COMPRESSOR HAVING SINUSOIDAL IMPELLERS

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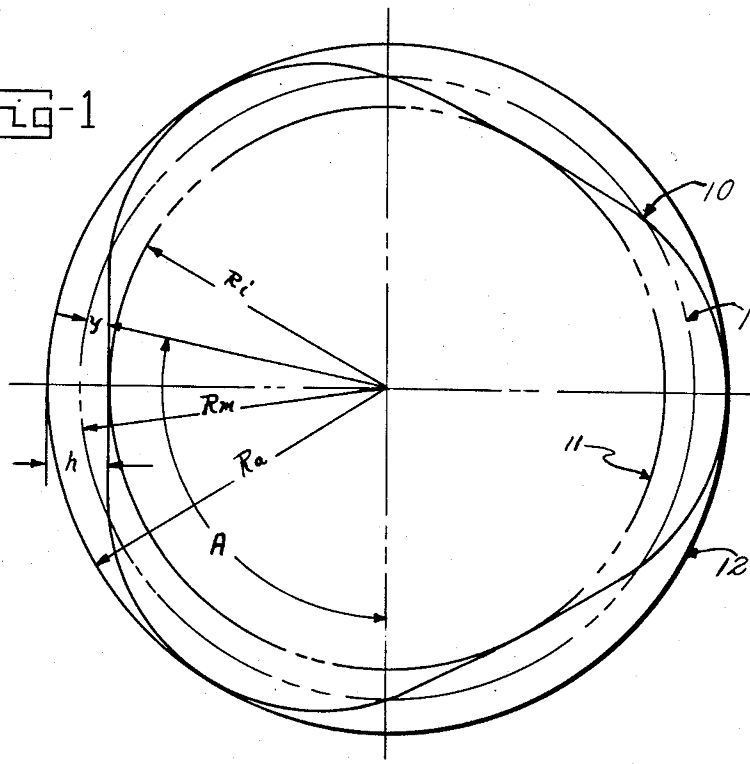
Fig-1



