Productivity Enhancement of CNC Machines by Tooling Control

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Abstract - **In modern industries when automated machines are considered as one of the most important constituent in enhancing the productivity. CNC machines are used in most of the industries to bring about an increase in the rate of production. Some organizations could not digest such large and rapid changes due to the conditions in the company. The time saved using the automated machines is lost completely in excessive loading, unloading, setting and machining time due to improper tooling and clamping. The work targets reduction in cycle time, by implementation of new tools and working on improving the process parameters taking into consideration the materials and the type of machining operations used in manufacture of the components on automated machines.**

Keywords - Productivity, CNC lathe, VMC, cycle times, machining, automated machines.

I. INTRODUCTION

In the recent period the small and medium scale enterprises are developing and emerging as manufacturers giving quality products at a more decent cost. Top Gear Transmissions is one such enterprise. Top Gear Transmissions, one of the leading manufacturers of planetary gear boxes, sugar mill drives, winch drives and custom built gear boxes. The company is known for the quality and reliability of the products. The company previously had its focus on quality. No work was done keeping in mind the productivity. The project is expected to focus on this area and is aimed at increasing the productivity by tooling control.

A gear box assembly is made up of planetary carriers, planet gears, sun gears, planet pins, ring gears, input/output shafts, casings etc. Accuracy of every component is very important in a gear box assembly which makes it mandatory to machine these parts on CNC and VMC machines. CNC machines are used for finish turning whereas VMC machines are used for drilling, boring and milling.

As the focus was on quality of the product, not much has been done in enhancing the productivity of the machines. When looked with a productivity point of view and the current capacity of machines, the company lags behind in many aspects. The problems observed that affected the productivity were high product variety, setting time, reduced speed and feed values to increase tool life and programming errors. The objective of the project will be reducing the cycle time and increasing the productivity of the machines by improving the current tooling.

II. PROPOSED METHODOLOGY

The main area of focus will be on increasing the productivity which is done by studying various parameters.

2.1) Tooling Study

The tooling used for the manufacture of various components was studied in detail along with the loading, unloading, tool approach, tool retract and tool change timings. The time required for each component was recorded. As the component machined on CNC and VMC are a group of similar components but with different dimensions the work was focused on very few components at a primary stage. Every group of components studied thoroughly along with the tooling used presently in order to machine these components. The cycle time required for these components was recorded in detail to get a clear idea on the area to focus.

1) 380 HCR Casing

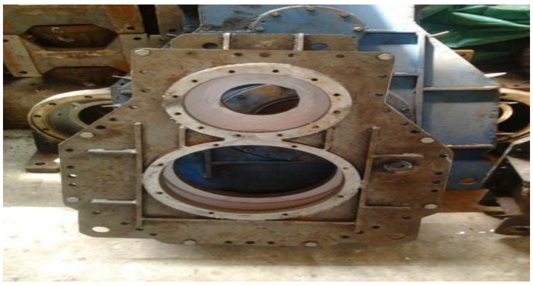

Fig 2.2.1 380 HCR Casing

The 380 HCR Casing is used for a gear box called sugar mill drive. As the component is large and heavy the loading and unloading operations is more. The cycle times along with the loading and unloading operations were calculated using a stop watch. **Table.[1]**

2) FX 121 Casing

Fig. 2.3.1 FX121 Casing

The machining operations on the casing done using VMC machine were recorded and analyzed properly. The casing had six holes that had to be finish bored and some drilling operations also. The job was machined after it was clamped on machine bed using simple clamps. A lot of time was wasted on job mounting and truing the job. Various different options of operations to be performed were tried on the casing. **Table [2]**

i) One shot hole finishing for all six holes

ii) Machining the job using 1st side and 2nd side operations

3) Input Output Carrier

Fig 2.1.1 380 O/P Carrier

The input and output carriers are one of the vital components in the gear box assembly. The pocket carrier houses the planet gear and the sun gear in it. The accuracy for the component is very important. Any kind of errors in the drilling and boring operations results in run out of the carrier. This disturbs the balancing of the assembly. The cycle time of each operation was recorded using a stop watch. **Table [3]**

2.2) Suggestions for improvement

All machining processes in the manufacture of the components were studied and various operations affecting the cycle time to a larger extent were detected. In order to bring about a change in the manufacturing time of these components, it is essential to find a suitable solution for this problem.

The areas which the focus was on are listed below with respect to the component:-

1) HCR Casings

i) R 419 Coromill Cutter Sandvik make was selected. The cutter was studied properly and an estimated cycle time was also calculated. The cutter reduces the manufacturing time of the casings by upto 50 percent.

ii) A fixture for mounting the casing is also part of the project. The casing due to its large weight is difficult to handle. Hence the fixture has to be designed to clamp it true as soon as mounted over the fixture.

