MAE 3260 Final Group Work: Exploring a System of Interest

Report

Outline: Option #1: one report, same grade for all

Page 1: Cover Page

Page 2-9: Hypothesis, Fluid Processing, Cheap Blenders, Expensive Blenders, Comparison

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Title: Why does my roomate's cheap blender suck?

Topic of Interest: Blender Control System

Abstract:

Blenders are used to mix a variety of ingredients, from dry mixes to chunks of frozen fruits. Because they are expected to blend such an array of different resistances, their motor and rotating system plays an integral role in ensuring 'adaptability' to different needs. We will investigate what the different modes actually do, as well as compare different models of blenders. Cheaper blenders function differently than expensive ones, such as a Ninja and Vitamix. This is a result of many factors, including the use of closed/open loop systems to enhance productivity.

Students/Roles:

Student	Task/Role
Matt Pianka	Focused on the cheaper blender by analyzing the different components that make it up to be able to create a block diagram.
Max Kinder	Analyzed the control system of a cheaper blender and its components to create a block diagram of the control system.
JT Thomforde	Analyzed the expensive blenders, misconceptions and came up with the block diagram, control theory, and comparison between the systems.
Paige Cobrin	Researched the disturbance parameters of blender systems, including investigating expensive blender sensors. Organized and formatted final report.

List of MAE 3260 Concepts or Skills Used in This Group Work:

- Block diagrams
- Open-loop system:
    - Steady state behavior
- Active control:
    - Feedback control law
    - Disturbance rejection

Hypothesis:

A low-cost blender behaves as an open-loop system, delivering a fixed power input to the motor for each preset regardless of changes in load. In contrast, higher-end blenders use closed-loop motor control, increasing power in response to added resistance in order to maintain a target torque.

Fluid Processes in Blending:

In order to understand how each version of blender operates, we will first analyze the fluid processes involved with blending various types of foods and liquids. This is relevant to the system because it accounts for the forces met by the blade, which in turn impacts the performance of the motor. There are several forces that create disturbance with the blades of a blender, the two primary forces being viscous shear force and cavitation force. There are also inertial forces, impact from solids, turbulent fluctuations, and vortex formation at play affecting system's power output, but they are less of a focus when considering the closed loop input of a blender motor system.

Standard blender blades are blunt, not sharp [1]. While this seems to be a counterproductive feature, it optimizes the blender performance by creating pulverization rather than slicing. Blenders use their motors to drive power into the blades, which then spin with a strong torque to pulverize the ingredients. More complex blenders, such as a Vitamix, are "designed to maintain an even torque and cool temperature" which indicates that there must be a feedback loop control system driving the underlying torque mechanism as the external forces vary throughout a blending process [1]. The blades are met with a shearing force, due to typically high Reynolds numbers of the given mixture, which acts against the driving motor. At the same time, however, air pockets are being created due to the pressure drop of fluids accelerated around the blades - called cavitation bubbles. When these bubbles collapse, they create localized shock waves that help break up the ingredients within the mixture. So, shear stress works against the motor, while cavitation works with the motor to decrease the resistance. The fluid mechanics behind a blender are far more complex, but from a high level, the productivity is optimized by inciting a vortex shape where air and liquid can be sucked down straight to the blades.

