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Experimental Study of Leakages in Reciprocating Compressors

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***Abstract*— An assessment of various observing procedures was connected tentatively on responding compressors. Eg. Dynamic chamber weight and crankshaft Instantaneous Angular Speed (IAS), for the recognition and conclusion of valve deficiencies in a two - stage responding compressor which was effectively distinguished and analyzed the flaw in machine. The spillage was distinguished and the impact of the shortcomings on compressor execution was checked and the distinctions with the ordinary, exhibitions were noted and were utilized for the recognition and finding of flaws. The venture finishes up with what is thought to be an one of a kind methodology for condition checking. To begin with, each of the two most helpful strategies is utilized to create a Truth Table which points of interest the circumstances in which every system can be utilized to distinguish and analyze a shortcoming. The Truth Tables were joined into a solitary Decision Table which will give a one of a kind and solid strategy for recognition and analysis of each of the individual shortcomings brought into the compressor. This gives precise analysis of compressor.**

Keywords—Compressor, Reciprocating, Crankshaft, Instantaneous Angular Speed

I. Introduction

Reciprocating compressors are a standout amongst the most well-known machines being used in industry. The auspicious discovery of shortcomings, which might impact the execution, is relied upon to help in both decreasing upkeep costs and expanding the plant proficiency. Compressor valves can be the biggest single reason for unscheduled responding compressor shutdowns. The compressor is one of the primary parts of warmth pump as it sets its mass stream rate which oversees the warmth streams. It is consequently the first part of the warmth pump to be displayed. This task presents another checking method for the responding compressor.

A definitive point is to create a 'Choice Table' which will permit, the interesting ID of any of the given valve flaws. It likewise presents the estimation of prompt precise velocity (IAS) so as to evaluate its suitability for condition checking (CM) and prescient upkeep. Much consideration has been paid to observing and diagnosing deficiencies in responding compressors. The sorts of compressors utilized as a part of local warmth pumps are typically the responding and scroll ones. Responding compressors are for the most part utilized similarly as low warm power is concerned (warming water) while scroll compressors are broad for space warming.

A wide range of models of those two sorts of compressors with various degrees of multifaceted nature are found in the writing. From one perspective, there are models of responding compressors in which the compressor is partitioned in a few volumes (components, for example, pressure chamber, valves.).Those models require information exceptionally hard to get or known just by the constructor and non-accessible in the datasheets. The volumes of the diverse components and the successful range of valves are likewise required.

II. Methodology

- A responding air compressor was embraced for the trial study as appeared in Fig 1. To perform the trial think about, an optical encoder, weight transducers and other essential instrumentation was appended to the compressor. The weight transducers were introduced on the leaders of the first and second stage barrels by penetrating a little gap in the chamber head, where the weight sensor was introduced. The optical encoder was mounted to the end of crankshaft on the flywheel at the compressor crankshaft side. A marker was utilized to give a trigger on each complete unrest of the flywheel.

- The information procurement programming is an upgraded Windows based interface, ready to perform online information testing and screen compressor parameters, for example, quick precise rate (IAS) and element weigh.

- The taking after area demonstrates the exploratory information measured of momentary precise pace (IAS) over a compressor cycle for three estimations of the release weight, 0.27, 0.54 and 0.82 MPa. The deliberate of the IAS was changed over the cycle and fluctuated with release weight. Variety of IAS with variety of release weight was experienced.

- The variety was minor, in the middle of 453 to 455 rpm. For 0.82 MPa the base IAS was 423 rpm, for 0.54 MPa comparing to 428 rpm and 0.27MPa relating to 434 rpm.

Fig 1: Experimental Setup test rig

III. Detection of Suction Valve Leakagaes in Stage I and II

A. *Leakage of 1^{st} Stage suction valve*

The valve spillage happens essentially at the suction point in the suction valve and at the release valve at the release point. The high weight barrel releases into a tank in which the weight was measured as 816kPa (120psi), while the low weight chamber releases direct to the second stage with a back weight of around 260kPa (38psi). Unmistakably the impacts of spillage in the suction or release valves of first and second stages are prone to be not quite the same as one another. The deviation of the weight signal from ordinary because of valve spillage can be seen plainly, amid release and extension, especially of the first stage. The suction valve of the 1ststage opens prior the more prominent the spillage, because of the lower leeway weight in the barrel brought about by the spillage itself. Spillage through the 1ststage suction valve likewise causes the first stage release valve to open later and close prior. A defective suction valve in the 1ststage can influence the weight in the 2ndstage and thus valve development, where both the suction valve and the release valve open somewhat later, both because of the lower than typical weight encourage from 1^{st} stage.

