SRS
Superior Riding Systems

Stillwater, OK

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SRS, Superior Riding Systems, strives to design a mechanical horse simulator that meets the Rockin' B standards of excellence. Additionally, this simulator will be able to mimic both a bucking bronco and all the gaits of a horse. This machine will excel in both ease of operation and reliability while giving the most enjoyable and realistic experience to the customer.

Statement of Work

SRS, Superior Riding Systems, has set out to create a bucking horse to meet the Rockin' B bucking machines standards. These standards of excellence include reliability, ease of operation, low maintenance and kinematical correctness all at a competitive cost.

Rockin' B has set forth objectives to create the physical motion for both a bucking machine and a riding simulator. When set up for bucking, the machine must be capable of simulating the vertical motion of a horse while rotating on the current bucking bull platform. Rockin' B has developed an effective means for rotating the apparatus, and wishes to continue to use that set-up. Rockin' B owner Bill Beaty supplied his current base to use for this project. The spring-loaded lean mechanism for the current Rockin' B bulls should also be maintained in the new design in accordance with the request of the owner. The mechanism must also be easily controlled. The movements should be logical such that adjustment of the controllers will generate a horse-like movement no matter how randomized the controlling. The owners have requested that the controls be capable of being operated by two hands alone, and that all functions be able to be controlled without removing the hands from the controllers.

When set up as a riding simulator, the machine should be capable of performing the various gates of a horse such as the walk, trot, lope, and canter. This aspect of the machine is used as a training device for various equine events as well as various therapeutic functions. This conversion of a rough and rowdy bucking machine into a gentle riding machine will be a challenge. Ideally, the machine would convert from a bucking machine into a riding machine mechanically. Unfortunately, the design may call for the machine to be converted manually. This is not viewed as a significant concern, however, as it is not expected that the machine will be used as a bucking bronc one minute and a riding trainer the next. Generally speaking, only one mode will be used. The ability to convert between the two, however, creates a very versatile machine. One issue is the need for the animal to vary the amplitude and frequency of the movement of the front and rear portions of the animal independent of one another or synchronized based on which gait is selected. Studies have been done such that the most realistic experience can be accomplished by this machine. Video has been taken to determine the different motions of live horses. The speed (up and down cycles/minute) and vertical motion of each gait has been recorded. If the desired motion of the animal is not fully understood, then the simulation of this motion will be impossible. SRS's goal is to create a single machine that simulates both a bucking bronc as well as the gentle riding aspect.

By request of the owners, hydraulics will not be used due to the maintenance and leak issues associated with them. Rockin' B requested that the mechanism remain constrained within the space envelope of the current bull fiberglass body. The current frame will not be realistic in the way the rider sits. When on a bucking bronc, the rider is reaching forward to the neck of the animal to spur it. With the current bull frame, the neck appears to be too wide and short to create a natural ride. Furthermore, use of the current frame would create safety concerns, as pinch zones would be present underneath the frame. The pivot point of frame will also have to be moved toward the front of the animal to more accurately simulate the motion of a horse rather than a bull.

Safety is a significant concern, and should be considered so that the machine will not behave outside the desired actions of the rider/controller. Pinch and trap zones underneath the frame of the body should also be minimized or eliminated. The increased vertical lift of the mechanical horse will create possible pinch zones under the machine. These safety concerns will be addressed by both changing the design of the frame as well as incorporating devices which will shield a fallen rider from the moving mechanisms underneath the machine. Also, consideration will be given to minimizing controller error that may result in an unsafe situation.

Literature Review, Research, Investigation, Testing

There were a variety of different documents and videos that were collected over the year that were useful in the design and creation of the mechanical horse.

Patent Search

Nine somewhat relevant patents were discovered during the preliminary research stages. Most of these patents related to toy riding simulators, primarily for children. None of these posed any limitations on this design. The only patent which had any real significant to this project was that owned by Bill Beaty, SRS's sponsor. This, obviously, had no limitations on design, and in fact aided to help incorporate certain aspects of his current bull mechanism into the horse design. These patents are attached in Appendix A.

Video Analysis

In the early part of October a video was taken over the walk, trot, and canter gaits, as well as the transition between the three. Additionally, a video was shot over the overall motions that were created in each of the gaits. The video was used to determine displacement of the horse. The overall speed vs. overall vertical displacement that was created in each of the three gaits was recorded. This will help in the creation of each cam and aid in creating the most realistic ride possible.

A video over the bucking side of the animal was also reviewed. This video showed the motions and movements that the horse creates while in the buck mode.

Horse Gait Analysis

A study conducted over the horse gaits was acquired from Michigan State University which helped to quantify the movements of each gait of a horse. The study contained data on cyclical speed as well as the three dimensional movement of a horse in each gait. This aided in cam design as it provided a quantitative assessment of each movement of the riding horse. The results of this study are attached in Appendix B.

Personal Experience

Personal experience also played a large role in what was found to be relevant in each source. Getting on the horse various times throughout the later half of production gave an understanding of what was created and if it was going to work as well as hoped. After reviewing this several times various problems were encountered and throughout testing this allowed a better understanding of what was needed to change in the cam design as well as point out other problems encountered.

Horse Movement

This riding simulator, in order to create a realistic ride for every aspect of the horse, is going to simulate the three gaits of walk, trot, and canter. Additionally, the machine will be capable of conversion into a bucking horse.

Walk

The walk is a four-beat lateral gait where each beat is independent of the other. Each beat is distinct and can be easily heard. The walk is natural, and it is the slowest of the gaits. When riding during the walk one feels a very smooth shoulder transition on the front end followed by the same feeling in the hindquarters. This gives the rider an overall slow and smooth ride.

Trot

The trot is a two-beat diagonal gait where there is actually a period of suspension where all four legs are off the ground. The right hind and left front move together, and the left hind and right front move together. For a rider this is a very rough ride. Most riders will go into a post position or just kick the horse up in to the next gait. During the trot the vertical displacement of the horse is greater than that at the walk.

Canter

The canter is a three beat gait where there is a forward to back rock created from the hindquarters. While cantering, the horse is either on the left or right lead. A horse on the right lead would have its right leg hitting the ground in front of, not before, the left leg. When turning in a circle to the right, the horse should be on the right lead, and when turning to the left, should be on the left lead. So the horse should always be leading with it's inside leg. This gait will have the greatest displacement vertically as well as create a larger rocking feeling than any other gait. This gait provides a very smooth and steady feel for the rider.

