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fea and multiphysics

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Judge Irwin asked a very important question which I feel I must answer. He was particularly concerned about my estimate of the load required to forcibly remove the tag that I wore (which I estimated to be less than 15 kg). This estimate did not appear to be consistent with some of the mechanical fatigue tests that had been conducted at loads of ~37 kg – such that the load at each clip was greater than the 15 kg. This apparent discrepancy is easily dealt with and it concerns the manner (particularly the angle) in which the load is applied. It is useful first however to review the simple relationships between applied force, cross sectional area and resultant stresses.

Consider therefore the two rods of polycarbonate in Fig.1. The polycarbonate material behaves in the typical manner that is shown in Fig.1(a). That's to say that under the action of an applied load there is an initial (linear) elastic response, followed by a yield point at some value of the stress, followed (after a period of irreversible plastic deformation) by fracture.

The stress that develops in a rod, under the action of an applied force (F), is equal to the applied force divided by the cross sectional area of the rod:

$$\sigma = \frac{F}{A} \tag{1}$$

Where σ is the stress. If the stress exceeds the critical stress ($\sigma_{fracture}$) shown in Fig.1(a) then the rod will fracture. The rod in Fig.1(c) has a smaller cross sectional area than the rod in Fig.1(b). Since the cross sectional area is smaller, the force required to generate the critical stress for fracture ($\sigma_{fracture}$) is lower for the rod in (c) than it is for the rod in (b).

The cross sectional area in which applied forces are accommodated is therefore very important.

