

Project Report: GenAI-powered RAG-based Vehicle Design Rule Assistant

1. Objectives

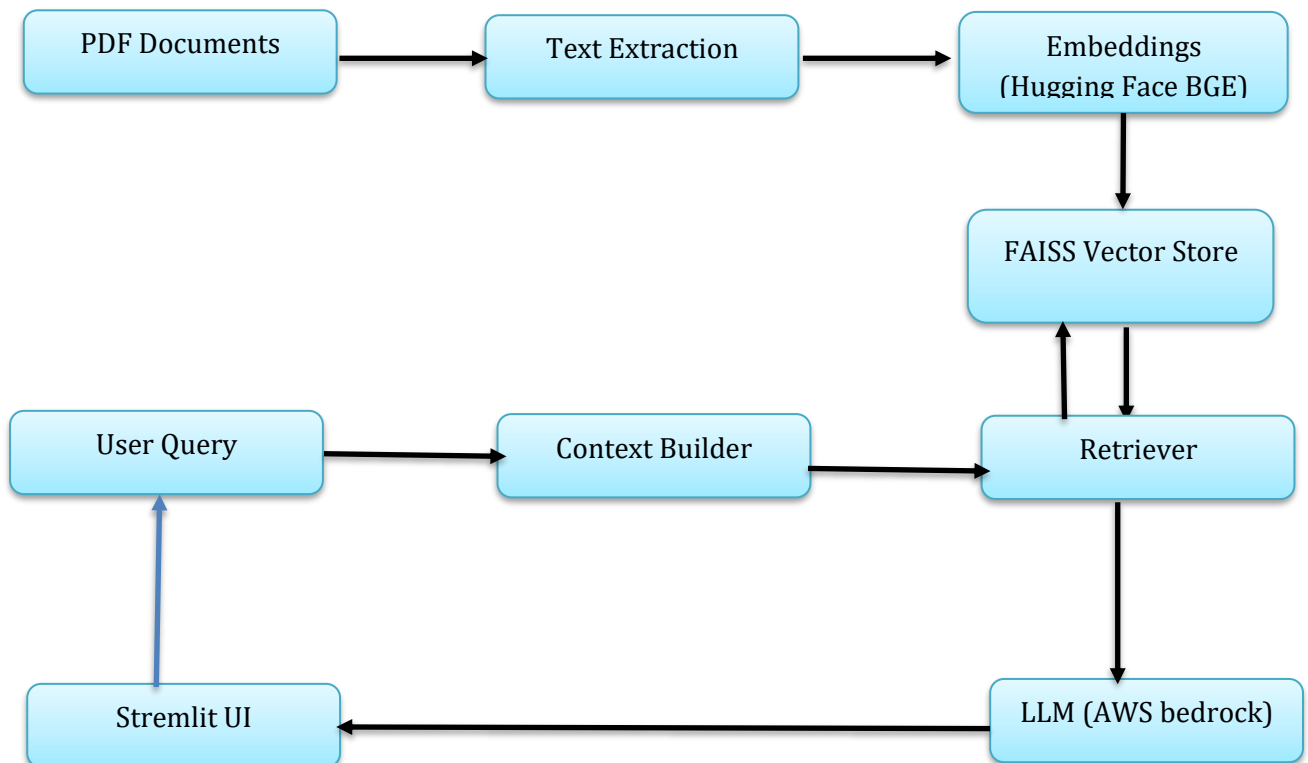
The objective of this project was to develop a Retrieval-Augmented Generation (RAG) based assistant to help engineers and designers access and interpret vehicle design rules efficiently. The system is designed to answer technical queries with contextually accurate, traceable, and document-grounded responses.

2. Design

The system design is centered around combining information retrieval with large language models (LLMs). The design flow can be summarized as follows:

1. PDF documents (e.g., Plastics Design Guides) are ingested and preprocessed.
2. Text and tables are extracted using PyPDF Reader and stored in a structured format.
3. Embeddings are generated using Hugging Face's BGE model (BAAI/bge-large-en-v1.5).
4. A FAISS vector store is created for efficient similarity search.
5. User queries are matched against the FAISS index to retrieve relevant context.
6. The retrieved context is passed to an LLM (Amazon Bedrock's Mistral).
7. The LLM generates an answer, citing the relevant sections from the documents.
8. A Streamlit-based UI presents the chat interface and responses to the user.

System Design



3. Implementation

The project was implemented using Python, LangChain, FAISS, HuggingFace embeddings, and Amazon Bedrock LLMs. The following modules were developed:

- `embedd.py` – Handles PDF text extraction, chunking, and embedding creation.
- `faiss_index.py` – Manages loading of FAISS indexes.
- `llm_setup.py` – Defines query formatting and interaction with LLMs.
- `memory.py` – Provides conversation memory utilities.
- `prompt_setup.py` – Stores prompt templates.
- `utils.py` – Builds structured context from retrieved documents.
- `bedrock_llm.py` – Connects to Amazon Bedrock LLMs (Claude/Mistral).
- `streamlit_ui.py` – Implements the Streamlit-based interactive chat UI.

4. Challenges Faced

One of the major challenges encountered was related to document chunking. Initially, a page-wise chunking strategy was implemented, but it did not work effectively due to uneven distribution of content and incomplete context in certain chunks. To resolve this, a paragraph-level chunking strategy was adopted, which significantly improved retrieval quality and contextual accuracy of the answers.

5. Lessons Learned

Through this project, the following lessons were learned:

- Document chunking strategy is critical for improving retrieval quality.
- LLM responses are highly dependent on the quality of context provided.
- Maintaining conversational memory enhances the user experience.
- A clear and structured UI (Streamlit) helps users trust and engage with the system.
- Combining retrieval with generation ensures more reliable and fact-based answers compared to pure LLM outputs.