2) FX 121 Casing

For FX 121 Casing most of the time lost is similar to that of the 350 HCR Casing mentioned above. Most of the time is consumed in loading, truing and circular pocketing.

i) A suggestion given in order to avoid the increased loading and truing time, was to develop a fixture that can locate the job true and get the job clamped within no time.

ii) And to reduce the machining time, the solution given is similar to that of the HCR casing. The same R419 High Feed milling cutter which was suggested for the HCR casing was suggested for this casing also. The cutter can reduce the machining time of the component to a great extent. The estimated reduction in cycle time after using the cutter is about 50%.

3) 160-300 Pocket Carriers

i) A clamping fixture that will clamp a maximum of six 280 carriers at a time. This will result into reduced loading and unloading time on an average.

ii) The drills used at present are HSS drills which are to be replaced with U- Drills which automatically facilitates lesser cycle time.

iii) Operations such as reaming which takes comparatively longer time then boring are to be replaced with the latter operation to have a commendable reduction in cycle time.

The circular pocketing operation was found to be very less productive when compared to the helical interpolation operation where the tool can be used at very large speed and feed values.

2.3) Selection of the new tool

In the manufacture of a HCR and FX 121 casing the maximum time taken is for circular pocketing. Both the components were machined in one single setting. The drawing of the job shows that there is a large gap (210 mm) between the upper and the lower ring which are to be finished on the VMC. The present tool i.e. the rough boring bar was modified with a 180 mm attachment to reach the lower ring. This resulted in a large overhang. Due to this overhang the tool had to be run at 10 % capacity which increased the cycle time to a large extent.

The second point was that of the Ø 63 Kyocera make milling cutter. This cutter has 5 cutting edges. The cutter has a capacity of taking about 1.5 mm axial and 2 mm radial depth of cut. With a tool of this capacity a ring of DiaØ 360 mm and depth 48 mm will take about 50 min on an average to machine one single hole. The HCR casing has four such holes. This will take about 160 min to rough machine all the four holes. The finish operations followed the process.

A new high speed and feed milling cutter was found to be useful in our case as it was available in variety with required diameters, axial and radial depth of cuts as per the requirement of the customer. Primarily it was just the HCR casing that required a development in its tooling as there was a need for reduction in cycle time. Later FX 121 casing was added into the project. This required a completely different study as the new tool had to accommodate the requirements of both the casings. The cost factor was also taken into consideration. The previous tool suggested was not a wrong suggestion in any terms. The reason of replacing the previous suggestion of shell milling cutter with a shell milling cutter it was not fitting into the current company scenario. The shell milling cutter shows its cost and performance results when used along with an automated set up. But taking in to consideration, the current situation it was more suitable to purchase Coromill 419 High feed milling cutter.

Fig 2.3.1 Coromill 419

The cutter is a high feed milling cutter. The cutter has a maximum feed rate of 3000 mm/min which could be run at 1000 rpm according to the axial and radial depth of cut. The cutter has 5 pentagonal inserts with 5 cutting edges and the cutter is attached directly to the BT – 40 holder.

In market there are a lot of tool manufacturers providing shell milling cutters. In the process of procurement of the tool, 3 manufacturers were asked to send the quotation for tool which included Sandvik, Kyocera and Widia. The parameters and capacities of each of the manufacturers were studied with reference to the cutting parameters, types of cutters, MRRs and the cost.

In the process the SanvikCoromill 419 Milling Cutter proved to be a front runner as it was found to be more capable with respect to our applications. Sandvik tools also have a better life when compared to other tool manufacturers.

2.4) Proposed Cycle time Reduction:-

All the components studied above required very high cycle times. The new cycle times were proposed with new group of tooling and fixtures were calculated using the parameters provided in the catalogues of the tool manufacturers. These parameters used are not the maximum limits of these tools. The tools are expected to run at 70 % capacity in the experimental stage and later the 100 % capacity will be imposed. The fixtures are to be designed and manufactured yet. The manufacture of fixtures will bring about a reduction in loading, unloading and job setting time. The proposed cycle times are mentioned in **Tables [1], [2] and [3].**

The sample calculation used for the calculation of the estimated cycle times for milling using

