JAN 6 1997

RESERVE DESK

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1996

DESIGN

EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

-- Please sign your name on the back of this page --

GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

DESIGN QUALIFIER

FALL 1996

IMAGINE

Harry: "So Pete, when are they going to automate this line so we don't have to do this back breaking work anymore?"

Pete: "I don't know. Personally, I am getting sick and tired of having to inspect each one of these bags myself. Can't we get one of them new fangled gizmos to do it for us."

Joel, butting in: "Yeah, but I still wish they would automate this line so we wouldn't have to worry about placing each bag into the container properly. I just know there has got to be an easier way."

And so went the griping until the shift ended, and Harry, Pete and Joel went home, and the new shift began and so did the complaining.

THIS EXAM We are interested in learning what you know and your ability to reason. If for some reason you do not follow the question or are confused kindly adjust the question suitably and proceed with your answer. Be sure to list and justify all of your assumptions explicitly. Do let us know the adjustments/ assumptions you have made.

Read the entire exam first. This exam covers design methods, design analysis and realizability. Please attempt all three questions and spend **EQUAL** time on each of them.

ORALS We start the orals by giving you the opportunity to tell us how Design fits into your doctoral research. Please come prepared to make this opening statement. If you do not do an adequate job on the written exam, you may be asked to discuss this in the oral.

ACKNOWLEDGEMENT The Problem Statement and sketches are provided by Wiley Holcombe from GTRI. This information is what he has developed for one of his clients.

PROBLEM STATEMENT

Wiley does a lot of consulting. His services are in demand because Wiley has the knack to get his clients involved - just enough to be useful but not too much - in his projects.

Wiley's client has a line of 10 lb, bagged, frozen, food products that are manually loaded into a 6 in. x 8 in. open-top paperboard carton. The input to this packaging system currently consists of two vertical form-fill-seal baggers that drop the product onto the conveyor line. The bagged product is randomly positioned and oriented on the conveyor belt, and the bags may be overlapping each other. As the bags move down the conveyor at the rate of 60 bags per minute, three workers remove each bag separately, briefly check for seal integrity by sense of feel, and then place each bag into its own individual carton. The accuracy of the placement of the bag in the carton is important for the sealing operation of the carton. If a part of the bag extends outside the edge of the carton or if the contents of the bag extend above the top of the carton, then the sealing operation may fail and manual intervention will be required at a later point. In addition, poorly placed bags result in a waste of cartons when the sealing operation is unsuccessful, and the bag must be repacked into another carton. There is also a waste of manual labor and production.

The cartons are also on a conveyor moving at a rate of close to 60 cartons per minute. The operator is required to place the bags into the cartons as they are moving down the conveyor at this high rate of speed. This is a difficult task for the worker.

Due to the wide variety of products Wiley's client is constantly running different product types down the same line. Products range in various sizes, weights, and the speed requirement of the line varies. Any automation that is to be added to the line must be able to perform its task regardless of the product being processed at that time.

Wiley's task is to generate, evaluate and develop ideas for automating the packaging line. One of the main concerns of Wiley's client for the future operation of the plant is the dwindling labor pool. This task is also particularly hard on the human from an ergonomic point of view. The speed of the operation and the types of motion required by the task tend to lead to the repetitive motion injuries to the worker. This has led Wiley's client to start looking for alternative solutions to their present processing technology.

Constraints on the design follow: The equipment must support two shifts seven days a week and operate for many years. The environment that the machine is to operate in is very difficult to account for in the design. the temperature and humidity of the workplace could adversely affect the performance of the machine(s). Furthermore, since the machine(s) is to be installed in a food processing industry controlled by the USDA. USDC and FDA, the design must meet the stringent cleaning requirements as defined by these government agencies and meet applicable EPA and EPD environmental regulations. The system must also be applicable with OSHA, UL and ANSI worker safety regulations and standards.

Wiley has generated 20 different concepts for consideration. Six of these are appended at the end of this exam.

METHOD

a) Describe a process that you would use to arrive at the best from the six concepts for further development. Wiley has developed 20 concepts. Wiley would like to be cost-effective in terms of his time invested AND would also like to keep his design freedom open. How would you advise him to proceed? What are some of the root assumptions and limitations for the successful application of the method you propose? HINTS: Anchor your recommendation in the context of Pahl & Beitz and / or the Decision Support Problem Technique. Be sure you include input from Wiley's client in your recommendation.

