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A New Type of Cooling-Air Generator for Cooling-air Grinding

Yulin CAI[1,a], Hua ZHANG[1,b],Yefeng LIU[1,c], Huanhuan ZHAO[1,d],
Jun Yao [2,e], Haitao Huang [2,f]

[1] College of Energy and Power Engineering, University of Shanghai for Science and Technology, Shanghai 200093, P.R.China

[2]Shanghai Machine Tool Works Ltd, Shanghai 200093, P.R.China

[a]e-mail:caiyulin0000@163.com, [b]e-mail:zhanghua3000@163.com, [c]e-mail:yfliu209@163.com, [d]e-mail:aqa57@163.com, [e]e-mail:yfliu209@163.com, [f] e-mail:yfliu209@163.com

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Abstract. Cooling-air grinding is one sustainably alternative processing technology to traditional grinding. In order to study the discipline and characteristic of cooling-air grinding, a new type of cooling-air generator for cooling-air grinding was designed and set up in the paper. And the compressed air of the system and the main processing equipment were introduced in detail. Performance tests showed that the device was able to meet the design requirements.

Introduction

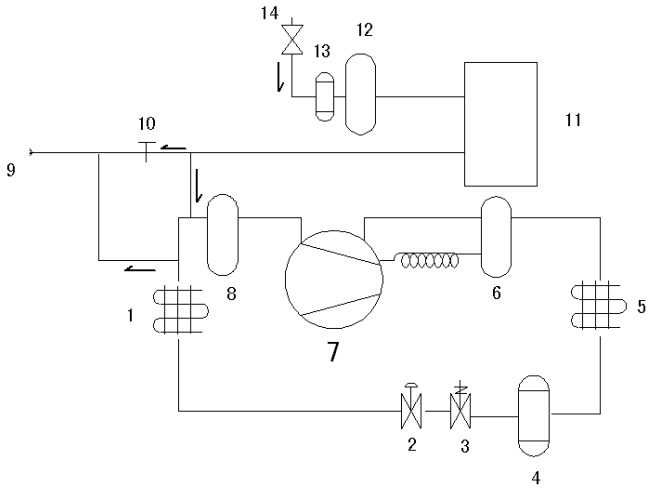
Grinding plays an important role on a precision machining and high-hard material processing, but high production machining of steel inherently generates high cutting zone temperature. Such high temperature causes dimensional deviation and premature failure of cutting tools. It also impairs the surface integrity of the product by inducing tensile residual stresses and surface and subsurface micro-crack in addition to rapid oxidation and corrosion[1-2].So it is essential to remove heat effectively. In particular, in order to improve the machining performance and especially to increase the tool life and to improve the surface quality of the specimen. Different methods such as high-pressure coolant, minimal quantities of lubricant, and nitrogen for cryogenic cooling of the tool are studied [3-10].

The traditional way of cooling is flood coolant which is customarily used to increase tool life and to improve specimen surface finish in machining. It is also responsible for some adverse effects on the environment and users' health. However, cutting fluids pose serious health and environmental hazards. Operators exposed to the cutting fluids may have skin contact with these fluids, inhale mists or vapor, or even swallow mist particles of these fluids. Because of their toxicity, there may be health problems such as dermatitis, problems in the respiratory and digestive systems, and even cancer. Improper disposal of these cutting fluids may cause serious environmental problems such as pollution. The strict regulations and their enforcement when using cutting fluid have, therefore, been tightened. The waste disposal and post-handling of the cutting fluids and other related costs have, therefore, been increasing. All these factors coupled with the fact that the consumption of the cutting fluids has been rising correspondingly, have caused companies and organizations to implement strategies to reduce the use of cutting fluids in their production activities.

Cooling-air Generator and Procedure

The cooling-air cutting needs to supply low-temperature air at high pressure and high speed through the nozzle to the cutting zone. A cooling-air generator has been designed, fabricated and tested. The schematic view of the cooling-air set up is shown in Fig. 1. The air compressor is a device to compress

air. The function of the receiver is to reduce the flow pulsation and store the compressed air. The filter separates oil、water and solid particles from the air to purify the air. Alumina is used in the adsorption dryers to dry compressed air in order to avoid cooling frost or moisture when the compressed air is cooled in the evaporator. The dried and compressed air is cooled through the evaporator and then jetted to cutting zone. The environmental air and chilled air is mixed by bypass valve for achieving the accurate controls of the outlet temperature (-30℃~0℃). Moreover, the nozzle is a multichannel nozzle, as shown in Fig. 2, so the noise made by vortex air beside the nozzle's outlet can be reduced effectively.



