International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.3, 2015

RESEARCH ARTICLE

ISSN: 2321-7758

DESIGN OF THE CURVED FLANK FOR THE STAR WHEEL TOOTH IN SINGLE SCREW COMPRESSORS

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Article Received: 29/04/2015 | Article Revised on:03/05/2015 | Article Accepted on:06/05/2015

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ABSTRACT

The wear of star-wheel teeth is an important problem in single screw compressors. Besides the tooth flank shape and material is the basic factors affecting the wear resistance. In order to prolong the service life of star wheels, a new curved flank of the tooth is proposed. Section profile of the tooth flank is a curve, which could be elliptical, hyperbolic and involute. The screw groove flank is the envelope surface corresponding to the surface of the tooth flank. During the tooth meshing with the groove, the contact line moves in the tooth flank area.

Key Words – single screw compressor, wear, curved flank, tooth profile

I. INTRODUCTION

The primary components of a typical single screw compressor are a screw rotor and star wheels. The star wheels and the screw rotor constitute two meshing pairs, which are also special worm-gear pairs. The screw is cylindrical with helical grooves. Mated in the screw are star wheels on either side of the screw that rotate in opposite directions from one another. Usually, the star wheels are driven by the screw, and teeth seal grooves to confine the pockets of gas as they move along the screw grooves. Compared with other kinds of compressors, the single screw compressor should have many advantages due to its symmetrical structure and well balanced radial gas pressure on the screw rotor. However, its discharge capacity decreases sharply after several hundred hours running. This behavior is no doubt attributable to rapid wear of star-wheel tooth flank surface meshing with the screw groove. Single Screw compressor is a rotary, positive displacement compressor which incorporates a main screw and two gaterotors. Compression of the gas is accomplished by the engagement of the two gate rotors with the helical grooves in the main screw. The drive shaft imparts rotary motion to the main screw which in turn drives the intermeshed gate rotors. The compressor is comprised of three fundamental components that rotate and complete the work of the compression process. This typically includes a cylindrical main screw with six helical grooves and two planar gate rotors, each with 11 teeth. The rotational axes of the gate rotors are parallel to each other and mutually perpendicular to the axis of the main screw.

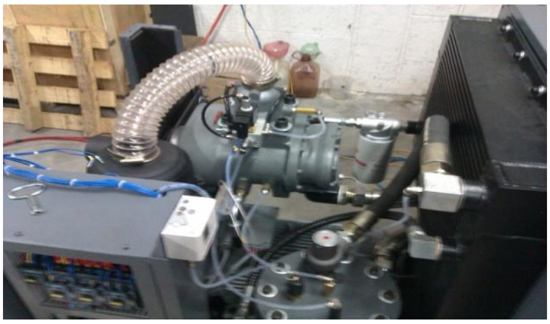


Figure 1 : Inside view of single screw compressor

II. MAIN COMPONENTS AND SPECIFICATIONS

A. AIR-ENDS

The screw element is the most important part of any screw-type compressor. It's that part of the machine where the actual compression takes place. It is the heart of the rotary screw air compressor. Often, the compressor screw element is also called air-end. They are constant flow (volume) with variable pressure compressors. Which mean that at a given speed (rpm), they always supply the same amount of air (in liters per second for example), but can do so at different pressures.

B. THE ROTARY SCREW ELEMENT

Rotors have different kinds of bearing son both sides so they run smoothly for years without any maintenance. There are usually two pairs of bearings on both sides, bearings for radial loads (loads because of the turning of the rotors) and axial bearings. Because the screw 'push' are to one side (the high pressure side) the rotors want to move to the opposite direction. The axial bearings take on this load. We can also see that the male rotor has an axle that sticks out with a gear on it. This is the driving gear. Sometimes it's a pulley.The element is water-cooled, for this purpose there are water cooling pockets in the element housing (the green parts). The gears are lubricated with oil, as is indicated by the yellow/brown parts. Oil-injected screw elements don't have this, since they are cooled by the injected oil. There is a sealing between the oil and the compressed air compartments, to prevent any oil from contaminating the compressed air (specific for oil-free compressor elements).The housing can be disassembled for maintenance. Air-ends come in many different sizes, but they all look basically the same. Here are some photos of air compressor elements.

C. TOOTH FLANK

The groove flank is the envelope surface. Section profile of the new tooth flank is a curved line, which could be elliptical, hyperbolic, or involute. During the tooth meshing with the groove, the contact line between the meshing pair could move continuously in almost the whole area of the tooth flank. Meanwhile, the meshing area of the star wheel increases significantly. This design is expected to improve the lubricating between the tooth flank and the groove flank, and to prolong the service life of this meshing pair.

