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An experimental investigation into localised low-velocity impact loading on glass fibre-reinforced polyamide automotive product

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ABSTRACT

In the automotive industry, more and more engineered parts are shifting from metals to engineering plastics. However localised impact loading and long term ageing effects of under-the-hood plastic components is not well understood. In this paper, localised low velocity impact experiments and simulations were conducted on glass fibre-reinforced polyamide sump to investigate typical flying stones impact scenarios. Complete components were manufactured by injection moulding techniques for the experimental samples. The samples were then subjected to a range of low velocity impact using drop weight tower and flying projectiles from an air gun. Damage assessments were then performed following the experiments. In parallel, finite element analysis using LS DYNA was carried out to virtually benchmark and to predict the strength and fracture behaviour of stressed plastic parts. This has permitted to perform numerous impact tests in different situations with varying parameters. The study results show the significant contribution of the design in terms of shock absorption. The specific sump design with a protective ribbing combined with a superior material increases considerably the impact resistance. The paper will provided detailed discussions and results from both the experiments and finite element analysis investigations.

1. Introduction

The under carriage of any road going production vehicle contains many vulnerability components. Driving on gravel surfaces, tough roads, near construction sites or during road maintenance can cause stones to be ejected from the wheels which then are projected into the air and could possibly damage the under carriage area of a vehicle or the vehicle can hit a boulder with potential serious consequences on low-fitted components. The main concern of this research is the impact performance and damage caused by those stones to a recently converted engine oil pan for light utility vehicles into PA66 reinforced with 35% of short glass fibre. Fig. 1 shows an early version of the thermoplastic oil pan that has been damaged by foreign flying debris, identified as a stone by the fragments left on the impacted surface (Fig. 1a). The engine oil was seeping out through the crack from the inner side (Fig. 1b) to the outer side of the pan (Fig. 1a).

Damage tolerant design of vehicle components requires a methodology to predict the likelihood of critical impacts occurring over the operational lifetime of the vehicle. Such information could be provided by examination of the damage caused in previous incidents, so that the locations of severe impact damage can be mapped out. In practice, the limited availability of such detailed records makes this approach very difficult to utilise. An alternative approach relies on understanding the complex lofting processes of objects by wheels, which may be considered as an impact event given the high speed at which a tyre may contact the object [1].

A number of investigations were conducted to assess the threat of impact damage caused to vehicles or aircrafts by tyre-lofted runway debris, yet there is limited understanding in the stone lofting process and in the influence of stone characteristics [3,1,4–7]. It comes out that a compilation of stones collected from roads or airfields led to stones of various shape with different overlaps, orientations and densities. However, the conditions most conducive to stone lifting concerns stones with small diameters lofted following four different mechanisms. The tyres can hammer or pinch the stone, and in the process the stone can be deviated by some asperity on the road. Finally, the tyre tread grooves could throw stones upwards. The tread of a tyre is typically a few millimetres in width. Table 1 shows the variables and attributes of the stone impact phenomenon [8].

The characteristics of stones likely to cause damage into the engine oil pan presented in the Fig. 1 were quantified allowing the measurement of road stones typical mass and size [9]. The granite stones shown in Fig. 2a weigh less than 17 g and all fit into the damaged area between two consecutive ribs except the two big

