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A concurrent engineering approach to the development of a scroll compressor

Z. Jiang[a], K. Cheng[b,*], D.K. Harrison[a]

[a]Department of Engineering, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, UK
[b]School of Engineering, Leeds Metropolitan University, Calverley Street, Leeds LS1 3HE, UK

Abstract

The scroll type of compressor is becoming popular and widely used in refrigeration and air conditioners. But it is time consuming to design and manufacture the compressor since its components are of complex shape and of high precision requirements. This paper presents a concurrent engineering approach to computer-aided design and manufacturing of the compressor. The authors use C++ programming and Pro/ENGINEER as engineering tools to implement the proposed approach and associated design development. A visualised solid model of the compressor was developed. The solid model designed was enhanced by use of an optimisation system. Finite element analysis and an expert system were used to study the model, which is useful for improving the quality of manufacturing and assembly accuracy at the later stages. Manufacturability, process planning and NC tool path code generation are included in the approach. Concurrent engineering concepts were used throughout the design and manufacturing processes.

Keywords: Concurrent engineering; Solid modelling; CAD; CAM; Compressor

1. Introduction

Conventionally the design and development activities of compressors were performed separately by designers and manufacturing engineers. The designers design compressors or their components using a serial engineering approach to conceptual design and thermodynamic calculations. They perform design analysis and verification using sophisticated computing tools before fabricating and testing a prototype compressor. When it comes to manufacture the product, the manufacturing process is established largely based on experience, intuition and empirical rules. As a result, development of a product takes a long time and ties up expensive manufacturing capacity for non-productive initial processes.

In recent years, the concept of concurrent engineering (CE) has been proposed to overcome such serial design and manufacturing problems [1]. In the practice of CE, product, process and all life cycle issues are considered and reviewed simultaneously throughout all phases of the development cycle. The CE process treats design for manufacturability, assemblability, testability, quality, service, delivery time and cost attributes equally (Fig. 1) and in parallel with product design for performance with particular reference to refrigeration capacity, power consumption, size, weight, noise and reliability. It also provides early visibility for any changes regarding manufacturing, test, quality, and maintenance, etc. CE integrates the expertise from the various engineering disciplines during the actual design phase. When a design is verified, it is already a manufacturable, testable, and serviceable high quality design. The design review is held just to make sure that nothing was missed in the process. The whole focus of CE is on a "right first time" process, rather than on the "redo-until-right" process that is so common in the compressor industry.

A survey of the literature shows that much research work has been done in the CE area. Hartley [2] and Prasad [3] give a comprehensive description on the CE methodology and associated issues. Cheng [4] developed CE environment for product design. Syan and Menon [5] described CE implementation and practice aspects in quite detail. But there is little research on the concurrent design and development of complex-shaped mechanical components, which are very important for general machinery, which is an area that CE can fit well and also challenge the design and manufacturing engineers in many aspects including design analysis, solid modelling (SM), NC machining and inspection.

The authors' aim is to develop a CE approach to the concurrent design and development of complex-shaped mechanical components for achieving high quality compo-

* Corresponding author. Tel.: +44-113-2833098; fax: +44-113-2833110.
E-mail address: k.cheng@lmu.ac.uk (K. Cheng).

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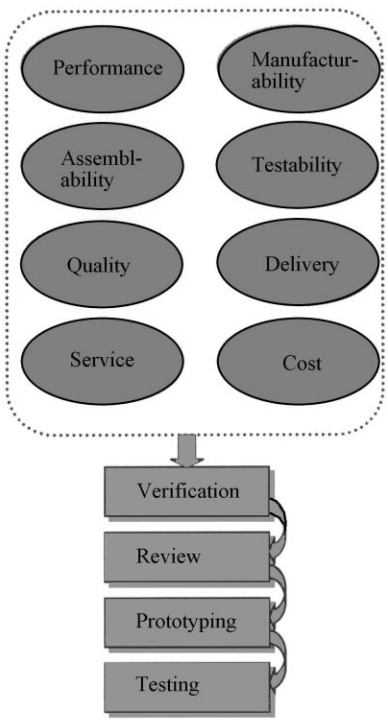

Fig. 1. The CE process.

nents at a low cost in a shorter time. A scroll type of compressor was taken as an example to research the approach. The approach is implemented with Pro/ENGINEER and C++ programming. The work presented is a part of a project being undertaken at Glasgow Caledonian University.