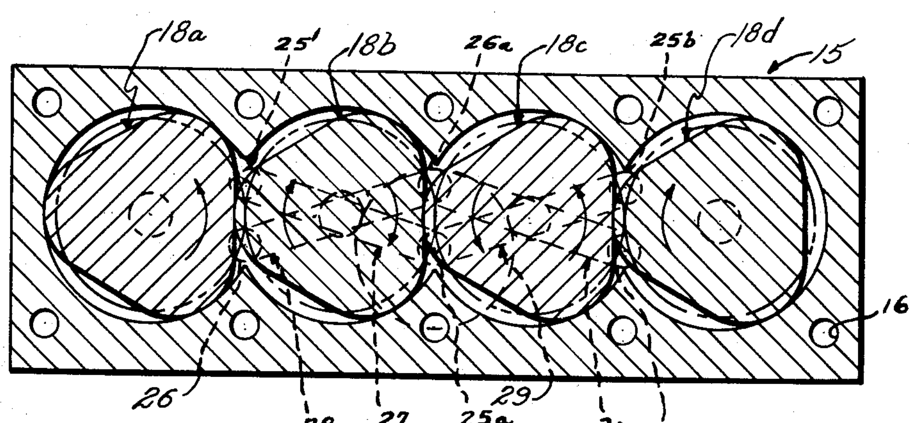




Fig-2

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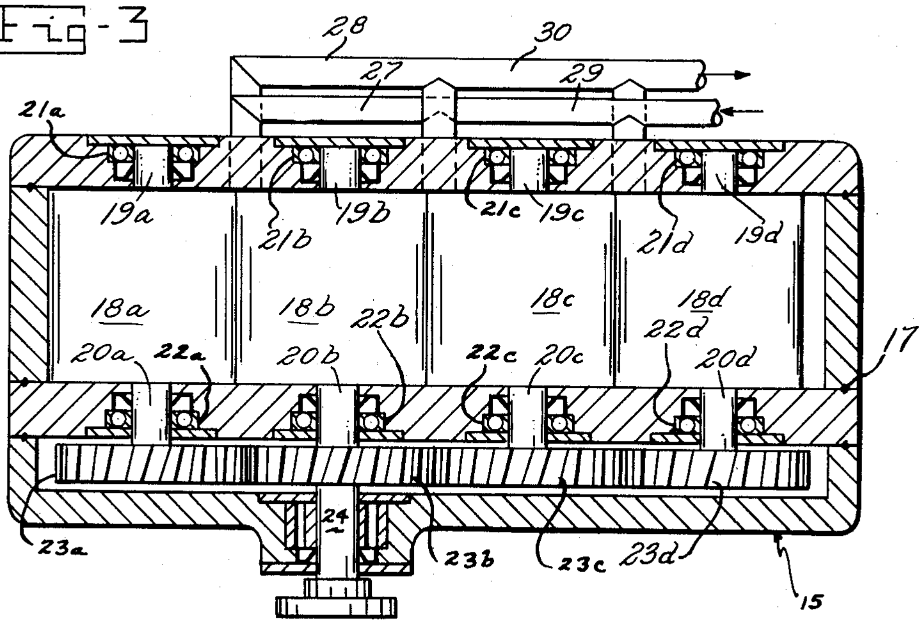
Fig-3



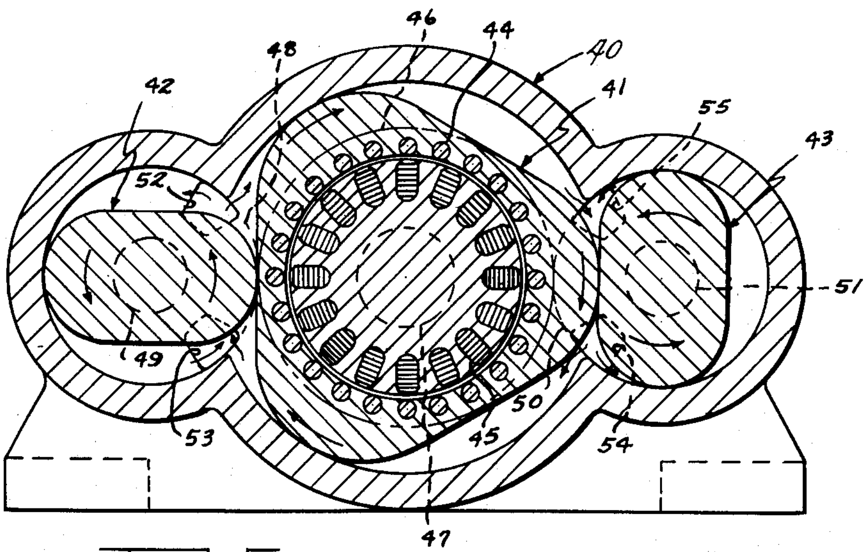




Fig-5

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COMPRESSOR HAVING SINUSOIDAL IMPELLERS

