ECODESIGN: A RETROFIT DESIGN CONCEPT FOR 3-AXIS GANTRY, COMPATIBLE TO ND: YAG BASED PULSE LASER

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A wide range of precision Laser Machine Tool is available in international market. Majority of these have a part positioning system of a range of 200 × 200 × 50 mm and resolution of 50–100 micron. The initial cost of the machine is not permitting its use to SME's. It is highly essential to minimize the cost of machine by keeping the same functional utility in mind. Hence an attempt is made to design machine by Retrofit approach than radical approach. In this approach, components are selected from salvage considering its sustainability in terms of topology, accuracy and repeatability to build a 3-axis gantry since major cost in the machine is of gantry system. Economical and Ecological "EcoDesign" is presented in this paper by End of life use of the components those are taken from thrown out equipments. Nd:YAG based pulsed laser workstation is conceptualized with high resolution precision, X-Y-Z Gantry system. Precision slides for X-Y movements are taken from out-of-order dot matrix printers. Precision Z-axis slide is taken from out-of-order petrological microscope slide. The system provides a retrofit design concept that is compatible to a 250 x 250 x 50 mm pulsed laser workstation.

Keywords: Laser workstation, X-Y-Z Gantry, End-of-life, EcoDesign, Retrofit.

1. INTRODUCTION

Laser suppliers like Oxford Lasers, Rofin Lasers, Resonetics Laser etc. are some of the companies in the precision laser machine tools market [1].

From the data available, these workstations, have a gantry of 250 × 250 × 50 mm and a resolution of 50–100μm. Majority of the machines uses Nd:YAG laser head. The beam of laser is delivered by the optical fiber. X-Y movements are motorized and Z-axis is manual. Motorizing Z-axis is at an additional cost. All the machines are radically designed i.e. by conventional approach. Major cost is of gantry for work positing system rather than the cost of laser head, power supply and beam optics together.

2. OBJECTIVES

The research project undertaken with following objectives:

- To provide a 3-axis gantry compatible to use with Optical fiber Connection of Nd: YAG laser. (It should be compatible with other types of lasers also)
- To use the concepts of retrofit designing to make it more economical

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3. ECODESIGN

"Eco" refers to both economy and ecology [2]. It is the integration of environmental considerations at the design phase, considering the whole product life cycle from raw materials acquisition to final disposal.

The field of EcoDesign is also called design for the environment. Research on EcoDesign is largely focused on how to systematically integrate environmental considerations in the development of products, services and systems. As the research field of EcoDesign is still evolving, different researchers are constantly redefining the view of what EcoDesign is. A few definitions are presented here, 'EcoDesign *considers environmental aspects at all stages of the product development process, striving for products that make the lowest possible impact throughout the product life-cycle*'. In this definition, it is the physical artefact that is the focus of EcoDesign. Another definition takes a broader perspective and also include services in their definition of EcoDesign: *EcoDesign is a broad term implying a balanced view of the whole product life cycle and design effort focused on reducing the major environmental impacts of a product or service* [2].

Eco-efficiency and dematerialization are different environmental ambition levels. The basic business contribution to sustainable development is eco-efficiency, a term the World Business Council for Sustainable Development (WBCSD) invented in 1992.The WBCSD defines eco-efficiency as 'being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity' [3].

The Council has identified four aspects of eco-efficiency that make it an indispensable strategic element in today's knowledge-based economy:

- '*De-materialization: Companies are developing ways of substituting knowledge flows for material flows*
- *Closing production loops: The biological designs of nature provide a role model for sustainability*
- *Service extension: We are moving from a supply-driven economy to a demand- driven economy*
- *Functional extension: Companies are manufacturing smarter products with new and enhanced functionality and selling services to enhance the products' functional value*.'

The WBCSD considers dematerialization to be part of eco-efficiency. Eco-efficiency is often referred to as 'doing things right', meaning that the environmental impact per functional unit is reduced. Focusing on input orientation, as dematerialization does, has the effect of avoiding introducing material into the societal loop by reducing the overall amount of materials and energy used.

4. PRODUCT DEVELOPMENT AND ENVIRONMENTAL BENEFITS

The literature on EcoDesign often calls for higher levels of innovation in order to achieve environmental benefits. Innovation levels are often divided into categories on the basis of the scope of the *possibilities* for achieving environmental benefits. A four-stage Charter and Chick model for environmental benefits, using the categories Repair, Refine, Redesign and Rethink (see Figure 1). This four-step model is widely used in EcoDesign literature [2].

The four stages move incrementally from making small changes in a product to totally redesigning the product or business systems. Repair of a product focuses on solving emergency problems. Refine focuses on achieving eco-efficiency in products. Redesign focuses on reaching a state where environmental factors are incorporated from the start and fundamentally change the design of the product. Rethink, the last stage, focuses on designing a totally new product, new product functions or new business concepts. One of the strategies that can be applied at this stage is dematerialization, in which products are substituted with services. Moving from the redesign stage to the rethink stage requires significant leaps in thinking. For example, attention will have to be paid to cyclic material loops.