REALIZABILITY

b) Develop an initial set of specifications for the device. Pick two concepts. Quickly decompose the system down into appropriate subsystems. Now decompose the system by functions and create a function structure for the problem. Describe your embodiment of the design. Critically evaluate these two embodiments in terms of manufacturability, initial cost, maintenance cost, parts availability, reliability and other criteria that may be important to you. If you were a Chief Engineer in that plant, which one would you recommend to be further developed and why ?

ANALYSIS

c) Let's say that the Bag Tosser Concept (Concept #1) has been selected as the "best" concept for further development. Answer at least **ONE** of the three problems. Make any reasonable assumption.

(1) We are interested in determining the **deflection** of the section of the bag conveyor that overhangs the carton conveyor since we do not want the two to hit each other. Start by drawing the **shear diagram** for this section of the conveyor. Then **formulate** and **solve** the necessary equation(s) to determine the deflection of the conveyor given the dimensions and loading condition shown in Figure 1. Be sure to state any assumptions you make.

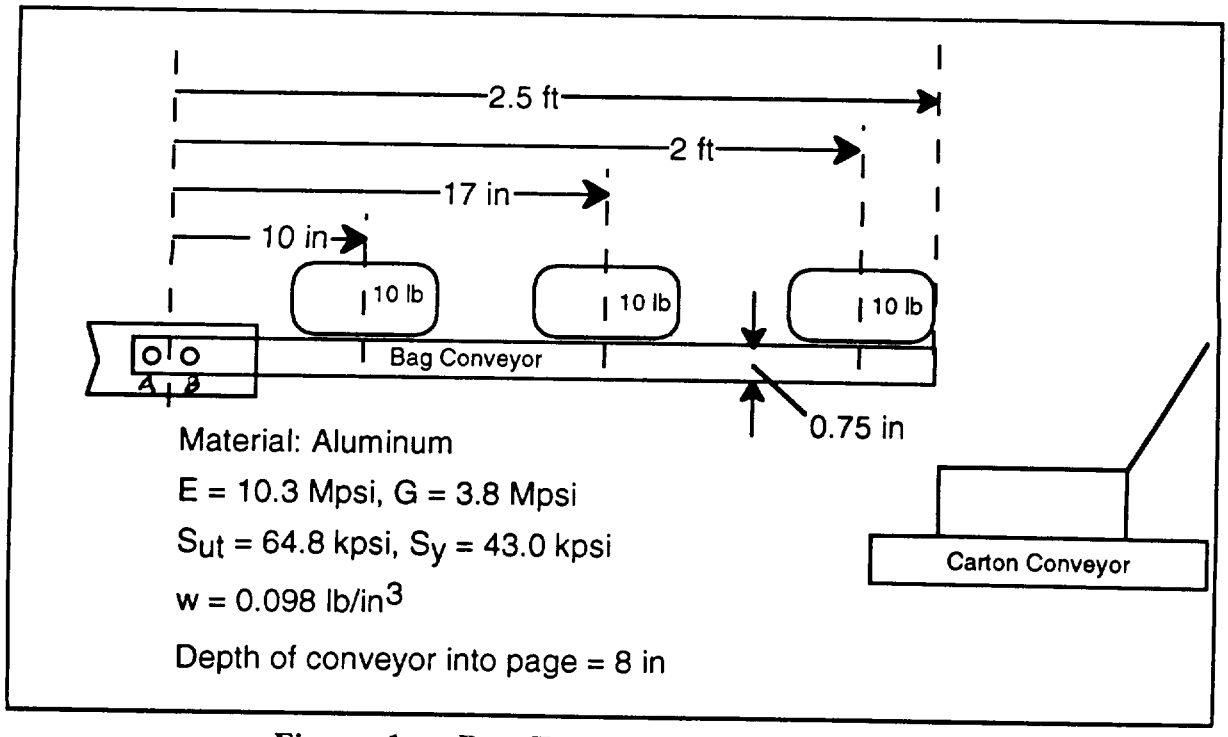


Figure 1 -- Bag Tosser Concept Dimensions

Some equations that you may find useful are given in Figure 2.

