

INTEGRATED STEERING KNUCKLE INSPECTION FIXTURE DESIGN

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Abstract: The study aims at designing a new fixture assembly which will be used for the inline inspection of bend in a part of a component manufactured. The component manufactured is the steering knuckle and the bend has to be detected in the tie rod of the steering knuckle. The already existing fixture assembly does the work of Inspection of bends in the tie rod of the steering knuckle, but it is associated with certain demerits due to which it allows the steering knuckles with bend to pass the inspection test, though their tie rods have bends in them. In most cases the bend is detected and the part is rejected, but in some cases the parts with bends are also shown correct which are then passed for further operations. Later these bends are detected when they reach the vendor and the assembly of steering knuckle cannot be done properly with other mating parts like the hub, drag link and suspension. The bends are detected and then rejected which causes productivity loss to the company. Two types of bends are to be detected in the tie rod arm i.e. the lateral bend and the longitudinal bend. The lateral bends are successfully detected in all cases in the existing fixture assembly, only the problem of efficiency of the existing fixture assembly is with the detection of longitudinal bend. A new fixture assembly has to be designed such that it detects both lateral and longitudinal bends with their values with 100% efficiency.

Index Terms - Steering knuckle, Fixture design, Tie rod bend inspection, Error elimination, Snap Gauge and Go No-Go gauge.

1. INTRODUCTION

Steering knuckle is that structure on the wheel hub, to which the tie rod ends of the track rod transfer motion to the wheels. Tie rod ends and the track rod are the links of the steering system of the vehicle, which are designed according to a particular steering geometry. There are two types of steering knuckle i.e. universal steering knuckle and integrated steering knuckle. We have the integrated steering knuckle to deal with. Parts of integrated steering knuckles are illustrated as follows:-

1. Jaws: A fork shaped rigged section into which the front axle beam fits. The King pin is used to prevent translator motion between front axle beam and steering knuckle though it allows turning motion between them. A draw key is press fitted perpendicular to king pin for locking the assembly
2. Stub: Stub is a conical section which narrows at the end. It has a hole at its end for locking wheel by stopper pin. Stub hold the bearing of the wheel. The brake plate is held concentric to the stub. A pin is press fitted at the end hole of stub to prevent axial motion of wheel.
3. Steering arm: steering arm is a bent arm like structure which may be attached permanently, detachable on integrated to steering knuckle. The steering knuckle is connected to track rod (tie rod) through ball joints. The tie rod is further connected to steering mechanism for steering the vehicle in the desired direction.
4. Boss: complete brake housing system casing is bolted to the boss of the steering knuckle. The purpose of brake housing system is to apply brakes as per the consent of driver. It is connected to bearing and unitized wheel end for assembling the wheel.
5. Torque plate knuckle: They are like 2 outer pads integral to the flange of steering knuckle. Unitized wheel end is connected to hub assembly on one side while it is bolted to the torque plate on the other side.
6. Flange: Flange is the central thick plate-like section which has all the parts over it. It may be simple plate or may have curved surface. It acts as a reference for all the parts of steering knuckle.

Steering Knuckle Fixture:-

Steering knuckle Fixture is needed for checking the bending errors in the tie rod of the steering knuckle. During the manufacturing process of the steering knuckle the processes of forging and pressing are used. During these operations the tie rod of the steering knuckle does not have any support. As a result of having no support during the manufacturing, there are chances of tie rod getting bent in lateral or longitudinal direction. This bend has to be checked and the components which exceed the tolerance limit of bending in any direction have to be rejected and sent back for the pressing to eliminate the bend. If the bend is not eliminated then the same part with error moves