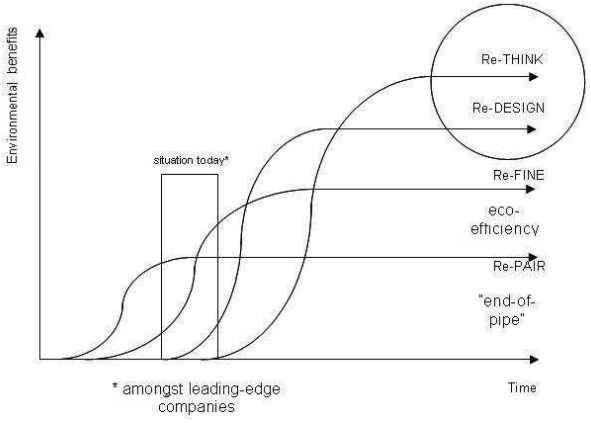

Figure 1. A four-step Charter and Chick model of approaches to environmental improvements in product development [2].

The Charter and Chick model has been used to show that the approach to product development in leading-edge companies concentrates on the lower steps in the model, which have less potential for environmental benefits. Over time, companies need to focus more on redesign and rethink strategies. In rethink strategies, the business strategy is also affected by EcoDesign activities and environmental work is shifted from being focused on products and becomes embedded in business solution.

5. CURRENT PRACTICES FOLLOWED

Xerox [4] published a report in 2003 namely, "We can't remanufacture the earth". At Xerox, they strive to ensure that their products, supplies, solutions and services not only offer the best value and quality, but also contribute to a better environment. They kept Environmental commitment to become a Waste free company in everything they do. The Xerox's waste-free goal is to create products that minimize waste during manufacturing, use by the customer, and at the end of products' initial life cycle. The brochure explained the reuse and recycle policies. The parts those don't wear out, why to throw them out? All the Xerox equipments are now developed with remanufacturing in mind. Equipment remanufactures and the reuse and recycling of parts diverted 161 million pounds of waste from landfills in 2003.

Parts reuse has significantly reduced the amount of raw material and energy needed to manufacture new equipment.

Konica Minolta [5] promotes a sound environmental design from a comprehensive perspective. They are promoting their manufacturing processes under the "Design for Environment" concept that takes all environmental issues into account such as prevention of global warming, product recycling and elimination of hazardous emissions.

Xerox [6] again maximized the end-of-life potential of produces and components by incorporating reuse considerations into the design process. Parts are designed for durability over multiple product life cycles. Parts are easy to reuse and recycle and are coded with deposition instructions. By reusing the components 70 to 90% by weight and without scarification of performance, new product is rebuilt.

EPSRC [7] concentrated on clean EcoDesign and its economical and ecological benefits.

Charter [8] stressed on the environmental product policy at national level in Europe. He explained that outside G8, there has been dramatic economic growth in China and India. But environmental concerns are taking a back seat in the short-term product policy and EcoDesign are in still early stages.

Karsten [9] defined EcoDesign as "eco" refers to both economy and ecology.

6. DESIGN CONCEPTS FOR 3-AXIS GANTRY

Keeping EcoDesign in mind and meeting the work envelope of 200 × 200 × 50 mm having about 100 micron resolution as per the laser literature, a gantry is designed. This conceptual model can be developed further integrating with regular design process and computer interfacing for 3-axis control with a closed loop feedback.

6.1. Steps followed in Retrofit Design Process:

i. Rethink the concept i.e. outline of the 3-axis gantry from retrofit point of view. In that major stress was given on identifying the gantry requirements for Nd YAG based pulsed
ii. Searching of the most suitable and compatible parts.
iii. Checking of whether those selected parts satisfy the desired requirements.
iv. Preparation of the detailed paperwork and SolidEdge model of the selected parts.
v. With the help of drawings and models, decide the support structure and do the modifications whenever it required..
vi. Used additional parts/sub-assemblies to achieve the set goal.
vii. Prepared the assembly accordingly, and simulate it on the SolidEdge.

