CHEMICAL ENGINEERING TRANSACTIONS

VOL. 66, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216

DOI: 10.3303/CET1866137

Application of Image Processing Algorithm in Chemical Production Technology

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With the development and application of industrial CT technology, the nondestructive testing of materials and the manufacturing errors of materials can be effectively monitored and controlled. The basic principle of Industrial CT technology is to adopt the ray bundle of passing through the measured object to get the fault projection data, and then with the image reconstruction method the projection data will be scanned to get two-dimensional grey image. The traditional industrial CT technology is also facing the problem of image quality and image segmentation in image processing field. The industrial CT technology has been improved, in order to make expanders which can meet the needs of LNG liquefaction factories, and effectively control the quality of expanders. First of all, this paper analyzes the expander of LNG production equipment. Secondly, it introduces the industrial CT technology in detail. Then, it introduces the algorithm of image processing. Finally, combined with the new industrial CT technology, it conducts some experiments to verify that the proposed method can effectively detect the equipment like the core components of the expansion machine.

1. Introduction

With the development of technology, new materials and new equipment are more and more widely used in the development of technology. High strength steel is mainly used in the production of key parts. As a kind of clean and high quality fuel, natural gas has attracted more and more attention. However, as global environmental problems become increasingly serious, reducing the use of oil, coal and other energy sources is becoming the focus of national energy structure adjustment. Accelerating the use of clean energies like wind energy, nuclear energy, solar energy, and natural gas is the major energy use policy in China. The control of the expander rotor quality can effectively avoid chemical production problems caused by the production of expanders. However, any material is not perfect. There a variety of defects in the material. In addition to defects, manufacturing errors also lie in the producing process. There are two ways to find defects in the material. One is destructive, that is, cutting the material or other preparation methods to observe the internal defects. Another method can be used without damage to the material, which is also called non-destructive testing method.

Liquefied natural gas (LNG) can make up for the deficiency of pipeline natural gas because of its small size and convenient transportation. The volume of natural gas can be reduced by 600 times after being liquefied. Liquefied natural gas can play a great role both in large-scale transportation on the sea, and in the blank area of the natural gas pipeline on the land. Liquefied natural gas production cannot be separated without air separation equipment, whose core is the expander. The precision of the expansion machine have a great influence on the service life and the normal operation of the whole chemical production equipment. As the air separation equipment manufacturing in the world develops rapidly, the requirements of domestic users and large scale equipment have been improved greatly. Therefore, air separation equipment manufacturing capacity also has a great development. However, the study of turbo expander is always in the leading position in Europe and the United States, and Europe and the United States have mastered the research and manufacture of large and oversize turbine technology. In 1883, Tower (1883) finds the dynamic pressure phenomenon in the radial sliding bearing test of railway vehicles. The results of Tower are verified by Reynolds (1886) in 1886. Some researchers conduct integral transform on Reynolds equation under the assumption of infinite bearing, and obtain the analytical solution of simplified Reynolds equation. In 1929,

Please cite this article as: Chen L., 2018, Application of image processing algorithm in chemical production technology, Chemical Engineering Transactions, 66, 817-822 DOI:10.3303/CET1866137

Michell (1929) proposes the theory of infinitely short bearing. Air Liquide is the only air separation equipment manufacturer in French, which at present has more than 130 subsidiaries in many other countries, and can make large air separation equipment with their flow in and above 93440m /h. British Oxygen Company is mainly engaged in the design and manufacture of air separation equipment, and it can make air separation equipment which can simultaneously extract argon, helium, neon, and krypton. Cryostar Company, a subsidiary of Linde Group, is a recognized manufacturer in the field of liquid expander and cryogenic liquid pumps in the world (Marcuccilli and Zouaghi, 2007; Josef., 2010; Asutosh, 2010). Dresser-Rand has been one of the outstanding suppliers in the field of energy recovery turbine expander.

CT image processing is widely used in medicine. As a new research field, more and more scholars have paid attention to it. In 1895, the famous German physicist Roentgen discovers X –rays (Zheng et al., 2009; Tang and Chen, 2016). In 1970s, Computer tomography is born. CT creates a digital imaging precedent, but it is different from the ordinary X-ray imaging. CT shows the sectional anatomy images, whose density resolution is much higher than that of X-ray images. It is a revolution in medical imaging technology. CT has been widely used in the diagnosis of central nervous system, head and neck, lung, heart and large blood vessels and organ diseases (Wu, 2003). In 1970s, industrial CT technology is applied to the field of materials science. Industrial Computer Tomography (referred to as Industrial CT or ICT) is a kind of technique which uses rays to pass through the object and then conducts attenuation and reconstruction. It can obtain the lossless high-resolution grey image in the detected object. The internal structure, material, defect and density distribution of the tested parts can be accurately and visually reflected by industrial CT technology. At present, the industrial CT technology has been widely used in the field of non-destructive testing and non-destructive evaluation, and it has been recognized as the world's best non-destructive testing means (Legacy, 2008).