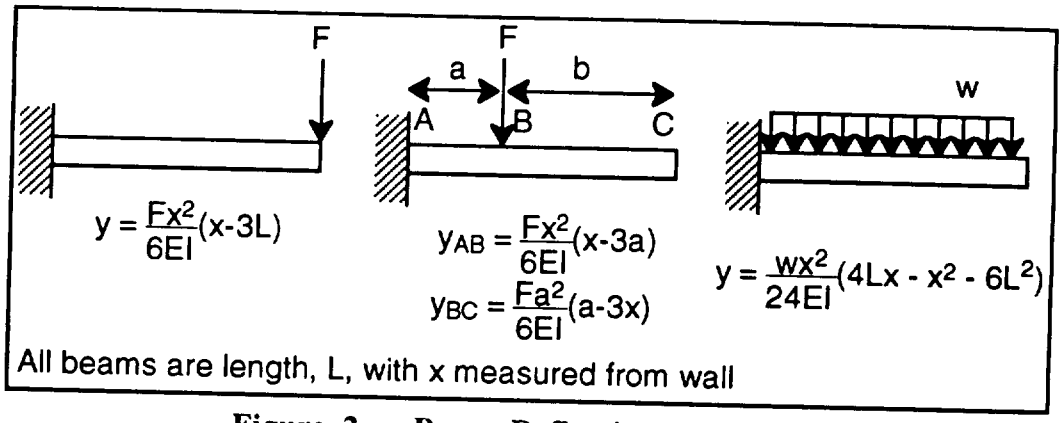


Figure 2 -- Beam Deflection Equations

(2) Next, let's look at the two bolts that connect the overhanging conveyor section to the main conveyor line. The bolt group consists of two 1/4"x20 bolts, located on the centerline of the conveyor section as shown in blown-up picture of the bolt group in Figure 3. Assume that the bolt has the same material properties as the conveyor belt (see c (1))

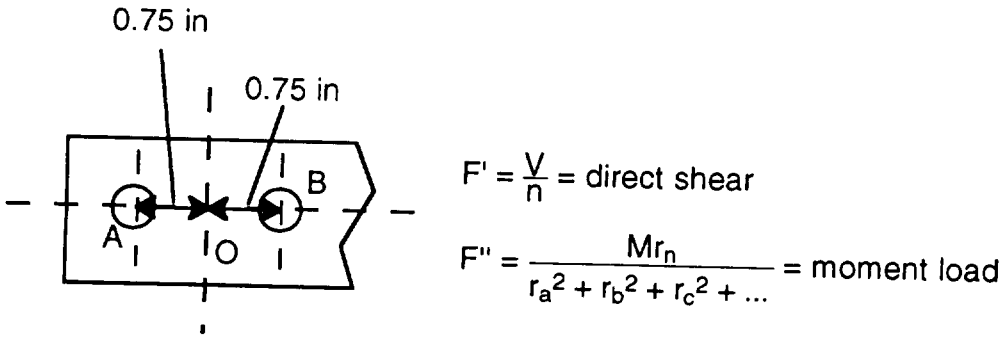


Figure 3 -- Bolt Group Dimensions

i) What is the load in each bolt?
ii) What is the maximum shear stress in the bolts?

(3) Finally, let's consider failure and fatigue. What are the possible modes of failure in the conveyor section? In the bolts? Lastly, what is the factor of safety for infinite life for the conveyor? Use the Goodman line given by: $\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{n}$. Some equations you might find helpful.

$$S_e' = 0.504 S_{ut},\ S_e = k_a k_b k_c k_d k_e S_e',\ k_a = 2.7 S_{ut}^{-0.265},\ k_b = \left(\frac{d_e}{0.3}\right)^{-0.1133},$$

$$d_e = 0.808(hb)^{0.5},\ k_c = 1 \text{, bending, } k_d = 1 \text{, temperature effects}$$

