatic pipes to the cylinders. The movement of the arm is taken care of by pneumatic cylinder of stroke 570mm. In total the robotic arm uses three position magnetic sensors, one each at both ends and another in the intermediate position for dropping the finished blade.

B. Gravity Feeder mechanism

The feeder unit performs the duty of feeding the raw materials to the gripper so that further actions will be carried out by the robotic arm eventually. The most important point that has to be noted here is the raw material is fed to the gripper with the help of simple gravity and a pneumatic cylinder. Hence one of the most important unit in automation is just simply driven by combination of science and technology without any hard usage of energy. This is where maximum level of cost is been brought down.

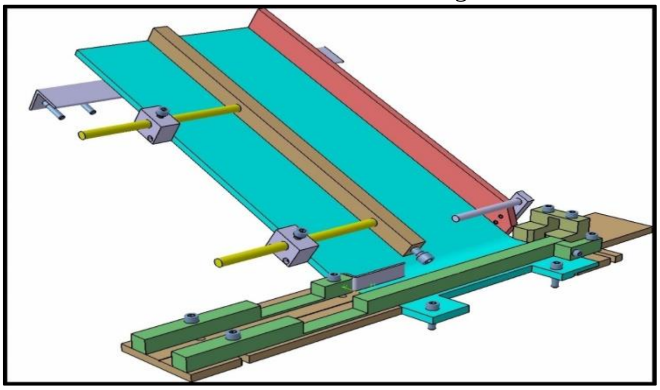

Fig. 3: Assembled CAD Model of Robotic arm

This unit incorporates three platforms, cylinder platform, Slide pad and the sliding platform. All these three platforms are made using 10mm thick steel plate. The plates are hard chrome plated to enable smooth sliding of the blade raw material. The raw slabs are placed one after the other on the inclined Slide pad. The sequence is that the first slab slides down and is stopped by the stopper at the front. Now, the cylinder pushes the slab through 280mm to the sliding platform through push rod. The gripper picks the slab from the sliding platform and push rod returns to its home position. Therefore, the next slab slide down and occupies the platform waiting to get pushed by the push rod. Provision is made for altering the front stopper according to the size of the blade raw material.

C. Gripper

The first stage in the design process is to design the gripper and select the actuator to control it. The size, length and weight of the gripper are determined according to the requirement. The gripper is pneumatically operated and is procured as a standard unit. However, the fingers were to be designed and fabricated according to the application it’s employed to. The stroke of the gripper is 41mm and according to the graph the holding force lies between 30 - 40 Kgf which is pretty much sufficient to hold even the maximum blade size. The main aim of the gripper is to lift the finished high profile blade which is quite challenging due to its availability in different sizes and is not at all standard. Hence, gripper fingers were designed and fabricated in-house using aluminium material mainly to reduce the weight. Separate pair of small aluminium block called as sub-finger was also made which is actual part that holds the blade between them. These sub-fingers are clamped loosely to the main finger through an Allen screw to offer some play. This play is counterfeited by a pair of springs between them. The main intension here is to ensure that the gripper confines to the different profiles of the blade.

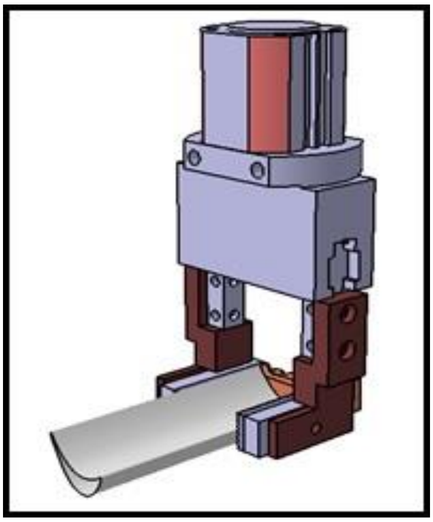

Fig. 4: CAD Model of Pneumatic Gripper

D. *Ground Mounting*

Vibrations will be induced in the setup i.e. the whole setup starts vibrating when the Y-arm and Z-arm moves to and forth. These vibrations are mainly because of the poor bottom support structures of four legs of the robot. To overcome this problem this unique vibration pads were procured. Though a standard part available it served the damping needs and also it avoided the need for grouting the automation setup.

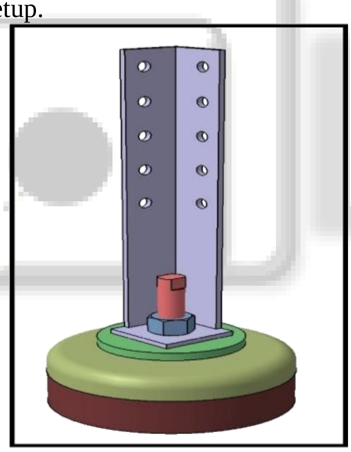

Fig. 5.Ground Mounting

E. *Finished Blade collecting Mechanism*

Finished blade collector is a device used for collecting the finished blades. The working of this mechanism is simple. The unit consists of two sliding panels inclined at certain angle jus to ensure that the blade slides easily after dropping it. When the Y-arm is retracting back, gripper drops the blade on the first sliding panel so that the blade easily slides and drops on to the second sliding panel which is placed perpendicular to the former one. The finished blade gets collected at the end portion of the second sliding panel from where it should be collected after certain time period. This process repeats for all the blades. The design of finished blade collector is shown in the Fig.5.

