Pearson BTEC Level 4 Higher Nationals in Engineering (RQF)

Unit 11: Fluid Mechanics

Unit Workbook 4

in a series of 4 for this unit

Learning Outcome 4

Hydraulic Machines

Contents

INTRODUCTION

Explore the operating principles and efficiencies of hydraulic machines

- *Hydraulic machinery:*
  - Operating principles of different types of water turbine.
  - Reciprocating and centrifugal pump theory.
  - Efficiencies of these different types of hydraulic machinery.
  - Environmental concerns surrounding hydraulic machines.

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose — Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory — Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example — The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question — Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge — You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video — Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

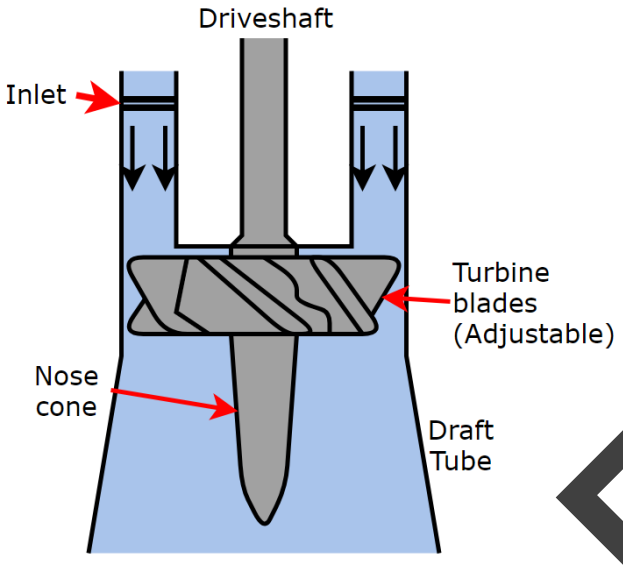

Figure 4.2: Kaplan Turbine

The Kaplan turbine can have a number of configurations:

- Full Kaplan (adjustable inlet vanes and turbine pitch)
- Semi-Kaplan
  - Adjustable inlet vanes – fixed turbine pitch
  - Fixed inlet vanes – adjustable turbine pitch
- Simple propeller turbine (fixed inlet vanes – fixed turbine pitch)

Figure 4.3 shows an estimated efficiency curve for the four systems.

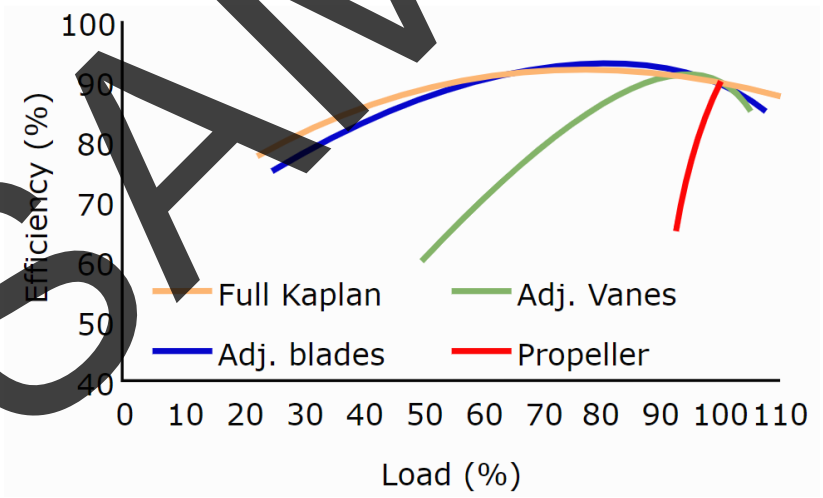

Figure 4.3: Efficiency against load of various Kaplan turbines

4.1.3 Francis Wheel

The Francis wheel is also a reaction turbine. The Hoover Dam in Nevada, USA uses 17 Francis turbines powered by the flow of the Colorado River. A schematic of a Francis wheel turbine is shown in Fig.4.4. While the Pelton wheel and Kaplan turbines both use an axial inflow to the turbine (straight line), Francis turbines use a radial inflow, but the flow ends up axial once leaving the turbine. The fluid flows in and is slowly guided

4.2 Pumps

4.2.1 Centrifugal Pump

A centrifugal pump is one that uses rotation to move the fluid, shown in Fig.4.5. It has a very similar shape and design to the Francis wheel turbine. The fluid is brought into the system through the centre of the impeller (which, typically, is not the centre of the volute) and constant rotation through the impeller blades will direct the fluid to push out through the discharge pipes. Due to the shape of, and position of the impeller, as the distance between the impeller and the volute increase, there is a build-up in pressure in the system, which will push the fluid out of the system.