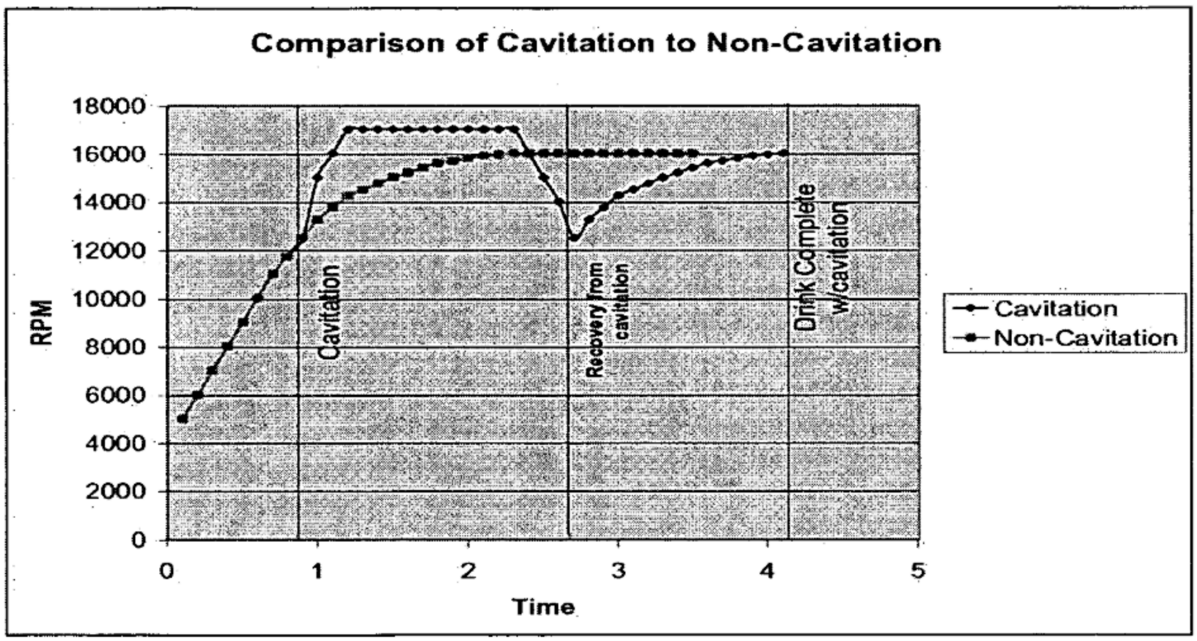


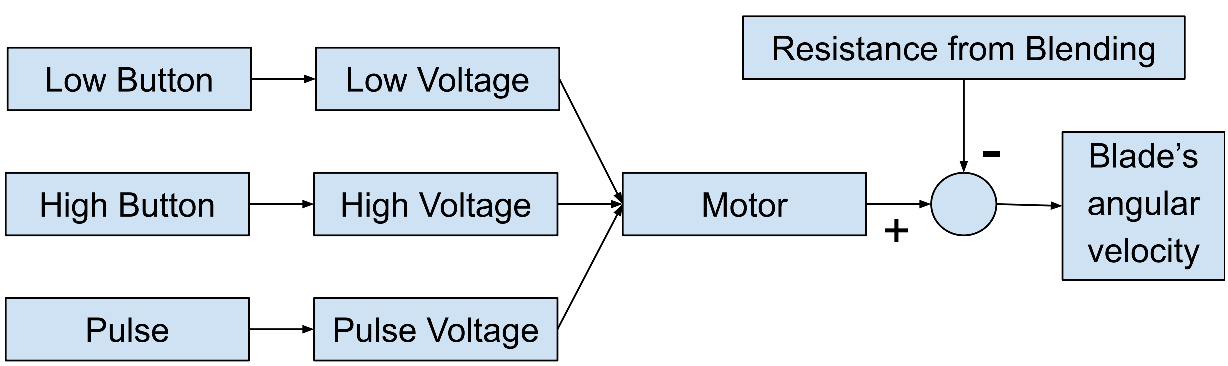
Figure: *Comparison of motor speed behavior over time under different operating conditions, illustrating distinct system responses during cavitation and non-cavitation states [4].*

The power output is intentionally set to manage the resistance the blender ‘anticipates.’ There are both peak and running horsepower that are listed for typical blenders. Peak horsepower refers to the “burst of power the motor needs to overcome resistance” whereas running horsepower is for standard operating conditions. Most blenders use 1-2 horsepower. Another source stated that the best results for any blender always occur at 700-1000 watts. Many expensive blenders, such as Vitamix, are “designed to maintain an even torque” as they run, but the peak horsepower seems to be an intentional overshoot to account for the stronger shear forces when starting the blending process, before ‘steady state’ is achieved.

Cheap Blenders

Cheap blenders utilize a generally simple control system relying on the user to develop intuition on how to use their own blender. This simplicity allows the blender to be produced cheaper and faster allowing them to compete on price rather than sophistication. The Oster Turbo 5-speed blender is a good example of a common cheap blender being one of the cheapest blenders Target carries. This blender is a pretty simple design with four buttons that control a motor spinning a blade. There is no complex feedback system or circuitry. As seen in the block diagram below the input into the system has three different settings. Each button has a different input voltage associated with it that is achieved by making the power supply to the motor go through a circuit to modulate its voltage. The motor’s torque and speed are only determined by this input voltage and have no feedback to vary the motor's output based on the current the motor is drawing. The motor’s speed of rotation is resisted by the resistance the blade experiences so after factoring that in we get the final angular velocity of the blade.