$$k_e = 0.75 \text{ from operating conditions}$$

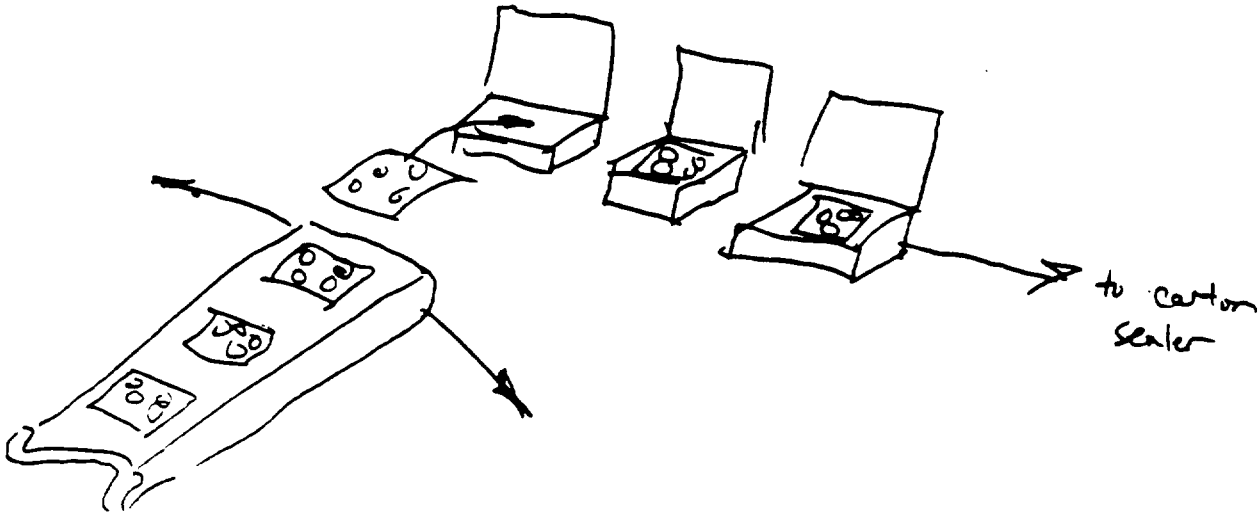
Explicitly show calculations for σ_a and σ_m, draw the Goodman diagram, and estimate the factor of safety based on the diagram.

Concept Name: Bag tosser

Concept Description: Bag is moved on belt from the bagger. It leaves the belt conveyor in a trajectory that intersects the path of the carton. The "induction" belt conveyor may be reciprocating in an arc. These induction conveyors are used in tilt-tray sorting systems.

Possible variations on concept:

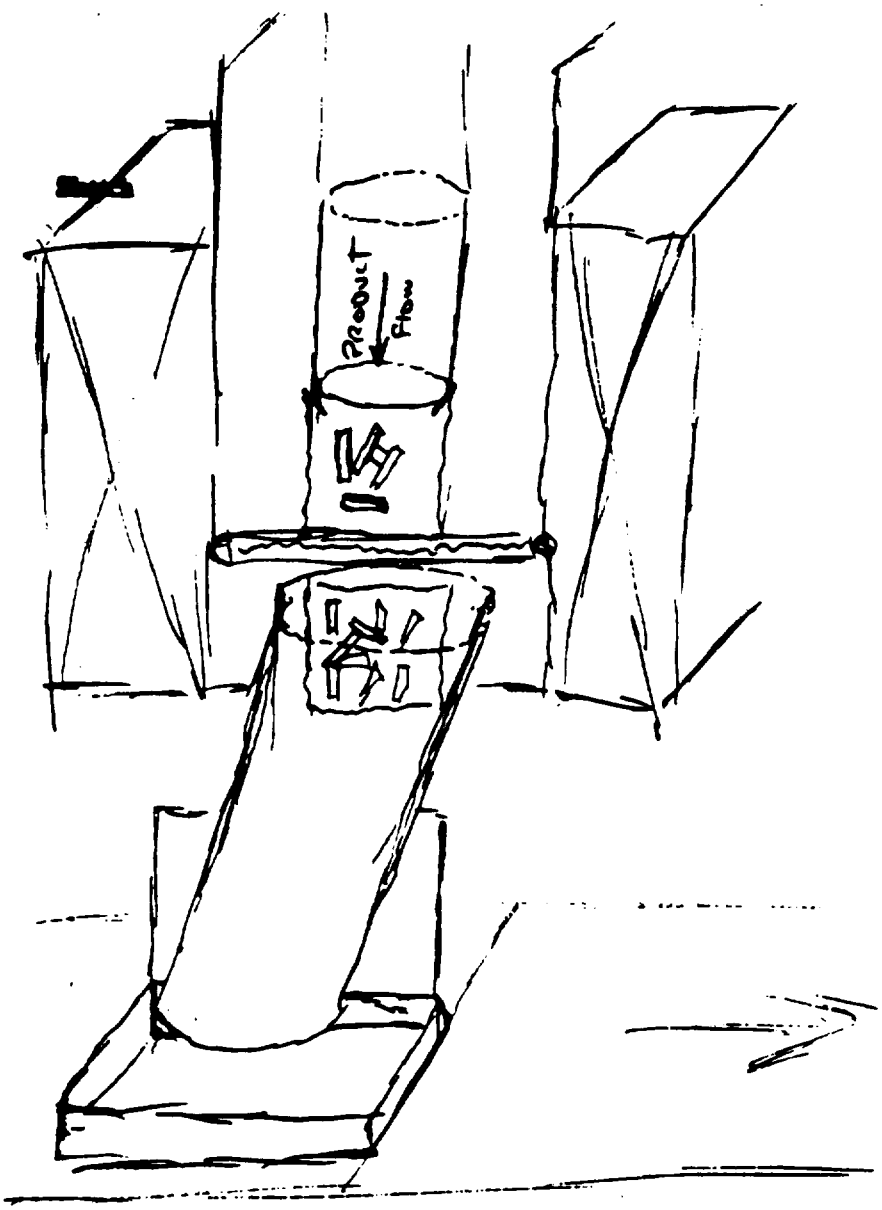
:tch



pluses	minuses	interesting
imitates the manual operation uses an existing technology	-orientation of bag in the carton is suspect -timing of bags to cartons -how do you account for no carton/no bag and no bag/no carton?	If bag is properly oriented on the conveyor, will it arrive in the carton at the correct orientation?

Basis for Analysis Question

Concept Name:
Concept Description: Bag falls. into chute. falls into carton at an angle.
Possible variations on concept:
Sketch



Shaping - height of discharge of bagger. degree of available space - between bag. carton and
Strengthening - Product containment achieved
Reinforcing - Timing of product. carton and interface of multiple baggers, cartons
Take up - R.K . GT. RSP
Comparison - same handling of bag off bagger
Faults - bag not cut properly or overfilled could jam chute

pluses	minuses	interesting
• product containment • labor reduced • reliability of mechanism (gravity) • potential recovering of produt waste from bad bags • simple. no additional machine is required • Cheap!	• timing • multiple paths • product height discharge space • can't guarantee bag orientation in carton searing problems • How do you check seal integrity. inspect for metal or inspect product	• carton at an angle to facilitate getting the bag completely in the carton • if you make the chute more funnellike. you can assure that bagged product will alight in the exact right place • might consider the funnel chuteas a moving thing (back and forth. or side to side. or whatever. to control the placement of the bagged producer

