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Design and Development of Hydraulic Fixture for Basak Cylinder Head Machining

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Abstract: The Fixture are work holding Device used to Locate and fix the position of work pieces for machining, Assembly, Inspection, and other operations. A Fixture consists of an arrangement of Clamping and locators. Locators are utilized to decide the introduction and position of a work piece, and Clamps Forces on the workpiece with the goal that the work piece is squeezed against locators and resting pads .The present day slants in industry are towards receiving the pressure driven methods, since it Saves time produces Accuracy and provides Flexibility. Designing of hydraulic Clamping Fixture Was Considered to be lengthy And Complicated Procedure. Since it needs a decent mindfulness about, dimensioning and Tolerances, producing forms, clamping and cutting powers during operations. But now a day the work becomes less difficult due to introduction of intelligence in the field which saves a great amount of money and time. In this project the same methodology is adopted for designing analyzing the designed hydraulic fixture. The hydraulic fixture is designed for Engine cylinder Head to perform Milling operations using Vertical machining centers. Theoretical and Numerical method are used to calculate the maximum stress and deformation for clamping forces of 12.5KN with the hydraulic pressure 50, 60 And 70 bar.The Setup time, production rate, production capacity and manufacturing lead time for the milling operation by hydraulic Fixture is calculated.

Keywords: Hydraulic fixture Clamp, SolidedgeST8.

I. INTRODUCTION

Fixture is a device which holds a work piece during machining processes. The word fixture is due to the reason that it will always be in static position either attached to a machine or table.

The precision achieved while machining the work piece depends solely on the design and performance of fixture. Other devices of tooling which are used for the purpose of positioning of parts can also be considered as fixtures. Fixtures comprise of locators and clamping devices.

Increment in cutting force enables the work piece to glide on locators, as a result the reference position of work piece and the desired precision to which the work piece is to be manufactured is not achieved. Hence necessary arrangements have to be made so that the work piece is positioned in correct position. In doing so, care should be taken that work piece reference surfaces should not be subjected for plastic indentation i.e. clamping forces should not exceed the maximum limit. The fixture planning involves conceptualizing a basic fixture taking into consideration the material, geometry of the work piece, operations that are to be carried out, equipment required for the operations and the operator.

II. OBJECTIVES OF THE PROBLEM

1. Fixture design to achieve higher accuracy for for the milling operation
2. Decrease in cycle time
3. Increase in manufacture rate and Production Capacity
4. Decrease in cost of manufacturing
5. Reduction in manufacturing Lead Time.
6. This development involves study of stresses and Deformation acting on a fixture. The stresses will be predicted theoretically. These results will be validated by comparison with the analysis using software.

III. METHODOLOGY

The manufacturing industry provides wide range of products to fulfill the need of today's market.

Design procedure

- Study with observation of the components shape and dimensions.
- Based on shape and dimensions of the components suitable location and clamping devices are provided

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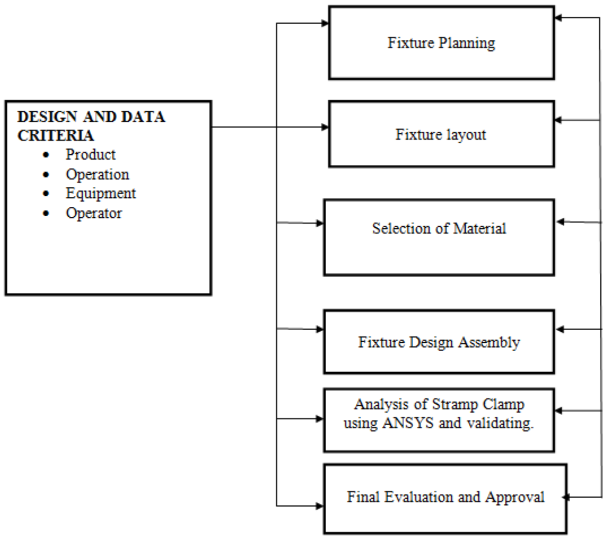

Fig 1: Flow Chart

Study for BASAK Cylinder Head .

Length– 600 mm, Height – 125 mm,
Width – 215 mm, Weight – 55 kg

Fig 2: Component

Studies for Principle Location

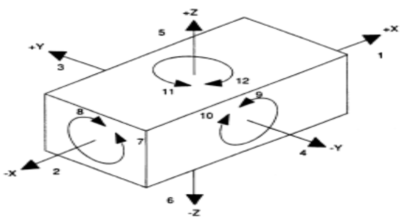

Fig 3: locating purpose the 3-2-1 principle

For locating purpose the 3-2-1 principle is used in designing this milling fixture.