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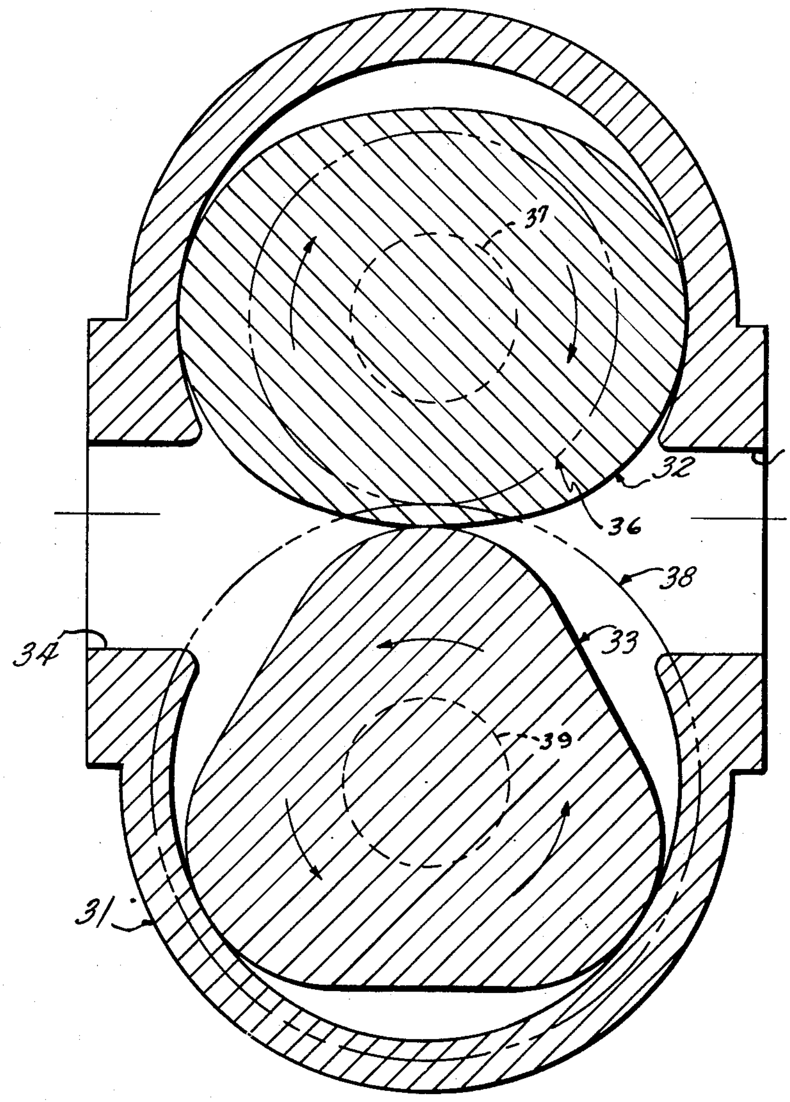


Fig-4

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# United States Patent Office

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2,939,628

## COMPRESSOR HAVING SINUSOIDAL IMPELLERS

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3 Claims. (Cl. 230—141)

(Granted under Title 35, U.S. Code (1952), sec. 266)


The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to a compressor having an improved impeller construction and, more particularly, to a compressor having the profile of its impellers formed according to a particular equation.

In certain uses of compressors, it is desirable that the noise level produced by the pumping of the impellers of the compressors be as low as possible. One example of such a use of a compressor is in a closed respiratory system employed in an aircraft wherein each occupant of the aircraft is supplied oxygen under pressure because of the low atmosphere at the high altitude at which the aircraft is operating. The well-known type of compressor such as a Root blower type, for example, has an untolerable noise level because of the high fluctuations due to flow and pressure. This is because the volume pumped by such a compressor varies greatly and creates a high noise level. Since this noise level is transmitted to the person being supplied oxygen, it cannot be tolerated for long periods of time as is required in operating aircraft at high altitude. The present invention satisfactorily solves this problem by employing impellers for a compressor in which the profile of the impellers is such that a substantially constant volume is pumped by the impellers. This is because the chambers formed between the impeller and the interior wall of the compressor have a small volume and are of a smooth shape. This construction reduces the fluctuations of the flow and the noise created by such flow during high speed rotation of the compressor. The present invention also reduces noise due to the impellers cooperating with a minimum of stress therebetween.

An object of this invention is to provide a compressor having a low noise level.

Another object of this invention is to provide an impeller for a compressor that may pump a substantially constant volume from the inlet to the outlet.

Other objects of this invention will be readily perceived from the following description.

This invention relates to a compressor unit comprising a housing having inlet means and outlet means with at least two impellers rotatably mounted therein. The impellers are connected together by suitable means to synchronously rotate to cooperate to pump fluid from the inlet means to the outlet means at a pressure increase. The profile of each of the impellers is formed according to the equation,

$$y=\frac{h}{2}\sin nA$$

where $y$ is the profile height in a radial direction measured from a mean circle at any point having a radius $R_m$ to the profile adjacent to that point, the radius $R_m$ being the mean between a radius, $R_a$, of the circumscribed circle of the profile and a radius, $R_i$, of the inscribed circle of the profile



$$\left(R_m=\frac{R_a+R_i}{2}\right)$$

$h$ is the maximum height of the profile and is equal to the difference between the radii of the circumscribed and inscribed circles ($h=R_a-R_i$), $n$ is the number of lobes on the impeller; and A is the angle measured from the point where the profile crosses the circumference of the mean circle to $y$. The distance between the centers of two adjacent impellers is equal to the sum of the mean radii of the two adjacent impellers.

