Scientific Journal of Impact Factor(SJIF): 3.134

e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 9, September -2015

DESIGN AND DEVELOPMENT OF QUICK TOOL CHANGER FOR ECONOMIC CLASS INDUSTRY

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Abstract — *Design & development deals with selection, processing and engineering of material along with identifying, modifying and testing the product making it ready for production. The need of quick tool changer during design and development of automatic milling machine is identified by* ***Solar Industries, G.I.D.C, Makarpura****, Vadodara. Milling is all about machining process with the assessment of various milling cutters. For economical class industries these milling operation turns uneconomical in automatic milling machine using automatic tool changer initially. As per the need of Solar Industries we have designed a quick manual tool changer and tested it with analysis software to prove our results and make this design economical as for small industries, Every Single Penny Counts?*

Keywords- *CNC, Tools, Levers, ATC*

I. INTRODUCTION

Product development is the process of creating a new product to be sold by a business or enterprise to its customers. In the document title, Design refers to those activities involved in creating the styling, look and feel of the product, deciding on the product's mechanical architecture, selecting materials and processes, and engineering the various components necessary to make the product work. Development refers collectively to the entire process of identifying a market opportunity, creating a product to appeal to the identified market, and finally, testing, modifying and refining the product until it is ready for production. A product can be any item from a book, musical composition, or information service, to an engineered product such as a computer, hair dryer, or washing machine. This document is focused on the process of developing discrete engineered products, rather than works of art or informational products.

The task of developing outstanding new products is difficult, time-consuming, and costly. People who have never been involved in a development effort are astounded by the amount of time and money that goes into a new product. Great products are not simply designed, but instead they evolve over time through countless hours of research, analysis, design studies, engineering and prototyping efforts, and finally, testing, modifying, and re-testing until the design has been perfected.

The process of developing new products varies between companies, and even between products within the same company. Regardless of organizational differences, a good new product is the result a methodical development effort with well defined product specifications and project goals. A development project for a market-pull product is generally organized along the lines.

II. MILLING MACHINE

Milling is the machining process of using rotary cutters to remove material from a work piece advancing (or feeding) in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes. Milling operates on the principle of rotary motion. A milling cutter is spun about an axis while a work piece is advanced through it in such a way that the blades of the cutter are able to shave chips of material with each pass.

Figure 1.1: Vertical Milling Machine

For this reason, steps in the primary recycling process are:(1)separate the waste by specific type of resin and by different colors and then wash it,(2)the waste has better melting properties so it should be extruded into pellets which can be added to the original resin. This type of recycling is very expensive compared to other types of recycling due to the requirements of plastic properties mentioned above. If the waste can be easily sorted by resin but cannot be pelletized due to mixed coloring contamination, then waste can be fed into molding application, and regarding reactants properties, it is less demanding.

III. TOOL CHANGER

It is a means to change the tool in any machine with the use of various mechanisms either through operated manually or computerized linkages. Base on the means of the operating the mechanism of the tool changing it is classified as 1.Manual/conventional tool changer (MTC) 2. Automatic tool changer (ATC) [5]

3.1. Manual/Conventional Tool Changer (MTC):

This type of tool changer are being operated manually by human arm with the assistance of mechanical components including lever, linkages, bearings, belt, gears, etc

Usually NC mills (Manual Tool Change) are supplied with some type of quick-change tooling system to accomplish this task. Most of small vertical turret mills are manufactured with an R-8 spindle taper that will accept R-8 collets as shown in figure 3.1. Then R-8 collets and R-8 tool holders require the use of a draw bar.

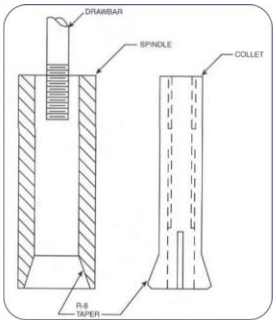


Figure 3.1: R-8 Spindle and Collet


Figure 3.2: A Quick change tooling system used for manual tool Change

The quick tooling system consists of a **quick release chuck** held in the machine holder and set of tool-holders that hold the individual tools needed for a particular part program. The chuck is a separate tool-holding system that says in the spindle during the tool change the tool holder is removed from chuck it is also called the tool changer. A tool holder containing the next required tool is installed in the place as shown in figure 3.2.[12]