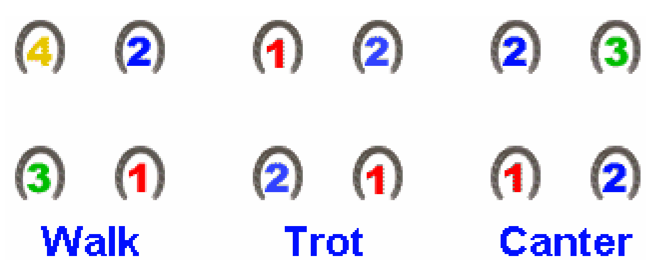


Figure 1: Step Sequence of Each Gait

Buck

Bucking horses are usually bred specifically to buck. They will initially leap out of the chute with a large vertical rise from the front end. Most horses will continue this leap with rise from the front end followed by the front end falling down and the hindquarters making a large rise and kick out with the back two legs. This motion is very similar to a see-saw but with an added vertical lift. There are, however, some bucking horses that will do more of a run and buck at the same time. This buck is very small compared to the first example. There is a lot more horizontal leap than vertical leap in this example.

Figure 2: Front End Jump of a Bucking Horse

Figure 3: Hind End Kick of a Bucking Horse

Engineering Specifications / Customer Requirements

No hydraulics

Should fit within existing bull frame

Must use existing spin mechanism

Incorporate side-rocking motion from existing fiberglass body space

Possible use of two motors in parallel to create vertical motion

Possible movement of center shaft using pneumatics

Consider mechanical horse for training/riding purposes (no bucking)

Consider possible shoulder movement to simulate all gaits of a horse

Modeling/Simulation

A simulation has been made on ProE of four preliminary designs. These computer simulations have allowed design problems to come to light. It was determined that there would be size issues with the each design, including the final design, regarding fitting the mechanism underneath the frame of the animal. The use of ProE will allow the design to be modified quickly and easily and to be tested for interference zones prior to construction.

See attachments.

Preliminary Designs

A number of possible design concepts were developed in order to determine the direction this project needed to go. Since this project intended to generate a multi-purpose machine that, within reason, can simulate all riding natures of a horse, design trade-offs must be made. By design trade-offs it is meant that the design can not be allowed to become so complex that either cost or longevity becomes a serious issue. Since there is an array of directions that this project can go it was important to follow a process of elimination that would leave the most suitable design. Designs were eliminated from consideration on concerns over cost, reliability, realism and controllability.

The first design concept was to take the mechanisms of the mechanical bull, and simply add a pneumatic/hydraulic cylinder vertically move the current bucking mechanism. In light of the request of the sponsor's requests, a non-hydraulic concept that would use a large linear actuator in the place of the pneumatic/hydraulic cylinder was considered. Pneumatics would not give the desired accuracy to provide a realistic simulation.

The second concept used two motors much like the one currently in use on the bucking-bull mechanism. They would run pitman arms to generate the vertical motion paired with a slide mechanism to accept the side loading. In this concept the lower amplitudes of movement seen in walk, trot, and canter would be attained by oscillating the motors at partial rotations. This option, however, would only give one single motion. All of these options would require additional motion control mechanisms to generate the cyclical nature of the ride.

A revision of that design used two motors, but instead of oscillating the motors at partial rotation, a variable stroke pitman arm would be developed to attain the three gates of the horse as well as different degrees of bucking. This concept eliminates the need for oscillatory controllers; the timing between the two motors, however, is crucial in generating a horse-like ride and would require significant electronic control.

The obvious alternative to using two motors was to use a single motor to power the two degrees of motion, the pitch and the vertical translation. A mechanical drive system would be used to distribute the power to two different pitman arm units so that proper timing of the buck and jump would be ensured. The variable throw pitman arm would be used to generate the lower amplitudes of the gates as discussed earlier and it was proposed that this should be an active control allowing the amplitude to be altered mid-ride. It was noted that during bronc riding, the animal often jumps vertically several times before doing any bucking. This could be simulated if the throw distance of the buck pitman arms could approach zero and therefore this was added to the design. An electronic controller would need to be developed, eliminating operator error, that would allow the direct control over the timing between the two pitman arm sets to improve the realism of the ride. While complexity was growing with this concept, this concept was viewed as being feasible and realistic enough to justify evaluating this possibility to the fullest.

During this evaluation, it was found that a simpler option could obtain the same effects. This concept would make use of an electric clutch-brake to engage the buck pitman mechanism to the drive after a few vertical jumps had been made at the beginning of a bronc ride to simulate the phenomenon mentioned earlier. To reduce the amplitude of the ride motions to walk, trot, and canter levels, it was necessary to develop manually modifiable pitman throws. While linear actuators were used to control the length of the pitman arms in the previous, spring loaded pull pins will be used on the manually operated ones. This decreased operator ease is offset with a far smaller package size, better reliability, and lower cost. The biggest issue with this design is developing a potentiometer based clutch engagement to make the timing consistent in a bronc ride and yield the correct feel in the gaiting modes.

Feasibility Evaluation of Preliminary Concepts

All of the non-cyclic as well as the twin motor concepts were eliminated since they would be difficult to generate a realistic ride. Even if a realistic ride could be obtained, the complex electronics required to control such a mechanism would significantly increase the cost of the machine.

While the single motor, electrically controlled pitman arm concept would be capable of a very realistic, easy to alter ride, it proved to be problematic. In order to get linear actuators that had the travel needed for the pitman arm adjustment, they needed to be anywhere from two to three times the stroke in contracted length. This would have meant that the entire space under the fiberglass body would be filled with spinning parts to the detriment of the stability of the framework. Vibration would have also been a large issue since each linear actuator weighs approximately twenty pounds with a center of gravity nearly six inches off the axis of rotation. This was determined not to be the most effective design, and therefore, these were not pursued.

The single motor, manually adjusted pitman arm, electric clutch-brake operated concept provided a realistic ride and relative ease of operation in the bucking mode. While this concept allows the different gaits of a horse to be simulated, the simulation did not contain the accuracy desired for this project.