B. *Leakage of 2^{nd} Stage suction valve*

There additionally happens a spillage in the second phase of the suction valve as decided. The impact of the defective suction valve in the second stage is to expand the deliberate weight in the first stage. The 1ststage suction valve opens later because of expansion of the leeway chamber weight, and the release valve opens later in light of the fact that the spillage through the 2ndstage suction valve expands the weight in the funnel between the barrels, requiring a more prominent weight contrast to open the release valve of the 1ststage. There is a slight reduction in the greatest weight came to in the 2ndstage chamber, the release valve closes somewhat prior so re-development happens marginally prior, the suction valve open prior and there is a little upward move in the suction line.

IV. Detection of Discharge Valve Leakages in Stage I and II

C. *Leakage of 1^{st} Stage discharge valve*

The Table 1 demonstrates the tentatively measured element weight in the 1^{st} and 2^{nd} stage barrels for a 1ststagedischarge valve. As consequence of the spillage the barrel weight expected to open the 1ststage release valve is reaches quicker. The explanation behind this is high weight air moving through the release spill raises the pressure weight over that which ordinarily exists. As result the weight expected to open the valve is come to sooner. Suction valve movement is likewise adjusted in light of the fact that the higher barrel weight marginally postpones the time at which the weight turns out to be sufficiently low to open the suction valve. The 1^{st} stage release valve spillage additionally influences the 2^{nd} stage barrel weight and the subsequent valve developments. The purpose behind this is the weight from the 1ststage is lower than for reference condition and this current make's low nourish weight the 2ndstage. The impact increments when the spillage seriousness increments. Between wrench points of around 130o to around 230o the IAS waveform is moved upwards (expanding IAS). This is because of the lower weight in the 2ndstage barrel amid its pressure stroke and ensuing lower burden following up on the crankshaft. Between wrench points of around 240o to around 280o the IAS is moved downwards (diminishing IAS).This is because of the higher weight in the 1ststage barrel amid its pressure time created by the high weight spillage back through release valve amid suction and subsequent higher burden following up on the crankshaft.

D. *Leakage of 2^{nd} Stage discharge valve*

The deliberate variety in barrel weight in both 1^{st} and 2^{nd} stage chambers, because of a 2^{nd} stage cracked release valve. The most evident perception is the 2^{nd} stage release valve opens prior the more prominent the spillage, since high weight air streaming once again from the capacity tank through the release spill brings the weight up in the barrel over that which regularly exists. As result the weight expected to open the valve is come to sooner. The 2^{nd} stage suction valve opens later the more prominent the spillage, for the same reasons the release valve opens prior. The most extreme weight came to in the 1^{st} stage cylinder increments with spillage. The 1^{st} stage suction valve opens later the more noteworthy the spillage in light of the fact that the higher barrel weight defers the time at which the weight is sufficiently low to open the valve. The release valve of the 1^{st} stage closes later in light of the fact that the higher weight saw amid the suction time of 2^{nd} stage leads to higher weight in the cooling framework which, thusly, prompts the release valve of 1^{st} stage opening later. Between wrench points of around 30^{o} to around 130^{o} the IAS is changed as saw from the trial perusing and increments amid the suction time of both first and second stages which come about because of higher weight spilling back and acting to compel the cylinder down the barrel, bringing down the heap following up on the wrench shaft. Be that as it may, between wrenches points of around 140^{o} to around 350^{o} the IAS worth is changed and diminished generously. This is the consequence of higher than typical weights amid pressure in both 1^{st} and 2^{nd} stages. The previous is because of back weight from 2^{nd} stage barrel bringing about higher release weight for the first stage