Industrial CT has been widely used in the detection of material defects and parts' manufacturing error analysis. However, with the development of industry, some defects in industrial CT image and the contour segmentation cannot meet the needs of industrial production. In this paper, the industrial CT technology has been improved. First of all, this paper analyses the expander of LNG production equipment. Secondly, it introduces the industrial CT technology in detail. Then, it introduces the algorithm of image processing. Finally, combined with the new industrial CT technology, it uses some experiments to verify that the proposed method can effectively detect the equipment like the core components of the expansion machine.

2. Expander technology for LNG production plant

Long-distance natural gas pipeline transportation generally uses high-pressure transportation, since the high pressure natural gas contained in the high-pressure gas transmission line always contains a great deal of energy. Because the terminal pressure of users in the downstream is relatively low, generally below 0.4MPa, the natural gas receiving stations and gate stations in the cities need to properly make pressure reduction according to downstream users' different requirements for gas pressure (Xiong, 2006). In the process of pressure regulating, high pressure natural gas will produce a large pressure drop, and release a lot of energy (Shao, 2009). The basic principle of using pressure energy of high pressure natural gas pipeline to produce LNG is that the mechanical energy, which is generated by volume expansion of high pressure natural gas during depressurization, is used to continue pressurizing high-pressure natural gas. After expanding, the temperature of the gas is reduced. Then after repeated expansion, the temperature can reach more than 100 degrees below zero, and through the heat exchange, LNG will be produced. One end is the cantilever single stage centripetal turbine coaxial drive unit. The other end is the cantilever centrifugal turbocharger, and if the turbocharger is used to improve the expander inlet pressure, the refrigeration capacity and output work of the expander will be increased. This type of unit is called a positive turbo expander. Figure 1 is a schematic diagram of using turbo expander refrigeration to produce LNG.

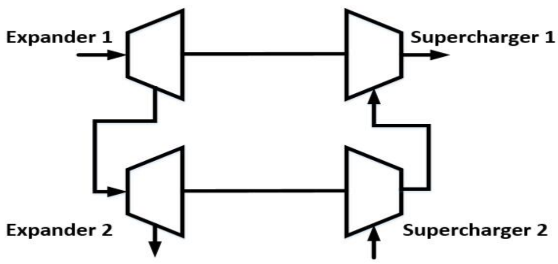

Figure 1: The schematic diagram of using turbo expander refrigeration to produce LNG

2.1 Turbo expander

Turbo expander is a kind of equipment that uses the expansion of the gas to do work and produce cold quantity. It is also an important part of low temperature air separation equipment and gas separation and liquefaction equipment. When passing through the turbine expansion machine, high pressure gas' expansion process can be summed up as follows. High pressure gas speeds up in the static nozzle ring, and outflows after ripping into the cascade passageway. The change of the inlet and outlet momentum makes the air flow to the gate, then the kinetic energy of the air flow is reduced and the stagnation enthalpy is decreased, so as to achieve the purpose of external work and refrigeration. The turbine is to achieve energy conversion through utilizing the rate change of the working fluid. The working fluid expands in the turbine expander to obtain kinetic energy, and the energy is output by external wheel, in order to reduce the energy and temperature of the working fluid. This production process is also called differential pressure liquefaction process. High pressure natural gas achieves constant entropy expansion and depressurization in the turbo expander, and the cooling capacity of this process is:

$$Q = m(h_{in} - h_{out})\eta_1 \tag{1}$$

Among them, Q is the refrigeration output, m is the gas mass flow rate, h_{in} and h_{out} are respectively the import enthalpy and export enthalpy of expander working substances, η_1 is the turbine efficiency. If all of the expansion work is used, the process of energy loss is:

$$\Delta E = T_0 S_g = T_0 m(s_2 - s_1) \tag{2}$$

Among them, ΔE is the loss of energy, S_g is the entropy, s is the entropy ratio. Figure 2 is the internal structure of the expander.