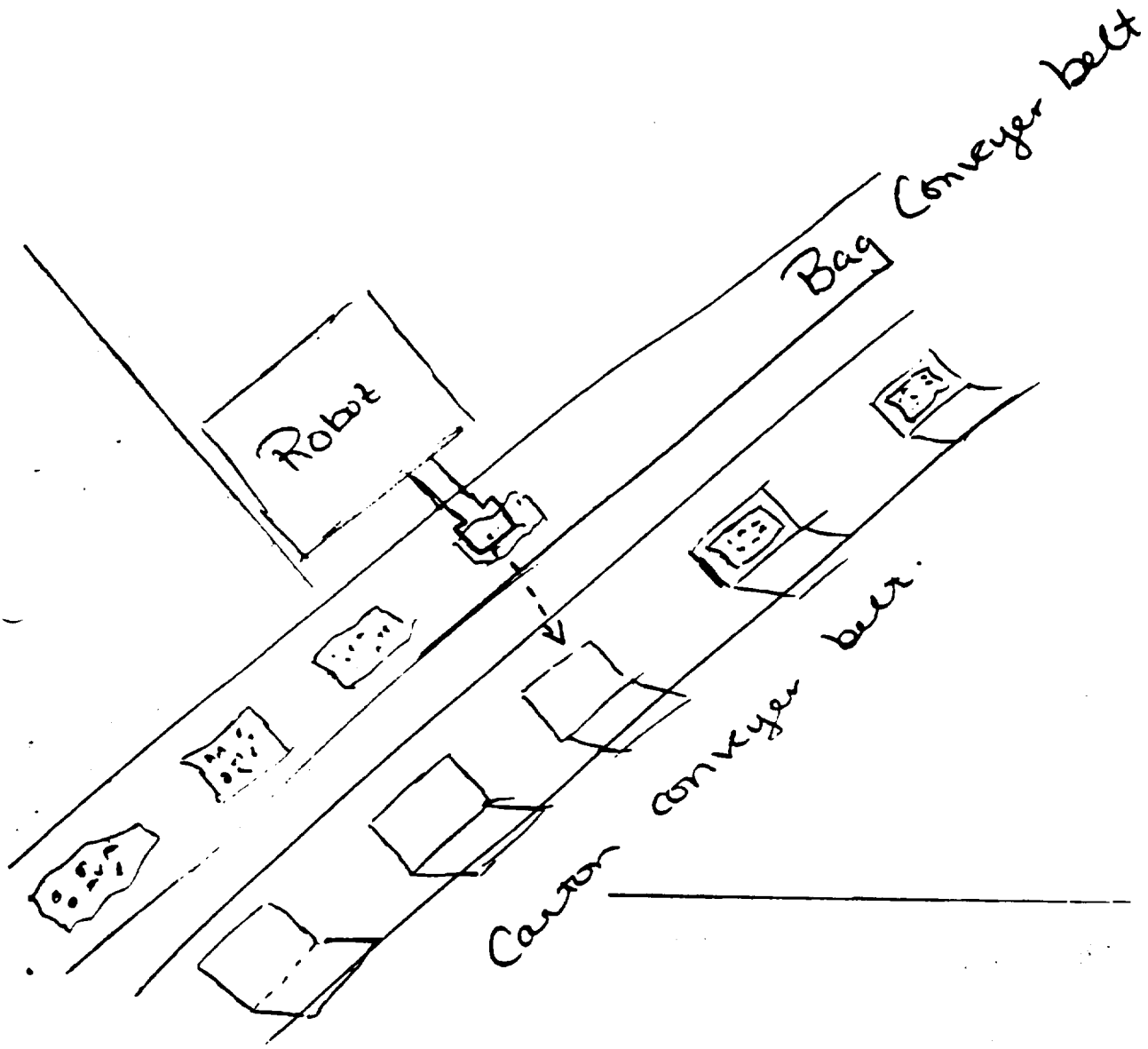
Concept Name: Robot Arm

Concept Description: Load the carton by picking up the bag. using a robot. with suction and loading it (bag) into the carton

- Robot arm can move up and down as well as in and out. The bags must be synchronized with the cartons.
  Actually - no need to move up and down

Possible variations on concept:

Sketch



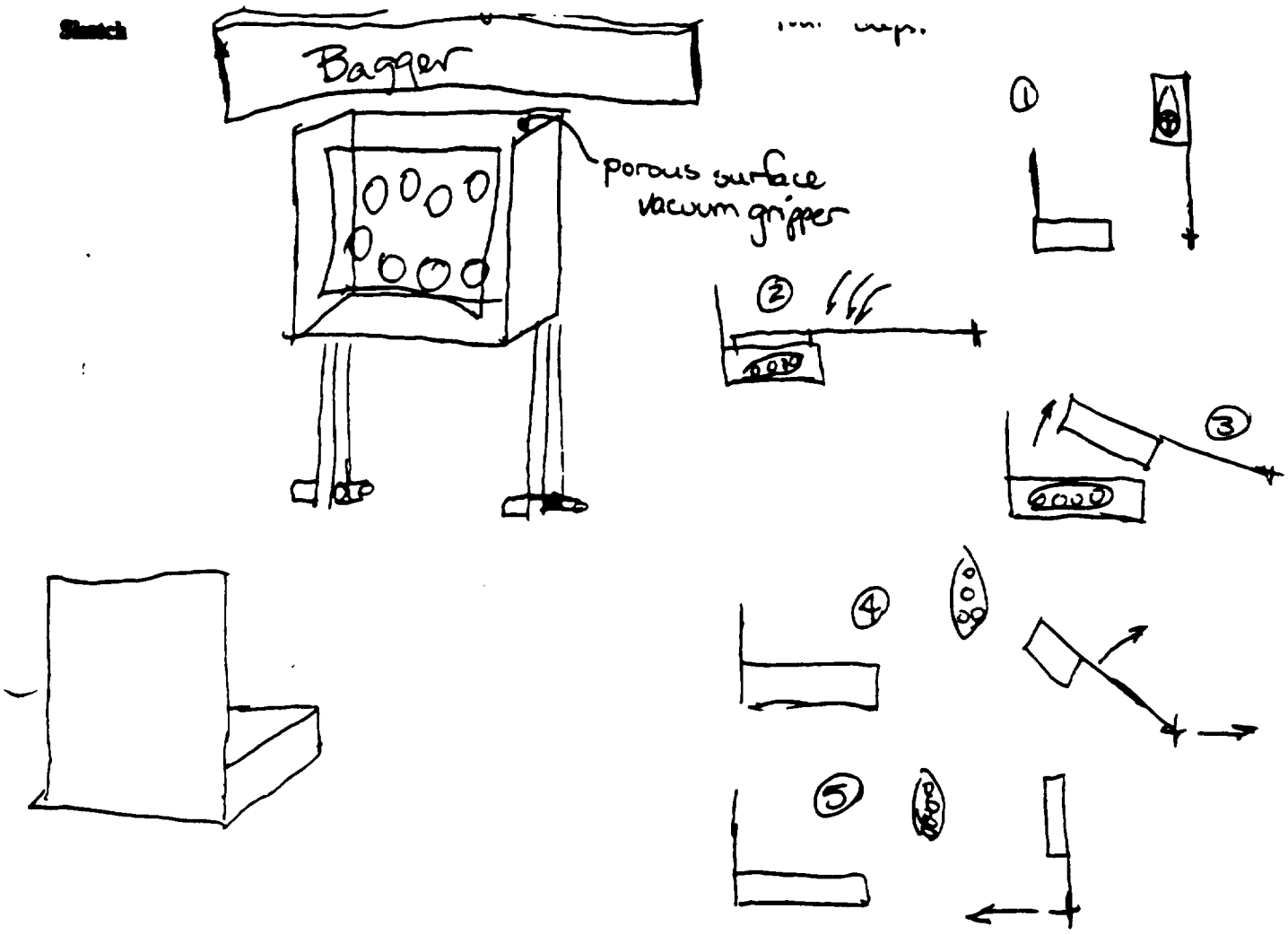
pluses	minuses	interesting
-suction arm motion can place the bag in box to ensure entire bag is in box -imitate human motion -can use existing belt format -multiple picks	-too slow (?) -suctioning may harm product -if the bags and cartons are not completely synchronized. system falls apart	-could add vision if needed need to develop timing