3.2. Automatic Tool Changer (ATC):

An Automatic tool changer or ATC is used in computerized numerical control (CNC) machine tools to improve the production and tool carrying capacity of the machine. ATC changes the tool very quickly, reducing the non-productive time. Generally, it is used to improve the capacity of the machine to work with a numbers of tools. It is also used to change worn out or broken tools. It is one more step towards complete automation.[1]

The CNC machines are designed to perform a number of operations in a single setting of the job. A number of tools may be required for making a complex part. In a manual machine, the tools are changed manually whenever required. In a CNC machine, tools are changed through program instructions. The tools are fitted in a tool magazine or drum. When a tool needs to be changed, the drum rotates to an empty position, approaches the old tool and pulls it. Then it again rotates to position the new tool, fits it and then retracts. This is a typical tool changing sequence of an automatic tool changer (ATC). [1]

3.2.1. Drum Type ATC

For holding small number of tools usually not more than 30, Stored on periphery of drum and tool search speed is faster.

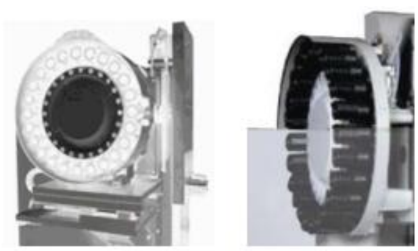


Fig: Drum Type ATC

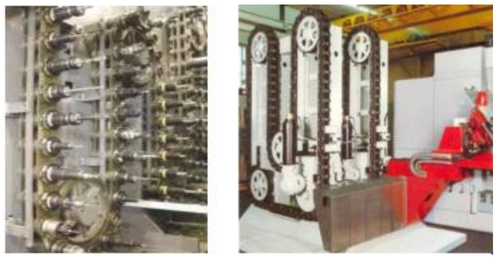


Fig: Chain Type ATC

3.2.1. Chain Type ATC

For more number of tools (40 or more), tools search speed is less. As soon as the tool selection command is received by the system, the selected tool comes to a fixed place known as tool change position. The selected tool is transferred to the spindle from magazine after the previous tool is transferred to the magazine from spindle. This is called tool change cycle. [14]

3.3. Lever

A lever is consisting of a beam or rigid rod pivoted at a fixed hinge or fulcrum. It is one of the six simple machines identified by Renaissance scientists. The word comes from the French lever, "to rise", cf. a Levant. A lever amplifies an input force to provide a greater output force, which is said to provide leverage. The ratio of the output force to the input force is the ideal mechanical advantage of the lever. [11]

IV. DESIGN AND DEVELOPMENT OF QUICK TOOL CHANGER

The sectional view of the spindle which is to be applied is being shown in the fig. This yellow rod shown in the Fig is push rod which is responsible for the hold and release of the tool into its collet. The green colour part just beside the push rod depicts the disc spring which restricts the motion of the push rod whenever a power supply is being provided to the push rod.

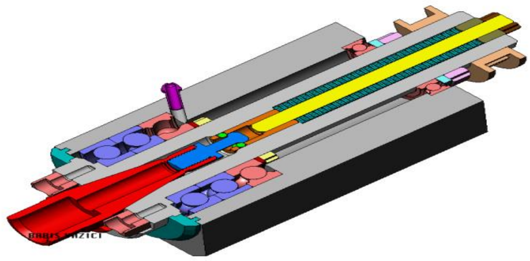


Figure 4.1: Sectional view of the spindle

The torque which is being transmitted to this rod allows the rod to go downwards. As a result of which the tool could be disengaged from the tool holder. Now by understanding the whole mechanism come across the facts that the amount of force applied to push rod should be greater than the spring force then only it could transfer linearity motion to disengage the tool. The current design of the tool changer is being shown in fig. When pneumatic cylinder used then required torque to the push rod of the tool changer. The torque required to transmit the motion to the push rod against the spring force = 4500 N-mm. [1]

4.1. SOLUTION

Considering the need of the industry and the requirements modification in the design of a tool changer, I have tried to rise up with satisfying solution meeting both the customer demands and design requirements of the tool changer. This paper is based on the design and development of a lever mechanism where I have utilized the concept of hand lever to transmit around torque from human arm to the fork end of the hand lever. This fork end is joined with the bell cranks lever by means of a fixed pin joint in order to transmit the torque in an efficient manner without much loss.