Final Design

At the midpoint of the project development, Rockin' B owner Bill Beaty turned the focus more toward the riding simulation aspect of the design. While the bucking machine was still an important goal, Beaty felt that he could corner a new market with a riding simulator.

This direction led to the development of a completely new design. A series of cams would be developed to give the machine the vertical lift necessary. A cam for each mode (walk, trot, canter and buck) would be created to simulate each ride. In addition to the vertical movement created by the cams, a rotational pitch would be created using Pittman arms similar to the current bull design. In order to simulate each gait, the arms would need to be variable in length with the capability to be taken to zero throw for the trot mode.

Design Specifics

This design runs off of a 180 Volt, 9.6 Amp DC motor run through a 25:1 reduction ratio gearbox. The motor, using a synchronous timing belt, turns a shaft at the back end of the machine which contains the various cams. These cams run against a large roller mounted to the lower frame of the mechanism. The shape of these cams determines the vertical movement of the machine.

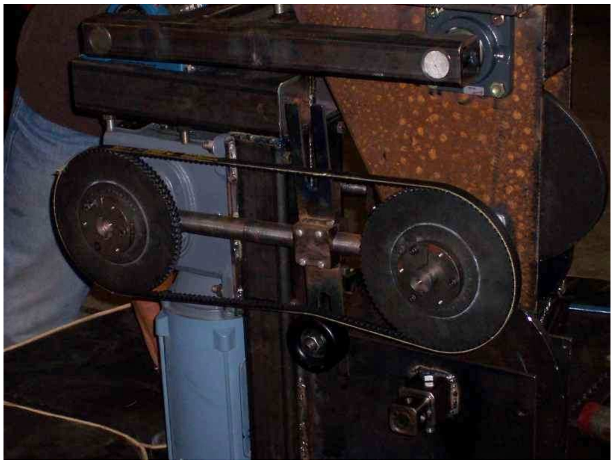


Figure 4: Synchronous Belt Drive

Cam Shaft

Up to three cams at one time are mounted onto a one and one half inch sleeve that fits around an inch and one eighth diameter shaft. These cams are held in place with a keyway between both the sleeve and the shaft and a separate keyway between the cams and the sleeve. Additionally, the cams are prevented from shifting side to side with two large, one and one half inch hex nuts that clamp down on the cams from threads cut on either end of the sleeve. The entire mechanism is held between two flange bearings mounted to the outside of the frame.

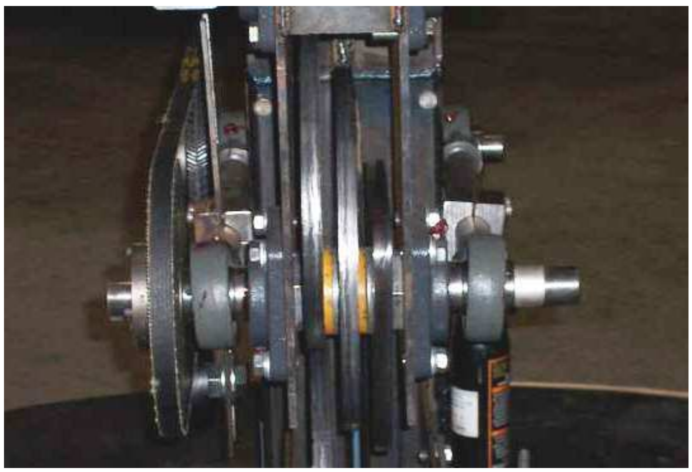


Figure 5: Cam Shaft

Four-Bar Linkage System

In order to stabilize the vertical lift of the machine and to provide a forward to back rocking motion, a four bar linkage system has been implemented with one set of arms running from the gearbox to the cam shaft. The bottom portion of the four-bar linkage is composed of two (2) one and one eight inch shafts, threaded and screwed into #&$*(#&$*#& bearings on either end. Because the lower portion of the linkage system does not provide significant enough stability for the amount of motion this machine will create, the top portion of the linkage system will be an H-bar. This reinforced design will create the stability necessary to contain this amount of movement.

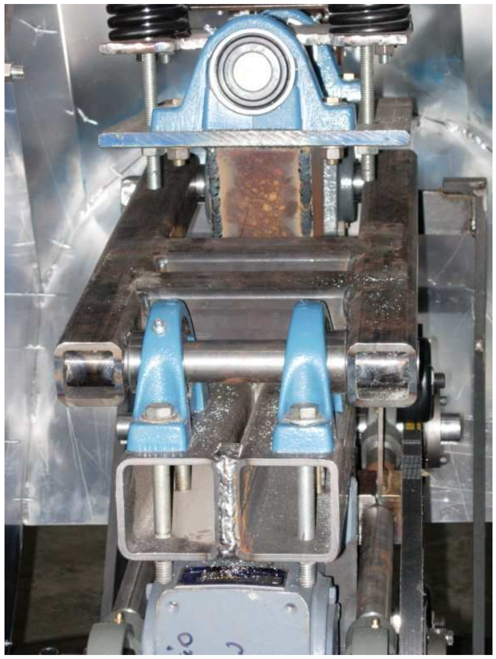


Figure 6: H-Bar Linkage

Pittman Arms

Mounted to the end of the cam shaft will be two variable-length Pittman arms that will serve to create the pitch of the animal. These arms will be manually variable between modes, with multiple bolt holes in the drive bar of the mechanism. At their longest – in the bucking mode – these arms will create twelve inches of drop between the high point and low point of the pitch on the back end of the body. Additionally, twenty-two inches of drop will be created in the front end of the machine.

Figure 7: Pittman Arms

The driven portion of the Pittman arms will be comprised of an angled bar that reaches to the mounting frame of the body. This bar is mounted to the frame such that the body of the horse is level when the Pittman arms are at the midpoint between their highest and lowest.

Body Mounting Frame

The body mounting frame mounts to a pair of pillow blocks bolted to a horizontal plate which allow the pitch from front to back. These bearings will then mount to plate mounted on two other pillow blocks mounted on a different plate, which allow the side to side roll of the body. This side to side movement is limited by a pair of fairly rigid springs mounted to these two plates. The body is mounted to the frame by two bolts in top of the structure, as well as two bolts on either side.