The attached drawings illustrate preferred embodiments of the invention, in which

Fig. 1 is a schematic view of a profile of an impeller formed according to the present invention;

Fig. 2 is a sectional view of one form of compressor embodying the impellers of the present invention;

Fig. 3 is a sectional view, partly in elevation, of Fig. 2;

Fig. 4 is a sectional view of a compressor embodying another form of impeller construction; and

Fig. 5 is a sectional view of a compressor having impellers formed according to the present invention.

Referring to the drawings and more particularly to Fig. 1, there is shown a profile **10** of an impeller for use with a compressor. The profile has an inscribed circle **11** of radius $R_i$ and a circumscribed circle **12** of radius $R_a$. The profile **10** has a mean circle **14** of radius $R_m$. It will be understood that the radius of the mean circle is equal to one half the sum of the radii of the inscribed and circumscribed circles; thus,

$$R_m=\frac{R_a+R_i}{2}$$

The maximum height of the profile **10** is indicated by $h$ and is the difference between the radii of the circumscribed and inscribed circles; that is, $h=R_a-R_i$. The height of the profile **10** in a radial direction, measured from the mean circle **14**, at any point is indicated by $y$ and is calculated from the equation,

$$y=\frac{h}{2}\sin nA$$

The number of lobes of the impeller is represented by $n$. The angle A is measured from the point where the profile **10** crosses the mean circle **14** to the point at which $y$ is taken. Thus, the profile **10** is designed from the equation set forth above.

It will be readily seen from Fig. 1 that when a three lobe impeller, such as shown in Fig. 1, has its profile formed by the present invention, that $y$ reaches a maximum, either negative or positive, every sixty degrees since the angle is multiplied by three. This, of course, produces three positive maximum values of $y$ and three negative maximum values of $y$ in the profile **10** of Fig. 1. If the profile of the impeller had only two lobes such as shown, for example, in Figs. 4 and 5, a maximum value of $y$, either positive or negative, would occur each ninety degrees so that there would be four maximum values, two positive and two negative, of $y$. This is readily seen from an observation of the impellers of Figs. 4 and 5 that are formed with two lobes.

By forming the profile of the impeller according to the law of sines, it is seen that a smooth curve is formed wherein two adjacent impellers rotate in opposite directions. The distance between the centers of the two adjacent impellers is equal to the sum of the radii of the mean circles of the profiles of the impellers whereby they cooperate with a minimum of stress therebetween.

The impellers, which are formed according to the law of sines as shown in Fig. 1, may be used with the compressor of Figs. 2 and 3. The compressor unit has a casing 15 formed of a plurality of sections joined together by suitable means such as bolts (not shown) passing through bolt holes 16 in the casing 15. Rubber rings 17 serve to prevent leakage between the portions of the casing 15. A plurality of substantially identical impellers 18*a*, 18*b*, 18*c*, 18*d* are rotatably mounted in the casing 15 through extending shafts 19*a*, 19*b*, 19*c*, 19*d* and 20*a*, 20*b*, 20*c*, 20*d* on opposite ends thereof, which are disposed in bearings 21*a*, 21*b*, 21*c*, 21*d* and 22*a*, 22*b*, 22*c*, 22*d*, respectively.

Each of the impellers 18*a*, 18*b*, 18*c*, 18*d* is connected through its respective shaft 20*a*, 20*b*, 20*c*, 20*d* to a plurality of synchronous gears 23*a*, 23*b*, 23*c*, 23*d*. The gear 23*b* has a shaft 24 extending therefrom outside of the casing 15 to be connected to a suitable power source. As the impeller 18*a* is rotated, fuel is pumped (see Fig. 2) from an inlet 25 to an outlet 26 at a pressure increase. The impeller 18*b* pumps fluid from the inlet 25 through an outlet 26*a* and from an inlet 25*a* to the outlet 26. The inlets 25 and 25*a* are connected by a conduit 27 while the outlets 26 and 26*a* are connected by a conduit 28. Likewise, the impeller 18*c* pumps fluid at a pressure increase from an inlet 25*b* to the outlet 26*a* and from the inlet 25*a* to an outlet 26*b*. A conduit 29 connects the inlet 25*a* to the inlet 25*b* and a conduit 30 connects the outlet 26*a* with the outlet 26*b*. The impeller 18*d* pumps fluid from the inlet 25*b* to the outlet 26*b*. It will be observed that the direction of rotation of the impellers is shown by the arrows.