I have assembled the longer effort arm of bell crank lever with the hand lever through a flexible pin joint and the load arm is being connected to the (coupler). This is rectangular cross section at the central of which a groove of required dimension is being drilled out to fix. Then other end of the section that has a female cone provided on into which the male cone mounted on the drawbar gets engaged to provide it the required force of 4500N to move linearly downwards and disengage the tool. [2]

Figure 4.1.1: Ball Crank Lever

Figure 4.1.2: Hand Lever

V. DESIGN OF THE MECHANISM FOR PUSHING THE DRAWBAR

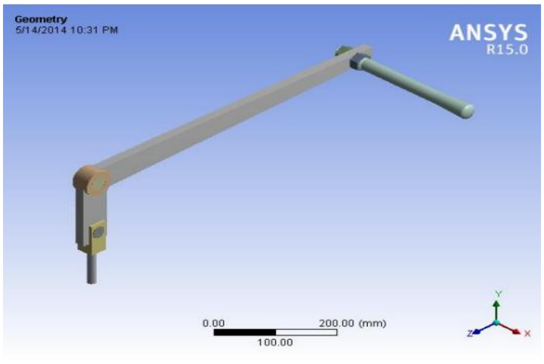


Fig 6.3: Lever Mechanism for Tool changer

Figure 5.1: Design of Lever Operated Mechanism

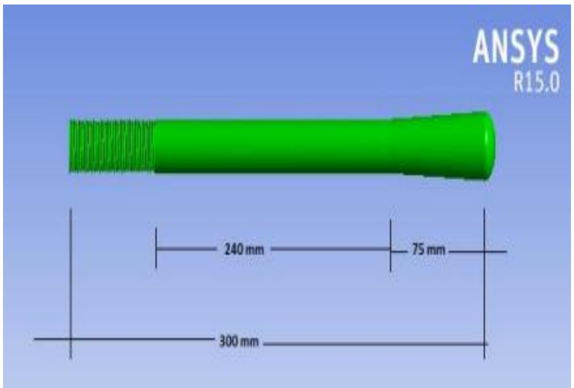


Figure 5.2: Cross-sectional View of Hand Lever

P: Force applied at hand L: Effective length of lever

σ: Permissible tensile stress τ: permissible shear stress

For Mild steel, σ=186 Mpa τ=410Mpa

1. Diameter of pin obtained by considering shaft under pure torsion.

Twisting moment of shaft,

$T=P*L$

$T=\pi/16* \tau* d^3$

Suppose required effective length=270 m

Diameter of hand lever for proper torque transmission based on pin dia. of lever = 25mm

Now the effort the man can apply =100 N

Consider overhang factor = 1.5 * P = 100 *1.5=150 N

So, $T=P*L$

$T= 150* 270$

$= 40500$ N mm

Now checking for the induced stress in this material

$T=\pi/16* \tau* d^3$

$40500= 3.14*(25)^3* \tau /16$

$\tau =13.2 N/ mm^2$

$<= 186$ M Pa

So the given design of hand lever is safe against the stresses. [2]

5.1. Design of Bell Crank Lever

Experimental analysis for determination length of lever arm considering

L_1=Length of load arm

L_2=Length of effort arm

The leverage ratio for the bell crank lever

$W/T = L_2/L_1$

$4500/1350 = L_2/L_1$

$L_2/L_1 = 3.333$

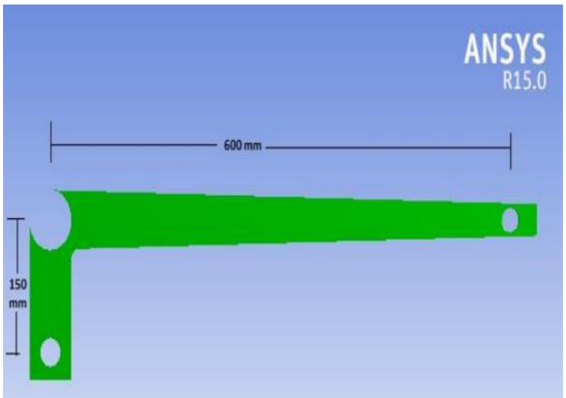


Figure 5.3: Design of Bell crank Lever

Now in order to obtain a safer leverage ratio experiment for two to three length of three effort and load arm considering the space constraint of the machine.

