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ENGINE VIBRATION ANALYSIS WITH MATERIAL DEVELOPMENT TOWARD MRE BASED ENGINE MOUNTS

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ABSTRACT

Diesel engines generate strong vibrations that must be measured and controlled to maintain comfort and durability. The training at Universitas Sebelas Maret (UNS) introduced the basic principles of vibration and included demonstrations using accelerometers, tachometers, and DewesoftX. This knowledge supports ongoing work on developing soft materials for diesel engine mounts. Early progress includes fabricating Thermoplastic Rubber (TPR) 65A filament, testing the printability of Thermoplastic Polyurethane (TPU) 65A, and preparing for magnetorheological elastomer (MRE) development using carbonyl iron particles (CIP). Several challenges were faced, especially in keeping filament quality consistent and printing soft materials reliably. The training helped link vibration measurement concepts with material development, providing a basis for future 3D-printed MRE engine mount prototypes.

KEYWORD

Vibration, magnetorheological elastomer, engine mount, extrusion, additive manufacturing

INTRODUCTION

Vibration from internal-combustion engines is a major source of noise, structural stress, and reduced ride comfort. Diesel engines produce even higher vibration levels because of their high compression ratios, strong combustion pulses, and heavier moving components, which generate dominant low-frequency vibrations around 20–200 Hz (Velmurugan et al., 2019). Without proper isolation, these vibrations can shorten component lifespan, reduce comfort, and cause structural fatigue.

An engine mount secures the engine to the chassis and plays a key role in controlling vibration transmission. It must support the engine’s weight while isolating vibrations across different operating conditions (Adhau et al., 2013). Elastomer-based mounts are widely used because of their compliance and damping ability, but conventional mounts have fixed stiffness and damping values. As a result, they cannot perform optimally under the wide load and speed variations typical of diesel engines (Song et al., 2022). During the one-month training at Universitas Sebelas Maret (UNS) with Prof. Ubaidillah, I learned fundamental concepts of engine vibration and measurement techniques. Demonstrations (Figure 2) using accelerometers, tachometers and DewesoftX helped me understand how vibration data is captured and analysed to identify dominant frequencies and engine-order excitation. This knowledge has directly shaped my research direction.

Figure 1: A photo with Professor Ubaidillah from UNS

Figure 2: Demonstration on how vibration is captured using sensor and DewesoftX software.

I am now exploring soft thermoplastic elastomers, particularly thermoplastic rubber (TPR) 65A for diesel engine mounts due to their elasticity and damping capabilities. Since TPR 65A in 1.75 mm filament form is not commercially available, I began fabricating custom TPR filament for extrusion-based 3D printing, while using commercial thermoplastic polyurethane (TPU) 65A for initial printability tests. By combining vibration-analysis knowledge from the training with ongoing material development and MRE formulation, this project aims to create MRE based diesel engine mounts that provide tunable stiffness and damping under magnetic fields. The remaining sections of this report outline the training insights, material fabrication progress, and the path toward prototype MRE diesel engine mounts

MRE CONCEPT FOR DIESEL ENGINE MOUNTS

MREs are made by mixing a soft elastomer, like TPR with CIP. When exposed to a magnetic field, the iron particles align, stiffening the material and altering its damping behavior (Gomez et al., 2025). This changes the mount's natural frequency, reducing vibration transmissibility. For diesel engines, where vibration varies with load and RPM, an MRE mount can adjust its stiffness and damping via the magnetic field, improving vibration isolation (Priyandoko et al., 2021).

RELEVANCE TO DIESEL ENGINE VIBRATION CONTROL

Elastomer mounts reduce vibration transfer from the engine to the vehicle (Choi et al., 2022). MRE-based mounts enhance this by providing tunable stiffness and damping, adapting to changing engine conditions. By shifting the mount's natural frequency and dynamic response under a magnetic field, MRE mounts lower vibration transmissibility across frequencies, reducing structural fatigue and improving durability (Tao et al., 2025). This supports both vibration-analysis training and diesel vibration mitigation efforts.

MATERIAL DEVELOPMENT FOR ENGINE MOUNT

To align with the vibration isolation in diesel engine mounts, soft elastomers were chosen for their damping ability and durability under cyclic loading. Because commercial TPR 65A filament in 1.75 mm is not available, custom filament fabrication was started using a single-screw extruder. A major challenge was keeping the filament diameter consistent while controlling cooling and surface quality when processing low-hardness TPE (Mark, 2013). Hence, to better understand the behaviour of soft materials during printing, commercial TPU 65A filament was used for preliminary trial prints (Figure 3).