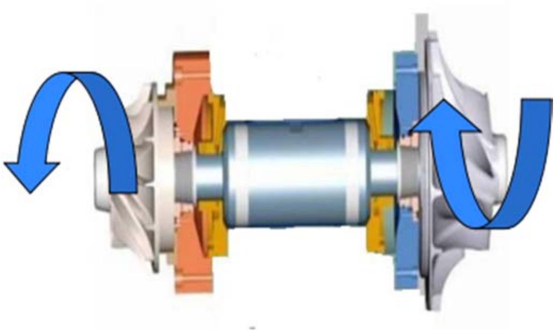

Figure 2: The internal structure of the expander.

2.2 Analysis of expander rotor system

The working environment of turbine rotor system is quite complex. There are the expansion flow and compressible flow of gas at both ends of the impeller, and different gradients of pressure and temperature are formed on the surface of the expansion wheel and boosting wheel, so the rotor system is both affected by and temperature field. Since the flow field will affect the boundary conditions of the temperature field, different fields will influence each other. In addition, the centrifugal force, caused by the rotation of the rotor, and other forces also increase the complexity of the engineering problem. The expansion wheel is the output power unit of the rotor system. Gas flows and expands in the expander to drive impeller, whose velocity, temperature and pressure will decrease, and then the total energy will also decrease. While the boosting wheel is the rotor components in the system, in which the gas is compressed, and the speed, temperature and pressure will be larger, then its total energy will increase. As the core component of the expander, the mechanical strength of rotors is very important to the production. Figure 3 is the mechanical model of turbo expander rotor.

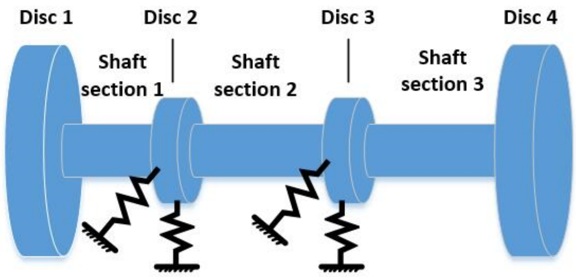

Figure 3: The mechanical model of turbo expander rotor.

3. Research on industrial CT technology

The basic principle of Industrial CT technology is to use the ray bundle of passing through the measured object to get the fault projection data, and then with the image reconstruction method the projection data will be scanned to get two-dimensional grey images. Through the analysis and measurement of the image, we can get the information of the detected objects, such as the inside and outside structure, size and density [8-7]. It is not only applied to aerospace, pyrotechnics, precision machinery and other important products, but also applied to the automotive, petroleum, geology, archaeology and many other fields.

Computer tomography scan imaging technology is an image contrast technology which combines both computer technology and ray scanning technology. It uses an accurate X-ray beam and high sensitivity detectors to make continuous tomography through surrounding detected objects. In every process, firstly the detector receives the attenuation X-ray information, and the A/D converter inputs the output digital to the computer, then the X-ray absorption coefficient of each point in different fault planes will be got after high-the speed operation of computer. Finally, these data will be used to make up the matrix of the image. CT image is composed of two parts: and pixel size. Among them, pixel intensity reflects the X-ray absorption degree of the detected objects, and the pixel size reflects the fine degree of the image, i.e. the spatial resolution of the image. CT image is a grey level image. Compared with the X image, the black area is low density because of its low density and low X-ray absorption.

Industrial CT system is generally composed of X-ray source, detector, mechanical scanning system, data acquisition system, control system and so on. The combination of X-ray source, detector and mechanical scanning system determines the effect of mechanism error on the imaging quality of industrial CT, which is very important for the industrial CT system.

4. Image segmentation algorithm

Support vector machine (SVM) is a machine learning method based on statistical learning theory, whose theoretical basis is the structural risk minimization principle. The VC dimension is an important index to describe the function set or machine learning capability.VC dimension reflects the learning ability of the function set. In the case of finite dimensional training samples, when the number of samples is fixed, the greater the VC dimension of machine learning is, the more complex the learning mechanism of the learning machine to the training samples is. The statistical learning theory is based on VC dimension, and deduces the relationship between expected risk and empirical risk, which is called the world of generalization. The principle of empirical risk minimization is to obtain the empirical risk through the known training data, and use the empirical risk to approach the minimum value of the desired risk. In the case of finite samples, the learning machine should not adopt the empirical risk minimization principle. Researchers put forward the principle of structural risk minimization (SRM). Its basic idea is that firstly, the function set is divided into multiple subsets,. Then array these function subsets in ascending order according to the VC dimension, and seek empirical risk minimization for each subset. Finally, based on their empirical risk minimization and VC dimension, obtain the actual minimum risk of each subset.