1—Evaporator 2—Expansion valve 3—Electromagnetic valve 4—Receiver 5—Condensser 6—Oil separator 7—Refrigeration compressor 8—Liquid-vapor separator 9—Nozzle 10—Bypass valve 11—adsorption dryer 12—air compressor 13—Filter 14—Air inlet

Fig.1 The schematic view of the cooling-air generator

Vapor Compression Refrigeration System Design. In order to obtain cooling-air at -30℃~ 0℃ required by experiment, the single stage evaporation compressor refrigeration cycle is selected and the refrigerant is R404A which is a low boiling point refrigerant. The cycle mainly is composed of four parts: the compressor, condenser, expansion valve and evaporator.

Low noise injector. Injector is a terminal device of the cooling-air generator. Its structure determines the distribution of the cooling-air which plays a key role on the grinding process. The jet uses compressed cooling-air, so there is annoying high-frequency ear-piercing sound that grates on the ear. Its noise usually exceeds to 100dB. The noise is harm to hearing, so it must be lower than 85dB. This noise is caused by gas vortex near the exit of injector, and its intensity is decided from the nozzle shape and gas pressure. These show that the stronger the air flow is, the greater the noise will be. So a new type injector is designed in the paper. Based on the theory of subsonic impact jet flow, the inner air flow passage structure is designed according to Eq.1.

$$r = r_1\{1-[1-(\frac{r_1}{r_0})^2]\frac{(1-3\chi^2/l^2)^2}{(1+3\chi^2/l^2)^2}\}^{-1/2}. \quad (1)$$

Where, r_0 、 r_1 is the injector's radius of inlet and outlet, m. l is the distance between inlet and outlet, m. x is distance of any point on wall from injector 's inlet, m.

In this kind of air flow passage, compressed air in the injector will be expanded gradually and completely. Transverse gradient pressure and radial velocity at inlet cross section gradually become smaller and tend to zero at outlet. So the uniform velocity fields can be got, and the back flow can be removed. The structure of the multichannel injector is showed in Fig.2.The injector head is designed

to multi-channel form of small diameter, and air flow can be controlled accurately. In this condition, the airflow is a uniform, straight, strong airflow. And the noise can be significantly reduced.

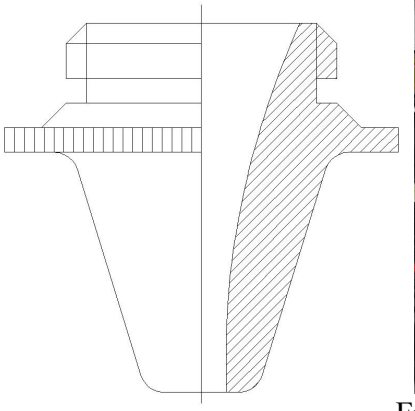


Fig. 2 Multichannel nozzle

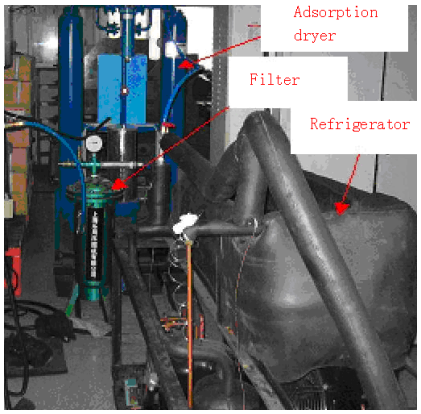


Fig. 3 Cooling-air generating device of the actual object.