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IV. RESULTS AND DISCUSSIONS

A. *Plots obtained at various pressure with respect to change in Crank Angle at 3kgf/cm²*

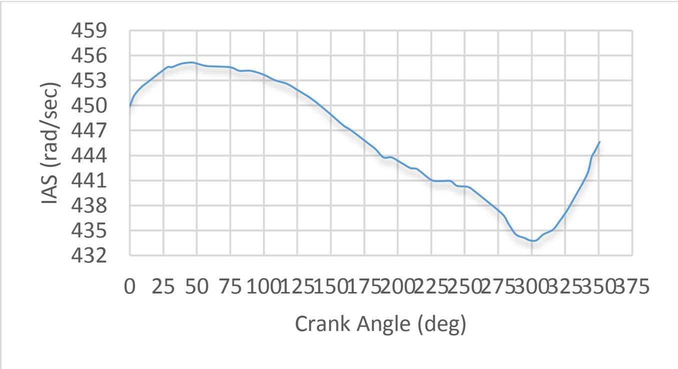

Fig 2: Pressure vs Crank Angle at 3 kgf/cm2

B. *Plots obtained at various pressure with respect to change in Crank Angle at 5kgf/cm²*

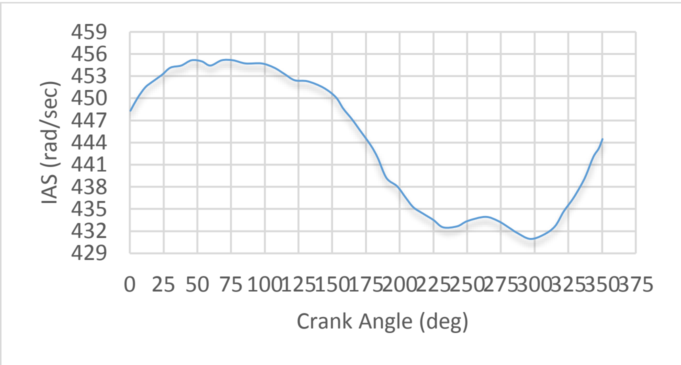

Fig 3: Pressure vs Crank Angle at 5kgf/cm2

C. *Plots obtained at various pressure with respect to change in Crank Angle at 7kgf/cm²*

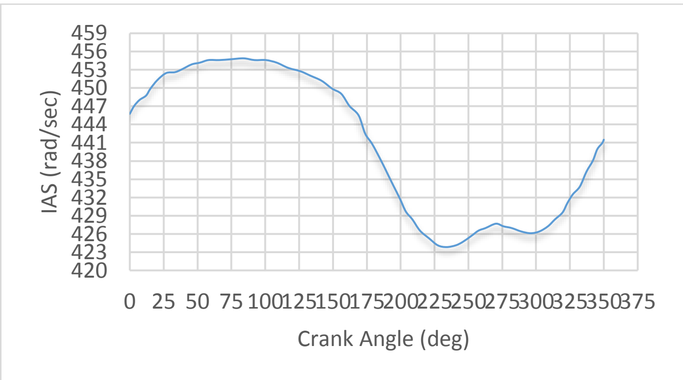

Fig 4: Pressure vs Crank Angle at 7 kgf/cm2

D. *Plots obtained at various pressure with respect to change in Crank Angle for Low Pressure Cylinder at 3kgf/cm²*

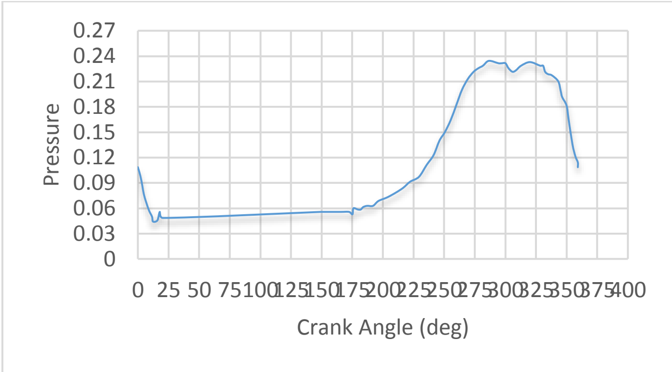

Fig 5: Stage-1 Pressure vs Crank Angle at 3 kgf/cm2

E. *Plots obtained at various pressure with respect to change in Crank Angle for Low Pressure Cylinder at 5kgf/cm²*

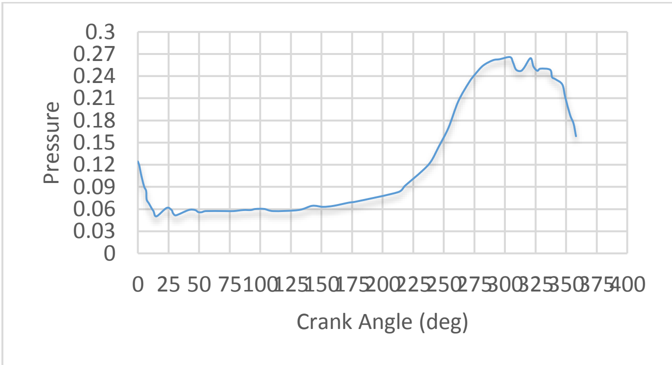

Fig 6: Stage-1 Pressure vs Crank Angle at 5 kgf/cm2

F. *Plots obtained at various pressure with respect to change in Crank Angle for Low Pressure Cylinder at 7kgf/cm²*

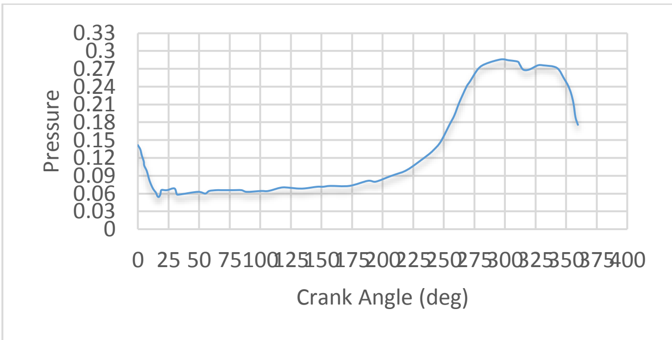

Fig 7: Stage-1 Pressure vs Crank Angle at 7 kgf/cm2

G. Plots obtained at various pressure with respect to change in Crank Angle for High Pressure Cylinder at 3kgf/cm²

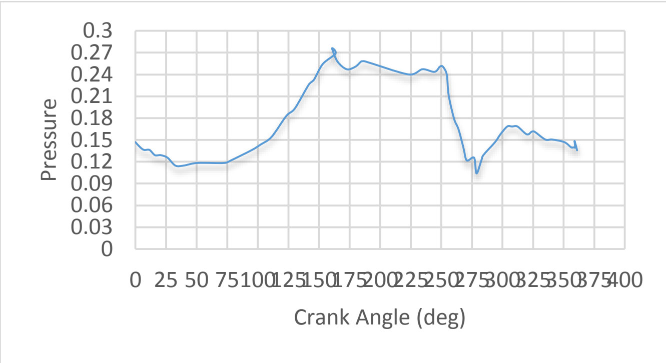

Fig 8: Stage-2 Pressure vs Crank Angle at 3 kgf/cm2

H. Plots obtained at various pressure with respect to change in Crank Angle for High Pressure Cylinder at 5kgf/cm²

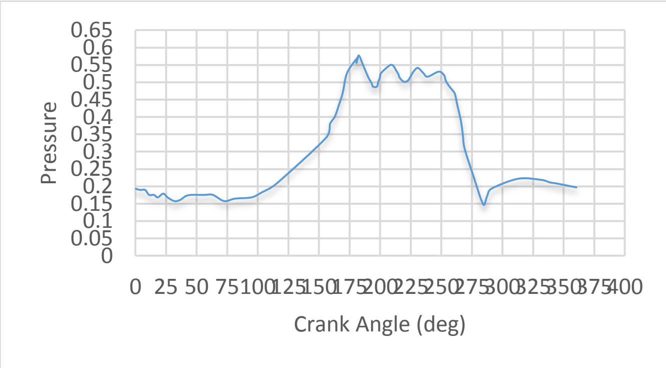

Fig 9: Stage-2 Pressure vs Crank Angle at 5 kgf/cm2

I. Plots obtained at various pressure with respect to change in Crank Angle for High Pressure Cylinder at 7kgf/cm²

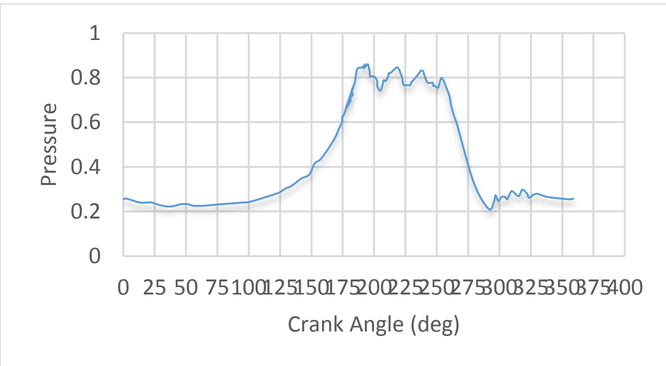

Fig 10: Stage-2 Pressure vs Crank Angle at 7 kgf/cm2

V. DYNAMIC PRESSURE ANALYSIS (TRUTH TABLE)