With the introduction of the kernel function, SVM has shown its outstanding advantages in solving nonlinear problems. Low dimensional space vector sets are usually hard to partition, and the solution is to map them to high dimensional space. But the kernel function smartly solves this problem exactly. In practical problems, the kernel function is usually given directly. At present, the most commonly used kernel functions are the following three types.

RBF kernel function: $k(x_i, x_j) = \exp(-\frac{\|x_i - x_j\|^2}{2\sigma^2})$ (3)

Polynomial kernel function: $k(x_i, x_j) = [1 + (x_i \cdot x_j)]^d$ (4)

Sigmoid kernel function: $k(x_i, x_j) = \tanh[\gamma(x_i \cdot x_j) + c]$ (5)

Different kernel functions and their parameters have great influence on the classification performance. Therefore, it is important to select the appropriate kernel.

5. System Improvement and Implementation

The pressure energy loss of high-pressure natural gas pipeline mainly exists in the process of adjusting pressure in the sub transmission station. In order to realize the recovery and utilization of energy, the pressure in long natural gas pipeline transportation station can be recycled to produce LNG, which is also known as pressure liquefaction production device. In view of the high efficiency of the turbine expander, it can always be used as the equipment for recovering the pressure energy.

The rotor is the only high speed operating component in the turbo expander. It has a great influence on the efficiency and stability of the expander. The structural parameters of the rotor have a great effect on the critical speed, and the main parameters are the bearing span, the length of the main shaft, the sealing length, the diameter of the shaft, the position and the size of the thrust plate. High quality rotor is essential to the production of the factory. Advanced industrial CT can be used to detect rotor. Detecting parts' manufacturing errors and internal material defects can avoid operation risk when the factory produces LNG. In this paper, optimizing the industrial CT image can effectively improve the efficiency of industrial CT detection.

In the actual engineering application, the quality of Tomography image obtained by industrial CT scan cannot satisfy the application requirements. In this paper, the image is enhanced to improve the image quality, and then the contour of the CT image is segmented and extracted. Histogram equalization is firstly used to enhance the image. Secondly, the SVM algorithm is used to segment the image.

(1) Calculate the frequency of each gray level in the histogram of the original image.

(2) The gray value is calculated by the gray value transform function.

(3) Update the gray level distribution of the image to complete the gray level histogram equalization.

(4) The kernel function of SVM algorithm is improved, and the new kernel function is constructed by using 2-2 weighting the three functions RBF kernel function, Polynomial kernel function and Sigmoid kernel function.

(5) Optimize the weights to find the best combination of the best weight.

(6) Use the improved algorithm to segment the CT image contour.

With regard to the expander rotor of LNG production factories, the optimization algorithm for CT image is put forward in this paper. It is not only helpful for rapidly extracting expander rotor image region that needs detecting, but also helps to compare and verify CAD drawings and designing drawings, which greatly improves the efficiency and accuracy of industrial CT detection.

6. Experiment and Analysis

6.1 System Platform

In order to verify the effect of this algorithm, we choose the expander rotor of a certain LNG production factory as CT sample. The improved method is applied in the experiment. Experimental results show that the proposed method can quickly and accurately detect the size of the specimen. Our experimental environment contains: Hardware environment Intel (R) Core (TM) i5-4300M @ 2.60GHz, 4G memory, and Windows 7 software environment, with MATLAB as the design language. Fig.4 is the specimen of experiment.

Figure 4: The specimen of experiment.

6.2 System Operating Results and Analysis

In order to test the accuracy of the industrial CT image, this paper conducts actual measurement on the sample. Besides, the vector size value and the actual measurement value are compared to analyze the error so as to achieve the purpose of inspection accuracy.

Table 1: The comparison between the ICT vector size and the actual measured value.

Size	Design size(mm)	Measurement(mm)	CT size(mm)
Size 1	220.50	220.41	220.46
Size 2	150.00	150.10	150.11
Size 3	10.00	10.03	10.03
Size 4	55.00	55.17	55.10
Size 5	35.00	35.01	34.01
Size 6	50.00	50.05	50.03

Experimental results show that the proposed method can effectively display the image contour of the sample, which has obvious advantages in improving the detection efficiency of industrial CT images.

7. Conclusion

In this paper, the industrial CT technology has been improved. First of all, this paper analyses the expander of LNG production equipment. Secondly, this paper introduces the industrial CT technology in detail. Then, this paper introduces the algorithm of image processing. Finally, combined with the new industrial CT technology, some experiments are carried out. Results show that the proposed method can effectively detect the core components of the expansion machine and other equipment.

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