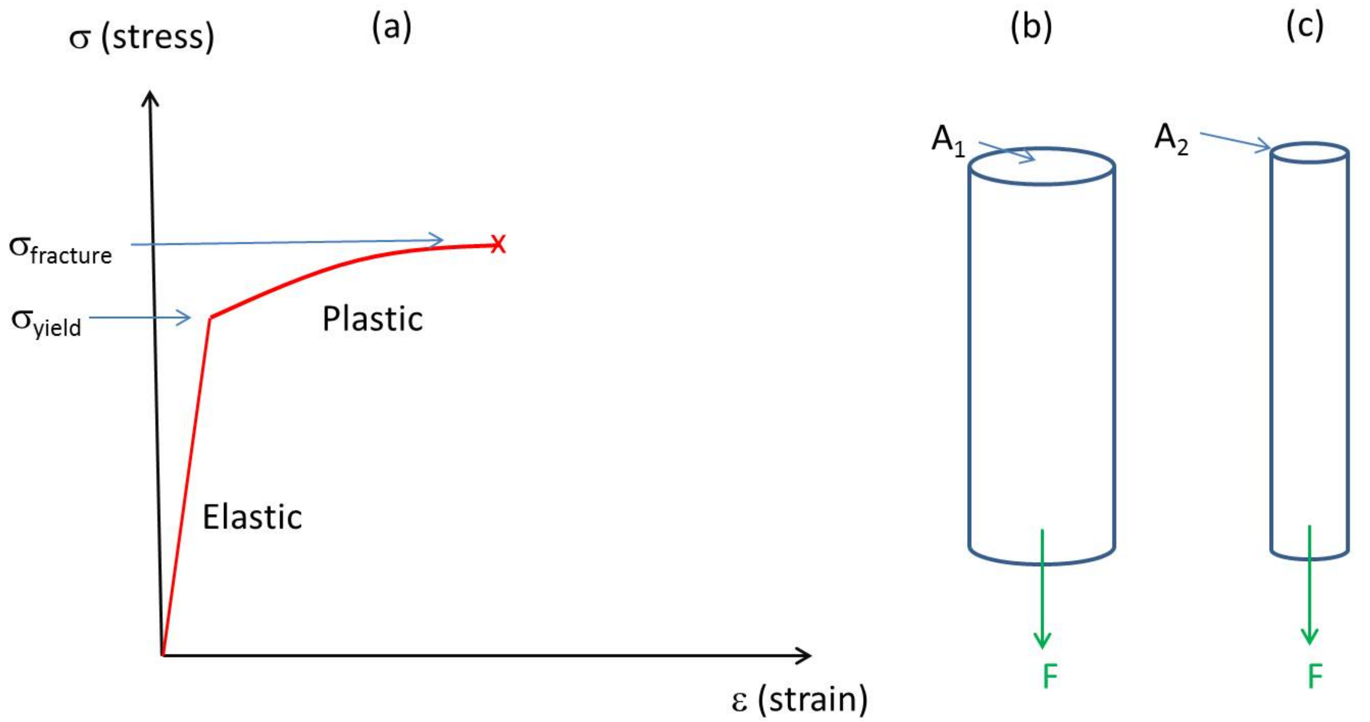

Figure 1: Demonstration of the relationship between applied force, cross sectional area and the resulting stress

Let us consider therefore the scenario in Fig.2, which shows two of the curfew tag clips. Let us further assume that they are linked to each other via a strap, as is the normal case. The clips are constrained from moving by retaining seats in which the lugs sit. If a load is applied in the axial direction, as shown with the arrow, then the applied load is accommodated principally in the hinge regions of the clip. There are 8 hinge regions in the clip. The cross sectional area which accommodates the load is indicated in red. Tests show that, with this configuration of applied load, the clips fracture at ~70 kg, but only after significant plastic deformation.

Now consider the case in Fig.3, in which the load is applied in such a way that only one of the two clips is loaded and when only 1 of the 8 hinge regions accommodates the majority of the load. This is the sort of loading scenario that emerges when the strap is pulled at an angle – either deliberately or when accidentally snagged. It is the sort of event that arose when I deliberately pulled the tag off my own leg. In this instance, the applied load is accommodated across a much reduced surface area. In fact, if only 1 of the 8 hinge regions is loaded, then the lower bound force to cause complete failure of this clip is just 1/8th of 70 kg (since the relationship between stress, force and area is a linear one – as seen in Eqn.1). In reality the angled load is accommodated across an angled plane area but this will not affect in any significant way the conclusion that the loads required to cause failure can be substantially less than those reported if the clips are loaded in particular ways.