Figure 3: Trial print sample using commercially TPU filament

These trials helped to evaluate printability at different temperatures and speeds, revealing issues such as warping, stringing, and dimensional inaccuracy, similar to findings in earlier elastomer printing studies. This early insight is useful for predicting problems before producing TPR-based or MRE based filaments

For engine mounts applications, the material must offer high damping, suitable stiffness, fatigue resistance, thermal stability, low creep, and compatibility with additive manufacturing. These characteristics are essential for sustaining long-term vibration loads while maintaining mechanical integrity in diesel engine environments. Both TPR and TPU show these qualities at this early stage, making them good baseline materials for later MRE formulation and prototype development.

CURRENT CHALLENGES ENCOUNTERED DURING PROCESSING

During filament extrusion, keeping a stable 1.75 mm diameter is difficult with TPR (Figure 4d) because its low hardness and high softness cause deformation during pulling and cooling. For MRE filaments (Figure 4c), an added challenge is CIP sedimentation during heating, as the density difference between the polymer and iron particles can create uneven particle distribution and inconsistent magnetic behavior. There is also a risk of thermal degradation when processing TPR or TPR based MRE above about 200–220 °C, where oxidation, chain scission, and discoloration may occur. Additionally, TPR has high melt elasticity, leading to strong die swell after exiting the die (Figure 4a), which results in unstable filament shape and difficulty maintaining roundness and smooth surfaces (Figure 4b).

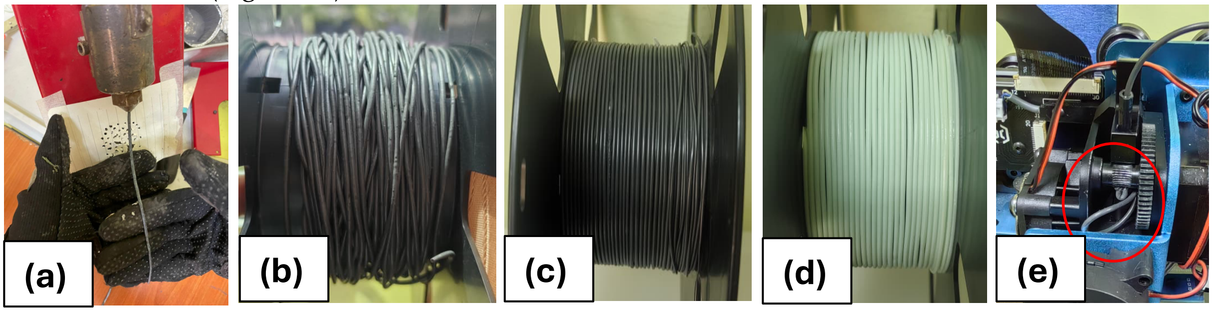

Figure 4: (a) swelling MRE filament, (b) inconsistent filament diameter, (c) MRE filament, (d) TPR filament, (e) MRE filament buckling

During printing, a direct drive extruder is generally required to ensure proper feeding of low shore hardness materials and reduce soft filament buckling (Figure 4e). These materials also tend to produce severe stringing and oozing at their typical processing temperatures due to their low melt viscosity and delayed solidification behaviour. Furthermore, dimensional inaccuracy is frequently observed because soft filaments compress inside the extruder gear, causing inconsistent extrusion flow and under or over deposition. When printing MRE filaments containing CIP, nozzle clogging becomes a significant issue, primarily due to particle aggregation, increased melt yield stress, and poor dispersion within the polymer matrix. To maintain extrusion stability and avoid flow interruption, very slow print speeds typically below 10 mm/s are necessary. In addition, soft-material fused filament fabrication often suffers from weak interlayer bonding, which is particularly problematic for fatigue-critical components such as engine mounts, where cyclic loading requires high interlayer cohesion and stable mechanical performance over time.

Application Specific Challenges for Diesel Mount

Achieving the required dynamic stiffness for diesel-engine vibration isolation is challenging because diesel engines produce strong low-frequency excitations, so the elastomer–MRE system must be carefully tuned to suppress these harmonics. Long-term durability is also critical, as engine mounts experience millions of load cycles and high temperatures that can cause fatigue, creep and viscoelastic degradation. Another key challenge is controlling CIP orientation during fabrication, since particle alignment directly affects MR tunability, stiffness increase and overall vibration-control performance. Balancing printability with mechanical and damping properties is also necessary, because softer materials like TPR and TPU print more easily but may have lower stiffness or fatigue strength, while stronger composites can reduce extrusion stability and dimensional accuracy.

CONCLUSION

The training at UNS provided foundational exposure to engine vibration analysis and strengthened understanding of diesel engine dynamic behaviour. While hands-on time was limited, the demonstrations using accelerometers, tachometers, and DewesoftX clarified how vibration data supports diagnostics and mount development. Parallel early-stage work on filament extrusion and soft-material printing represents an important step toward developing MRE based diesel engine mounts using additive manufacturing. Although challenges remain particularly with soft polymer extrusion, MRE uniformity, and dimensional accuracy however, the knowledge gained during training offers a valuable basis for advancing the research project.

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