In Table I, a time domain analysis only was performed and information about the valve fault is contained in the amplitude of the pressure signal and its time of occurrence within the cycle. Table II shows the Truth Table for the IAS signal for the four common valve faults. Here a time domain analysis only was performed and information about the valve fault is contained in the amplitude of the angular speed and its time of occurrence within the cycle. This leads to increase the load acting on the crank shaft. From the Truth Table, a number of identification markers for the different valve faults may be seen. For example, lower than normal IAS over the range of crank angles 0 to about100° indicates a leaky 1st stage valve. A substantial decrease in instantaneous angular speed from about 130° to about 360° should be taken as a strong indication of a leaky 2nd stage discharge valve.

TABLE I. DYNAMIC PRESSURE TRUTH TABLE FOR VALVE FAULTS IN RECIPROCATING COMPRESSOR

Signatures	1st Stage SV				1st Stage DV				1st stage CP		2nd Stage SV				2nd Stage DV				2nd stage CP	
	Valve open		Valve close		Valve open		Valve close				Valve open		Valve close		Valve open		Valve close			
	-	+	-	+	-	+	-	+	L	H	-	+	-	+	-	+	-	+	L	H
1st stage leaky SV	*					*	*		*							*				
2nd stage leaky SV		*			*			*		*	*				*		*		*	
1st stage leaky DV		*				*	*		*			*				*				
2nd stage leaky DV		*				*		*		*	*				*					

TABLE II. DECISION TABLE

Faults	Signatures	1st Stage Suction Valve				1st Stage Discharge Valve				2nd Stage Suction Valve				2nd Stage Discharge Valve			
		Valve open		Valve close		Valve open		Valve close		Valve open		Valve close		Valve open		Valve close	
		-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+
1st stage leaky SV		*					*	*							*		
2nd stage leaky SV			*			*			*	*				*		*	
1st stage leaky DV			*				*	*			*				*		
2nd stage leaky DV			*				*		*	*				*			

VI. CONCLUSION