6. Conclusion

The GenAI-powered RAG-based Vehicle Design Rule Assistant successfully demonstrates the potential of combining retrieval techniques with generative AI models for domain-

specific applications. This approach can be extended to other engineering and technical fields where reliable and traceable information retrieval is essential.

7. GitHub Link

<https://github.com/AIscientist-GK/GenAI-powered-RAG-based-Automotive-Design-Rule-Assistant>

Please Scroll down for screenshots

Main App Interface

GenAI-powered-RAG-based-Automotive-Design-Rule-Assistant

who are you

I am an assistant, here to provide information and answer questions based on the provided sources, which appear to be excerpts from a design guide for plastics. I can provide responses as a technical subject matter expert (SME) on Plastic trim Design, based on the information in these sources. However, I don't have access to any additional information outside of these sources. If you have a specific question related to plastic trim design, feel free to ask!

Source Pages

This also shows page number from where the information is retrieved

Query - 1

what is surface energy and what is surface energy for PE material?

Surface energy, also known as surface tension, is a measure of the energy at the surface of a material. It is expressed in dynes/cm and is a measure of the material's surface energy. It is important in bonding processes because it affects the wetting of the adhesive to the material's surface.

The surface energy for PE (polyethylene) material is typically in the range of 30-31 dynes/cm. This low surface energy can make it difficult to achieve a good bond, as the adhesive may not wet the surface effectively. To overcome this, surface treatments such as flame treatment, corona discharge, plasma treatment, or the use of primers may be necessary to increase the surface energy and improve the bonding process.

18.4 ADHESIVE AND SOLVENT BONDING

Bonding is a surface process, so the properties of the joint surface have an important bearing on the joint strength. We want the adhesive to spread out over the joint and to penetrate into tiny irregularities on the joint surface, and for this to happen the adhesive must 'wet' the plastics surface. The key factor in wetting is surface tension. If the surface tension of the adhesive is higher than that of the surface, the adhesive will not wet the joint. Instead it will tend to form a bead, like water on wax. Unfortunately, many plastics have low surface tensions, making wetting difficult. Surface tension is expressed in dynes/cm; the value is known as the dyne level. It is a measure of the material's surface energy. Guide values for untreated plastics are given in Table 1. The lower the value, the more difficult it will be to achieve a good bond. Remember that additives and surface

Polymer	Surface energy (dynes/cm)
PP	29-31
PE	30-31
PBT	32
PVC plasticised	33-38
POM	38
PMMA	38
Polystyrene	38
PPS	38
ABS	35-42
PVC-U	39
Polyamides	38-46
PET	41-44
Polycarbonate	46
PPO	47

Typical surface energies of untreated plastics
Sources: 3M and Sabreen Group

Query - 2



What is operating pressure formula for calculating bearing capability.



The operating pressure (P) in a plastic bearing can be calculated using the formula:

$$P = (F / (L * D)) * 10^6$$

where:

- F is the load on the bearing (in Newtons),
- L is the bearing length (in millimeters),
- D is the shaft diameter (in millimeters), and
- The result is in megapascals (MPa).

This formula allows you to calculate the operating pressure, which is an important factor in determining the bearing's capability.

Source Pages

processing time:

The bearing capability can be calculated from the operating pressure and velocity. The operating pressure (P) is given by:

$$P = \frac{F}{LD}$$

where F = load on the bearing, L = bearing length and D = shaft diameter.

The sliding velocity (V) is derived from:

$$V = \pi DN$$

where N = rotational speed of the shaft.

Bearing wear (W) is proportional to operating pressure times sliding velocity, and is given by the expression:

$$W = K(PV)$$

where K is a wear constant known as the K-factor.

The K-factor is a good guide to wear

Query - 3



What are main things to keep in mind when designing screw bosses.



When designing screw bosses, consider the following guidelines based on the provided sources:

1. Function and forces: Consider the function of the boss and the forces acting on it during assembly and service.
2. Support ribs: Anchor the boss to the base wall with buttress ribs, and if possible, anchor the boss to the side wall with a flat rib. This provides additional support and rigidity.
3. Rib arrangements: Avoid rib arrangements that result in small mould cores or complicated mould machining set-ups. There is a right and a wrong way to support bosses, as extending the boss outside diameter to meet the wall can result in thick sections leading to sink marks, voids, and long cooling cycles.
4. Hole and thickness: The quality of a screw connection depends on stripping torque and pull-out force. The boss design should ensure that the screw can withstand both screw insertion forces and the load placed on the screw in service. The size of the hole relative to the screw is critical for resistance to thread stripping and screw pull-out.
5. Material and safety factors: The screw boss design factors depend on the material. For critical applications, testing is recommended to ensure proper performance.
6. Testing: If the application is critical, test the screw boss design to ensure it meets the necessary requirements and safety factors.

By keeping these guidelines in mind, you can design screw bosses that are functional, robust, and suitable for their intended application. Remember that these are general recommendations, and the specific requirements of your project may necessitate adjustments to these guidelines. Always consult detailed plastic product design guidelines and consult with raw materials suppliers, plastic product designers, and plastics processors for detailed information.

Ask any question/concept related to plastic design



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What is the depth factor for designing the same.

Follow up question. This chat bot remembers the last five messages. proof - Memory function working correctly.



The depth factor for designing a screw boss depends on the material of the plastic part. The table provided in the source gives depth factors for various plastics materials. For example, the depth factor for ABS is 2.0, for PA 6 it is 1.85, and for PC it is 2.2. To determine the minimum thread engagement depth, multiply the screw thread diameter by the appropriate depth factor for the material.

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Source Pages



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