Cheap Blender Block Diagram



Internal Workings of Cheap Blender

One of the more complex internal systems in the Oster Turbo 5-speed blender is the button system. Each button pushes an off bar behind it perpendicular to the direction the button is pushed in. This bar is controlled by the off button and allows the user to easily turn off the blender. Each button also has a different voltage associated with it so the systems are semi-independent of each other. The two continuous buttons work in a pretty similar manner to each other. Once they are pushed in, they push the off bar over and catch on a notch on it so they remain pushed in to give a visual to the operator that the system is on and which setting the system is using. Finally, when the button is pressed in, it completes its respective circuit allowing the input voltage from the plug to flow through the voltage control circuit and power the motor. The off button has no circuit associated with it and only serves to control the off bar. As the off button is pushed in, it pushes the off bar opposite the way it was pushed by the powered buttons. This counter motion allows the bar to release the latch of power buttons releasing them to the out position and therefore breaking the circuit powering the motor. The final button is the pulse button which simply pushes the off bar, but does not catch, as it has no latch. The lack of a latch means that the button activates the circuit for as long as the operator holds the button allowing for quick pulses of blending. In addition to the system to control the buttons, blenders also often include systems to mitigate vibrations. Passively contouring vibrations is not necessary to the operation of the blender so not every cheap blender includes this but it significantly improves the blenders performance. The patents and generally available information about the Oster Turbo 5-speed blender did not specify if it utilized such a system. To counter vibrations generated by the blending motion, the blender will house the motor suspended to allow it to vibrate without vibrating the whole blender. The motor is still relatively close to its casing to eliminate the chance of motor damage and to reduce stress on the motor shaft, but it is able to move to a degree. The flexible supports holding the motor provide some passive damping of the motor's vibrations. In addition to this, allowing for small vibrations the motor will often spin a counter weight opposite the direction of the blades to help balance the shift of the system's center of mass as the blades spin with the substance the blender is blending.

Misconceptions About Smart Blender Technology

High end blenders appear fundamentally more sophisticated than cheaper alternatives. Expensive blenders typically advertise stronger motors, blades, and an increased number of blending modes [5]. In addition to these differences, many premium blenders use marketing terminology such as Auto-iQ, BlendSense, or Auto-AI, which implies an intelligent system capable of sensing the contents of the blender and autonomously achieving the best blend [6] . Consumer reviews and promotional content reinforce this perception by suggesting that these systems actively detect what ingredients are present in the blender and continuously adjust the blending process using a closed loop control system. This framing encourages the belief that premium blenders contain sensors capable of directly measuring specific food properties such, and then continuously adapting motor behavior to “blend to perfection.”

However, no commercial blender manufacturer publicly releases detailed electrical schematics or control algorithms for their products. There are no optical sensors, pressure sensors, or torque transducers measuring the food directly. Instead, the only sensor in the system is the electrical response of the motor.

Proposed Control Theory for BlendSense and Auto IQ Systems

Rather than employing a continuously adaptive, high-bandwidth closed-loop system based on direct food-property measurements, it is far more likely that advanced blenders rely on electrical torque estimation from motor current to classify blending conditions. This estimation likely occurs during a brief probing or “sensing” phase, after which the system selects from a set of predefined blending programs optimized for different load conditions.

In this framework, the blender does not explicitly identify specific ingredients (e.g., bananas versus ice), but instead categorizes the mixture into generalized classes such as thin, thick, or frozen based on the motor’s electrical load behavior. These classifications are inferred from metrics such as average current draw, current ripple caused by intermittent blade impacts, motor spin-up time, and transient unloading events associated with cavitation. Once classified, the controller initiates a corresponding preset blending pattern and executes it until blending completion criteria are met.