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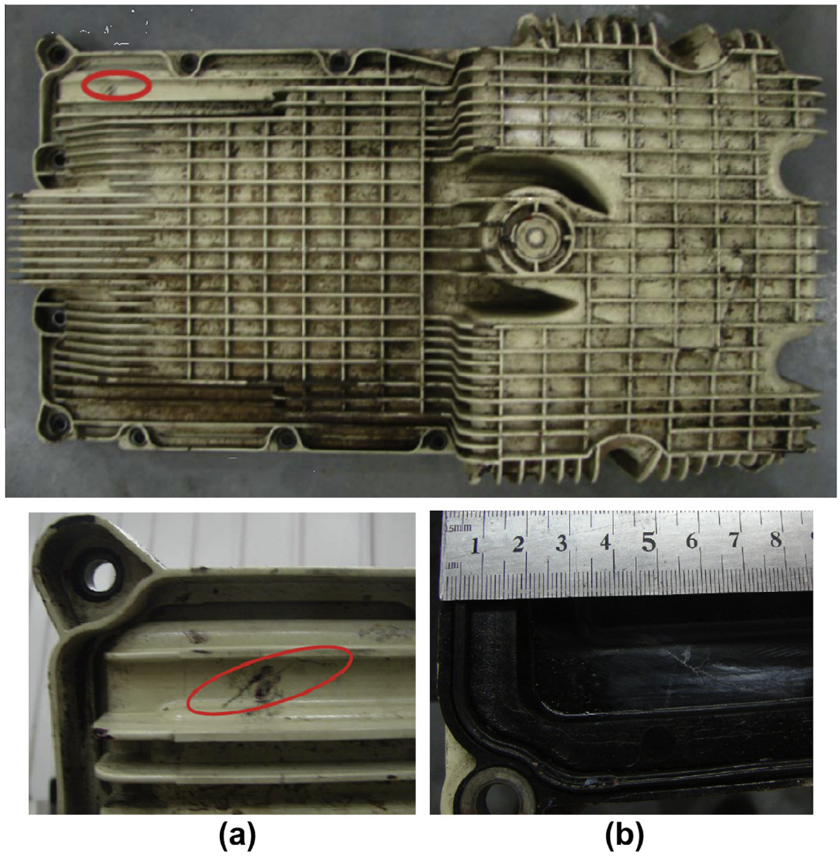

Fig. 1. Thermoplastic oil pan crack failure, (a) outer side, and (b) inner side [2].

Table 1
Stone impact phenomenon.

Variables	Attributes
Projectile	Shape, mass, density and material constants (modulus, Poisson's ratio)
Impact conditions	Velocity and angle of incidence
Ambient conditions	Temperature and humidity
Component system	Type (material properties), thickness (injection moulding), stiffness (ribbing), strain rate properties, moisture uptake

stones on the right side; the rounded stone weighs 21 g and the larger one weighs 78 g. There are variable gaps between the ribs in the area of impact. A 87 g random stone with a pointy profile is able to fit into the gap where damage is evident, Fig. 2b. A possible solution would be to reduce the rib spacing so as to exclude more stones, Fig. 2c. However, the mistake would be to overload the oil pan structure with protective features. The compromise is in the balance in where more or improved ribs are disposed in the areas prone to impacts.

2. Experimental testing

2.1. Materials and manufacture of oil pan samples

Two commercial grades of polyamide 66 with 35 wt.% of short discontinuous glass fibre, Ultramid A3HG7 (PA66-GF35) and Ultramid A3ZG7 (rubber toughened PA66-GF35) were manufactured by BASF. The rubber modifier in the rubber-toughened material has been intimately melt-blended into the base material. Previous

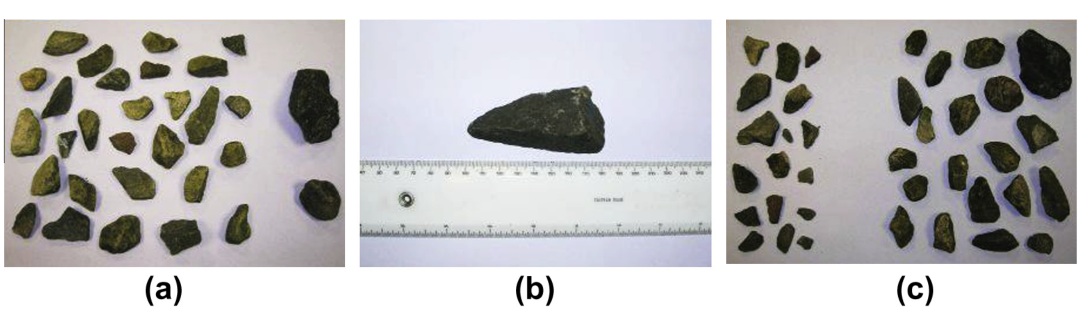

Fig. 2. Collection of random stones.