AMES

The Efficiency of
Various Hand Hoists

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THE EFFICIENCY OF VARIOUS HAND HOISTS

BY

ALBERT WILSON AMES

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ALBERT WILSON AMES

ENTITLED

THE EFFICIENCY OF VARIOUS HAND HOISTS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE

O. A. Lutiwiler
Instructor in Charge

APPROVED:

HE HEAD OF DEPARTMENT OF MECHANICAL ENGINEERING
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Efficiency of Various Hand Hoists.

INTRODUCTION.

Hoisting devices are as old as civilization, but it was not until the year 1854 that a safe, powerful, convenient and portable hand hoist was invented by Thomas A. Weston. This was the modern differential of today based upon the principle of the old Chinese windlass. The efficiency of this device is so low that the load is self-sustained. The development of hand-hoists or chain blocks, as they are commonly called, has increased the lifting power of a man and his efficiency nearly three times that of the differential hoist. The purpose of this thesis is to show the relative efficiency between several types of hand-hoists.
Classification of Hand Hoists.

There are but three distinct types of hand hoists viz. -
differential, screw and spur geared, each increasing in lifting
power and efficiency in the respective order named.

General Discussion of Types.

The differential hoist has its velocity ratio determined
by the differential sheave. Its efficiency is so low that it is
self-locking, that is, it sustains the load, due to the internal
friction.

The screw hoist transmits its power thru a worm to a
gear fastened to the load sheave. The efficiency of the screw
hoist depends upon the velocity ratio or pitch of the worm and
the self locking feature is dependent upon whether the efficiency
is below or above 50%. If the efficiency is above 50% the load
must be sustained by an additional device.
3.

The spur geared hoist consists of a gear reduction by plain spur gears or epicyclic gear train. It has a high efficiency and therefore must have a sustaining mechanism. In this type the functions of hoisting and lowering are separate in-as-much-as the lowering force simply releases the brake sustaining mechanism so that the load may run down.

Automatic brake or sustaining mechanism.

All automatic brakes used in hoists work on the same general principle as follows:-

Each consists essentially of four parts: (1) a plate or friction surface fastened to the power shaft; (2) a dog or pawl on the frame of the hoist engaging with the teeth on a (3) friction surface plate or disc turning freely on the power shaft; (4) a power sheave turning freely on a screw thread cut on the power shaft, though its motion is generally limited.

The action is as follows:- To hoist the load, the power sheave screws upon the shaft and clamps the friction surfaces so that the shaft with its attached friction disc rotates with the power sheave.

The load is sustained by the pawl on the frame engaging with the teeth of the disc and in turn prevents the disc and shaft from running back.

To lower load, the power sheave or hand wheel is turned so as to unscrew the wheel from the shaft. As this is unscrewed the pressure between the friction surfaces is relieved, and the
load due to the action of gravity will run down thereby rotating the power shaft and at the same time tending to clamp the hand sheave against the friction surfaces, unless the power sheave is continually unscrewed.
Method of Procedure in making Tests.

All hoists tested were of 2000 pounds capacity that being the average size available for testing. The pull required on the hand chain to raise one quarter, one half, three quarters, and full load for each hoist was noted, also, the amount of chain overhauled for raising the load one foot, the pitch of chains, number of pockets on chain sheaves and the velocity ratio of the gear train. With this data the ratio of the useful work to the applied work or in other words the efficiency for each load could be easily calculated.

The pull on the hand chain was measured by means of a traction dynamometer hooked to the chain and the pull applied directly to the dynamometer. For the heavy pulls a lever was used to give a steady pull on the dynamometer. The fulcrum of this lever was anchored to the floor, and the dynamometer was attached to the short arm while the force was applied on the long arm. The following illustration will show the general arrangement. The load was drawn up near to the hoist, as shown, simply for the photograph, the tests being made while the load was in a lower position and the dynamometer hung and worked freely.
GENERAL ARRANGEMENT OF APPARATUS.
Differential Hoist.

The hoist used was an old one but in good condition and well lubricated.

The cut shows the type and make used, also comparative sizes manufactured.
The following is a data sheet with calculations.

Hoist—Weston Differential.
Make—Yale and Towne.
Capacity—2000 pounds.

<table>
<thead>
<tr>
<th>Load lb.</th>
<th>Pounds Pull on hand chain</th>
<th>Efficiency Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raising</td>
<td>Lowering</td>
</tr>
<tr>
<td></td>
<td>Actual</td>
<td>Average</td>
</tr>
<tr>
<td>$\frac{1}{4}$</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>$\frac{1}{2}$</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>84</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>210</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>217.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chain—10.75 inches per 7 links, pitch $=\frac{10.75}{7} = 1.54$ inches

Number of pockets on differential sheave 14 and 15.

$\frac{10.75}{7} \times 15 = 23.05$ in. hand chain per rev. of diff. sheave.

$\frac{10.75}{7} \times 14 = 21.5$ " " " " " " " "

$\frac{1.55}{2} = 0.775$ in. load raised per rev. of diff. sheave.

$\frac{23.05}{0.779} = 29.75$ velocity ratio of hand chain to load.

