

OEM's Approach on Design and Evaluation of Plastic Clamps

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ABSTRACT

The automotive industry, known for its competitiveness & innovations globally, researches for continuous improvement of part performances along with reduction of cost & weight. These are amongst the top priority goals across all OEMs. In the long list of automobile parts, pipe clamps have paved their way of design through generations from being of metal to plastic that has expanded its scope of application & performance.

In an automobile, plastic clamps are widely used to hold single or multiple water, fuel or brake pipes of various diameters to vehicle body at various locations such as underbody (prone to stone chipping) or engine room (prone to high temperatures), etc. Plastic clamps are preferred over metallic clamps for their cost, weight, performance & productivity. Primarily, in all application areas, a clamp must be able to hold the pipes with consistent & sufficient performance that is quantified through parameters such as thrust force and pipe removal force. Hence, selection of ideal material becomes an important factor. As an example, clamps at underbody application are highly prone to stone chipping, so the impact resistance specification of material becomes an important factor for the durability performance. On the other hand, the design aspect becomes significant in cases such as increasing safety protection of pipes from surrounding parts during crash event, dampening the vibration transfer from pipe to vehicle body for better NVH performance.

This paper focuses on articulating perspectives of OEM's designers on available knowledge about plastic clamps based on their experiences and propose a novel approach for design & evaluation of plastic clamps.

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INTRODUCTION

Plastic clamps of various shapes are widely used in an automobile for fixing various types of tubing such as brake pipes, fuel pipes, water pipes, etc. Their wide use across the industry can be attributed to their cost effectiveness, formability & lightness and the most common materials used are POM, PA6, PA66, etc. with additives such as EPDM, GF, etc. These clamps are mounted on vehicle body or floor or on other automobile components where they hold the required pipe by clamping it.

These clamps are also expected to provide additional functions based on their application area such as having better impact resistance strength, NVH reduction property, etc. Thus, the key functions of the clamp can be easily classified into two categories:

- i. Primary Function
 - Proper mounting on vehicle body
 - Proper holding of tube
- ii. Secondary Function
 - Stone chipping impact resistance
 - Crash protection feature
 - NVH reduction

To meet the above functionalities as per OEM's requirement, a lot of consideration is required for designing the clamp to meet the required specifications followed by the evaluation of the clamp during design & subsequent stages to confirm its performance. The clamp manufacturers already design & evaluate these performances based on their knowledge and standards. This paper describes an OEM's perspective on these design philosophies & evaluation methods of plastic clamps based on application experience at vehicle level & suggesting additional guidelines to relate more to real-time environment.

CLAMP DESIGN CONSIDERATIONS

As already discussed, a clamp must be designed to meet its primary functions. In case, an OEM requests for secondary functionalities also, the clamp designer must ensure that primary functions are always met in every case. In this section, design consideration based on OEM's perspective shall be explained for both primary & secondary functions.

Clamp Design for Primary Functionality

As already explained, the primary functions of the clamp with their detailed break-up are:



- i. Proper mounting on vehicle body
 - a. Clamp mounting insertion force
 - b. Clamp mounting removal force
- ii. Proper holding of tube
 - a. Tube insertion force
 - b. Tube thrust (axial) force
 - c. Tube removal force

In every case, clamp must ensure that there is no damage to the mounting parts (hole, stud bolt, etc.), tubes & its surrounding parts.

Clamp Mounting Insertion & Removal Forces

Most of the clamps in the vehicle require mounting on the vehicle, except in few cases, where clamps are used only to hold multiple tubes but not mounted anywhere. In our study, we have classified clamp mounting as following:

1. Bolt stud mounting (Fig. 1)

Clamp has a lug feature that holds the thread of the bolt stud. Most commonly, M5 bolt studs are used.

2. Bolt & nut mounting (Fig. 2)

Clamp is mounted using bolt & nut combination. The bolt or the nut can also be insert-molded inside the clamp.

3. Slot mounting (Fig. 3)

Clamp has a feature that locks itself in the slot provided on mating panel. The slot shape can be circular or rectangular, etc. as per requirement. Rectangular slot is used where clamp rotation has to be restricted.

