Design and Manufacturing of Hydraulic Fixture for Connecting Rod Bush Boring

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ABSTRACT

Connecting rod is key piece of engine. It ought to be precisely machined with the obliged resilience. Additionally the varieties of measurements in workpiece to workpiece ought to be low so it will be simpler to amass in engine. At the same time, it has been observed that in the majority of the cases the process duration needed for boring the connecting rod was an excess and furthermore with the lower resilience precision in exhausting operation because of traditional installation. In machining fixtures, workpiece deformation due to cutting and clamping forces has to be minimized to maintain machining accuracy. As hydraulic techniques save time, generate accuracy and are more flexible, recent trends in industry are adopting these techniques. The fixture designed is hydraulic operated and used for pin hole bush boring operation of connecting rod. Crank hole of connecting rod had to be uniformly clamped for boring pin holes of NTBC, V28 and N14 engines. Vulcanized segmented clamping bushing having rubber and steel sections is used to obtain uniform clamping, which resulted into minimized bend, twist and accurate centre distance of connecting rod. The Statistical process study helped in investigating the product quality and product maintained within specified tolerance limits.

***Keywords**: Hydraulic fixture, Bush boring, uniform clamping, rubber locator, Connecting rod*

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1. INTRODUCTION

In case of fixture, clamping, holding between fixture and workpiece is important. The most important criteria's for fixturing are position accuracy, workpiece stability and workpiece deformation. A good fixture minimizes workpiece geometric error. Force analysis is concerned with checking whether the forces applied for clamping are sufficient to maintain static equilibrium. Fixtures must correctly locate the workpiece in a given orientation with respect to the cutting tool or measuring device. The designed fixture is only concerned for pin hole bush boring of connecting rods used in NTBC, V28 and N14 engines only. Locator of old fixture was of mild steel and it was not uniformly clamping the crank bore. The old locator consisted of two parts, the first is inner ring and second is outer ring. The two rings included a passage in between them, through which the pressurized oil is supplied by hydraulic circuit. The inner ring is stationary whereas the outer ring is moving. When pressurized oil is supplied through the circuit, the outer ring will expand on account of hoop stresses which results in clamping. This kind of clamping is non uniform as there is no provision for 360 degree clamping. In new fixture, locator used has rubber and steel, where rubber helps in flexibility and steel has strengthening ability, hence it helps in uniform clamping.

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1.1 Related Work

Fixtures are typically grouped by the sort of machine on which they are utilized. Apparatuses can likewise be recognized by a sub characterization. If a fixture is intended to be utilized on a milling machine, it is known as a milling fixture. On the off chance that the undertaking it is planned to perform straddle processing, it will be called a straddle-milling fixture.

While designing this work, a good number of literature and titles written on the subject by renowned authors are referred. All findings and conclusions obtained from the literature review and the interaction with fixture designers are used as guide to design the present research work. The design of machining fixture relies on designer experience and implicit knowledge to achieve a good design. In order to facilitate its application, the explicit definition of the fixture design process and the knowledge involved is a prior and a fundamental task to undertake. Additionally, a fundamental and well-known engineering principle should be considered: the functional requirements and their associated constraints should be the first input to any design process. A relevant issue when considering requirements, taking this as a general concept, is to make explicit the meaning of two main terms: Functional Requirement (FR) and Constraint (C). Functional Requirement (FR), as it stated by different authors, 'represents what the product has to or must do independently of any possible solution'. Constraint (C) can be defined as 'a restriction that in general affects some kind of requirement, and it limits the range of possible solutions while satisfying the requirements' [2]. Various areas related to design of fixture like machining fixture knowledge, optimizing workpiece setups, modeling of forces, improving workpiece location and high efficiency tools [3-7] are already been very well described by various renowned authors.

The following is a partial list of production operations which use fixtures.