Figure 8: Body Mounted to Frame

Cam Design

The most important part of this process – necessary to create a lifelike ride – was the design of the cams used to create the vertical lift. In order to create these cams, a computer simulation called *Working Model* was used. For a realistic ride to be created, it was necessary for the body of the machine to fall at the speed of gravity as each cam was on the downturn.

Bucking Cam

The bucking cam is the largest and most aggressive of all of the cams. The cam rises quickly, creating seven inches of vertical lift, then hangs for a short moment of time before falling at gravitational speed.

Figure 9: Bucking Cam

Canter Cam

The canter cam is only a slightly smaller version of the bucking cam that has been modified to rise less aggressively. The axis of rotation, however, has been shifted closer to the center of the cam. This creates less vertical lift than in the bucking cam, producing a smoother ride.

Walk Cam

The walk cam institutes the same basic principles as the bucking and canter cams. In the walk, however, the vertical lift is very minimal, only three quarters of an inch. The cam – much smaller than the two previously mentioned cams – is only four and one quarter inches in diameter.

Trot Cam

The trot of a horse is a very high frequency motion. In order to create this rapid movement, a three lobed cam was created. This shape creates the quick, choppy movement that is desired. By creating three movements in each rotation of the cam, the movement can be simulated at a fairly low rotation of the motor. This was necessary in order to create the desired speed in the trot simulation. In the trot, there are two and one half inches of lift in each motion.

Figure 10: Trot Cam

Structural Analysis

Once the basis of the design had been decided upon, the actual components and parts layout of this devise needed to be determined. Bearings, bushings, pulleys, belts, shafts and structural members needed to be selected or designed. It was known that bearings or bushings of proper sizing were necessary to obtain the lifespan and quietness of operation desired. Surface qualities of the cams were a particular concern for quiet operation and lifespan.

Bearing Analysis

Pillow-block bearings currently in use by the bull design were first considered for any major rocking joint due to availability. They appeared acceptable since the service life was to be nine million cycles at 1400 pounds. The new application in question for the pillow-block bearings were in the joints of the upper four-bar link that will be referred to as the “H” bar due to its shape. Considering the shorter service life of roller bearings such as these in an application where complete rotations are never obtained, oil impregnated bushings were also considered for these joints. The service life was found to be similar to that of the roller bearings in the rocking application but this was not deemed enough of a reason to abandon the easier to install pillow-blocks. This is due to the lack of availability of a pre-machined pillow-block and face-mount retainer for the bushings within the cost of the bearings. Face mounted bearings to support the other end of the “H” bar were selected that had the same cycle life at load specifications of the pillow-block mounted bearings.

The bearings used in all the body rocking mechanism are all adapted directly from the bull design. The pillow blocks support the body mount in both the rocking and the spring loaded sway just as in the bull. The pitman arm ends are freed by the same bearing used in the bull design as well. The down arms that connect to the pitman arms are largely the same as the ones used in the bull but are angled and lengthened. The precedence set by the long life of the bull design deemed all of these design features worthy to continue in the horse design.

Shaft Analysis

Since complete rotations were obtainable in the camshaft face-mount bearings the same base bearings were used, just in a smaller shaft size of 1 1/8" rather than 1 ¼" like that use with the "H" bar. The Lower four-bar link "hanger" cased bearings also had an equal rating to the others but would see less loading as well as complete revolutions. The special "hanger" bearing cases are typically used in heavy duty augers where the bearings are suspended by 1 1/8" threaded shafts perpendicular to the axis of rotations. This made these cases very pleasing in forming the lower links since a simple 1 1/8" bar could connect the two bearings and thus power transmitted by belt across the joint.

The cam follower was deemed a good place for the oil impregnated bushing since it has such a low rotational rate and high impact load on a single rotating point. The inch thick shaft that supports it was found to have minimal deflection in the configuration used in the design. One end of the inch shaft is welded to a square 1 ½" shaft that has the holes drilled in it for the alignment pin used to locate the follower under the cams. The other end of the shaft is threaded so a 1 ½" square shaft can be tightened down on the thrust ends of the bushing pressed into the cam follower hub so that there is no end play.

The most complexly loaded shaft in the design is the cam and pitman carrying shaft referred to as the camshaft. This 1 1/8" shaft was found to have minimal deflection even when the maximum bearing load and torsion from the motor input was applied in combination. Factor of safety was found to be slightly greater than four (4) in this loaded state. This was deemed satisfactory.

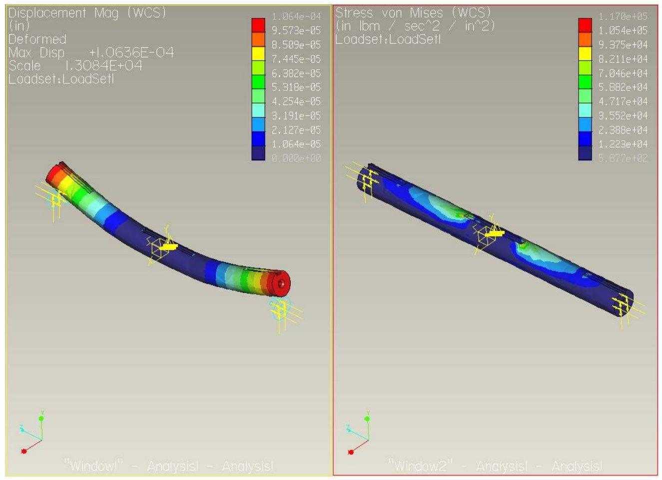


Figure 11: Shaft Stress Analysis

H-Bar Analysis

The “H” bar was of particular concern since it was the primary member that maintained rigidity to the moving upper framework. The pillar it was attached to through the pillow-blocks discussed earlier was know to be of ample rigidity and was not analyzed. The distance from the face-mount bearings connecting the “H” bar to the moving framework to the face-mount bearing stabilizing the cams could not flex significantly due to the small distance and material thickness. The rated bearing load was applied in opposing directions on the ends of the “H” bar in Pro-Mechanica to analyze the deflection. This coincided with the maximum load the moving framework, body, 400 pound rider, and a one second stop from full speed flat spin movement could induce on the system under normal operation on a cam positioned at the edge of the housing. The deflection was found to be less than 0.004” total twisted distortion. This would ensure that misalignment enough to derail the cams could not be due to the flex of the framework itself under normal operating conditions.