$\frac{\text{pounds load}}{29.75 \times \text{pull on hand chain}} = \text{efficiency}$.

Weight of hoist $= 49.5$ pounds.
9.

Screw Hoist.

Cuts show the external view and broken away casing of hoist tested. The square headed screw at the end of the worm is for increasing or decreasing the friction by screwing it in or out, this is accomplished by the screw taking the pressure off of the large surface at the end of worm or letting the pressure come there as the case may be. It is to be adjusted so that the load will not quite run down unaided.
Diagramatic drawing of screw hoist.

a. - Worm shaft.
b. - Hand chain sheave.
c. - Worm (steel).
d. - Gear (bronze).
e. - Casing and frame.
f. - Screw for adjusting internal friction.
g. - Thrust bearing surface.
Hoist.—Screw.

Make.—Edwin Harrington, Son and Company.

Capacity.—2000 pounds.

<table>
<thead>
<tr>
<th>Load</th>
<th>Pounds pull on hand chain</th>
<th>Efficiency per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Average</td>
</tr>
<tr>
<td>1/4</td>
<td>500</td>
<td>22</td>
</tr>
<tr>
<td>1/2</td>
<td>1000</td>
<td>50</td>
</tr>
<tr>
<td>3/4</td>
<td>1500</td>
<td>72</td>
</tr>
<tr>
<td>Full</td>
<td>2000</td>
<td>88</td>
</tr>
</tbody>
</table>

Pitch of hand chain, 11.8 per 7 links = 11.8/7 = 1.69 inches.

" Load " 11.55 " 6 " = 11.55/6 = 1.93 "

Lead of single thread worm = 1/2 inch.


" load " = 6.

Velocity ratio = \( \frac{28 \times 11.8 \times 19 \times 6}{7 \times 6 \times 11.55} = 77.7 \)

77.7 feet hand chain overhauled to raise load one foot.

\[ \frac{\text{pounds load}}{77.7 \times \text{pull on hand chain}} = \text{efficiency}. \]

Weight of hoist = 77 pounds.
This is a plain balanced gear train hoist with an automatic brake or sustaining mechanism. Instead of a pawl and ratchet this brake has a gear and pinion with special teeth which permit the gears to run in only one direction. This avoids the noise of a clicking pawl.

a.- Driving pinion.
b.- Gear.
f.- Gear on load shaft.
g.- Load chain sheave.
i.- Casing.
j.- Friction surface on shaft.
k.- Hand chain sheave.
l.- Free friction surface with teeth.
m.- Pinion acting as a pawl.
n.- Yoke for locking teeth.
Hoist.—Peerless.

Maker.—Edwin Harrington Son and Company.

Capacity.—2000 pounds.

<table>
<thead>
<tr>
<th>Load</th>
<th>Pounds pull on hand-chain</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raising</td>
<td>Lowering</td>
</tr>
<tr>
<td>lb.</td>
<td>Actual</td>
<td>Average</td>
</tr>
<tr>
<td>1/4</td>
<td>20</td>
<td>20.5</td>
</tr>
<tr>
<td>1/2</td>
<td>1000</td>
<td>40</td>
</tr>
<tr>
<td>3/4</td>
<td>1500</td>
<td>58</td>
</tr>
<tr>
<td>Full</td>
<td>2000</td>
<td>84</td>
</tr>
</tbody>
</table>

Pitch of hand chain, 11.8 per 7 links = \( \frac{11.8}{7} \) = 1.69 inches.

" " load " 10.45 " 6 " = \( \frac{10.45}{6} \) = 1.74 "

Pockets in hand sheave = 19.

" " load " = 5.

No. teeth in drivers = \( 10 \times 9 \) = .0948 gear ratio.

" " " driven = \( 38 \times 25 \)

\[
\frac{19 \times 11.8 \times 5}{.0948 \times 5 \times 7 \times 10.45} = 32.3 \text{ velocity ratio}
\]

\[
\frac{\text{pounds load}}{32.3 \times \text{ pull on hand chain}} = \text{ efficiency.}
\]

Weight of hoist = 79 pounds.
Spur gear type, "Imperial" hoist.

This Imperial hoist made by the Franklin Moore Company, Winsted, Connecticut, is a new hoist upon the market. It contains a plain spur gear train. It has a low velocity ratio and consequently a relatively high efficiency. Because of the high speed of hoisting and the hard pull on full load, this hoist is better adopted to light loads.
Hoist. - Imperial.

Maker. - Franklin Moore Company.

Capacity. - 2000 pounds.

<table>
<thead>
<tr>
<th>Load</th>
<th>Pounds pull on hand chain</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb.</td>
<td>Actual</td>
<td>Average</td>
</tr>
<tr>
<td>1/4</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>1/2</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>3/4</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Full</td>
<td>96</td>
<td>104</td>
</tr>
</tbody>
</table>

Hand chain 11.5 in. per 6 links, pitch = \( \frac{11.5}{6} \) = 1.92 inches.

Load " 10.6 " " 5 " " = \( \frac{10.6}{5} \) = 2.12 "

No. pockets on hand chain sheave = 15.

" " " load " " = 5.