6.2. The gantry requirements

The gantry is conceptualized considering the basic principles of EcoDesign.
These are:

- Design for environment i.e. part reuse,
- Cost effectiveness,
- Functional accuracy and reliability

The gantry should have precisely machined slides with resolution at least 100 micron.
It should have

- X- Motion (Top Horizontal slide) minimum 200 mm.
- Y- Motion (Base Horizontal slide) minimum 200 mm.
- Z- Motion (Vertical motion mounted on X-slide itself) minimum 50 mm. as shown in Figure 2

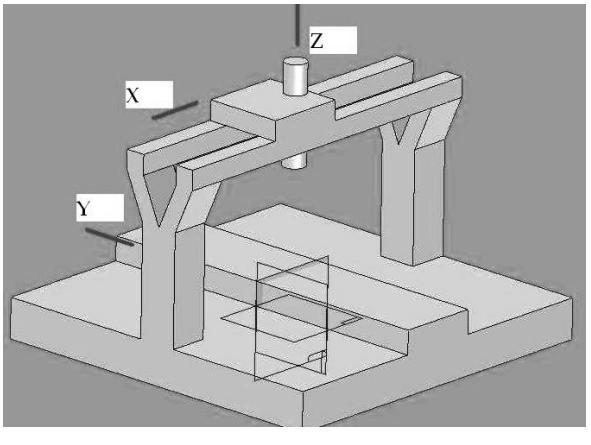

Figure 2. Conceptual workstation showing X-Y-Z slides.

All the three motions X-Y-Z are to be motorized and are to be compatible with computer interfacing. The structure has columns mounted on a base. X-slide is mounted on the top; Z-slide is mounted on the slider of X-slide, and Y-Slide is mounted on the base.

6.3. Components selected for Retrofitting

After finalizing detail design of gantry system then selection of parts for retrofitting is done on the following basis;

a. Weight: Components should have light in weight. Printer slides are light in weight. Hence those can satisfy the material requirement.
b. Shape and size (Topology): Part must be compatible with the gantry requirement. Those should have sufficient strength. In the printer, printer head is delicate, other driving components are sturdy. In case of laser machining, only self weight is criteria for design (obtained from SolidEdge assembly module) as cutting forces are absent. The slider has to sustain the load of Z-slide.
c. Positioning accuracy: Accuracy of the component affects the accuracy of the assembly. Laser systems are provided with a positional accuracy of 100 microns while printer slides have an accuracy of 10 microns.
d. Finish: Printer and microscope slides are mirror finished, hardened and ground.
e. Reliability: Here reliability refers to repeatability. The repeatability of character printing device (printer) and microscope slide is excellent. This feature is the most important as laser machining demands best positional repeatability as these machines are generally used for repeated cycles.

From many alternatives, following components are selected

a) X-Slide and Y-Slide: For the present work the slider with cylindrical guide ways with stepper motor and belt drive is selected from EPSON FX-100 dot matrix printer as shown in Figure 3. It has a travel distance more than 250 mm and the slider can house Z-slide components. (The printer chosen for this was available in scrap of institute.)

b) Z-Slide: A dovetail slide is selected from a petrological microscope, J SWIFT and SONS LONDON which provides a vertical travel of about 56 mm, sufficient for the desired 50 mm. The slide can house lens at the bottom side and optical fiber connection can be made at top. This slide has manual motion that is motorized.

Components are required to modify and additional parts are required to incorporate so as to achieve the aim. The slider is modified as shown in figure so as to have motorized Z-motion.

After modifications the laser workstations gantry is modeled in SolidEdge V14.

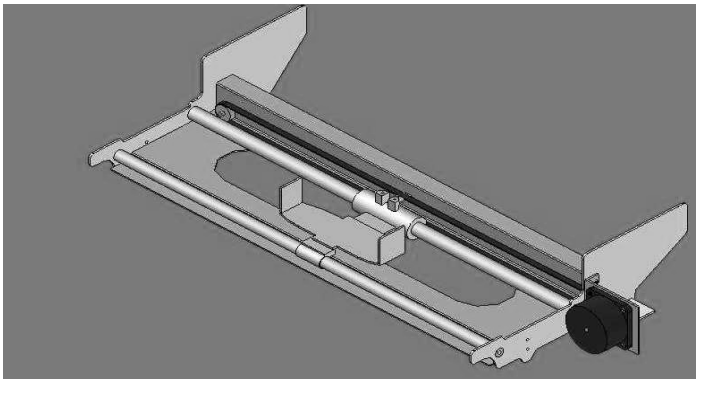

Figure 3. EPSON FX-100 dot matrix printer slide.

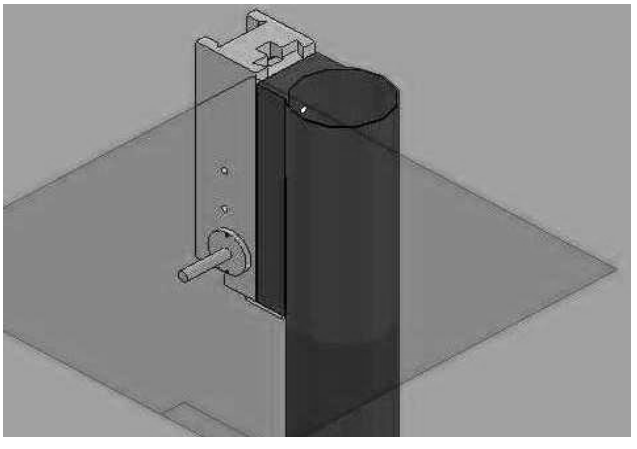

Figure 4. J SWIFT and SONS LONDON Petrological microscope slide.