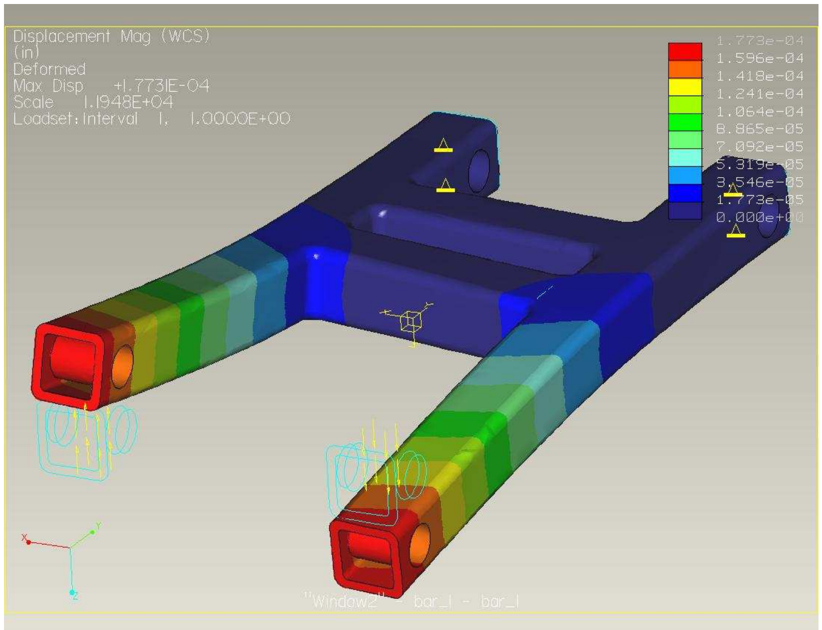


Figure 12: Displacement of H-Bar

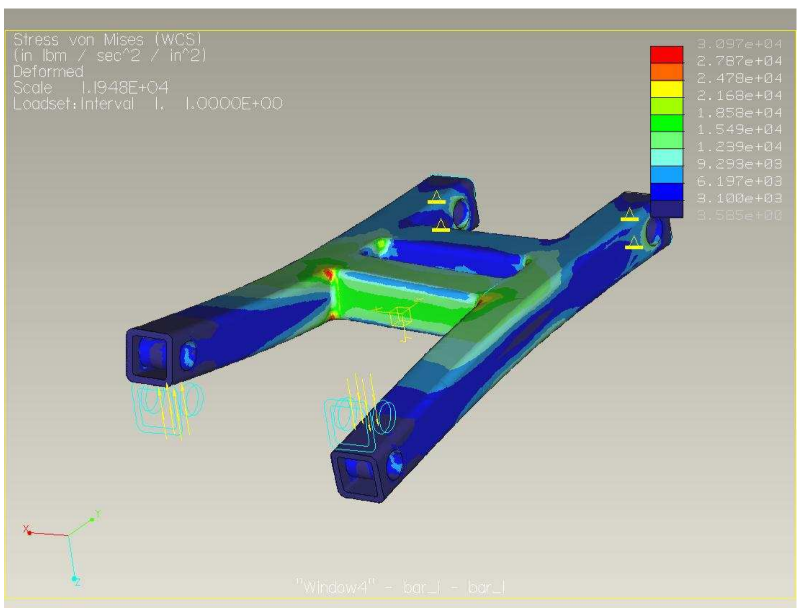


Figure 13: Stress of H-Bar

Cam Analysis

Cam smoothness was decidedly the most important factor in quietness of operation and therefore wearing surfaces were to be carefully profiled and finished. Lifespan of the cams themselves were difficult to analyze as far as surface wear. It was known that the larger the contact area the longer the life would be and therefore these factors were controlled. The cam thickness matched the thickness of the cam following roller, this ½" thickness was the maximum due to the space constraints of the camshaft with all bearings and pitman arms stacked on it. Since the thickness was not overly broad, the best way to maximize contact area was to increase the follower diameter to a maximum feasible value. This was found to be 14" in diameter for the follower. This large size pared with the large size of the cams made a good contact area without excessive deflection of the contact point on the cams. Since calculation of lifespan based on this information is neither a reliable nor a feasible function, the lifespan will have to be found by physically wearing out the prototype cams. Hardening of the cams edges was also considered but this would only increase the point stress at contact since the surface deflection would be less. This would induce more tendencies to gald and wear and therefore is not recommended.

Pittman Arm Adjustment

The adjustable pitman arm sleeves were originally designed so that pull pins that were spring loaded into their positions would be used. It was a concern that these pins would become dislodged from their holes in the event of a prolonged aggressive ride. For this reason threaded and bolted sleeves were designed and constructed in their place. The bolts were sized such that the full rated load of the linkage bearings could be used without bolt failure.

Design Troubleshooting

The cams were made by cutting out the patterns using a bandsaw by hand. This left ridges and flat spots on the cams that needed to be smoothed. After grinding and filing to approximately smooth, nearly invisible imperfections were still evident in the noise made by the machine at higher operating speeds. For this reason, more consistent means of cutting the cam patterns would be suggested for manufacturing such as CNC laser or water cutting. The chatter and sometimes banging was only evident as the framework began its decent towards earth. Since the cams were shaped such that at full throttle, the acceleration induced by the cams in the down-strokes were equal or slightly greater than that of the acceleration of gravity, a spring needed to be added in order to make the cam maintain contact with the follower. The spring was sized such that the service life was the greatest, meaning it had the highest number of wraps available in the space provided. Since solid projected lifespan data was not found on the particular spring selected, the number of wraps was the best estimator of lifespan. This spring and break-in use smoothed the operation significantly. Slight mushrooming of the cam follower did occur after extensive testing but not significant enough to warrant redesign nor did it affect performance.

The “H” bar and other related structures were found to be of ample rigidity after prolonged real-world testing. However, problems did become evident in cam alignment due to slip in the bolted joint between the main supporting pillar and the pillow blocks attached to one end of the “H” bar. This problem was remedied by welding key stock to the pillar such that the pillow blocks were locked in position.