1) U drill

Estimated Cycle time $= \frac{L+(0.3 \times d)}{\text{feed in} \frac{mm}{rev} \times rpm}$

$$= \frac{28 + (0.3 \times 14)}{0.05 \times 1500}$$

= .439

= 25 secs

2) Boring Operation

Estimated Cycle Time $= \frac{\text{Length to be bored}}{\frac{feed}{rev} \times rpm}$

$$= \frac{15}{0.06 \times 400}$$

= 0.625

= 37 sec

3) R 419 CoroMill Cutter

Volume of material to be removed

= π D x Breadth x width

= π x 90 x 5 x 26

= 36.73 x 10^3 mm^3

Material Removal Rate of the milling cutter

= a_p x a_e x feed mm/min

= 1 x 4 x 2500

= 10000 mm^3/min

= 10 cm^3/min

Estimated time for material removal

$$= \frac{\text{Volume of material to be removed}}{\text{Material removal rate of the cutter}}$$

$$= \frac{36.73}{10.}$$

= 3 min 48 sec

2.5) Development of Fixture:-

Planetary carriers are machined on a large scale using VMC machines. These components were machined using a universal chuck mounted on the VMC machine bed **Fig 2.5.1.a.** The carriers are being clamped using a manually operated universal chuck, which hold one work piece at a time. The types of the carrier vary from 160 to 300 and 3.6 to 7.5 in ratios according to the catalogue number, which also vary in dimensions respectively. With the present tooling a lot of time is being wasted for loading and unloading operations. A fixture is to be designed that would provide reduction in loading, unloading, setting and machining time. A need was found to develop a fixture that could clamp at least 6 carriers at a time. A hydraulic fixture was designed with a proposed reduction in cycle time along with some changes in the operations performed on 190 o/p carrier. **Fig 2.5.1.b** The Fixture can be used for other carriers with minute changes in the fixture.

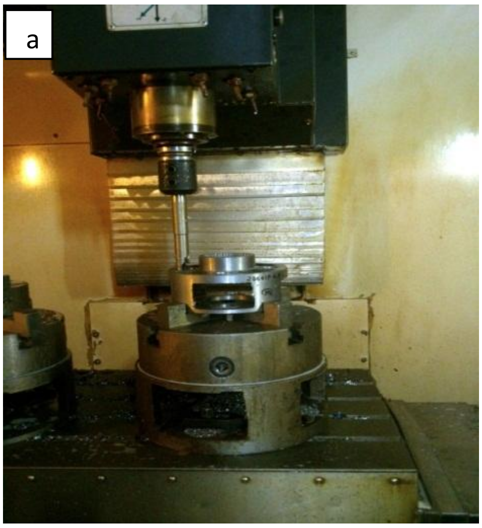

Fig 2.5.1.a Machining using Universal Chuck

Fig 2.5.1.b. Machining using Fixture

III. RESULTS

The cycle time reduction gives the exact increase in productivity of the machines. The cycle time readings for three basic components were recorded in at the beginning. Keeping in mind the reduction in cycle time, some tooling were suggested and an expected cycle time was calculated. The tooling required for the same were either purchased or manufactured. The cycle times after using the new tooling were recorded. The reduction in cycle time after application of the new tools and the fixture was found and the readings were compared.

Sr. No.	Name of Component	Initial Cycle Time	Proposed Cycle Time	Actual Cycle Time
1	380 HCR Casing	3 hrs 29 min	55 min 49 sec	55 min 55 sec
2	FX 121 Casing	2 hrs 32 mins	1 hr 2 min	1 hr2 min
3	190 Carrier	30 min 58 sec	10 min 55 sec	8 min 28 sec

Table 1. Cycle times

Table shows the cycle time readings in three different columns. The columns are titled as existing for the tooling that was used before the project started. Proposed for the tooling that was suggested to get a reduction in cycle time and the actual readings that were noted at the end after the suggested tooling was imposed. The exact comparison between these three phases is shown in the table. Some operations were changed, some were completely removed from the cycle in order to get a reduced cycle time.

The cycle time of the component called 380 HCR casing was reduced from **3 hrs 29 min to 55 min 55 secs.**

The second component for study is FX 121 casing shows the detailed study of the cycle in the existing cycle time column. The major reduction in cycle time was targeted in operation like circular pocketing. The projected reduction was achieved by using the new tooling. The cycle time was reduced form **2 hrs 32 min to 1hr 2 min**.

The detailed study of the machining cycle for 190 carrier was done. The cycle time was reduced by application of new tools and development of new fixture that would machine a total of six components. The cycle time for each component was reduced form **30 min 58 secs to 8 min 28 secs.**

IV. CONCLUSION

The increase in productivity was targeted with a reduction in cycle time of the components. To achieve this target the tools used previously had to be replaced with new high performance tools. A hydraulic fixture was successfully developed that would be useful in machining a large range of carriers. The fixture gave a reduction in setting, loading, unloading and tool change time. The reduction in cycle time was successfully achieved the highest reduction to be **73 % for 380 HCR casing and 190 carrier.**

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