T H E   U N I V E R S I T Y   O F   M I C H I G A N

COLLEGE OF ENGINEERING
Department of Mechanical Engineering

Interim Report

INVESTIGATION OF DESIGN MEANS FOR HOME LAUNDRY APPLIANCES

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INTRODUCTION

The process of design is undergoing a change from procedures based primarily on experience, intuition, and cut-and-try methods to procedures using quantitative analyses developed in the engineering sciences, such as optimization techniques and rational decision-making means. The University needs to find ways of teaching the design process; industrial personnel need to learn about methods developed since they completed their formal education; and industry needs to learn how to apply the latest methods to products and processes.

This project is intended to achieve some of these objectives. By providing financial support to be applied toward the solution of real industrial problems, it advances the educational phase, for it requires consideration of economic, production, and marketing factors, often neglected in classroom problems. Further, the Whirlpool visiting engineer has the opportunity to update his knowledge by attending classes, helping to supervise the research phases of the project, and observing and discussing current research in other areas. Finally, the results of the research should have a direct value to the sponsor.

AREA OF STUDY

The sponsor has designated the general area of study in this project as the design of home laundry appliances, with emphasis on the use of the computer to assist in this design. The project is particularly concerned with system optimization in a combination washer and dryer, pump design methods, and the design of a high-speed brushless motor. The four recipients of Whirlpool Fellowships are working on the several aspects of the project under faculty supervision as follows:

Project Phase	Student	Faculty Adviser	Department
A. Investigation of means of designing a one-horse-power brushless motor to operate at 18,000 rpm from a 110-volt, 60-cycle power source	Gee-In Goo	John Carey	Electrical Engineering
B. Investigation of means of designing pumps having the output characteristics and power demand used in home laundry appliances	James Morgan	Arthur Hansen Robert Keller	Mechnical Engineering
C. Investigation of means of designing the air-water circuit in a combination washer-dryer using an extraction process	Vern Wedeven Douglas Lane	Paul Youngdahl	Mechnical Engineering

The starting date of the project was July 1, 1965. There was no student or faculty activity until the beginning of the fall semester, in the last week in August. The Whirlpool visiting engineer, Mr. Ray Spiegel, used the interim time to become familiar with the University and some of the research in progress.

PROGRESS—FALL SEMESTER

The work done in each of the areas of investigation is summarized below.

A. INVESTIGATION OF MEANS OF DESIGNING A ONE-HORSEPOWER BRUSHLESS MOTOR TO OPERATE AT 18,000 RPM FROM A 110-VOLT, 60-CYCLE POWER SOURCE

Background studies of literature and market availability showed that integral horsepower high-speed brushless motors have been built, but have required a polyphase power source. Brushless direct-current motors which operate in this speed range are available in the one-hundred-horsepower size. Successful methods of commutation, using switching devices such as controlled silicon rectifiers, have been developed. The speed of these motors is a function of the frequency of the a-c power supply.

If the power source can be transformed to a frequency of 300 cps, it should be possible to design a motor to meet the stated criteria. A device to convert current from a-c to d-c and back is one possible means. Problems include obtaining a sinusoidal output and overcoming the impedance changes of the motor during its load cycle. Frequency transformers developed in Russia involve the use of a polyphase power source.

This problem presents a real challenge to the student who is working on it, and offers him an opportunity to study and learn. He intends to work toward developing a frequency multiplier to obtain a frequency of at least 300 cps.

B. INVESTIGATION OF MEANS OF DESIGNING PUMPS HAVING THE OUTPUT CHARACTERISTICS AND POWER DEMAND USED IN HOME LAUNDRY APPLIANCES

Conventional centrifugal pump design has followed highly empirical procedures based on "experience" or art. Pump manufacturers have guarded their own design techniques from competitors, and little useful information has been published. Further, most pump-design work has been applied to high-flow-rate, high-head pumps rather than to the low-flow-rate, low-head pumps needed for this application.

Four possible designs for a centrifugal pump have been examined:

1. Impeller and Volute Design With a Given Loading Distribution

This method, which uses basic fluid-mechanics theory, was developed by Professor A. G. Hansen. Blade loading is described analytically in a polar coordinate reference frame, as a function of pressure, radius, and area. Design of the volute is an integral part of the total pump design, and must be considered simultaneously with the impeller.