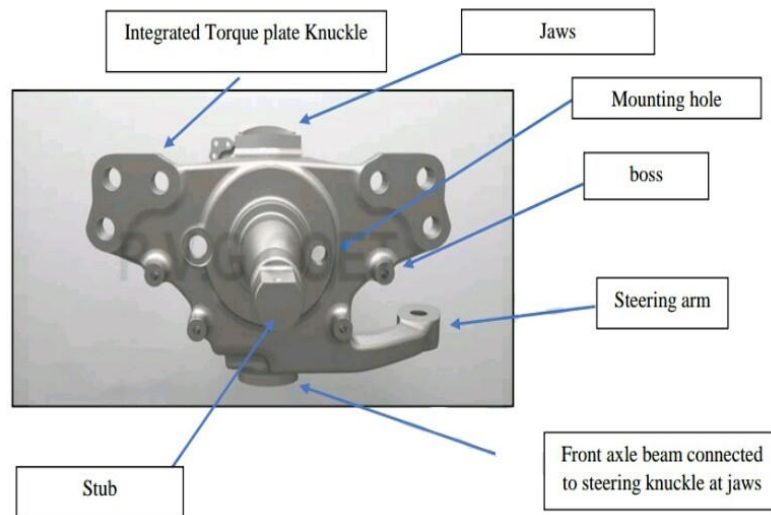


Fig 1. Parts of an Integrated Steering Knuckle

forward in the manufacturing line and gets dispatched to the vendor and later gets rejected which causes productivity loss of the company. To detect these bends in the tie rod, a steering knuckle fixture is used. The manufactured component is rested on the fixture and with help of Go No-Go gauges the bends are detected.

3.2 Data and Sources of Data

For this study the performance data of the old fixture design has been collected from the Bharat Forge Limited Hadapsar branch's New Fab Line inspection log book from the period of June 2016 to July 2018. The dimensions and profiles of the steering knuckle have been taken from drawing CUST's Forging Drawing no 3111 - X - 4756 Revision no 'A' dated 24/5/2016 from the new fab line department.

RESEARCH METHODOLOGY

1) 3-2-1 Principle of Fixture Design

The fixture configuration mainly consists of locators and clamps. The function of each locator is to provide a deterministic location of the workpiece whereas the function of each clamp is to exert suitable force on the surface of the workpiece to prevent it from losing contact with the locators. Based on the classical screw theory several formal methods for the fixture analysis have been developed. Most of the dedicated fixtures for prismatic parts are designed using the 3-2-1 locating principle. Here, 3-2-1 refers to 3 locators on the primary locating surface, 2 locators on the secondary locating surface and 1 locator on the tertiary locating surface of the workpiece. The twelve degrees of freedom of a free body in space are shown in Figure 6.1 and out of twelve, nine degrees of freedom are restricted by using 3-2-1 locating principle as shown in Figures

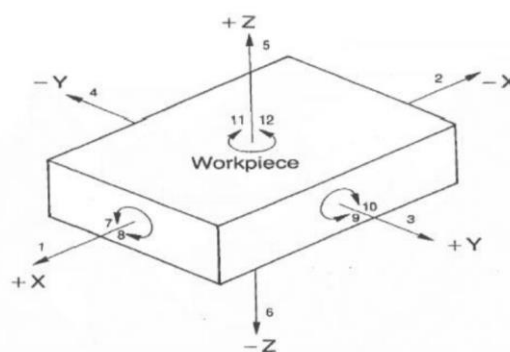


Fig 2. Twelve degrees of freedom of a body

Due to its less complexity and effectiveness, the 3-2-1 locating scheme has been used by most of the researchers. Kang and Peng (2009) illustrated the 3-2-1 locating method for a prismatic workpiece called valve body which is shown in Figure 2.5. The valve body is located by three perpendicular locating planes where the bottom surface of the valve body forms the primary locating plane, the secondary locating plane is the side surface contacting two locators and the tertiary locating plane is the side surface against one locator. Four vertical clamps have been applied on the top surface. For fixture clamping force optimization, the workpiece-fixture configuration used by Li and Melkote (2001a) is shown in Figure 2.6 where, L1-L6 are the workpiece-fixture locator contacts and Xg, Yg, Zg, are the global coordinate frames.