So, for different length, i.e. L_2=500 mm L_1=150 mm

Leverage ratio (L.R) = 3.33

L_2=600 mm and L_1 = 120 mm

Leverage ratio (L.R) = 5

For L_2 = 600 mm and L_1 = 150 mm

Leverage ratio (L.R) = 4

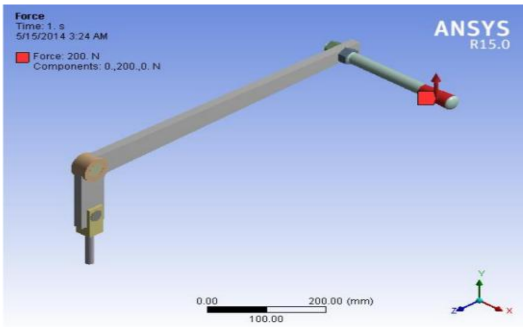
So we have finalized the avg. Leverage ratio considering the following length from safety as well as space constrains.

L_2 = 600 mm and L_1 = 150 mm

$L_2/L_1 = 4$

VI. ANALYSIS AND VALIDATION OF DESIGN IN ANSYS

Finite element analysis on lever mechanism: Boundary condition for mechanism with two different forces to check the feasibility of both designs. **Input Force**: 200 N, **Output Force**: 400 N



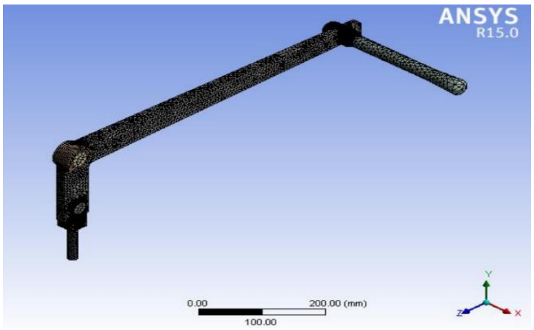


Figure 6.1: Force on manual tool changer Mechanism ***Figure 6.2: Meshing of Lever mechanism***

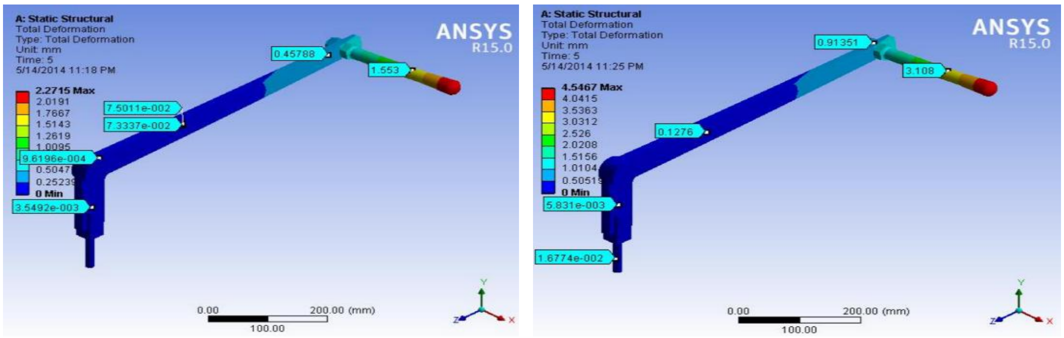


Figure 6.3: Total Deformation of Mechanism (200N & 400N)

On comparing the deformation, max shear stress and principal stress value for 200 N & 400 N. Find out the given value of deformation are within the range.

This could be validated as such that the % elongation value for Mild steel is 23%.

So % deformation of design= max deformation %elongation

= 2.2715/23 = 9.87% <= 23%

So deformation is safe and bearable.

Also the analyzed value of max shear stress & max tensile stress obtained is less than the design value which is equal to186 M pa & 410 Mpa. Besides this the directional deformation value as well as the principal stress obtained is within the range.

VII. CONCLUSION

This paper presented I have tried to bring an effective solution to the economic class industries in terms of providing them with a complete (solution to replace pneumatically operated tool changer of mini CNC milling machine into manually operated tool changer by utilizing the concept of lever for the transmission of huge amount of torque at the cost of least input force through human arm and by validating it in an analysis software ANSYS which could serve them with a dual feature of quick tool change along with a drastic improvement in the cost structure of installing a tool changer

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