

# An experimental and numerical investigation of additive manufactured and cast maraging steel targets under ballistic impact

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## Abstract

The advent of additive manufacturing in the defence industry introduces possibilities for complex, lightweight armour while at the same time revealing areas of uncertainty related to structural material properties and ballistic performance [1]. Maraging steel is a martensitic steel that takes on ultra high-strength post heat-treatment [2]. The low carbon composition of maraging steel makes it suited to additive manufacturing through laser powder bed fusion techniques. It is well established that high mechanical strength correlates with favourable ballistic perforation [3]. The combination of ultra high-strength and the flexibility of additive manufacturing gives maraging steel significant potential for protection applications, as has been demonstrated in initial experimental studies albeit the extreme brittle behaviour of the additive manufactured material under impact [4]. Previous studies have found promisingly little difference between the ballistic performance of additive manufactured aluminium compared to cast material of the same composition [5]. However, the performance of traditionally cast maraging steel alongside additive manufactured maraging steel under the same experimental ballistic test conditions has not yet been examined. It remains unknown to what extent the additive manufacturing process is responsible for the unfavourable strength vs ductility trade-off for maraging steel targets.

In this study, additive manufactured maraging steel in both the as-printed and heat-treated state has been studied alongside its cast counterpart under ballistic impact where it is subjected to large strains, high strain rates and possible temperature softening. The materials were characterised with uniaxial quasi-static tensile tests and the ballistic performance was disclosed in a ballistic range monitored by high-speed cameras. Images of fracture surfaces in a scanning electron microscope (SEM) and computerised tomography (CT) scans were taken to shed light on the observed material behaviour. An elastic-thermo-viscoplastic material model has been implemented to reproduce the impact response of the AM maraging steel target plates. The Johnson-Cook (JC) model is a widely used phenomenological relation for metallic materials under large deformations, high strain rates and high temperatures. A modified version of the Johnson-Cook model has proved reliable in numerous studies on ballistic impact [3], including at least one successful application with AM materials [5].

The additive manufactured maraging steel had a marginally lower experimentally determined ballistic limit velocity compared to that of the cast maraging steel both before and after heat treatment, despite possessing superior mechanical strength. However, in the majority of tests the damage inflicted on the bullet core during impact was far more extensive for the additive manufactured material than for the cast material. The capacity of the heat treated target to pulverise the armour piercing bullet upon impact appears to be limited to the additive manufactured material.

## References

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