No. teeth in drivers \( \frac{9 \times 14}{35 \times 34} \) = .1058 gear ratio.

\[ \frac{1.92 \times 15}{5 \times 2.12 \times .1058} = 25.6 \text{ velocity ratio} \]

Efficiency = \( \frac{25.6 \times \text{pull on hand chain}}{\text{pounds load}} \)

Weight of hoist = 71.5 pounds.
The "Triplex" hoist is a special gear hoist of the epicyclic type.

The cuts show a cutaway view of the hoist and the gear end with case removed. The load sheave is fastened to the yoke carrying the intermediate gears which revolve and turn the yoke thru the action of the driving pinion and the stationary annular gear.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
</tr>
</tbody>
</table>

\[
\frac{42 \times 29}{11 \times 12} = 0 - \frac{42}{11} - 1
\]

\[
1 + \left[ \frac{42 \times 29}{11 \times 12} \right] = 10.24 = \text{gear ratio}
\]

**Determination of gear ratio**
Hoist.—Triplex.

Maker.—Yale and Towne.

Capacity.—2000 pounds.

<table>
<thead>
<tr>
<th>Load</th>
<th>Pounds pull on hand chain</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raising</td>
<td>Lowering</td>
</tr>
<tr>
<td>16 lb.</td>
<td>Actual</td>
<td>Average</td>
</tr>
<tr>
<td>1/4 lb</td>
<td>500</td>
<td>20</td>
</tr>
<tr>
<td>1/2 lb</td>
<td>1000</td>
<td>40</td>
</tr>
<tr>
<td>3/4 lb</td>
<td>1500</td>
<td>70</td>
</tr>
<tr>
<td>Full load</td>
<td>2000</td>
<td>86</td>
</tr>
</tbody>
</table>

Hand chain 10.5 in. per 5 links, pitch = \( \frac{10.5}{5} = 2.1 \) inches.

Load " 10.6 " " 5 " " = \( \frac{10.6}{5} = 2.12 \) "

No. pockets hand chain sheave = 15.

" " load " " = 5.

Gear ratio from table on preceding page = 10.24

\[
\frac{10.24 \times 2.1 \times 15}{2.12 \times 5} = 30.5 \text{ velocity ratio of chains.}
\]

Efficiency = \( \frac{\text{pounds load}}{30.5 \times \text{pull on hand chain}} \).

Weight of hoist = 80 pounds.
"Cyclone" Hoist.

The illustrations show a general view and diagramatic drawing of the Cyclone hoist. The hand chain sheave \( i \) turns the pinion \( b \) which drives gears \( c \). Gear \( c \) is fastened to shaft and eccentric \( e \), so that as \( c \) turns the eccentrics cause the yoke with annular gear teeth \( f \) to oscillate and drive the load gearing.
Hoist.—Cyclone.

Maker.—Chisholm and Moore M'f'g. Company.

Capacity.—2000 pounds.

<table>
<thead>
<tr>
<th>Load</th>
<th>Pounds pull on hand chain</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raising</td>
<td>Lowering</td>
</tr>
<tr>
<td></td>
<td>Actual</td>
<td>Average</td>
</tr>
<tr>
<td>1/4</td>
<td>500</td>
<td>26</td>
</tr>
<tr>
<td>1/2</td>
<td>1000</td>
<td>44</td>
</tr>
<tr>
<td>3/4</td>
<td>1500</td>
<td>72</td>
</tr>
<tr>
<td>Full</td>
<td>2000</td>
<td>92</td>
</tr>
</tbody>
</table>

Hand chain 9.55 in. per 6 links, pitch = $\frac{9.55}{6} = 1.59$ inches.

load " 11.5 " 6 " = $\frac{11.5}{6} = 1.92$

No. pockets on hand chain sheave = 16.

" " " load " " = 6.

Driving pinion has 20 teeth.

Driven gear " 24 "

Yoke " 24 "

Load gear " 22 "

\[ \frac{20}{24} \times \frac{24 - 22}{22} = .07575 \text{ gear ratio}. \]

\[ \frac{16 \times 1.59}{.07575 \times 1.92 \times 6} = 29.2 \text{ velocity ratio of chains}. \]
Efficiency = \frac{\text{pounds load}}{29.2 \times \text{pull on hand chain.}}

Weight of hoist.= 90 pounds.
Efficiency-Load Curves for three types of Hand Hoists
Pull-Load Curves for three types of Hand Hoists.
CONCLUSIONS.

The efficiency varies inversely with the velocity ratio as is seen in the different types of hoists, but not to any mathematical degree of exactness. Any variation in the efficiency of hoists similar in other respects is due to the difference in workmanship and construction. This is shown in the "Cyclone" hoist which has the highest efficiency due to roller bearings on the load shaft. These last two statements are based upon tests and information other than that contained in this thesis. The lowering force on all hoists is small except when starting to lower. This gives a negative efficiency which is not given consideration in this work. In the geared hoists the braking mechanism should be so adjusted that after starting to lower, the load should run down simply by the weight of the arm on the hand chain. In the selection of a hoist many factors besides efficiency must be taken into account such as first cost, nature of work, actual time the hoist is to be in use and load variations.