The impellers of the compressors of Figs. 2 and 3 are spaced approximately .002 inch from each other and from the inner wall of the housing 15 if the diameter of each impeller is two inches. Any increase in the diameter of the impeller permits a greater clearance between the impellers and between the impellers and the inner wall of the housing. It will be understood that the high speed of the impellers prevents any consequential leakage of fluid through the space between the impellers and between the wall of the housing and the impellers. Since these impellers do not slide on each other or on the casing, wear is eliminated. This eliminates the requirement of lubrication so that oil free fluid is pumped by the compressor.

A compressor housing 31 is shown in Fig. 4 having impellers 32 and 33 rotatably mounted therein. It will be observed that the impeller 32 has only two lobes whereas the impeller 33 has three lobes. However, these impellers still cooperate to pump fluid from an inlet 34 in the housing 31 through an outlet 35 in the housing 31 at a pressure increase because the impellers are formed according to the law of sines, as spcifically explained in Fig. 1. It will be understood that the ratio of a gear 36, which is connected to the impeller 32 through a shaft 37, has a ratio to a gear 38, which is connected to the impeller 33 by a shaft 39, of 2:3. This insures that the impeller 32 makes three revolutions to every two revolutions of the impeller 33. It should be understood that the distance between the centers of the shafts 37 and 39 is equal to the sum of the radii of the mean circles of the profiles of the two impellers 32 and 33.

In Fig. 5, there is shown a compressor housing 40 having a three lobe impeller 41 and two impellers 42 and 43 with two lobes each on opposite sides of the impeller 41. The impeller 41 includes a rotor 44 of an electrical motor joined thereto. The impeller 41, including the rotor 44, surrounds a stator 45 of an electrical motor. Since the formation of the rotor as part of the impeller and the cooperation between the rotor and the stator is not a part of this invention but is described and claimed in my copending application, Serial No. 659,184, filed May 14, 1957, now Patent No. 2,918,209, it will not be described in detail here. The impeller 41 has a gear 46 connected thereto through a shaft 47. The gear 46 meshes with a gear 48, which is secured to the impeller 42 by a shaft 49, and with a gear 50, which is secured to the impeller 43 by a shaft 51. It will be noted that the ratio of the gears 48 and 50 to the gear 46 is 2:3 so that the impellers 42 and 43 rotate three times while the impeller 41 rotates only twice. It should be understood that the distance between the centers of the shafts 47 and 49 is equal to the sum of the radii of the mean circles of the profiles of impellers 41 and 42. Likewise, the distance between the centers of the shafts 47 and 51 is equal to the sum of the radii of the mean circles of the profiles of the impellers 41 and 43.



The impeller 42 pumps fluid from an inlet 52 to an outlet 53 while the impeller 43 jumps fluid from an inlet 54 to an outlet 55 at a pressure increase. While the impellers 42 and 43 are pumping, it will be understood that the impeller 41 is also pumping fluid from the inlet 52 to the outlet 55 and from the inlet 54 to the outlet 53. Thus, the impeller 41 is actually doing double work since it pumps three chamber volumes, a chamber volume being formed between the profie of the impeller 41 and the interior wall of the casing 40, from the inlet 52 to the outlet 55 and also pumps three chamber volumes from the inlet 54 to the outlet 53 at the same time.

An advantage of this invention is that there is no unbalance of the impellers at high speeds. Another advantage of this invention is that it is easy to make because of the sinusoidal profile, which may be inexpensively manufactured with high precision, for example, with polygon grinding machines. A further advantage of this invention is that the impellers may be synchronized through their gears to an accuracy that permits only a slight capillary space to exist between each impeller and the wall of the casing so that there is no sliding of parts and wear is eliminated without any requirement of lubrication.