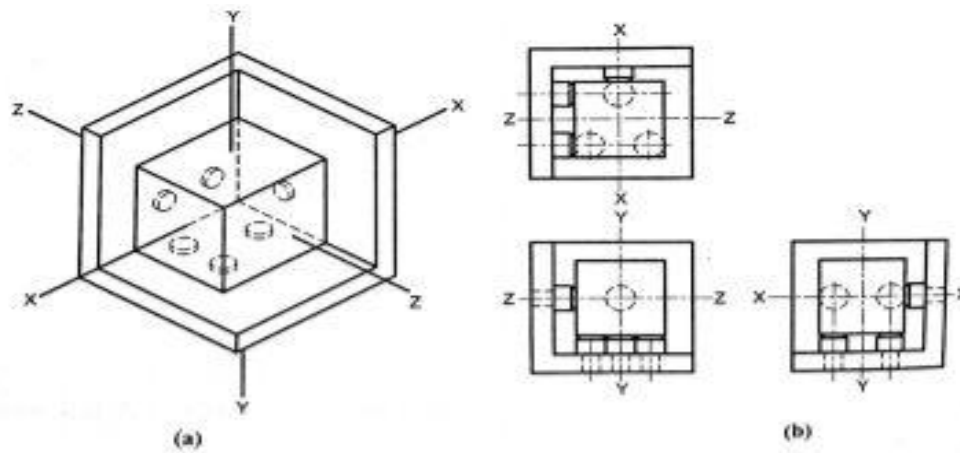


Fig 3. 3-2-1 Principle

Experimental Validation

The main objective that has to be achieved during the design of the fixture is that the fixture should be clamped such that the movement in all the degrees of freedom of the integrated steering knuckle is constrained. Let us analyse the fixture design (1) which is already existing and see if it restricts all the six degrees of freedom of the integrated steering knuckle or not. Then we will analyse the newly designed inspection fixture and see how many movements are constrained by it. Remember for the best fixture design all the six degrees of freedom must be constrained.

1)3-2-1 Analysis of the Steering knuckle inspection fixture 1

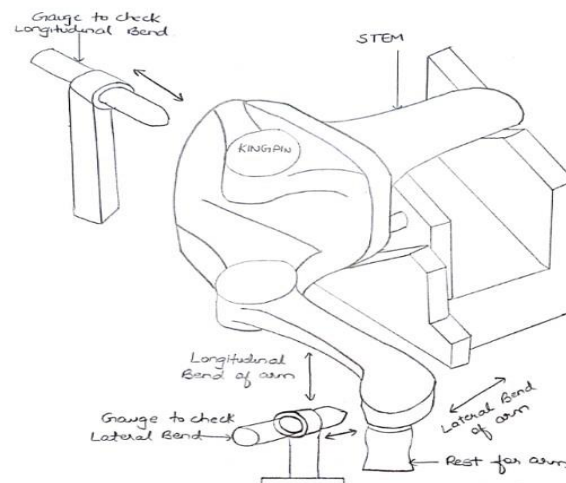


Fig 4. Steering Knuckle inspection fixture 1

In the above case as we can see, the mounting of the steering knuckle on the fixture has the following procedure:-

- Mount the Flange bottom on the front V - notch and king pin on the base plate.
- Mount the stem end on the back V - Notch of the fixture.
- Clamp the stem from top with the V clamp.
- Rest the tie rod end on the side end support.

By following the above mounting procedure on the fixture, the following degrees of freedom of movement are constrained of the Integrated Steering Knuckle.

- The downward movement is restricted by the V support of fixture.
- The upward movement is restricted by the V Clamp applied from the top.
- The right ward movement is prevented by the Two front and back V supports due to their geometry.
- The left ward movement is prevented by the Two front and back V supports due to their geometry.
- The front movement is restricted by the fixture front body only if the flang touches the stopper butts on the front body of fixture.
- The backward movement is not restricted and it solely depends on the pressure applied by the worker's hand on the component.
- The rotary movements are automatically restricted due to the component geometry and weight.

Thus we can conclude from the above analysis that the previous fixture design is not the best design of the fixture as it does not restrict all the six possible movements and only four movements are completely restricted and hence errors are introduced in the inspection procedure.