Table 1: Technical Specification of single screw compressor

Max Working pressure	15 bar
Min Working pressure	5 bar
Oil injected quantity	32 l/min
Max input power	30 kW
Max rotor speed	5300 rpm
Min rotor speed	2100 rpm
Ambient temperature	50 ^{0}C
Oil temperature	75 ^{0}C
Oil Tank capacity	600 lit

Table 2: Geometrical parameters of Tooth flanks in SSC (straight line tooth curvature)

PARAMETER	NOMINAL VALUES
Material	Nodular Cast iron
Diameter of the screw (D_{sr})	90 mm
Diameter of the star wheel (D_{sw})	85 mm
Thickness of the tooth	6 mm
No of teeth in screw (Z_{sr})	6
No of teeth in star wheel (Z_{sw})	11

III. PROBLEM IDENTIFICATION

In single screw compressor mostly wear occurred part is air end. The air end includes star wheel and screw rotor. When single screw compressor running the speed, temperature and pressure create the wear in star wheel and screw rotor. In below figure 2 indicate most wear occurring part. The most of the wear occurring part is star wheel.

Figure 2: Occuring wear in starwheel

IV. ANALYSIS OF EXISTING AND MODIFIED STAR WHEEL

Table 3 : Geometrical parameters of Tooth flanks in SSC (Elliptical tooth curvature)

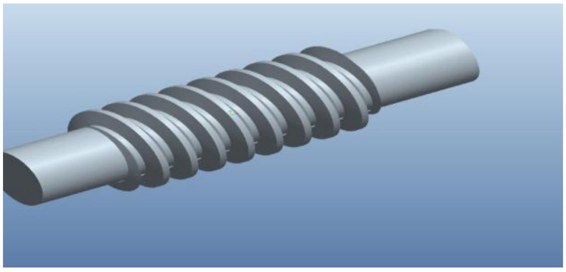
PARAMETER	NOMINAL VALUES
Diameter of the screw (D_{sr})	90 mm
Diameter of the star wheel (D_{sw})	85 mm
Thickness of the tooth	6 mm
Length of the elliptic curve (l)	4 mm
Angle of the axis	40 ^{o}, 43^{o}

(a)

(b)

Figure 3 : (a) Section view of the tooth flank at the tooth top(straight line tooth curvature), (b) Section view of the tooth flank at the tooth top(elliptical tooth curvature)

Model of star wheel



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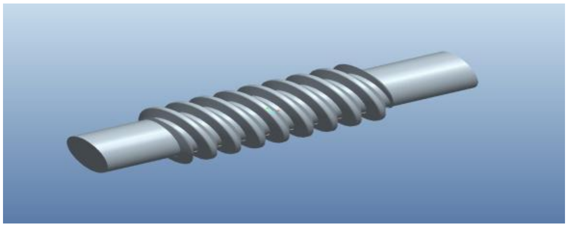
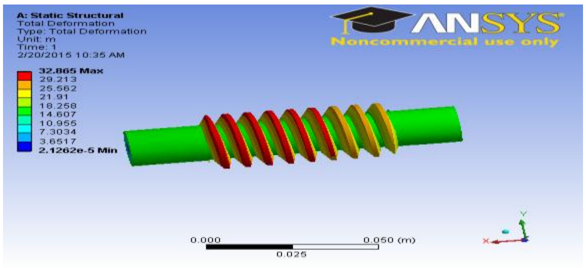


(b)

Figure 4: (a) Straight line curvature with 45^{o}angle, (b) Elliptical tooth curvature with 40^{o} angle

ANSYS results for deformation of star-wheel



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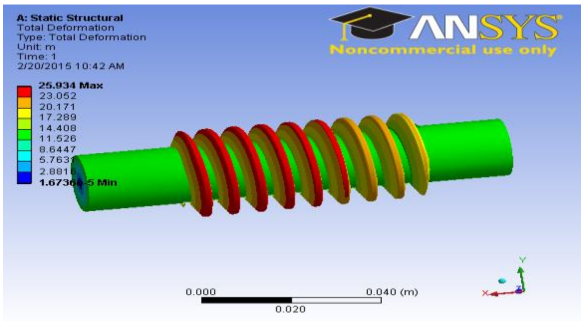

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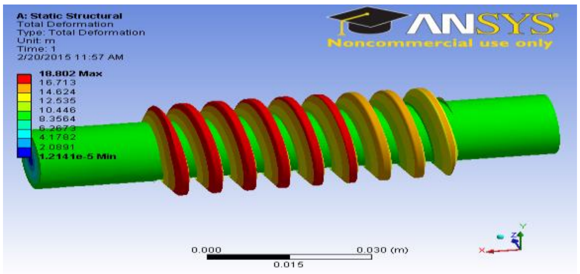

(c)

Figure 5: (a) Deformation of star wheel with 45^{o} angle, (b) Deformation of star wheel with Angle : 43^{o} angle, (c) Deformation of star wheel with 40^{o} angle