Concept Name: Reciprocating cup inserter

Concept Description: A four-sided. open cup is waiting for the bagged product at the bottom of the bagger stroke. A vacuum is started to grip the bag as the knife cycles. The arm rotates 90° to the waiting carton. The vacuum is switched to compressed air. The cup returns through a path that does not interfere with the next bagger stroke.

Possible variations on concept: might use a rotating device with two or four cups

Sketch



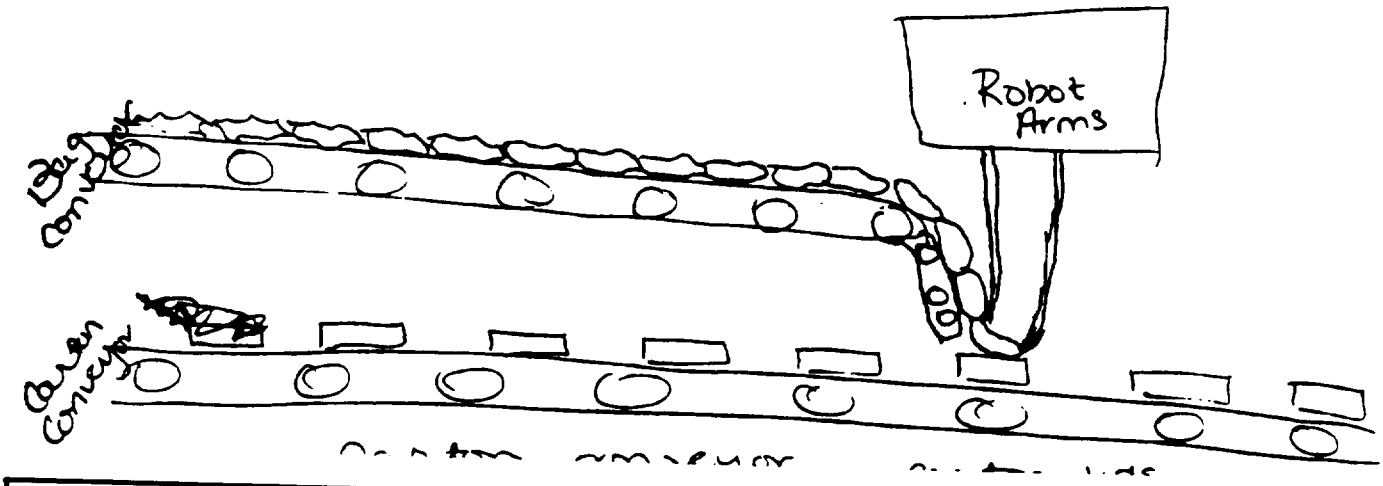
pluses	minuses	interesting
• bag position and orientation is captured at bagger • bag is confined to ensure that bag is place completely inside carton	•	• How about using a pistontype vacuum pump with the piston in series with the device acutator?