2)3-2-1 Analysis of newly designed fixture

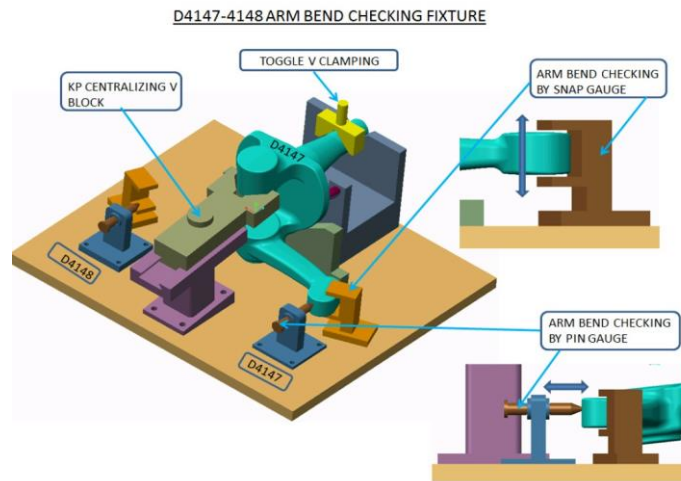


Fig 5. Newly designed

fixture

In the above case as we can see, the mounting of the steering knuckle on the fixture has the following procedure:-

- Mount the Flange bottom on the front V - notch and king pin on the base plate.
- Mount the stem end on the back V - Notch of the fixture.
- Clamp the front V-Clamp on the king pin.
- Clamp the stem from top with the V clamp.
- Rest the tie rod end on the side end support.

By following the above mounting procedure on the fixture, the following degrees of freedom of movement are constrained of the Integrated Steering Knuckle.

- The downward movement is restricted by the V support of fixture.
- The upward movement is restricted by the V Clamp applied from the top.
- The right ward movement is prevented by the Two front and back V supports due to their geometry.
- The left ward movement is prevented by the Two front and back V supports due to their geometry.
- The front movement is restricted by the fixture front body as the front V clamp continuously applies force on the kingpin in the forward direction which keeps the flanges touched to the support butts.
- The backward movement is restricted by the front V- Clamp itself
- The rotary movements are automatically restricted due to the component geometry and weight.

Thus we can conclude from the above analysis that the new fixture design is the best design of the fixture as it does restrict all the six possible movements and all six movements are completely restricted and hence no errors are introduced in the inspection procedure.

Thus the above two analysis justify the design of the newly designed fixture.

IV. RESULTS AND DISCUSSION

The main aim of designing the new fixture was to reduce the acceptance of the rejected components and increase the productivity of inspection.

Modern manufacturing aims at achieving high productivity to reduce unit cost. This necessitates workholding devices to be efficient, i.e. to increase the rate of loading and unloading to speed up the manufacturing cycle time. If t is the total time in seconds or minutes required for producing a part, then

$Q = 1/t$ - is the number of pieces produced in unit time, or the production rate.

Considering the fact that the total manufacturing time is usually composed of:

$$t = t_m + t_h$$

where t_m is the actual machining time and t_h is the setting up and handling time, hence, the production rate is given by:

$$Q = 1/(t_m + t_h) \text{ - piece per unit time}$$

Supposing Q_t is the ideal production rate whereby there is no handling time loss for a given machining operation, hence we have:

$$Q_t = 1/t_m$$

Now,

$$Q_t = 1 / (1/Q_i + t_h) = (1 / (1 + (t_h/t_m))) \quad Q_i = \beta Q_t$$

This factor $\beta = (1 / (1 + (t_h/t_m)))$ can be termed as production efficiency.

The variation of β with respect to Q_t is shown in Figure 1.2 for the various values of t_h . For an operation with a value of $t_m = t_h$, β is 0.5 whereas, if $t_h = 2 t_m$, β is 0.33 and the production rate is reduced. Figure 1.3 shows how t_m and t_h affect production rate. It is clear from Figures 1.2 and 1.3 that

(a) For a given t_m , reduction of t_h increases Q , (b) For a given t_h , reduction of t_m enhances Q .