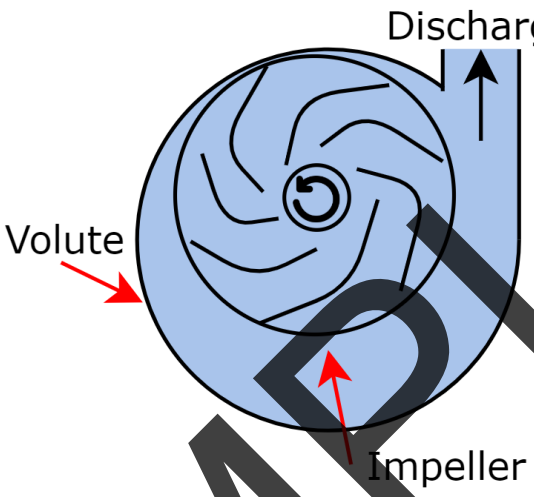

Figure 4.5: A centrifugal pump

The efficiency of a centrifugal pump is given as Eq.4.2:

$$\eta = \frac{\rho g Q h}{P_m} \quad (4.2)$$

Where:

- ρ is the fluid density $(\mathrm{kg/m^3})$
- g is the acceleration due to gravity $(\mathrm{m/s^2})$
- Q is the volumetric flow rate $(\mathrm{m^3/s})$
- h is the head energy added to the fluid (m)
- P_m is the mechanical power input into the system (W)

4.2.2 Reciprocating Pump

Reciprocating pumps are piston mechanisms that use pressure differentials to move fluid. A common use of this system is to extract water from mines to prevent flooding. The process of the system can be broken down into several stages.

$\theta = 0°$: The crank and piston system are considered to be top dead centre (TDC). This is the maximum reach of the piston. In this position, the intake valve is open, and the discharge valve is closed.

$\theta = 270°$: The piston is now pushing forward and pushing the water out of the discharge pipe.

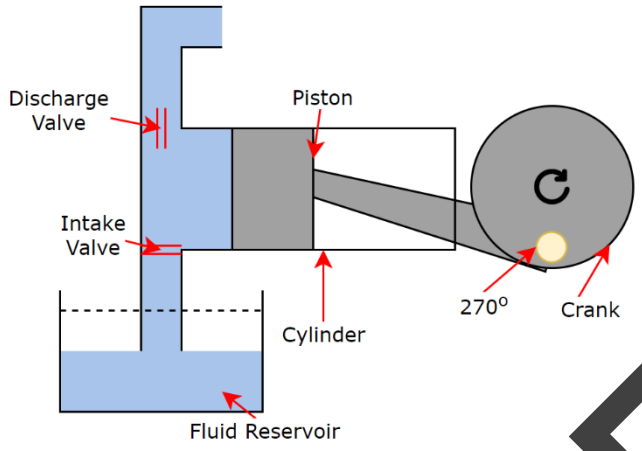

Figure 4.9: A reciprocating pump at $\theta = 270°$

$\theta = 0°$: The piston is now back to TDC, the system closes the discharge valve and opens the intake, ready for the cycle to repeat itself

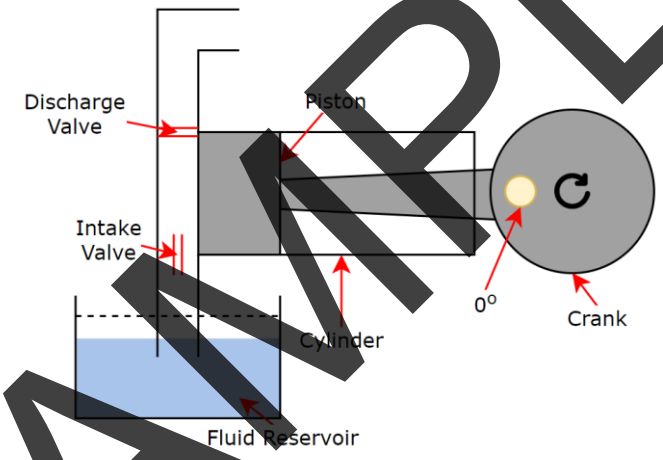

Figure 4.10: The final point of a reciprocating pump (back at TDC)