For the resting purpose the casting the cylinder head is machined at Z_1, Z_2, Z_3, Z_4, Z_5 and Z_6 locating positions. These machined surfaces Z_1, Z_2 and Z_3 are rested against the three rest pads and Z_4, Z_5 and Z_6 are rested against adjustable work support. So the cylinder block is no longer to move along Z- axis and this also prevent it from rotation around X and Y axis

Calculation of cutting forces

Diameter of milling cutter (D)= 255 mm
Revolutions per min (n) = 126 rpm
No of teeth on cutter (Z) = 20
Feed per tooth (Sz) = 0.3 mm
Depth of cut (t) = 6 mm
Width of cut (b) = 178.5 mm
Approach angle (x) = 90 deg

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Ψ_1& Ψ_2 = angle subtended at the entry and exit of the teeth.
Ψ_s = angle of contact with the workpiece, degree

Cutting speed (v) $v = \frac{\pi D n}{1000}$

Feed per min (S_m) $Sm = S_z \times Z \times n$

Metal removal rate (Q) $= \frac{b\,t\,Sm}{1000}$

Power at the spindle (N) $= U \times K_h \times K_\gamma \times Q$

Tangential cutting force $Pt = \frac{6120 \times N}{v}$

Tangential cutting force $P_t = 1601.2 \times 9.81$
Axial cutting force, $Po = 0.55\ P_Z$
Radial cutting force, $Pr = 0.35\ P_Z$
The tangential cutting force is resolved into vertical and horizontal direction.
Vertical tangential force $P_v = P_Z \times \sin(\Psi_1)$
Horizontal tangential force $P_h = P_Z \times \cos(\Psi_1)$

Table 1- Calculation of cutting forces

Cutting Speed (v)	=100.9m/min
Feed per min (s_m)	=756mm/min
Metal removal rate (Q)	=809.68 Cm^3/min
Average chip thickness (a_s)	A_s=0.27mm
Power at the spindle (N)	=26.4kw
Tangential cutting force (P_t)	P_t=1601.2kg
Axial cutting force	P_o=8639.62N
Radial cutting force	P_r=5497N
Vertical tangential force	P_v=11217.46N
Horizontal tangential force	P_n=10996.6N
Approach angle	(x) = 90°
Coefficient of friction	(μ) = 0.23
Clamping Force	**Q=8536.7N**

Strap Clamp Calculations

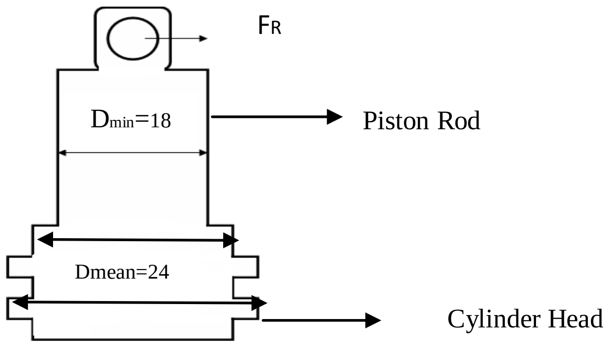

Fig 4: Hydraulic Cylinder

The Hydraulic Pressure Acting on Piston Head
$=F1 = (\pi/4) \times (Dmax)^2 \times (P)$
The cylinder head force acting on piston head
$=F2 = (\pi/4) \times (Dmean^2 - Dmin^2) \times (P)$
Average force acting on piston rod $=FR = F1 - F2$
Data;

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Dmax = Maximum piston diameter = 40 mm
Dmean = Mean diameter of piston = 24mm
Dmin = Minimum piston diameter = 18 mm
Hydraulic Pressure = P = 50, 60 & 70 bar;
The Free Body Diagram of clamp lever is shown in Figure

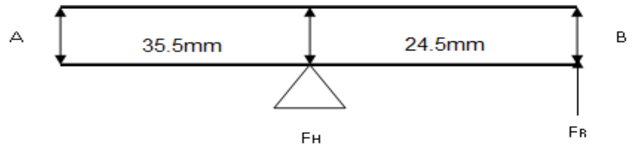

Fig 5: Free Body Diagram of clamp lever

Where,
C is the point where lever is hinged.
FH is reaction force at hinge.
B is point where net piston force (FR) applied
A is point where clamping force (FC) applied.
So from Free Body Diagram;
By Newton's first law of equilibrium;
Σ Vertical Force = 0
FC + FR - FH =
Also, by taking moment at point C equal to zero;