Concept Name: Bag as a towline

Concept Description: The bags are not split - they trace along the top conveyor in a row and when placed in the carton, then they are out. Robot arms place the bag in the carton and slices the plastic in between the bags. Carton lids are pointing toward the reader.

Possible variations on concept:

Sketch



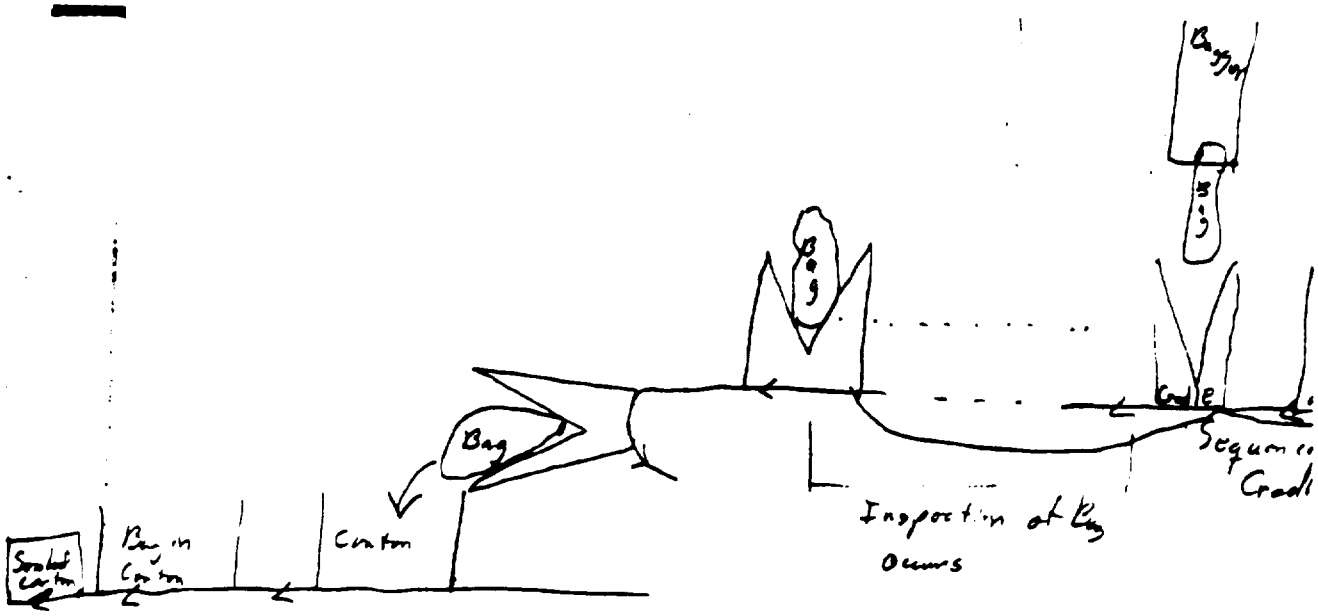
pluses	minuses	interesting
-The bags are more evenly to go flat into the box. -Product is not named	-The bag may still not get put in the box completely. -How do you separate the bags??	

Concept Name: Bag Cradle

Concept Description: In this concept the bag is dropped from the bagger into a cradle mechanism which holds the bag. A sequence of cradles are used so that the amount of time from bagger to carton insertion is increased to allwo inspection to occur and to provide buffer to sustain throughput of system while rejecting defective bags.

Possible variations on concept: Cradle could present bag to top-load or end-load carton.

Sketch



pluses	minuses	interesting
• cradle would not fail to capture carton unless timing was not correct • cradle structure could be used as guide to be sure that bag was properly positioned inside carton • presenting bag into open end of carton would allow momentum of bag to carry it into carton, perhaps with some assistance • change in carton forming process would mean less carton processing required for final sealing of carton	• bag may not drop properly into cradle • location of bag within cradle could cause problems • fixed cradle size could limit flexibility • would require modification of carton forming mechanism to allow for sealing of 2 side edges as carton was formed	• could have variable cradle size design to increase flexibility • could forming of bottom portion of carton and then sealing 2 sides while leaving the other side open be made to work reliably?