The high pressure cylinder discharges into a tank in which the pressure was measured as 816kPa (120psi), while the low pressure cylinder discharges direct to the 2nd stage with a back pressure of about 260kPa (38psi). Clearly the effects of leakage in the suction or discharge valves of 1st and 2nd stages are likely to be different from each other. The effect of the leaky suction valve in the 2nd stage increases the measured pressure in the 1st stage.

Discharge valve leakage resulted in higher pressure air returning to the cylinder when the discharge pressure is greater than the cylinder pressure. Thus on the determination of the valve leakage, 3% leakage is determined at the suction valve where as 8% leakage is determined at the delivery valve.

Dynamic cylinder pressure and Instantaneous angular speed are directly related and both proved useful information for fault detection and diagnosis. Dynamic pressure is an extremely powerful condition monitoring tool, the deviation of the pressure signal from the normal can be seen clearly. The valves' opening and closing for both 1st and 2nd stages may be clearly observed and show the difference between healthy and faulty valves (valve leakage). Also the increase of cylinder pressures due to leaky valves can be clearly observed. The experimental work have both demonstrated that instantaneous angular speed(IAS) analysis is capable of characterizing compressor operation at different discharge pressures, and successful detection of valve faults (e.g. leakage valves) can be made from deviation of the instantaneous angular speed(IAS) waveform from its baseline.
Comparison of the Tables I, II confirms the data regarding valve opening and closing times, and additional information is gained on either impact levels or cylinder pressure.

VII. NOMENCLATURE

1st stage CP	Cylinder pressure of 1st stage
2nd stage CP	Cylinder pressure of 2nd stage
L	Low pressure
H	High pressure
-	Valve open earlier
+	Valve open later
O	Open
C	Close
SV	Suction valve
DV	Discharge valve

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