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A New Single Screw Compressor Design that Enables a New Manufacturing Process

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A NEW SINGLE SCREW COMPRESSOR DESIGN THAT ENABLES A NEW MANUFACTURING PROCESS

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ABSTRACT

Existing single screw compressor designs, while offering promises of high efficiency and low noise, require manufacturing processes that are laborious, inflexible, and expensive. The machining of the main rotor usually requires a special machine tool designed exclusively for the manufacture of this component. This type of machine tool has a limited range of sizes and types of main rotors it can produce and is currently available only through a limited number of sources. It is believed that these manufacturing issues have played a role in limiting the commercialization of the single screw compressor.

Recently, a new single screw compressor design has been developed that greatly enhances the manufacturability of the compressor. This new design enables the main rotor to be machined on commercially available 5-Axis Computer Numerically Controlled (CNC) machining centers. These machines allow the manufacture of a large variety of main rotor types and sizes through their flexibility in programming and tooling.

INTRODUCTION

The concept of the single screw compressor was developed in the 1960's and is an offshoot of the twin screw compressor developed in the 1930's. The basic components of a typical single screw compressor are shown in Figure 1.

Initially, because of design and manufacturing issues with its rotors, the twin screw compressor found limited acceptance, but as these difficulties were overcome it found a wide range of applications. These applications include air compression, natural gas compression, and refrigeration compression both for stationary and mobile applications.

The single screw compressor however, is still in the throes of the design and manufacturing process developments needed to make it widely accepted. In particular, it has been difficult to conduct development programs on single screw compressors since the manufacturing methods available are restrictive in the types, sizes, and number of rotor flutes that can be produced. Only when these manufacturing issues are resolved will it be practical to conduct the development programs needed to refine the single screw compressor.

COMPRESSION PROCESS

The compression members of a single screw compressor consist of a main rotor, one or more gate rotors, and an enclosing housing. The compression process proceeds as follows. Gas enters a flute of the main rotor from the suction side. As the main rotor rotates, the gas is trapped in the region enclosed by a flute of the main rotor, a tooth of the gate rotor, and the inside surface of the housing. As the rotation of the main rotor continues, the volume of the enclosed region diminishes and compression of the gas takes place. As the tooth of the gate rotor approaches the end of the flute of the main rotor, an exhaust port in the housing allows the compressed gas to exit the compression area. This compression process takes place in each of the flutes of the main rotor and is shown in Figure 2. Since the gate rotor has two or more teeth engaged in the main rotor at any given time, multiple levels of the compression process are simultaneously taking place.

Since the gas is compressed in the region enclosed by a flute of the main rotor, a tooth of the gate rotor, and the inside surface of the housing, it is critical that the surfaces of these components mesh in a dynamic fluid sealing manner. Obtaining the required seal dictates that each of the components be precision machined.

EXISTING DESIGNS

Existing single screw compressor designs use gate rotors that have teeth with circular tips that coincide with the major diameter of the gate rotor. When the main rotor is viewed in cross section, the roots of the flutes form an hour glass shape that corresponds to the arc of the gate rotor teeth. This is shown in Figure 3. The difficulty with this concept is the manufacturing issues it raises, specifically the machining of the root of each flute of the main rotor.

EXISTING MANUFACTURING METHODS

With the roots of the flutes of the main rotor having an hour glass shape, the manufacturing methods that can be used are limited. The method usually employed uses a cutting tool that mimics the shape and motion of the gate rotor. This requires a machine tool designed exclusively for the manufacture of main rotors and is limited in the types, range of sizes, and number of flutes it can produce. These manufacturing restrictions make design parameter studies and prototype part development difficult at best. Also, the time required to machine a rotor is considerable, since this type of machine is limited in the range of cutting feeds and speeds that can be employed.

NEW DESIGN

A new design has been developed where, when viewed in cross section, the roots of the main rotor flutes are linear and the mating tips of the gate rotor teeth are also linear. As a result, the roots of the flutes of the main rotor are no longer an hour glass shape. Instead, the root of each flute is a ruled surface created by a ruling line that represents the linear tip of a gate rotor tooth as it sweeps through the body of the main rotor. This is shown in Figure 4.