Table 2: Calculation of Clamp forces at 50 BAR

Hydraulic Pressure Acting on piston head	F_1=6.28KN
Cylinder Head Force Acting on piston head	F_2=0.9877KN
Average Force Acting on piston rod	F_r=5.2942KN
FH is Reaction Force At hinge	F_c=3.652KN
Reaction Force	FH=8.943KN

Table 3: Calculation of Clamp forces at 60 BAR

Hydraulic Pressure Acting on piston head	F_1=7.541KN
Cylinder Head Force Acting on piston head	F_2=1.1877KN
Average Force Acting on piston rod	F_r=6.3533KN
FH is Reaction Force At hinge	F_c=4.3877KN
Reaction Force	FH=10.738KN

Table 4: Calculation of Clamp forces at 70 BAR

Hydraulic Pressure Acting on piston head	F_1=8.7976KN
Cylinder Head Force Acting on piston head	F_2=1.3856KN
Average Force Acting on piston rod	F_r=7.412KN
FH is Reaction Force At hinge	F_c=5.1153KN
Reaction Force	FH=12.5273KN

Similarly, Clamping Forces for 5 and 6 MPa hydraulic pressure are also calculated that is for 5 MPa pressure clamping force is **FH = 8.943 KN** ,for 6 MPa pressure clamping force is **FH = 10.738 KN** and for 7 MPa pressure clamping force is **FH = 12.5273 KN** respectively .Hence for clamping 70 bar hydraulic pressure is preferred than 50 and 60 bar. Pressure which is in tolerance with machining allowance.

Theoretical calculation of stress and deflection on clamps
Length A = 70 mm
Length B = 25 mm
The width w, of the clamp calculated as
The thickness of the clamp for a bolt diameter d is given by

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$$t = \sqrt{0.85dA(1-\frac{A}{B})}$$

t = 24.42 mm

The strap clamp is going to act like a simply supported beam with clamping force 12228.6 N is applied .
Moment equation for strap can be derived using the above vector diagram

$\sum F_Y$ is F+P=f

$\sum M_P$ is Af – Bf = 0 $\frac{100\times14684}{25}$

F = 8024.04 N

Substitute in equation $\sum F_Y$,

P = f – F = 14684 – 8024.04

P = 6659.96 N

The moment M about point f is force times perpendicular distance to the line of action of that force. Thus

$$M = \frac{fA(A-B)}{B} \qquad M = \frac{14684 \times 70 \times (70-25)}{25}$$

M = 665995.63 N-mm

The stress on the clamp is a function of the section modulus of the strap. Thus

$$\text{Sec. Mod.} = \frac{(w-c)\times t^2}{6}$$

Sec. Mod. = 27234 mm³

The stress on clamp is

$$\sigma = \frac{M}{Sec.Mod} \qquad \sigma = 24.454MPa$$

$$\text{Moment of inertia}, I = \frac{w\,t^3}{12}$$

I = 833333.3 mm^4

Maximum deflection $$y_{max} = \frac{Po\times(3a^2l-a^3)}{6EI}$$ $\mathbf{y_{max}=0.0267\ mm}$

Results obtained:

- Stress on the clamp **σ = 24.454MPa**
- Deflection of clamp $\mathbf{y_{max}}$ **= 0.0267 mm**

Also at 70 bar hydraulic pressure the cylinder Head is perfectly clamped and maintained its position and stability against cutting forces, within stress and deformation values which are below allowable limit and tolerance limit. Hence for clamping **70 bar** hydraulic pressure is preferred than 50 and 60 bar. Hence **0.00267**mm maximum deformation is observed at 70 bar pressure which is in tolerance with machining allowance.