The bucking cam proved to be too aggressive in conditions where a person heavier than 300 pounds wanted to ride slowly. The motor was incapable of lifting the rider at less than 60 percent power. This was deemed unacceptable and therefore the cam needed to be modified. The cam was trimmed such that the raising rate was decreased and therefore the peak input torque to rise would be reduced. The maximum height was maintained but the time at this high of position had decreased slightly. At the same rotational position as before modification, the point of contact was moved to approximately half the distance horizontally from the axis of rotation. This means that the torque required for lifting was cut in half. This enabled the machine to raise even riders of slightly over 300 pounds at 40 percent power.

The adjustable pitman arm sleeves mentioned earlier were found to be clumsy and difficult to operate compared to the spring-loaded pull pin design. For this reason, the sleeves were again redesigned so that spring clips pressed into the ends of large load-bearing pins would replace the bolts. This significantly decreased the time required to change modes of the machine and was deemed acceptable.

Safety

Since this device is to be used by untrained operators and rode by the general public, safety is a capital issue. Many measures had to be taken in an effort to protect the rider from contact with pinch zones and other potentially dangerous areas.

Padding

The primary protective measure is the padding and side skirt length of the body. This ensures that a rider will not be injured by the harsh movements of the bucking mode and will not be in danger of getting tangled in the moving mechanism below. This protects a seated rider well but there are many other dangers that develop once the rider has been thrown.

The largest and most obvious of these is the landing pads. These pads are the same as those found on the bull design but are of significant enough importance that they need mention here. The main rotating base is padded with a circular pad that rotates with the flat spin mechanism so that an entangled and dismounted rider does not get drug around the base against the friction of the pads. The padding beyond this central pad is a large air mattress that fits snugly against it and extends several feed in all directions to protect a rider that has been thrown a distance. These predictable situations are well protected for but what about riders that have an unusual dismount.

Shielding

Riders who are slung from the body but become entangled during the fall can become drug close to the moving parts beneath the body, for this reason extensive shielding was needed. All shields that enclosed moving parts were constructed of 1/8" thick steel plate. Boxes were made to cover the brush spool located below the cam follower through which the current passed to drive the bucking motor. A large shield mounted to the rotating base extends upward to cover the rear portion of the cam and cam follower area. This insures that riders slung over the back of the body do not contact the cams directly. The pulley and belt on the gearbox side is shielded so that riders thrown over the front of the body do not contact these rotating parts. The pitman arms and the linkages involved are a critical safety concern in the current design but since the body covers the arms so closely, shields were not constructed. This is one possible area for further safety improvements.

Budget

The proposed budget from the fall was $7,800 plus the cost of the base currently in use by Rockin' B. That budget turned out to be significantly higher than the actual cost. The estimated cost of creating this machine is $2,550 plus the current base, plus labor. Much of this saved cost comes from initially overestimating the cost of steel and the amount used. Additionally, the bearings currently used by Rockin' B were found at approximately half of the price they are currently purchased at.

PARTS LIST	
PARTS	**COST**
Provided Base	
Body Mounting Bracket	
Motor	$ 700.00
Gear Box	$ 500.00
Steel	$ 400.00
Bearings, Bushings, etc.	$ 304.83
Provided Bearings	$ 150.00
Sprockets & Belt	$ 82.10

Table 1: Budget

Superior Riding Systems

Kyle Stein, Luke Reed, Patrick Sievert
Biosystems and Agricultural Engineering

Rockin' B Bucking Machines

Cheyenne, OK

- Mr. William Beaty
- Used for television productions, music videos, concert tours, rodeo practice and all kinds of parties

Project Requirements

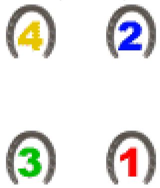
- SRS, Superior Riding Systems, has set out to create a versatile mechanical horse simulator
  - Bucking Bronc
  - Riding Simulator
    - Walk
    - Trot
    - Canter

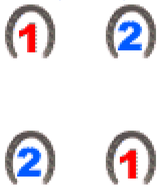
Project Research

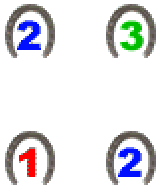
- Rodeo DVD
- Digital Video of Horse Gaits
- Personal Experience
- Horse Gait Analysis

Bucking Broncs

Horse Gaits







Design Criteria

- Vertical Lift
  - Each of the gaits as well as the buck
  - Naturally created
- Forward Rocking
  - Created by the horse while in stride
  - Hind quarters creates forward to backward direction
- Rotational Pitch
  - Created as motion is completed
- These motions coincide with one another and must be applied in our design to produce the most realistic ride possible.

Final Design

- Cams to create vertical lift
  - Roll against large cam follower
- Four-bar linkage
  - Provides vertical lift
  - Provides forward to back rocking motion
- Pittman arms to create pitch
  - Adjustable length to create varying degrees of pitch
    - Different Modes

Cam Design

- **Cam Design Software**
  - *Working Model*
  - Cams designed to fall at speed of gravity
- **Bucking Cam**
  - Seven inches of vertical lift
- **Walk & Canter Cam**
  - Smaller, less aggressive versions of bucking cam
- **Trot Cam**
  - Three lobes to create rapid bouncing feel