NEW MANUFACTURING METHOD

Since the ruled surface root of the new design has a linear line of contact with the gate rotor, it allows a rotating cutting tool with a flat bottom, such as an end mill, to be used to machine the sides and root of the flutes of the main rotor. The first pass of the end mill machines one side and a portion of the root of the flute and the second pass of the end mill machines the second side and the remainder of the root. Thus, with two passes of an end mill, one complete flute is machined in the main rotor. This sequence is shown in Figures 5A and 5B. The path of the tool is controlled using a 5-axis CNC machining center. This type of machine is commercially available and can be used to produce many sizes and types of main rotors through the flexible programming and tooling of the CNC machine. A schematic drawing of this type of machine and a main rotor work piece is shown in Figure 6.

This flexible manufacturing capability also enables design parameter studies to be completed in a short time and at low cost. All that is required to produce a main rotor of a different design is a new program and a different end mill. Thus, with simple program and tooling changes, main rotors can be produced of different types, different sizes, and different number of flutes. Additionally, this same manufacturing method can be utilized for high volume compressor production as well as prototype development.

WORK COMPLETED

At this time, the computer software to define both the new main and gate rotors as well as drive a 5-axis CNC machine has been developed. To prove the concept of the geometry, main rotor and gate rotor models have been produced on a 5-axis CNC machining center. Currently a project is under way to build a working compressor. The new design of main rotor and gate rotor is shown in Figure 7.

ONGOING WORK

Design work is continuing on additional developments for the single screw compressor in the areas of lower noise, reduced lubrication requirements, improved throttling, better maintainability, and higher compression ratios. Software development is continuing in the areas of 5-axis tool path generation, for both main rotors and gate rotors, and design aids for the product engineer. Work is also being done to improve the manufacturability of the gate rotor.

CONCLUSIONS

This new design, which enables a flexible, low cost manufacturing process that can be done on commercially available machine tools, will open the door for the proliferation of the single screw compressor. The ability to conduct design parameter studies that can be completed in a short time and at low cost, and explore such design variables as different rotor types, different sizes, and different flute configurations will dramatically accelerate the development process. Since these same low cost manufacturing methods can be used for high volume production, the single screw compressor will become a commonplace reality.

REFERENCES

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3. Bein and Hamilton, "Computer Modeling of an Oil Flooded Single Screw Air Compressor" Proceedings of the 1982 Purdue Compressor Technology Conference, Purdue University, West Lafayette, Indiana

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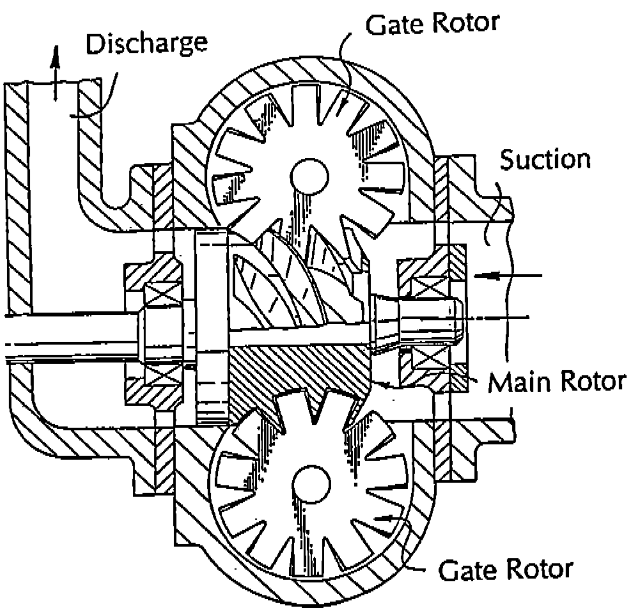