V. EXPERIMENTAL TESTING AND RESULTS

Rotational velocity of the star wheel (ω_{sw}):

$\omega_{sw} = (2\pi n_{sr}/60)\,P$

ω - Rotational velocity (rad/s)

sw - Star wheel

sr - screw rotor

n_{sr} - Rotational speed of a screw rotor (rpm)

$P = Z_{sw}/Z_{sr}$

Z_{sw} - No of teeth in star wheel

Z_{sr} - No of teeth in screw

P = 11/6

$\omega_{sw} = (2\pi*2510/60)(11/6)$

$\omega_{sw} = 481.88$ rad/s

Free air delivery :

$FAD = Q * (P_F - P_I) / (P_a * t)$

where,

FAD - Free Air Delivery (m^3/min)

Q - Total volume of the receiver (m^3)

P_I - Initial Pressure of the receiver (kg/cm^2)

P_F - Final Pressure of the receiver (kg/cm^2)

Pa - Atmospheric Pressure, (kg/cm²)

t - Average filling time (min)

FAD = 0.6*(15.295-5.098) / (5.098*5*60)

FAD = 0.0040 m^3/min

Table 4: Rotational velocity of the star wheel

S.no	Rotational speed of the Screw rotor n_{sr} (rpm)		Rotational velocity of the star wheel ω_{sw} (rad/s)	
	Existing	Modified	Existing	Modified
1	2510	2595	481.88	498.20
2	3066	3311	588.63	635.66
3	3294	3326	632.40	638.54
4	3352	3487	643.54	669.45

Table 5: Free air delivery

S.no	Filling time t (sec)	Free air delivery (m^3/min)	
		Existing	Modified
1	5	0.0040	0.0040
2	11	0.0011	0.0011
3	17	0.0011	0.0011

Table 6: Wear rate

S.no	Service life of the star wheel (hours)	Wear rate (%)	
		Existing	Modified
1	5	2	1.6
2	10	3	2.5

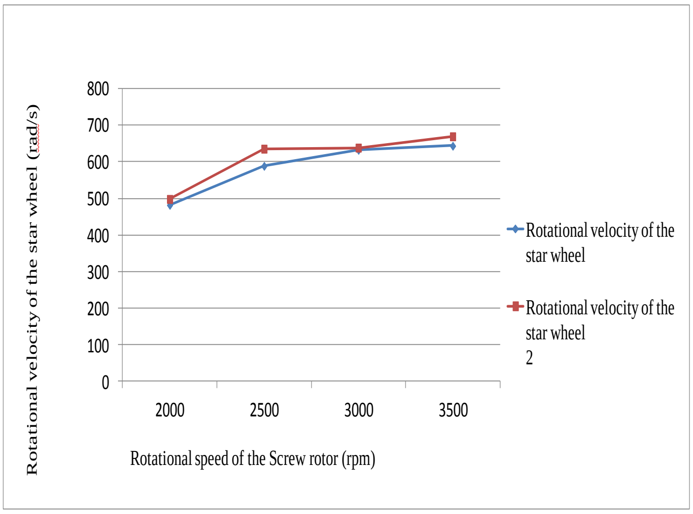

Figure 6: Rotational velocity of the star wheel

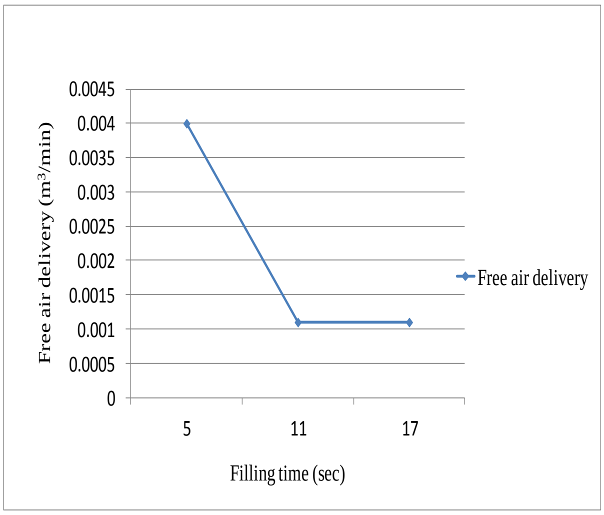

Figure 7: Free air delivery (FAD)

VI. CONCLUSION

The wear of star-wheel teeth is an important problem in single screw compressors. Besides the tooth flank shape and material is the basic factors affecting the wear resistance. From the above experimental analysis of straight line tooth profile occuring more wear rate. But the elliptical tooth flank is occuring less wear rate. The analytical results are also proved elliptical tooth flank curvature is better than straight line tooth flank curvature.

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