• Assembling • Boring_• Broaching • Drilling
• Forming • Gauging • Grinding

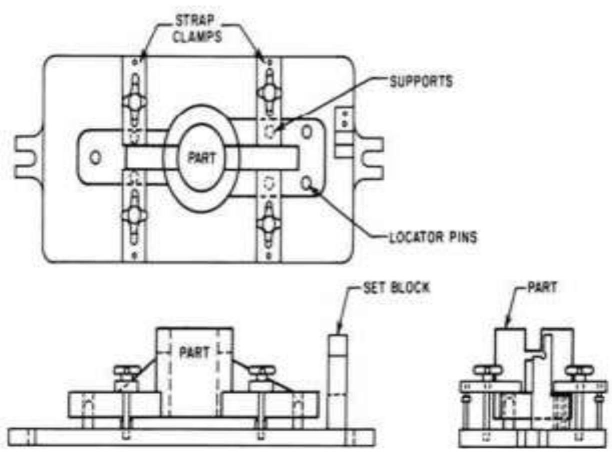

Figure 1.Plate Fixture [1]

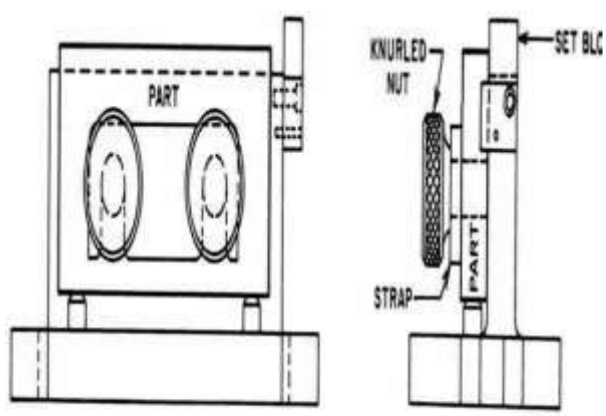

Figure 2.Angle plate Fixture [1]

Plate fixtures are the simplest form of fixture as shown in Figure1. The basic fixture is made from a flat plate that has a variety of clamp sand locators to hold and locate the part. The angle-plate fixture is a variation of the plate fixture as shown in Figure 2. With this tool, the part is normally machine data right angle to its locator. While most angle-plate fixtures are made at 90 degrees, there are times when other angles are needed. [2]

Centering, locating, orientating, clamping, and supporting, can be considered as the functional requirements of fixtures. In terms of constraints, there are many factors to be considered, mainly dealing with: shape and dimensions of the part to be machined, tolerances, sequence of operations, machining strategies, cutting forces,

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number of set-ups, set-up times, volume of material to be removed, batch size, production rate, machine morphology, machine capacity, cost, etc. At the end, the solution can be characterized by its: simplicity, rigidity, accuracy, reliability, and economy. Also, (i) Accurate location of the workpiece, (ii) Total restraint of the workpiece during machining, (iii) Limited deformation of the workpiece, (iv) No machining interference. In addition, as set forth by R. T. Meyer and F. W. Liou [6], dynamic machining conditions occur when a part is subject to machining forces.

An important characteristic of a workpiece-fixture system is that locators are passive elements and can only react to clamping forces and external loads, whereas clamps are active elements and apply a predetermined normal load to the surface of workpiece to prevent it from losing contact with the locators.

The methodology proposed for design of a fixture includes the realization of two stages. The first stage represents the knowledge of the objects like that move through the work part or along its surface. A viable fixture designed for a workpart experiencing dynamic machining must ensure: the workpart is restrained for all time, the clamping forces are not too large or small, deterministic positioning, accessibility, stability of the workpart in the fixture while under no external forces, and a positive clamping sequence.

3. PROBLEM DEFINITION

The major problem in the existing fixture is non uniform clamping by the locator which results into irregular twist, bend as well as inaccurate centre distance of the connecting rod. As stresses are developed and deformation takes place, connecting rods fail in long run. The final product lacks precision. The resulting final product after the machining does not meet the requirements of the client and hence the rejection rate is high. The new design the aims to overcome these problems.

Figure 3.Existing old fixture [7]

Figure 4. Close view of Locator [7]

4. CALCULATIONS FOR CLAMPING FORCE

Cutting speed, feed per revolution, power at the spindle, metal removal rate, mean torque, resultant cutting force and clamping force required by the locator are determined as follows:

1) To determine Cutting speed (n):

$V_c = \pi \times D_b \times n/1000$ m/min (1)

V_c= 180 m/min

2) Feed per revolution(f_n)

$f_n = z_c \times f_z$ (2)

f_n=0.08 mm/r

3) Power at the spindle (P_s)

$P_s = ap \times K_c \times f_n \times V_c \div 60000$ (3)