3D-FIXTURE MODEL

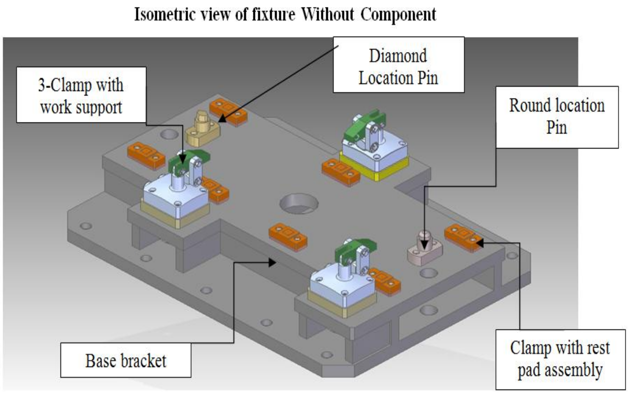

Fig 6: Isometric View of Fixture w/o component

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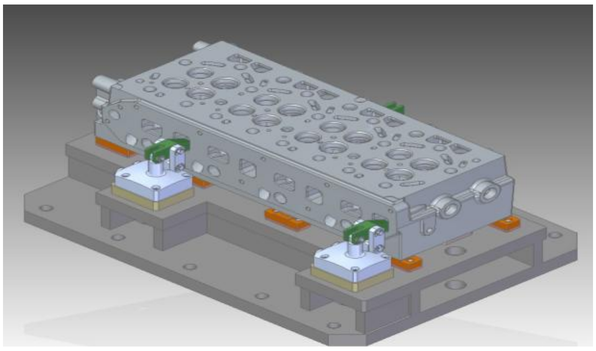

Fig 7:Isometric View of Fixture with Component

IV. RESULTS AND DISCUSSION

Performance comparison related to production rate and production capacity for Manual fixture and Hydraulic Fixture

Table 5 - Data for manual method

Quantity per batch, Q	10
Actual operation time per part, T_o(min/pc)	19.7
Work part handling time, T_h(min/pc)	3.6
Tool handling time, T_{th}(min/pc)	3.7
Setup time, T_{su}(min)	23.3

Cycle time, $T_c = T_o + T_h + T_{th}$ $T_c = 27.3$ min/pc

Batch processing time, $T_b = T_{su} + QT_c$ $T_b = 296.3$ min

Production time per work part, $T_p = \frac{Tb}{Q}$

$T_p = 29.63$ min

Production rate per hour : $R_p = \frac{60}{Tp}$

$R_p = 2.02$ pc/ hr

Production capacity per week

$PC = n_o S_w H_{sh} R$

Number of operations, $n_o = 1$

Number of shifts per week, $S_w = 12$ shift/ week

Number of hours per shift, $H_{sh} = 8$ hours/ shift

PC = 1 x 12 x 8 x 2.0=194

Production capacity PC = 194 x 4= 776 pc/ month

Production capacity PC = 776 x 12 = 9312 pc/ year

Manufacturing lead time

$MLT = n_o (T_{su} + QT_c + T_{no})$

MLT = 313 min

Hydraulic Fixture

Table 6 - Data for Hydraulic fixture Method

Quantity per batch, Q	10
Actual operation time per part, To (min/pc)	19.7
Work part handling time, Th(min/pc)	2.4
Tool handling time, Tth(min/pc)	1.0
Setup time, Tsu (min)	14

Cycle time

$T_c = T_o + T_h + T_{th}$

$T_c = 23.1$ min/ pc

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Batch processing time
$T_b = T_{su} + QT_c$
T_b = 245 min
Production time per work unit
T_p = 24.5 min
Production rate per hour
R_p = 2.44 pc/ hr
Production capacity
$PC = n_o S_w H_{sh} R_p$
PC $\cong$ 235 pc/ week
Production capacity PC = 235 x 4 = 940 pc/ month
Production capacity PC = 940 x 12 = 11280 pc/ year
Manufacturing lead time
$MLT = n_o (T_{su} + QT_c + T_{no})$
MLT = 264.7 min

Manual fixture
Manufacturing cost per hour = 5500 Rs/ hr
= 272.2 Rs
Manufacturing cost for 1728 parts = 9312 x 272.2
= 2535445 Rs.
Hydraulic Fixture
Manufacturing cost per hour = 5500 Rs/ hr
Manufacturing cost for 11280 parts = 11280x 225
= 2538000 Rs.

