GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1997

Design
EXAM AREA

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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

SPRING 1997

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, I 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.

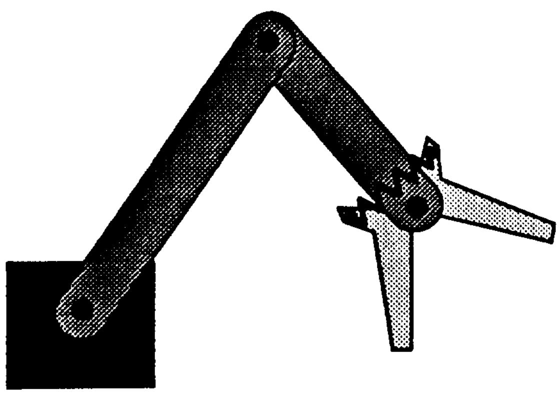
ACKNOWLEDGMENT The Problem Statement is provided by Wiley Holcombe from GTRI. This information is what he has developed for one of his clients.

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. One of Wiley's clients is in the frozen food packaging business.

The input to Wiley's client's 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 of 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. The 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 worker is required to place the bags into the cartons as they are moving down the conveyor at this high rate of speed. Wiley's client is constantly running different product types down the same line. Products range in various sizes, weights, and in the speed requirement of the line. 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. This is a difficult task for the worker; just imagine having to manually and accurately load bags of frozen food products into a 6 in. x 8 in. open-top paperboard cartons over a long period of time!!!!

Wiley's task is to generate, evaluate and develop ideas for automating the packaging line for bags varying in weight from 1 to 3 lbs. One of the main constraints is that Wiley's client has recently obtained a robotic arm at negligible cost from a local factory that fell victim to an unfriendly takeover. They are keen for Wiley to incorporate this arm into any of his proposed ideas.



Additional 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) are 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.

METHOD

a) What is the difference between original, adaptive and variant design. Wiley would like to be cost-effective in terms of his time invested AND would also like to keep his design freedom open. He therefore decides to embrace the notion of adaptive design using available assets, Describe a process that Wiley might follow to generate, evaluate and select concepts for automation given the constraint of utilizing the existing robotic arm. 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. Create a function structure. Generate two concepts. Describe your embodiment of these concepts (using available assets of course). 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 Wiley which one would you recommend to be further developed and why? COMMENT: If you are really, really short of time please share your views with respect to the issue of realizability with us.

ANALYSIS (attempt both part i and part ii)

c) At rest the two "fingers" of the gripper on the robotic arm are held apart by a helical spring. During preliminary testing and inspection of the robot arm, the existing spring failed, zinging by the head of one observer. Wiley's client would like to avoid such potential mishaps and wants you to design a new and improved spring.

i) Design a replacement spring for the robot arm using the information in Figure 1. At L_1 a small force is desired to facilitate easy spring replacement; as the gripper closes to L_2 the spring force increases but ideally should be kept below a maximum value. Be sure to state any assumptions you make.

HINT: the maximum allowed stress of 20,000 psi should occur when the spring is extended to length L_2.

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

ii) Has the spring been designed for infinite life? If not, when should Wiley's client replace the spring to avoid fatigue failures? Again, be sure to state any assumptions you make.

GIVEN: $S_e = 45.0$ kpsi, and $S_{ut} = 50$ kpsi

Useful Equations for Fatigue Loading of Springs:

$$\tau_a = K_B \frac{8F_a D}{\pi d^3} \qquad \tau_m = K_S \frac{8F_m D}{\pi d^3}$$

$$K_B = \frac{2C+1}{2C} \qquad\qquad K_S = \frac{4C+2}{4C-3}$$

And the modified Goodman:

$$\frac{\tau_a}{S_e} + \frac{\tau_m}{S_{su}} = \frac{1}{n}$$

(recall that for shear, $S_{su} = 0.67\ S_{ut}$)

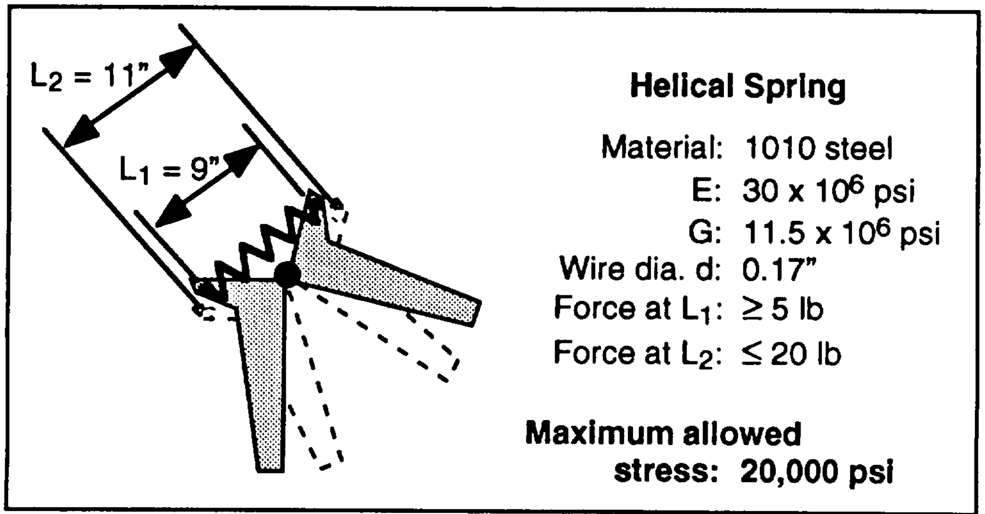


Figure 1 Gripper Spring Design Requirements

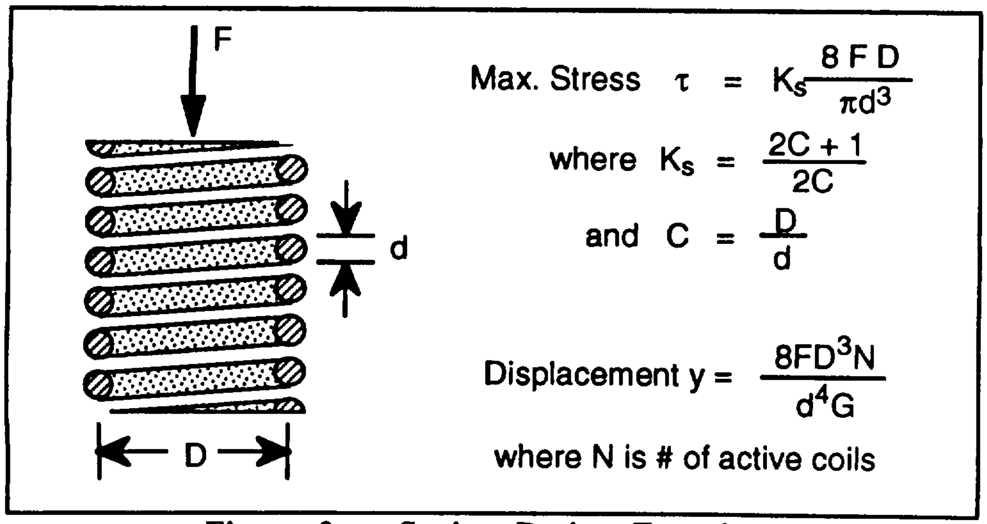


Figure 2 Spring Design Equations