Bucking Mode

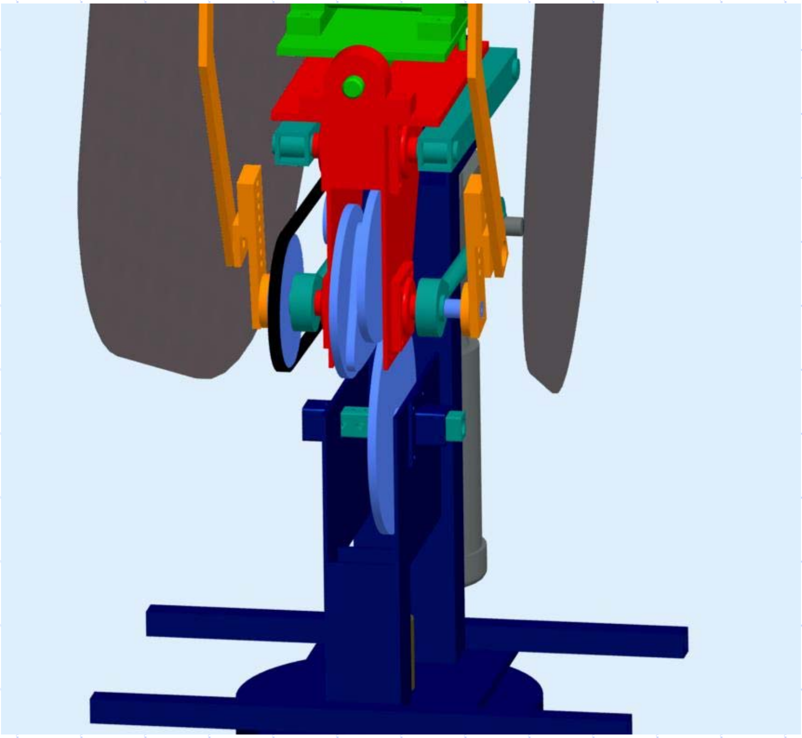
- Pittman arms set so back end is highest when cam is lowest
- Arms adjusted to longest setting
  - Twelve inches of kick in back end
  - Twenty-two inches of drop in front end

Riding Simulator

- Canter Mode
  - Arms set so back is highest while body is lowest
  - Smooth rocking motion
- Walk Mode
  - Toned down version of canter
- Trot Mode
  - Pittman arms set to zero pitch
  - Strictly vertical motion

Adjustment Between Modes

- Cam follower shifts to three selectable cams
  - Hydraulic jack raises mechanism
  - Alignment found by pinning holes
- Pittman arms unlocked and moved to appropriate location



Safety Precautions

- Shielding of pinch zones
  - Cam shield
  - Brush spool shield
  - Pulley shield
  - Longer body sides
- Padding of body and lower framework
- Stabilizer bars

Design Analysis

- Bearings, motor, gearbox, belt system, shafts sized for high service life.
- Stress analysis on weakest points prove parts overbuilt
  - 1 1/8” camshaft weakest loaded shaft
    - FOS = 4 at 150 ft-lb motor output torque
  - “H” upper four bar link critical for alignment
    - Torsional deflection at 1500 ft-lb = 1/8” at cam axis
- Cam life should be further analyzed

Troubleshooting

- Cam alignment solidified by fixing position of “H” link pillow blocks
- Sharp edges on body and D rings smoothed
- Slow ascent on bucking cam
- Reduce lift on walking cam
- Future hardening of cams and followers

Final Design Budget

Parts list		
Machining, welding, and assembly	$	1,600
Motors and Gear Boxes	$	2,850
Minor electrical components	$	950
Miscellaneous connectors	$	350
Bearings and power transmission	$	950
Steel	$	400
Total machine estimated cost	**$**	**7,650**

Thank You

- Mr. William Beaty
- Mr. Jim Friesen
- Mr. Don Lake
- Dr. Paul Weckler
- All BAE staff and faculty

Special Thanks To:

- Wayne Kiner
- All BAE lab staff

SRS
Superior Riding Systems

Stillwater, OK

Problem Statement:

SRS, Superior Riding Systems, strives to create mechanical bucking horses that meet the Rockin' B standards for excellence in bucking machines. These machines will excel in both ease of operation and reliability while giving the most enjoyable and realistic experience to the customer.

Statement of Work:

SRS, Superior Riding Systems, has set out to create a bucking horse to meet the Rockin' B bucking machines standards. These standards of excellence include reliability, ease of operation, low maintenance, kinematical correctness, and competitive cost.

Our sponsor has set forth objectives to create the physical motion for both a bucking machine and a riding simulator. When set up for bucking, the machine must be capable of simulating the vertical motion of a horse while rotating on the current bucking bull platform. Rockin' B has developed an effective means for rotating the apparatus, and wishes to continue to use that set-up. Bill Beaty supplied us with his current base to use for this project. The spring-loaded lean mechanism for the current Rockin' B bulls should also be maintained in the new design in accordance with the request of the owners. The mechanism must also be easily controlled. The movements should be logical such that adjustment of the controllers will generate a horse-like movement no matter how randomized the controlling. The owners have requested that the controls be capable of being operated by two hands alone, and that all functions be able to be controlled without removing the hands from the controllers.

When set up for ride training, the machine should be capable of performing the various gates of a horse such as the walk, trot, lope, and canter. This aspect of the machine is used as a training device for various equine events as well as various therapeutic functions. This conversion of a rough and rowdy bucking machine into a gentle riding machine will be a challenge. Ideally, the machine would convert from a bucking machine into a riding machine mechanically. Unfortunately, the design may call for the machine to be converted manually. This is not viewed as a significant concern, however, as it is not expected that the machine will be used as a bucking bronc one minute and a riding trainer the next. Generally speaking, only one mode will be used. The ability to convert between the two, however, creates a very versatile machine. One issue is the need for the animal to vary the amplitude and frequency of the movement of the front and rear portions of the animal independent of one another or synchronized based on which gait is selected. Studies have been done such that the most realistic experience can be accomplished by this machine. Video has been taken to determine the different motions of live horses. The speed (up and down cycles/minute) and vertical motion of each gait has be recorded. If the desired motion of the animal is not fully understood, then the simulation of this motion will be impossible. SRS's goal is to create a single machine that simulates both a bucking bronc as well as the gentle riding aspect.

By request of the owners, hydraulics will not be used due to the maintenance and leak issues associated with them. Rockin' B requested that the mechanism must also remain constrained within the space envelope of the current bull fiberglass body. The current frame will not be realistic in the way the rider sits. When on a bucking bronc, the rider is reaching forward to the neck of the animal to spur it. With the current bull frame, the neck appears to be too wide and short to create a natural ride. Furthermore, use of the current frame would create safety concerns, as pinch zones would be present underneath the frame. The pivot point of frame will also have to be moved toward the front of the animal to more accurately simulate the motion of a horse rather than a bull.

Safety is a significant concern, and should be considered so that the machine will not behave outside the desired actions of the rider/controller. Pinch and trap zones underneath the frame of the body should also be minimized or eliminated. The increased vertical lift of the mechanical horse will create possible pinch zones under the machine. These safety concerns will be addressed by both changing the design of the frame as well as incorporating devices which will shield a fallen rider from the moving mechanisms underneath the machine. Also, consideration will be given to minimizing controller error that may result in an unsafe situation. Furthermore, emergency stops will be installed to prevent injury in the event of a pin failure.