For purposes of exemplification, particular embodiments of the invention have been shown and described according to the best present understanding thereof. However, it will be apparent that changes and modifications in the arrangement and construction of the parts thereof may be resorted to without departing from the true spirit and scope of the invention.

I claim:

1. A compressor unit comprising a housing having a pumping chamber, inlet means and outlet means in communication with said pumping chamber, at least two impellers rotatably mounted in said chamber in predetermined minimum spaced relation to each other and the walls of said chamber to prevent leakage of fluid therebetween on normal operation of said impellers, means connecting the impellers together to synchronously rotate the impellers whereby the impellers cooperate to pump fluid from the inlet means to the outlet means at a pressure increase, the profile of each of the impellers being formed according to the equation

$$y=\frac{h}{2}\sin nA$$

where $y$ is the profile height in a radial direction measured from a mean circle at any point with a radius $R_m$ to the profile adjacent to that point, the radius $R_m$ being the mean between a radius, $R_a$, of the circumscribed circle of the profile and a radius, $R_i$, of the inscribed circle of the profile

$$\left(R_m=\frac{R_a+R_i}{2}\right)$$

$h$ is the maximum height of the profile and is equal to the difference between the radii of the circumscribed and inscribed circles ($h=R_a-R_i$), $n$ is the number of lobes on the impeller, and A is the angle measured from the point where the profile crosses the circumference of the mean circle to $y$, and the distance between the centers of two adjacent impellers is equal to the sum of the mean radii of the two adjacent impellers.

2. A compressor unit comprising a housing having inlet means and outlet means, at least two substantially identical impellers rotatably mounted in the housing, means connecting the impellers together to synchronously rotate the impellers whereby the impellers cooperate to pump fluid from the inlet means to the outlet means at a pressure increase, the profile of each of the impellers being formed according to the equation

$$y=\frac{h}{2}\sin nA$$

where $y$ is the profile height in a radial direction measured from a mean circle at any point with a radius $R_m$ to the profile at any point along a radial, the radius $R_m$ being the mean between a radius, $R_a$, of the circumscribed circle of the profile and a radius, $R_i$, of the inscribed circle of the profile

$$\left(R_m=\frac{R_a+R_i}{2}\right)$$

$h$ is the maximum height of the profile and is equal to the difference between the radii of the circumscribed and inscribed circles ($h=R_a-R_i$), $n$ is the number of lobes on the impeller, and A is the angle measured from the point where the profile crosses the circumference of the mean circle to $y$, and the distance between the centers of two adjacent impellers is equal to the sum of the mean radii of the two adjacent impellers, said impellers rotating at a predetermined minimum speed in predetermined minimum spaced relation to eliminate frictional wear therebetween.

3. A compressor unit comprising a housing having inlet means and outlet means, a plurality of impellers rotatably mounted within the housing and positioned in slightly spaced relation relative to each other making lubrication therebetween unnecessary, at least two of the impellers being substantially identical, means connecting the impellers together to synchronously rotate the impellers whereby the impellers cooperate to pump fluid from the inlet means to the outlet means at a pressure increase, the profile of each of the impellers being formed according to the equation



$$y=\frac{h}{2}\sin nA$$

where $y$ is the profile height in a radial direction measured from a mean circle at any point with a radius $R_m$ to the profile at any point along a radial, the radius $R_m$ being the mean between a radius, $R_a$, of the circumscribed circle of the profile and a radius, $R_i$, of the inscribed circle of the profile

$$\left(R_m=\frac{R_a+R_i}{2}\right)$$

$h$ is the maximum height of the profile and is equal to the difference between the radii of the circumscribed and inscribed circles ($h=R_a-R_i$), $n$ is the number of lobes on the impeller, and A is the angle measured from the point where the profile crosses the circumference of the mean circle to $y$, and the distance between the centers of two adjacent impellers is equal to the sum of the mean radii of the two adjacent impellers.


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