2. Scroll compressors

A typical scroll compressor is shown schematically in Fig. 2 [6,7]. Its principal components include a fixed scroll, an orbiting scroll, a drive shaft, frames, an electric motor,

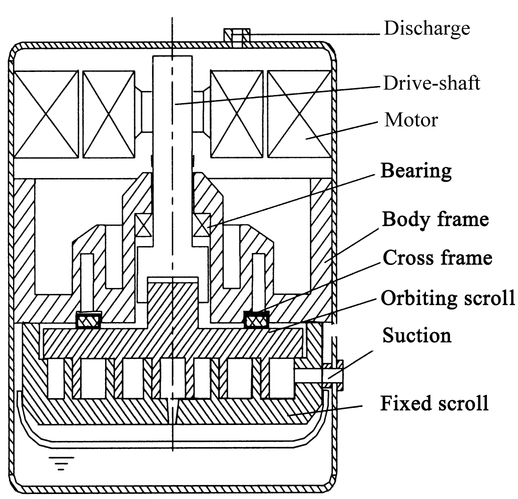

Fig. 2. The construction of a scroll compressor.

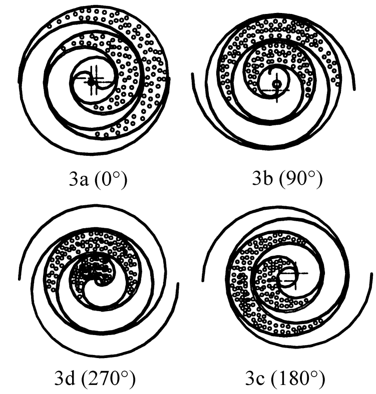

Fig. 3. The working procedure of scrolls.

etc. As shown in Fig. 2, the motor is placed at the top and the compressor at the bottom. The orbiting scroll is driven directly by the driving shaft connected with the motor rotor. The working process of this type of compressor is shown in Fig. 3. Two identical scrolls, i.e. the fixed and orbiting ones, whose axes of rotation do not meet each other and are assembled at a relative angle of 180° contact each other at several touch lines and form a series of crescent-shaped chambers. The orbiting scroll rotates around its own axis in a plane motion. In Fig. 3a the gas suction process is just finished, the centre of the orbiting scroll is at 0°. At this position, the gas is trapped within the outer chamber. As the orbiting scroll rotates, the outer chamber becomes smaller and smaller. Fig. 3b shows the centre of the orbiting scroll being at 90°. At this position, the outer chamber is in the suction process, the middle chamber in the compression process and the inner chamber in the discharging process. Fig. 3c and d shows the suction and compression process in progress simultaneously. This working cycle appears periodically.

Obviously, the manufacturing and assembly accuracy of the scrolls must be very high. Firstly, because at the same time the two scrolls may contact each other in the radial direction at several points. The larger the machined clearances and assembly clearances of the two scrolls, the much higher the leakage of the compressed gas will be. Secondly, the working surfaces of the scrolls are inner surfaces, which are more difficult to machine than the outer ones. Thus, this results in larger machining tolerances. As the requirements described above are so strict, the development of this type of compressor needs a relatively long time regarding design, manufacturing and assembly. The costs are high and hence it is ideal for the development process of scroll compressors to adopt the CE approach and tools which can support the whole process simultaneously and comprehensively.

3. The approach

The CE approach is shown in Fig. 4. Customer requirements are input into a pre-processing module written in