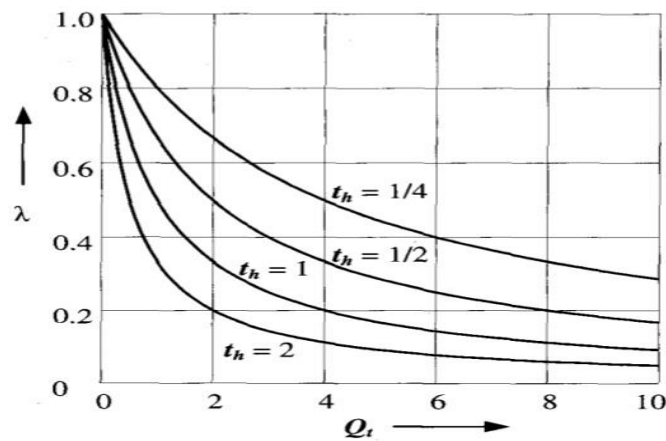


Fig 6. Effect of setting and handling time t_h on production efficiency (β)

In case of the existing bend inspection fixture the time taken for the inspection of each part is more and hence the productivity is less. The following analysis of the two fixtures helps us to understand how the newly designed fixture increases the productivity. In case of current inspection method on the existing fixture, after the workpiece is loaded the operator has to make sure that the flat flang portion of the steering knuckle is touching properly the rest buds by pushing the part towards the fixture away from him. After this the operator had to adjust the go - no go gauge to check whether the part is acceptable or not within both the limits for checking the bend in the longitudinal direction.

The following is the time required in seconds for each and every step of the bend inspection -

- 1) Checking the proper resting of the flang on the rest buds and applying manual force to properly adjust it - 5 sec
- 2) Checking the go - nogo gauge for the acceptance or rejection of a part - 10 sec

In addition to this, the worker fatigue also plays an important role when the operator once becomes tired due to continuous force application and constant checking of go - nogo gauge.

Now we will take into consideration the time taken by the operator while complete inspection of the bend on the newly designed fixture -

In the newly designed fixture there is no need for the operator to manually apply force and check whether the flang is resting on the rest buds or not. Instead a clamp has been provided that could be pulled and automatically the flang will get pushed against the resting buds. There is no need for the operator to cross check the proper execution of the task. Also this method of clamping reduces the effort and fatigue of the operator. Operator does not has to put a lot of attention too in the process too.

After the clamping has been done for the inspection of the bend in the vertical direction ie for checking longitudinal bend nothing has to be except the rotation of snap gauge to check whether the tie rod end passes through the snap gauge or not. This method is much easier than checking the go - nogo gauge and their functioning. The following time in seconds is needed for the inspection process of the newly designed fixture -

- 1) Clamping the steering knuckle against the rest buds - 2 sec
- 2) Rotating the snap gauge to check the passing of tie rod end - 3 sec

The other times takes for locating the steering knuckle on the fixture assembly and checking of the bend in the horizontal direction are same for both the old design and the new design. The average amount of time taken for all those processes is 40 sec. Now with all the available time data we can calculate the productivity and the net increase in productivity in the newly designed fixture.

Let t_s be the setting time or time taken for all other inspection process other than the vertical bend inspection and let t_i be the inspection time for the bend in vertical direction. So,

$t_s = 40$ and $t_i = 15$ (for old fixture) and

$t_s = 40$ and $t_i = 5$ (for new fixture)

Let us calculate for the old fixture first

$$t = t_s + t_i$$

$$t = 40 + 15 = 55 \text{ sec} = 0.9167 \text{ min}$$

We know that ,

$$Q_o = 1/t$$

$$Q_o = 1/0.9167 = 1.09 \text{ per min} = 1.09 * 60 = 65.4 \text{ per hour}$$

For the new fixture

$$t = 40 + 5 = 45 \text{ sec} = 0.75 \text{ min}$$

$$Q_n = 1/t$$

$$Q_n = 1/0.75 = 1.33 \text{ per min} = 1.33 * 60 = 79.8 \text{ per hour}$$

So due to the new design the operator can check 15 more steering knuckles for bend without fatigue and attention. Percent increase in the inspection efficiency is given by

$$\begin{aligned} \% \text{ increase} &= ((Q_n - Q_o)/Q_o) * 100 \\ \% \text{ increase} &= ((1.33 - 1.09)/1.09) * 100 \\ \% \text{ increase} &= 22.01\% \sim 22\% \end{aligned}$$

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