Table 7: Comparison of performance

Performance	Manual fixture	Hydraulic Fixture
Production rate, pc/ hr	2.02	2.44
Production capacity, pc/ yr	9312	11280
Manufacturing lead time, min	313	264

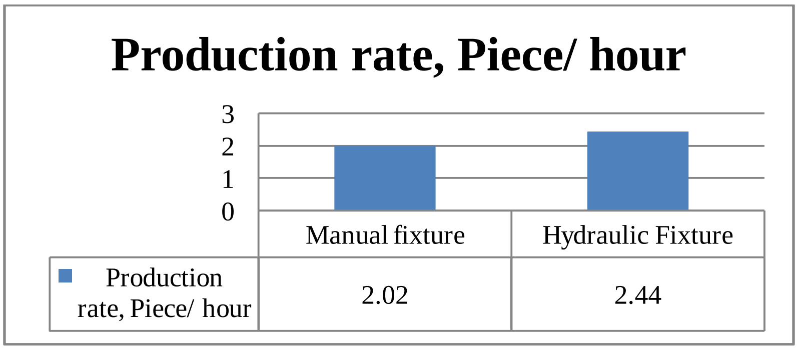

Fig 8: Comparison of Production rate

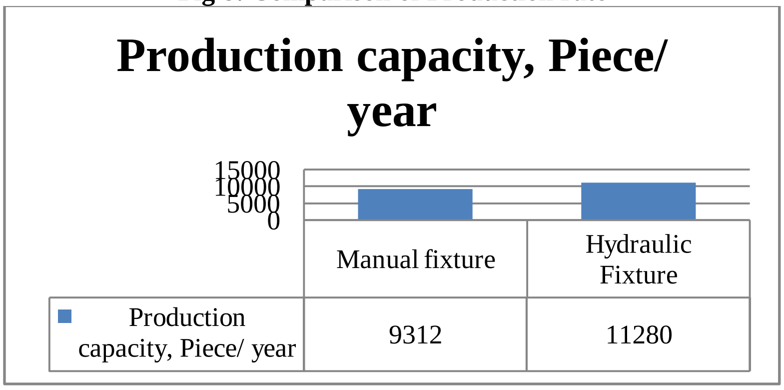

Fig 9: Comparison of Production capacity

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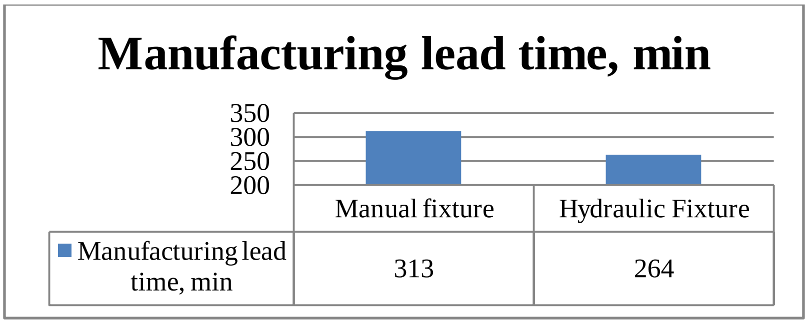

Fig 10: Comparison of manufacturing lead time

The setup time for operation by Using Hydraulic fixture is decreased. This leads to increase in production rate and production capacity of about 13.6 % and 14.2 % respectively. And decrease in manufacturing lead time for about 12.8 % and manufacturing cost for about 13.6 %. Hence this fixture increased the production rate, production capacity and decreased manufacturing lead time and manufacturing cost.

V. CONCLUSION

The Design requirements of the fixture were studied and according to condition. Confirmation of the fixture design is carried out. Meanwhile clamping forces are considered at 50, 60 and 70 bar hydraulic pressure by using analytical and numerical methods which are validated and are taken into consideration during the static analysis of the fixture and cylinder head, so from FEA result of fixture assembly design is to be considered for manufacturing the final fixture system.

1. At 70 bar hydraulic pressure the cylinder Head is perfectly clamped and maintained its position and stability against cutting forces, within stress and deformation values which are below allowable limit and tolerance limit. Hence for clamping 70 bar hydraulic pressure is preferred than 50 and 60 bar.
2. 0.00267 mm maximum deformation is observed at 70 bar pressure which is in tolerance with machining allowance.
3. The setup time for operation by Using Hydraulic fixture is decreased . This leads to increase in production rate and production capacity of about 13.6 % and 14.2 % respectively, and decrease in manufacturing lead time for about 12.8 % and manufacturing cost for about 13.6 %. Hence this fixture increased the production rate, production capacity and decreased manufacturing lead time and manufacturing cost.
4. The values of stresses and deformation obtained by software conforming with the values obtained theoretically within 9.2 % of error And 5.6% of error. This confirms that design is safe.

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