Figure 1. Single Screw Compressor

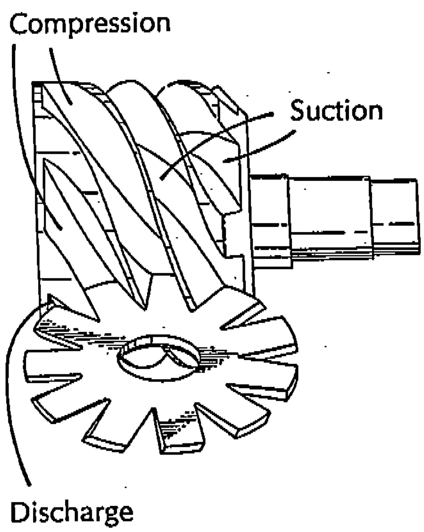

Figure 2. Compression Process

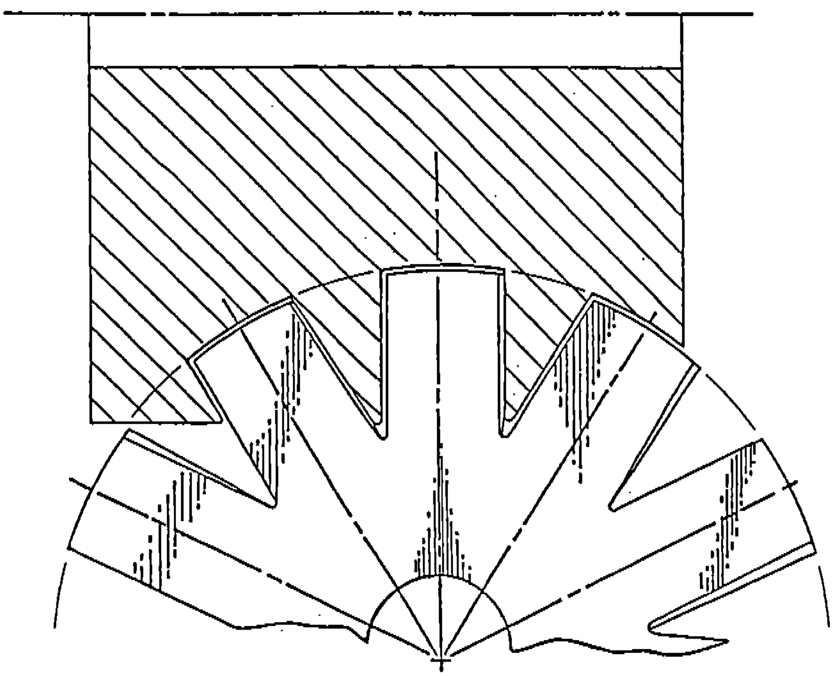

Figure 3. Existing Design
Curved Gate Rotor Tips and Hour Glass Shaped Main Rotor Root
(Section View of One Half of Main Rotor in Plane of Gate Rotor)