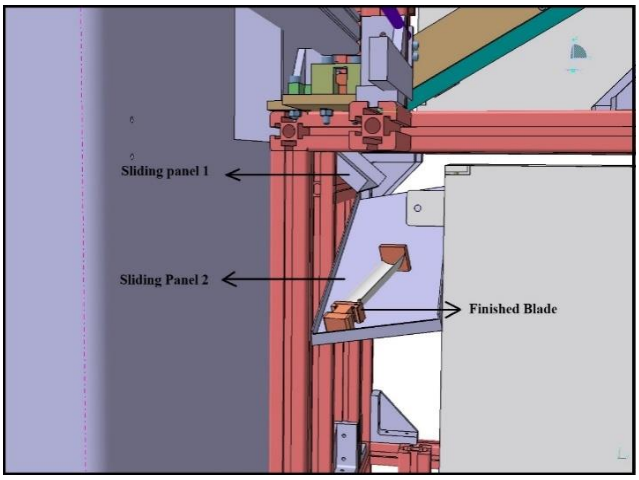

Fig. 5: Blade collecting Mechanism

The collector has the capacity to collect around 15 small sized blades at a time. Once if it is full, the operator has to unload all the blades from the collector.

III. STATIC LOAD ANALYSIS

Since the machining of each blade takes around 30-60 minutes on average, the robotic arm stays un-functional otherwise and it takes in load continuously in either conditions whether be it static or dynamic. So stress analysis was carried out for the arm and its related load taking components using ANSYS Workbench software.

Robotic arm being the main part carrying load during the picking and placing operation it's got necessity to know its merits and demerits under loading. The maximum stress in the case of the robotic arm will be at end of the steel plate which is been fixed and therefore acts like a cantilever beam under static conditions. The maximum stress σmax is about 1.38 MPa which is found to be much lower than the expectations. While one end of the arm is fixed the other end carries the gripper unit. Therefore this whole unit carries a load of 90N under idle conditions. The purpose of this calculation was to see where the maximum stress occurs on the robotic arm. Since aluminium arm is fixed at one end maximum stress is observed at this end where it is been bolted to the steel plate.

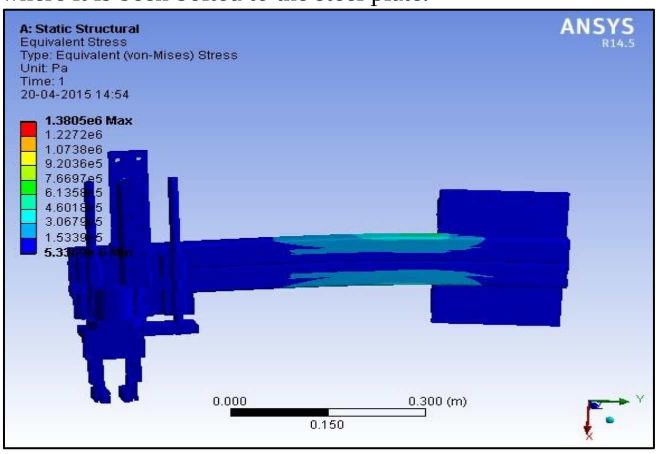

Fig. 6: Stress analysis of Robotic arm

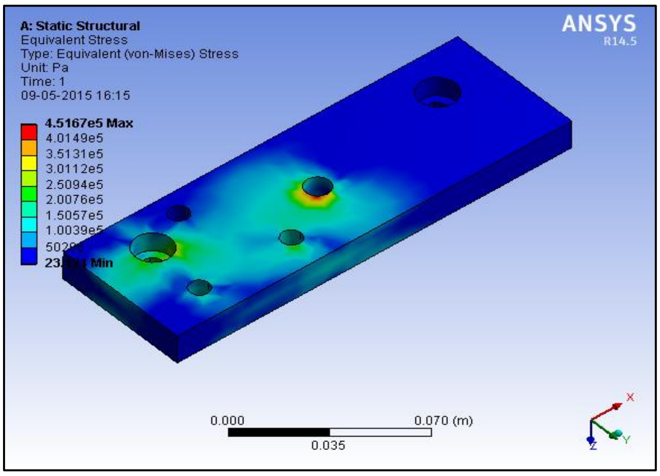

Fig. 7: Static Stress analysis of support plate

Gripper is clamped to the support plate which holds pneumatic piston aligner and the two guide rods on either sides of 16mm dia. This support plate is made of aluminium and plays a vital role in keeping hold of the gripper and its Z axis movements. The load that's falling on the plate is only about 35N which is the weight of the gripper together with its self-weight, in Z direction. The maximum stress is observed in the middle of the plate around centre hole with a magnitude of 0.451MPa and is depicted pictorially below. Since the load is less the stress seen also appears to be less.

IV. CONCLUSION

To design and develop automation for an industry has been very instructive. At the beginning stages, the process seemed to be complicated but as time led by more things peeped in simplifying the automating process. There were many factors to consider and eventually the thesis became more interesting, intrusive and challenging.

The bearings used for the sliding purpose of the robotic arm seem to bear the arm load theoretically. This when compared to the load capacity of the bearing given by the manufacturer seemed to be lesser. Therefore this proved to be efficient in utilizing tis purpose without causing any trouble during the implementation and trial of automation and hence is trustworthy in long run.

The mechanical static load analysis indicates that the material and the design could cope with the loads that the arm was exposed for. The analyzed result showed that the maximum stress induced in the material appears to be low and satisfactory. The material and the design approach could be changed if needed for increased strength and structural rigidity. The minimum and maximum blade length that could be operated here by the gripper will be from 80mm to 200mm whose width come in with four variations i.e., 3/4 , 1, 1.25 and 1.5 inches respectively.

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