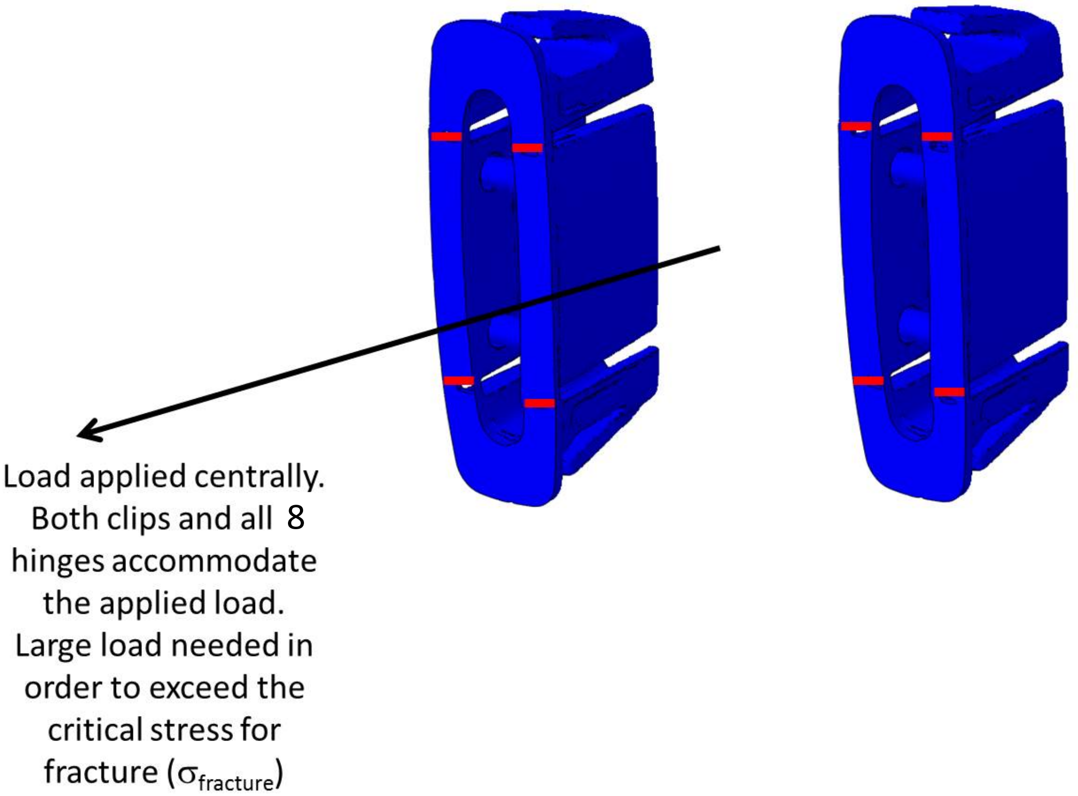

Figure 2: Schematic depiction of where and how the applied loads are accommodated in the clips when the strap is loaded centrally and axially away from the tag.

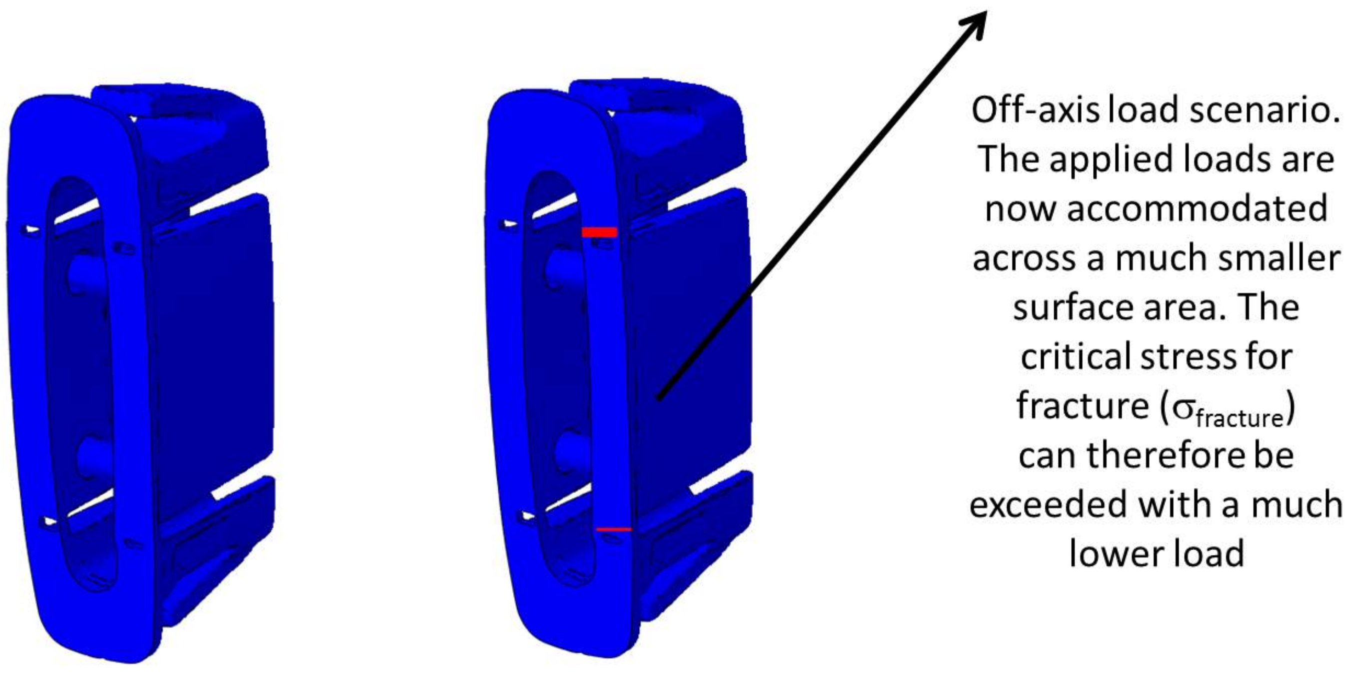

Figure 3: Schematic depiction of where and how the applied loads are accommodated in the clips when the strap is loaded off-axis

Yours Sincerely
Double Precision Consultancy Ltd

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