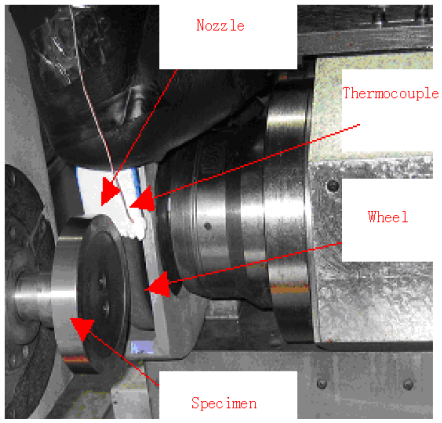


Fig. 4 Test scence of cooling-air grinding

Performance Tests of the cooling-air generator

The results of test. The device has been designed and built, as shown in Fig.3and Fig.4. Table 1 lists the performance test results. There are 2m distance between evaporator and injector and heat insulator were used, but there is still heat loss which caused the air temperature raise about 5 ℃.So air temperature is tested at the outlet of injector using T-type thermocouple. Test results showed: The cooling-air generator can provide the low-temperature air at the flow range of 0 ~ 34Nm^3 / h, at the absolute pressure range of 3 ~ 6bar and at the temperature range of -34 ℃ ~ 0 ℃. The device can fully meet experiment design requirements. In the condition of ambient temperature of 25℃, the device starting time is less than 30 minutes.

Table 1 The test result of the cooling-air generating device

NO.	Flow（Nm^3/h）	Absolute pressure (bar)	outlet temperature (℃)
1	24	3	-28
2	28	4	-30.6
3	30	5	-32.1
4	34	6	-34.2

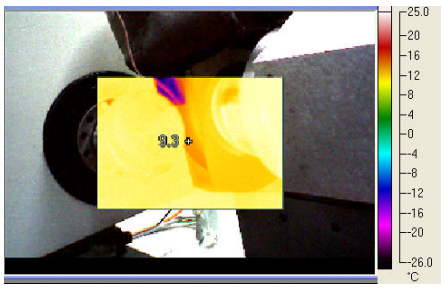


Fig.5 Temperature field of -35 ℃of jet gas、33Nm^3/h of flow 、293K of ambient temperature

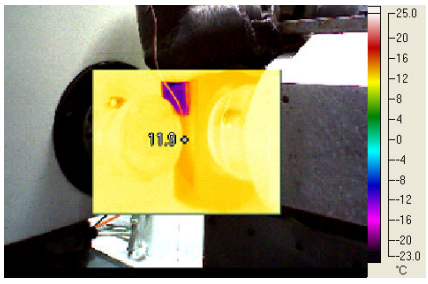


Fig.6 Temperature field of -25 ℃of jet gas、33Nm^3/h of flow 、293K of ambient temperature

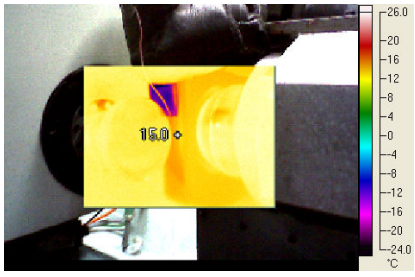


Fig.7 Temperature field of -15 ℃ of jet gas、33Nm^3/h of flow 、293K of ambient temperature

The test result of grinding zone temperature field. Temperature field of grinding zone is an important factor for studying the cooling effect.

The actual temperature field is measure by the infrared thermodetector Fluke Ti10. The results are showed in Fig. 5~7.From three Figures we can draw a conclusion that the grinding zone can reach lower temperature. The lower the outlet's air temperature is, the lower the grinding zone temperatures are.

Conclusion

In the paper, a new type of cooling-air generator for green grinding test is designed, fabricated and used. The device can provide the low-temperature air at the flow range of 0 ~ 34Nm3 / h, at the absolute pressure range of 3 ~ 6 bar and at the temperature range of -34 ℃ ~ 0 ℃. Also, the system of the device and its working process are introduced. Then, the refrigeration system and low-noise injector has been introduced in details. The cooling-air generator is regarded as one of the potential device for its many advantages such as reasonable design, simple structure, short start-up time, and easy control. Through performance testing, the device fully meets the design requirements. The research of successful development of the device provides better test conditions for the latter experiment test of cooling-air grinding performance.

Acknowledgments

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