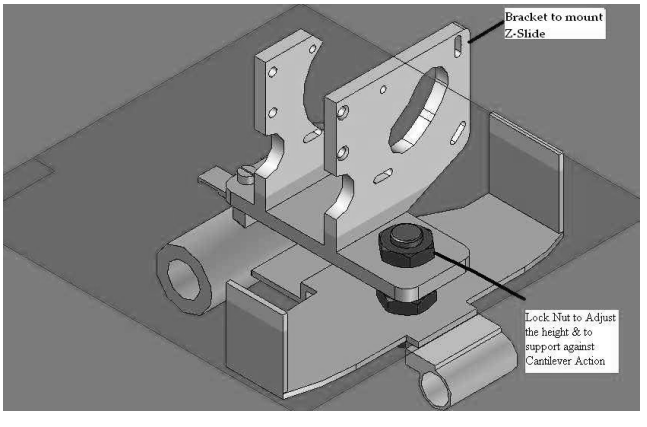

Figure 5. Modified slider of X-Slide.

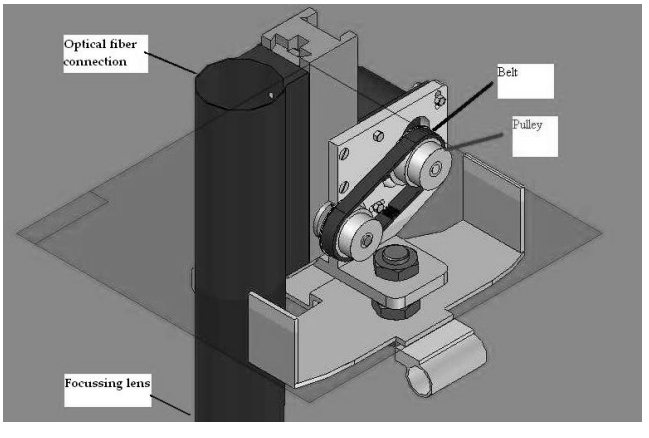

Figure 6. Motorized Z-slide.

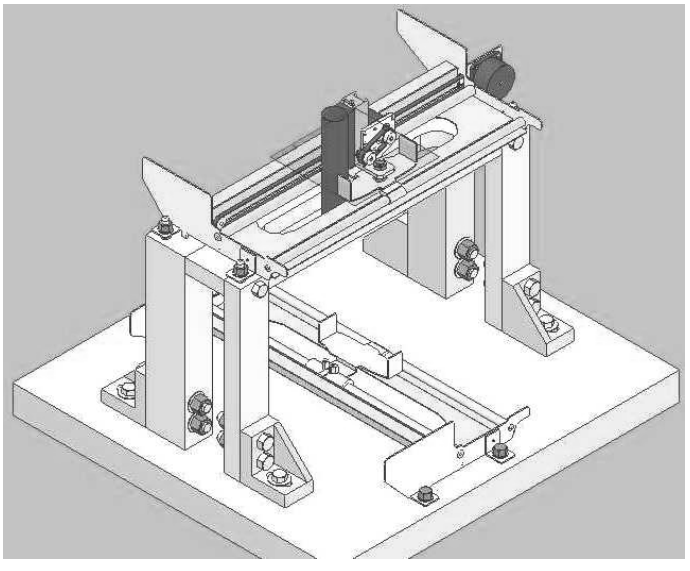

Figure 7. The laser workstation gantry is modeled in SolidEdge V14.

7. ECONOMICAL JUSTIFICATION

In the present market the CNC gantry for 50-100 micron resolution costs above INR 30 lakhs. Implementing the concept of retrofit i.e. reuse of parts, the gantry can be prepared in about INR 2 lakhs for the same specification.

8. CONCLUSION

EcoDesign is eco-product development and refers to integration of environmental considerations at all stages of the product development process. It is way of radical product redesign and rethinking, EcoDesign needs to be integrated at the early stages of product design. This approach is more suitable for designing the equipments which are not undergoes more stress during their working.

EcoDesign is also the design of a product, service or system with the aim of minimizing the overall impact on the environment even after end-of-life.

This workstation is compatible with other types of lasers also.

The methodology depicted in this paper is one way of developing business opportunities while also taking environmental considerations in to account.

The unit is not yet manufactured. As per the principles of EcoDesign, it should provide the correct functionality.

Further, the technique used in this paper is best for a particular product, but this methodology suggest rethink for the manufacturers so as to change the view from early stages of product design. This attempt concentrates on reducing the adverse impact on the environment.

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