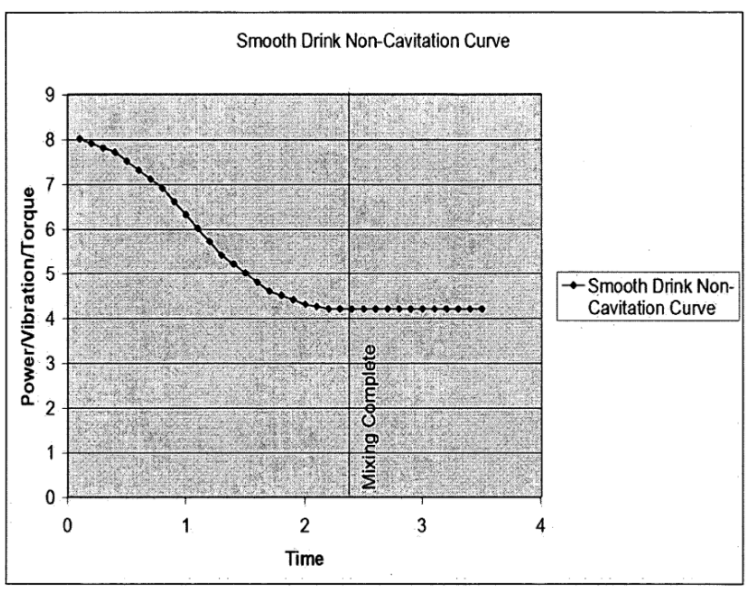
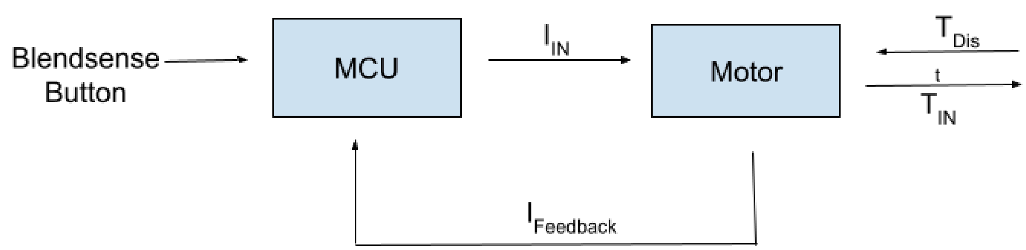


Figure: *Example visualization from a blender motor control patent showing how motor feedback changes over time during a blending process and can be used to identify blending completion or operating conditions [4].*

Completion of the blending cycle is also inferred rather than measured directly. As blending progresses and the mixture becomes more homogeneous, the resistance experienced by the blade stabilizes. This produces a measurable decrease in torque spikes and current ripple. When the motor current reaches a plateau for a sustained period, the controller interprets this as the system having reached finished condition. The system operates as a semi closed loop system, rather than a continuously adaptive, fully closed loop one. This approach offers significant advantages from a simplicity and reliability standpoint. It avoids the need for expensive sensors inside the blending chamber, reduces system complexity, and uses signals that are already available within the motor's electronics while still seeming highly intelligent to the user.

Block Diagram for Ninja Detect Power Blender Pro



MCU Stages

Stage 1: Run motor at low speed and sample input current to estimate load.
- Compute average current, ripple, spikes, and spin-up response.
- Classify mixture as thin, thick, or frozen based on electrical load.

Stage 2: Select corresponding Auto-iQ blending profile

Stage 3: Closed-Loop Blending
- Monitor motor current and adjust drive to manage load and cavitation.
- Detect stabilized current signature indicating a finished mixture.

Comparison of Cheap and Expensive Blender Systems

Cheap and expensive blenders are designed to perform the same task, but they differ in how robustly and consistently this task is carried out. In inexpensive blenders, motor power is limited, blade assemblies are weaker, and the control system is often open loop operations with fixed speeds. As a result, these systems rely on conservative design margins to avoid stalling or overheating. Variations in fluids, solids, and cavitation can push the operating conditions outside of the optimal range, leading to bad blends and motor shutdown. The absence of feedback and decision making means these blenders cannot adapt to changes in load as blending progresses. In contrast, expensive blenders combine stronger motors, higher quality blades, and a control system that monitors the motor's electrical response. While both systems rely on preset operating modes, the premium blender's ability to interpret motor feedback results in better performance across a wider range of mixtures.

This comparison only reflects a narrow subset of blender designs rather than the full spectrum of available products. Variations in motors, electronics, and implementation exist even within the same price tier, leading to significant differences in performance and control behavior across models. As such, the trends discussed here highlight broader design strategies by which premium blenders attempt to differentiate themselves from lower cost models through the use of more complex motor control rather than set speeds.

References:

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[6] “Ninja Detect™ Kitchen System Power Blender Plus Processor Pro With BlendSense™ Technology.” SharkNinja. https://www.sharkninja.com/ninja-detect-kitchen-system-power-blender-plus-processor-pro-with-blendsense-technology/TB401.html. [Accessed: Dec. 10, 2025].

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[9] Ernster, P. J., Collins, W. J., & Schaefer, G. H., *Multi-purpose kitchen appliance*, U.S. Patent 4,071,789 A, filed Feb. 26, 1976, and issued Jan. 31, 1978.