2. NASA Turbine-Pump Design Procedure

This method uses the momentum and continuity equations in differential form to express the following:

a. An equation for the derivative of the relative velocity in a direction normal to a streamline.

b. An equation for blade-surface velocity and head rise.

A numerical procedure has been outlined, but more mathematical analysis would be necessary before this method could be applied to centrifugal pumps.

3. Potential-Flow Theory Design

The potential-flow approach is based on a series of Japanese papers. The method defines a frictionless, idealized flow-potential function which is substituted into the governing fluid-mechanics equations to obtain expressions involving flow characteristics. The analysis uses the theory of straight cascades of thin wings, thin-wing lattice theory, etc., to derive expressions in terms of pump geometry.

4. Conventional Procedures Based on Experience and Art

One problem encountered in applying some of these methods is the lack of experimental evidence to substantiate some dubious assumptions and approximations used to simplify the analysis. No performance curves of actual pumps designed by some of these methods exist.

The present program includes designing and building a prototype pump based on the constant-blade-loading, polar-coordinate technique outlined in (1) above. A dynamometer test stand is being built to measure the performance characteristics of present Whirlpool pumps and of new pumps which are to be designed and built.

C. INVESTIGATION OF MEANS OF DESIGNING THE AIR-WATER CIRCUIT IN A COMBINATION WASHER-DRYER USING AN EXTRACTION PROCESS

The digital computer offers a tool for the design of a multicomponent system such as this, through simulation and optimization techniques. The design and performance of any one element may affect the design and performance of some or of all other elements in the system; and optimum design of one component may not yield optimum system performance.

The approach to this part of the program is to discover means of writing descriptions of the various elements and their performance which can be used for computer simulation. Elements being examined are those in the circuit between the clothes and the vacuum blower, which include a duct, a perforated plate, an extraction nozzle, a suds trap, a condenser, and a separator.

Condensation is a simultaneous-rate process of heat and mass transfer. The advantages of a direct-contact condenser over other types include (a) simple construction, (b) removal of lint and dirt from air, (c) no tube fouling, (d) good heat-transfer rates. By writing equations for each effect in the direct-contact condenser, one can derive expressions which will allow computer simulation. It will probably be necessary to do experimental work to obtain values for some of the parameters in these equations.

Describing the performance of a simple duct or nozzle is made a challenging task by the existence of two-phase flow in these passages. The phases do not move at the same velocity, and there may be one or more "flow regimes," such as bubble, plug, slug, stratified, spray, etc. Martinelli has done work which will make it possible to calculate the pressure drop, if flow configurations can be defined.

A search of the literature on vacuum extraction in drying has yielded little pertinent material. The applications reviewed there are related to textiles where there are controlled motion of fibers, a single type of fiber, and fibers with controlled or uniform thickness.

The separator serves to remove water and lint from the air stream without obstructing flow. Some of the parameters to be considered in optimization are separation time, cost, weight, strength, size, maintenance, and geometry. To gain an understanding of the process of separation, it was necessary to study the theory of particle dynamics. Theory for dust and solid particles can be extended to liquid particles when agglomeration and reentrainment effects are taken into account.

Of the types of separators investigated, the cyclone or centrifugal type offers good efficiency over a wide range of operating conditions, small pressure drop, simplicity of construction, low cost, and small size. The geometric proportions of these units have been determined empirically, but equations for calculating pressure drops are available. Experimental confirmation of calculated performance will be required in order to establish confidence in the methods used.

The work described above is all being done under the assumption of steady-state flow, although it is recognized that as clothes alternately cover, partially cover, and expose the nozzle opening, conditions are transient. Once the steady-state model of each section has been formulated, the investigation can be extended into the transient-performance range.

DISCUSSION

Because of the combined educational and research objectives of this project, research does not progress as fast as it would if it were the sole objective. Nevertheless, constructive work is being done, and valuable information is being gathered. It is difficult to evaluate the overall program this early in its operation.