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STUDY OF ACCELERATING TORQUE REQUIREMENTS OF A RECIPROCATING COMPRESSOR

AUTHORS

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ABSTRACT

During startability tests, a reciprocating compressor can either 1) start and run without any problem or 2) not start at all or 3) turns over but does not start or 4) starts and crosses the critical point and then stalls. Of the above phenomena, accelerating torque of the compressor depends on the pressure built up in the system. In the present paper, the torque requirements are studied and the performance of the theoretical motor design is compared at different voltages. And also different starting phenomena are then explained from the experimental results.

INTRODUCTION

One of the important parameters that is considered during the design of a motor for a hermetic compressor is the starting torque requirement. Using this starting torque, the lowest voltage down to which the compressor can start can be estimated. However, the starting torque alone is not sufficient for starting and running the compressor. The information needed is the accelerating torque characteristic of the pump.

For sustained running, the motor pull-up torque has to be equal or higher than the accelerating torque characteristic of the pump at all speeds till the compressor crosses the critical point. Parameters such as the balanced pressure at starting, the rates at which the suction and discharge pressures change depend on the system and operating conditions. The other parameters are fixed for a given compressor design. Friction, however, is a function of both the design and the operating conditions such as the amount of refrigerant dissolved in the oil and the speed. For a given motor design, only the winding temperature, and the voltage affect the pull-up torque.

An experimental method is described for evaluating the accelerating torque characteristic of the compressor and also a theoretical model for estimating this is presented.

At different supply voltages the motor torques are compared with torque requirements of compressor and the different starting phenomena are explained.
EXPERIMENTAL SET UP

The experimental set up consists of the following items:
- Test compressor without housings
- Torque and Speed sensor coupled to compressor shaft
- Drive motor coupled to Torque sensor shaft
- Special housing to enclose above items with air tight lid

The diagram showing the experimental set up is in fig 1.0.

The suction and discharge tubes of the test compressor are connected to a system. The system is charged after evacuation to normal charge. The leads of the drive motor are connected to the power supply and leads of the speed and torque sensor are connected to the indicators and indicators output connected to a storage oscilloscope. When the drive motor is energised the speed and torque values are recorded in the oscilloscope for a given time. Similarly the transient behaviour of the suction and discharge pressures are also recorded using storage oscilloscope. The observations of the experiment are listed in table 1.0.

The behaviour at lower speeds could not be recorded properly as the sensor used is not precision enough to record quick responses. However by using the precision instrumentation this can also be recorded.

The Frictional Torque is measured from first principles.

The experiment is repeated for a Low Back Pressure application compressor for which the recorded readings are given in table 2.0.

THEORETICAL MODEL

A. STARTING TORQUE

The starting torque requirement depends on the crank angle position (Reference [1]), the cylinder volume at that crank angle, system equalised pressure at the time of starting, piston area, the differential pressure required to open the discharge valve, the polytropic index for the refrigerant and the static friction. The starting torque can be expressed as

\[ T_s = f(P_e, V(\phi), P_c, A_p, n, x) + T_f \]  

\[ V(\phi) = V_c + A_p \frac{Cr}{2} \left[ 1 + \cos(\phi) + \frac{Cl}{Cr} \left( 1 - \frac{1 - \sqrt{1 - \frac{Cr}{Cl} \frac{2}{2} \sin(\phi)}}{2} \right) \right] \]

\( T_f \) is calculated based on Reference [2].
Ts  Starting Torque
Ap  Piston Area
n  Polytropic Index
Vc  clearance volume
Cl  Connecting rod length
Pe  Equalised pressure at the time of starting
Pc  Pressure in the cylinder to open the Discharge Valve

Tf  Frictional Torque
V(∅)  Cylinder Volume
x  Piston linear displacement
Cr  Connecting rod radius
∅  Crank Angle

B. ACCELERATING TORQUE

The transient behaviour of the suction and discharge pressures in the system are calculated using References [3-5]. The Indicated work is calculated from the polytroic equation

\[
W_i = \frac{n}{n-1} P_s V_s \left( \frac{P_d}{P_s} - 1 \right)
\]

(3)

Ps  Suction pressure
Pd  Discharge pressure
Vs  Volume of Vapour sucked

The accelerating torque is calculated as shown below

\[
T_a = W_i \times C + T_{df}
\]

(4)

C  Conversion factor
Tdf  Torque required to overcome Dynamic friction

Here Tdf is assumed to be 5% of the calculated Torque.

DESCRIPTION OF RESULTS

As shown in Fig 2 the motor selected for the HBP compressor behaves in the following manner at different voltages. At 120V motor does not start (No Start) at all. At 140V motor turns and stalls (Turns on No Start). At 160V motor starts and stalls after reaching the full speed. Above 160V it starts and runs without any problem.

As shown in Fig 3 the motor selected for the LBP compressor behaves in the following manner. At 120V motor does not start at all. At 140V and 160V the motor starts and reaches full speed and stalls. Above 160V it starts and runs without any problem.

CONCLUSIONS

The values calculated from the proposed theory are matching with the experimental values satisfactorily. Further studies in this direction may extend the applicability of this theory to different applications to predict the Torque requirements of the compressor and hence motor can be designed appropriately to suit the compressor.
REFERENCES


FIG 1. SCHEMATIC DIAGRAM OF TEST SETUP
## COMPARISON OF THEORETICAL AND EXPERIMENTAL DATA OF HBP COMPRESSOR

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<th>TIME (Sec)</th>
<th>SUCTION PRESSURE (Psia)</th>
<th>DISCH. PRESSURE (Psia)</th>
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### Table 1.0

## COMPARISON OF THEORETICAL AND EXPERIMENTAL DATA OF LBP COMPRESSOR

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### Table 2.0
FIG 2

SPEED VS TORQUE CURVES OF HBP COMPRESSOR AND MOTOR

FIG 3

SPEED VS TORQUE CURVES OF LBP COMPRESSOR AND MOTOR (CSIR)