= 0.94 kW

4) Metal Removal Rate

$Q = (D_b \times f_n \times 180)/4$ (4)

=19.62 mm^3/min

5) Mean Torque

$T_m = P_s \times 30000 \pi \times n$ (5)

=5.45 Nm

Tangential cutting force

$F_t = 1000 \times d \times f \times k_p$ (6)

F_t= 44226.8235 N

F= f × N …machine feed rate (7)

= 4404.54 N

K_p= Power factor (constant) = 0.85 hp/$inch^3$ /min

Maximum Clamping force =150kN

FOS= 2.9 (assumed)

$F_r = F_t \times 0.25$ (radial)=11056.705 N (8)

$F_f = F_t \times 0.5$ (axial) = 22113.41 N (9)

Resultant Force R= 50668.19 N

6) Factor of Safety

R × FOS =146.9372 kN (10)

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Therefore, Locator with 150 kN Clamping force range is selected.

Figure 5. Unit Design with CAD model [7]

Figure 6. Actual Fixture [7]

5. VALIDATION OF THE DESIGN PROCESS CAPABILITY ANALYSIS BASED ON MACHINE TRIAL

The case study shows the importance of statistical process control for monitoring and ensuring the product produce disable to satisfy customers' needs and requirements. Figure 5 shows CAD model for modified fixture with rubber locator and Figure 6 shows the actual fixture. The focus of the study was to investigate the process capability of the ongoing process as to decide upon the suitability of the machine to hold particular tolerance. In this study, in order to demonstrate the applicability of the proposed method and to make a clear decision about the capability of the machining process, the sample size was determined and a sufficient number of sample parts were inspected. A single sampling plan was implemented by using the lot-acceptance sampling plan. Samples were chosen randomly during the machining process. Table No.1 shows the readings for bend, twist of connecting rod using old and new fixture. Baker's Air Electronic Gauging system shown in Figure 7 is used to note the readings.

Figure 7. Baker's Air Electronic Gauging System to measure Bend and Twist of connecting rod

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	New Fixture		Old Fixture	
PART S.No	BEND(inches)	TWIST(inches)	BEND(inches)	TWIST(inches)
1	0.00016	0.00032	0.00017	0.00048
2	0.00000	0.00065	0.00019	0.00066
3	0.00007	0.00040	0.00013	0.00042
4	0.00020	0.00006	0.00026	0.00008
5	0.00040	0.00002	0.0005	0.00008
6	0.00060	0.00054	0.0009	0.0003
7	0.00000	0.00035	0.0001	0.00037
8	0.00076	0.00082	0.00079	0.00095
9	0.00040	0.00017	0.00042	0.00023
10	0.00000	0.00059	0.00016	0.00061
11	0.00015	0.00034	0.00019	0.00049
12	0.00072	0.00030	0.0007	0.00054
13	0.00036	0.00013	0.00042	0.00023
14	0.00057	0.00034	0.00065	0.0006
15	0.00042	0.00034	0.00044	0.0004
16	0.00020	0.00030	0.00022	0.0004
17	0.00005	0.00044	0.0001	0.00057
18	0.00001	0.00045	0.0001	0.00037
19	0.00008	0.00040	0.00012	0.00054
20	0.00012	0.00053	0.00022	0.0004
21	0.00017	0.00050	0.00018	0.00058
22	0.00007	0.00039	0.0001	0.00047
23	0.00005	0.00042	0.00015	0.00056
24	0.00039	0.00049	0.0004	0.00054
25	0.00010	0.00063	0.00019	0.00066
C_p	1.09000	1.25000	1.27	1.06
C_{pk}	1.04000	1.23000	0.56	1.02

Table No. 1 Readings for Bend and Twist of NTBC connecting rod [7]

6. CONCLUSION

With the help of this fixture workpieces are clamped with same clamping force range which is 150 kN in every cycle. Hainbuch locator has facilitated greater vibration damping due to use of vulcanized rubber along with steel. Large clamping range and fast conversion time is achieved. Compared to existing old fixture, this new proposed fixture is stable and capable. By this new fixture design, workpieces are clamped in same direction every time so a correct location is achieved and eliminating the variability in workpiece deflection from clamping force. As seen in Table No.1, achieved process capability (Cp and Cpk) is more than 1.00 in case of new fixture for both bend and twist of connecting rod as required.

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