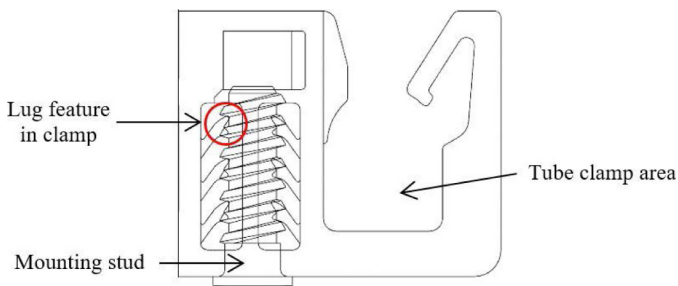


Figure 1. Bolt stud mounting

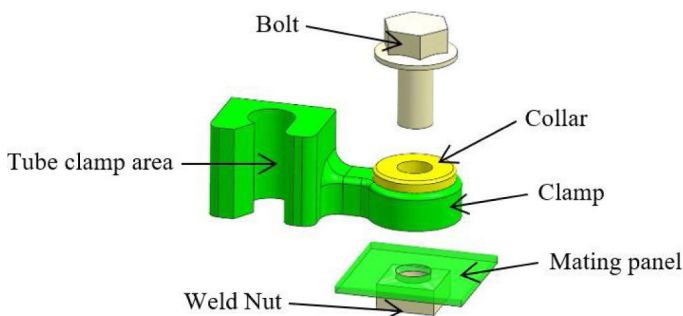


Figure 2. Bolt & nut mounting

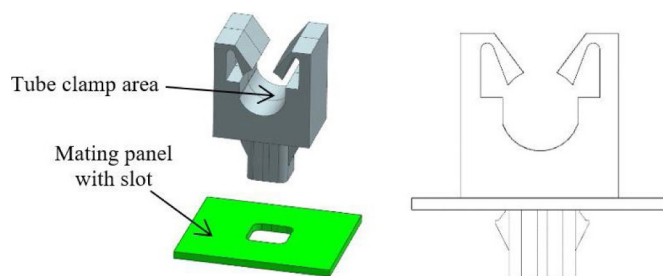


Figure 3. Slot mounting

The choice of these mountings types depends on the application area and performance requirement. The performance comparison is given in Table 1 that can help in choosing the appropriate mounting design.

Table 1. Performance comparison of different clamp mountings

Mounting type	Mounting Strength	Cost	Assembly Ease	Sealing across panel
BOLT STUD (Fig. 1)	Medium	Medium	Easy	Excellent
BOLT & NUT (Fig. 2)	High	High	Difficult	Good
SLOT (Fig. 3)	Low	Low	Easy	Poor

Clamp Tube Holding Forces

The design of tube holding features has an important role in the performance parameters of a clamp. On the basis of our study, we can classify the performance parameters as follows:

1. Tube Insertion Force

This force should be minimal to ensure ease of assembly.

2. Tube Thrust Force

This force should be enough to ensure to prevent axial slippage of tube and also must not damage the tube.

3. Tube Removal Force

This force should be enough to prevent the tube getting detached from clamp due to vibration during vehicle operation.

The basic shape of tube holding feature called flexible lugs is depicted in Fig. 4.

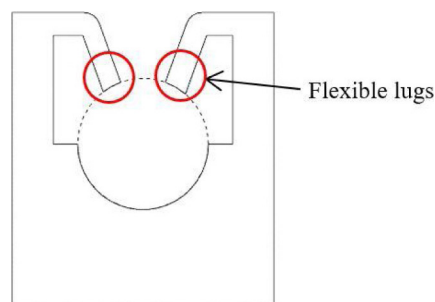


Figure 4. Flexible lug feature of clamp

Tube Insertion Force

During tube assembly into the clamp, it is observed that if the lug feature is not flexible enough it can cause difficulty in assembly due to high insertion force. In this condition, if the clamp material is brittle then it might break also during assembly. On the other hand, such design of lug feature can also damage the tube if tube is made up of soft material such as plastic (PA) or damage the tube protector or outer sleeve made up of soft materials such as PVC, EPDM, etc.

Therefore, during clamp design, it is necessary to ensure that the assembly should be easy as well as should not damage clamp & tube.

Fig. 5 describes the stage-wise movement of lugs while inserting the tube into the clamp. The flexible lug bends to allow the easy insertion of tube into the clamp. Once the tube is inserted, the flexible lug retracts back to its original shape and acts as a barrier to stop the tube from coming out.