Task List:

See attachment.

Literature Review, Research, Investigation, Testing:

A video several minutes long showing the different gaits of a horse was taken to determine the speed (cycles/minute) of the different gaits, as well as the amplitude of the vertical motion within each step. This will be used to configure the machine when in walk-trot-canter mode.

Nine somewhat relevant patents were found that will be used to steer our design. Included in the patents was one for William Beaty, owner of Rockin' B Machines. Having access to his patent gives us more allowances in what we can incorporate into the design. Each patent was printed off and kept for future reference. Most patents, however, have little or no significance in the design of this machine. Since the vast majority of the motion comes from entirely new designs, and the only portions which have been copied come from Mr. Beaty's original bull, no conflicts have occurred. Furthermore, as a brand new concept is being considered, past patents have had no influence on the design of this machine.

See Attachments.

Engineering Specifications / Customer Requirements:

No hydraulics

Should fit within existing bull frame

Must use existing spin mechanism

Incorporate side-rocking motion from existing fiberglass body space

Possible use of two motors in parallel to create vertical motion

Possible movement of center shaft using pneumatics

Consider mechanical horse for training/riding purposes (no bucking)

Consider possible shoulder movement to simulate all gaits of a horse

Modeling/Simulation Plans:

A simulation has been made on ProE of two preliminary designs. These computer simulations have allowed design problems to come to light. It was determined that there would be size issues with both the linear actuator and the final design, regarding fitting them underneath the frame of the animal. This has allowed adjustments to be made. See attachments.

Development of Design Concepts:

A number of possible design concepts were developed in order to determine the direction this project needed to go. Since this project intended to generate a multi-purpose machine that, within reason, can simulate all riding natures of a horse, design trade-offs must be made. By design trade-offs it is meant that the design can not be allowed to become so complex that either cost or longevity becomes a serious issue. Since there is an array of directions that this project can go it was important to follow a process of elimination that would leave the most suitable design. Designs were eliminated from consideration on concerns over cost, reliability, realism and controllability.

The first design concept was to take the mechanisms of the mechanical bull, and simply add a pneumatic/hydraulic cylinder vertically move the current bucking mechanism. In light of the request of the sponsor's requests, we developed a non-hydraulic concept that would use a large linear actuator in the place of the pneumatic/hydraulic cylinder. Pneumatics would not give the desired accuracy to provide a realistic simulation.

The second concept used two motors much like the one currently in use on the bucking-bull mechanism. They would run pitman arms to generate the vertical motion paired with a slide mechanism to accept the side loading. In this concept the lower amplitudes of movement seen in walk, trot, and canter would be attained by oscillating the motors at partial rotations. Further, this option would only give one single motion. All of these options would require additional motion control mechanisms to generate the cyclical nature of the ride.

More inherently cyclical models were then developed. The first of which would use the two motors design but instead of oscillating the motors at partial rotation, a variable stroke pitman arm would be developed to attain the three gates of the horse as well as different degrees of bucking. This concept eliminates the need for oscillatory controllers, however the timing between the two motors is crucial in generating a horse-like ride and would require significant electronic control.

The obvious alternative to using two motors was to use a single motor to power the two degrees of motion, the pitch and the vertical translation. A mechanical drive system would be used to distribute the power to two different pitman arm units so that proper timing of the buck and jump would be ensured. The variable throw pitman arm would be used to generate the lower amplitudes of the gates as discussed earlier and it was proposed that this should be an active control allowing the amplitude to be altered mid-ride. It was noted that during bronc riding, the animal often jumps vertically several times before doing any bucking. This could be simulated if the throw distance of the buck pitman arms could approach zero and therefore this was added to the design. An electronic controller would need to be developed, eliminating operator error, that would allow the direct control over the timing between the two pitman arm sets to improve the realism of the ride. While complexity was growing with this concept, this concept was viewed as being feasible and realistic enough to justify evaluating this possibility to the fullest.

During this evaluation, it was found that a simpler option could obtain the same effects. This concept would make use of an electric clutch-brake to engage the buck pitman mechanism to the drive after a few vertical jumps had been made at the beginning of a bronc ride to simulate the phenomenon mentioned earlier. To reduce the amplitude of the ride motions to walk, trot, and canter levels, it was necessary to develop manually modifiable pitman throws. While linear actuators were used to control the length of the pitman arms in the previous, spring loaded pull pins will be used on the manually operated ones. This decreased operator ease is offset with a far smaller package size, better reliability, and lower cost. The biggest issue with this design is developing a potentiometer based clutch engagement to make the timing consistent in a bronc ride and yield the correct feel in the gaiting modes.

Feasibility evaluation of top ranking concepts:

All of the non-cyclic as well as the twin motor concepts were eliminated since they would be difficult to generate a realistic ride. Even if a realistic ride could be obtained, the complex electronics required to control such a mechanism would significantly increase the cost of the machine.

While the single motor, electrically controlled pitman arm concept would be capable of a very realistic, easy to alter ride, it proved to be problematic. In order to get linear actuators that had the travel needed for the pitman arm adjustment, they needed to be anywhere from two to three times the stroke in contracted length. This would have meant that the entire space under the fiberglass body would be filled with spinning parts to the detriment of the stability of the framework. Vibration would have also been a large issue since each linear actuator weighs approximately twenty pounds with a center of gravity nearly six inches off the axis of rotation. This was determined not to be the most effective design, and therefore, these were not pursued.

The single motor, manually adjusted pitman arm, electric clutch-brake operated concept is the best option in terms of feasibility at this point, as it provides both a realistic ride and relative ease of operation. Additionally, this concept allows both the bucking motion as well as the different gaits of a horse to be simulated.

Determination of suitable designs:

While there is still much to be determined in the way of clutch-brake control methods, including the possibility that a manual switch may be adequate, this design appears to be the most suitable. The manually adjusted pitman arms may be replaced by electrically controlled ones if a much smaller package arm is developed, but until then, this design will be pursued.

Proposed Budget:

See attachment