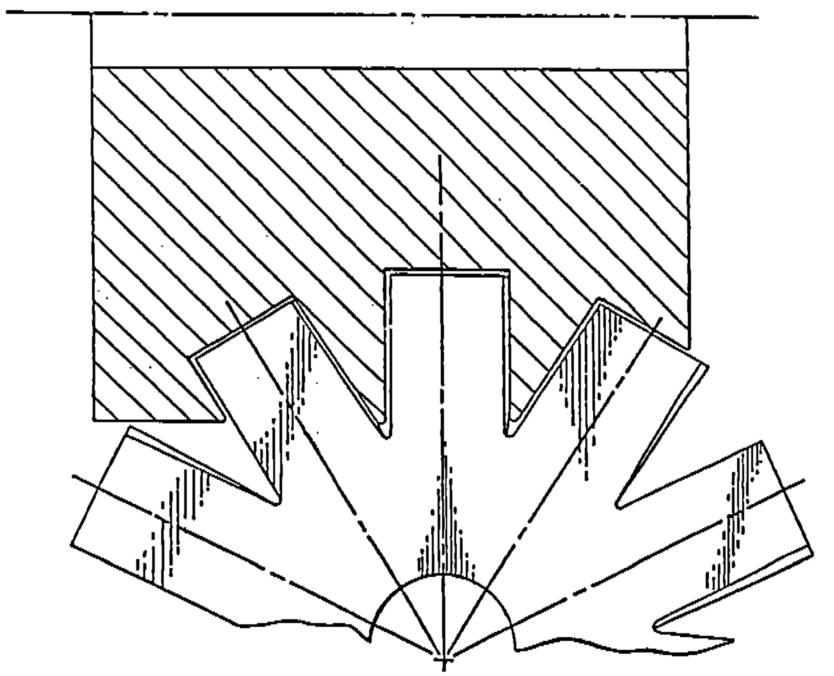

Figure 4. New Design
Linear Gate Rotor Tips and Ruled Surface Main Rotor Root

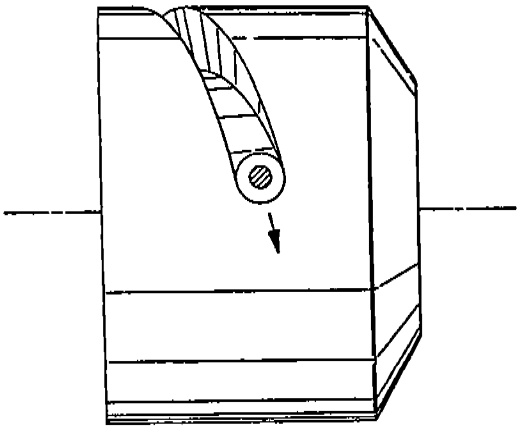

Figure 5A.
First Pass with a
Rotating Cutting Tool

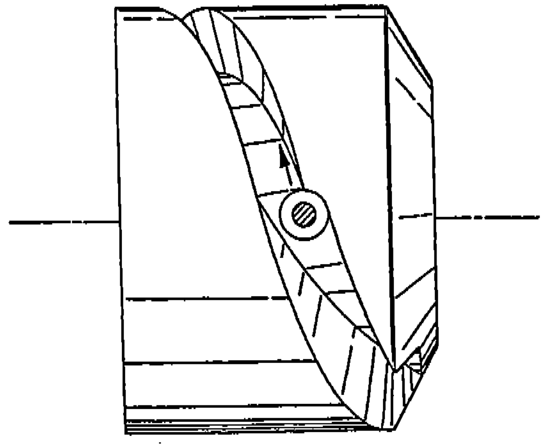

Figure 5B.
Second Pass with a
Rotating Cutting Tool

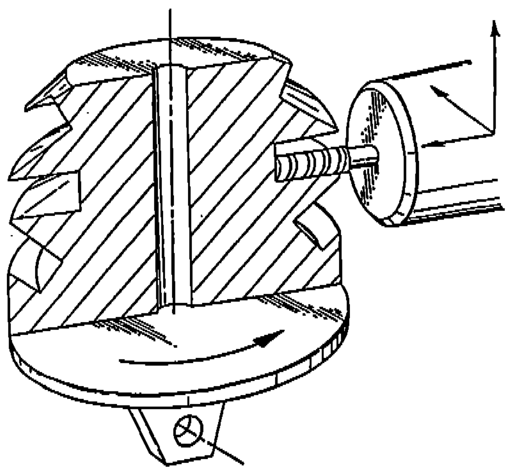

Figure 6.
Schematic of 5 Axis CNC
Machine Tool and Main Rotor

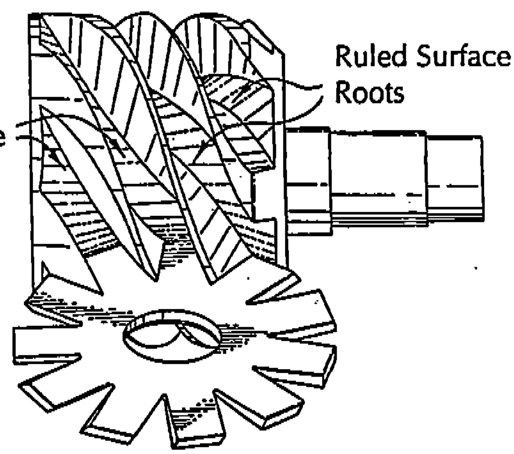

Figure 7.
New Design Main Rotor and Gate Rotor
with Ruled Surface Main Rotor Roots
and Linear Tipped Gate Rotor Teeth