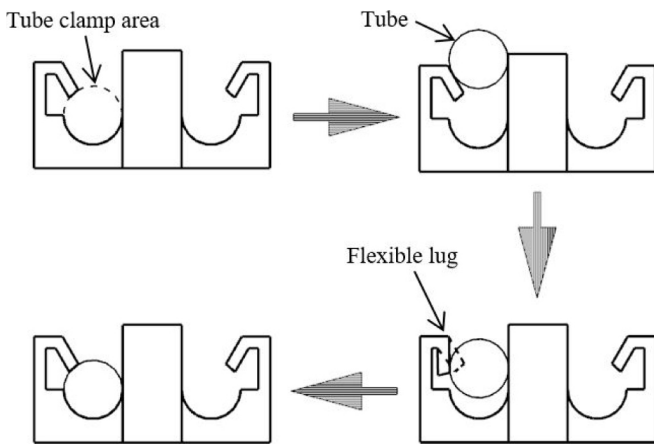


Figure 5. Tube insertion sequence and lugs movement

Refer the Fig. 6 which mentions about the parameters which have to be considered while designing the shape of flexible lug clamp.

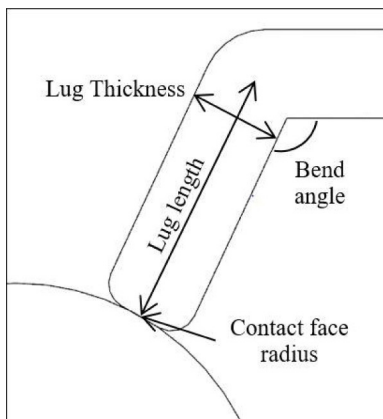


Figure 6. Flexible lug design parameters

Guidelines

1. The design must be made considering tube OD at maximum tolerance.
2. The lugs thickness should be designed such that, generally with variable thickness along section, the flexible lugs should

majorly bend but not the body of the clamp. Hence, the body of the clamp must be strong enough to bear such stresses with no major deformation. See Fig. 7.

3. The stresses on the lugs during maximum bend (Fig. 8) must be below the yield point in order to prevent the plastic deformation. If there is any plastic deformation, it shall negatively affect the tube removal force. Here, the most critical design consideration is that the lugs must also not be over stiff as it would increase the tube insertion force. Hence, the rule to be followed is:
As tube insertion in vehicle is done limited times during production or servicing, such high stresses do not occur continuously during vehicle life, so durability & creep performance can be met with the above condition.
4. During insertion of tube, the encircled surface of the flexible lugs in Fig. 9 must have sufficient radius in the contact area for smooth insertion of tube inside the clamp without any damage. Sharp corner at this contact surface of clamp can cause damage to the tube, particularly for tubes made up of softer materials.
5. The mating surface of tube & lugs should be smooth enough to allow easy retraction of flexible lugs after tube insertion. Various factors such as sharp corners of lugs, over-sized lugs, high bend angle of lugs, etc. can affect the proper retraction. In the event of improper retraction, the tube removal force is adversely affected. Also, the undersized leg and lower bend angle will result in loose fitment which will not fulfill the primary function of the clamp. The lug design must also be done considering minimum tolerance of tube outer diameter. For better understanding, see Fig. 10.

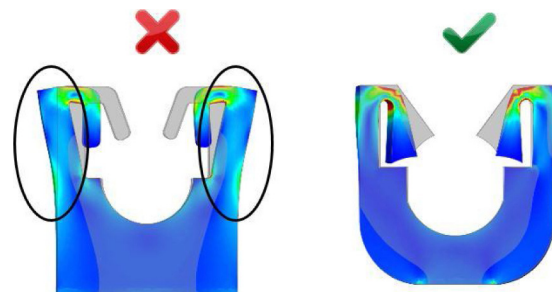


Figure 7. Clamp deformation during tube insertion

Max. Bending Stress on Lugs < Yield Stress

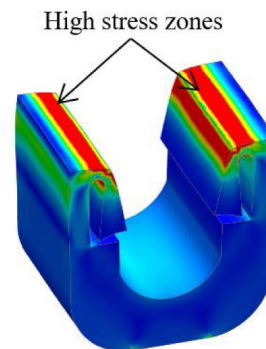


Figure 8. Stress concentration on lugs