CONTENTS

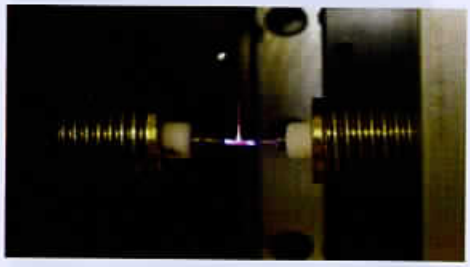
Vol. 30, No. 2, 2017

CHINESE JOURNAL OF MECHANICAL ENGINEERING

RESEARCH HIGHLIGHT

REVIEWS

Abstract: To satisfy the measuring demands for the micro components of the industry, micro/nano probing systems with various ball tips have been developed. However, most of them cannot be used to measure the real micro geometrical features high precisely because the parameters of the ball tips are not appropriate. The ball tips with a diameter of less than 100 μm, a sphericity and eccentricity of far less than 1 μm are required urgently. A review on the state-of-the-art of ball tips of micro/nano probing systems is presented. The material characteristics and geometric parameters of now available ball tips are introduced separately. The existing fabrication methods for the ball tips are demonstrated and summarized. The ball tips' future trends, which are smaller diameter, better sphericity and smaller eccentricity, are proposed in view of the practical requirements of high-precision measurement for micro geometrical features. Some challenges have to be faced in future, such as the promotion and high-precision measurement for the small ball tip's sphericity and eccentricity. Fusion method without the gravity effect when the molten ball tip solidifying is a more suitable way to fabricate a small diameter ball tip together with a shaft.



Abstract: The adoption of cold-extrusion forming for internal thread net forming becomes an important component of anti-fatigue processing with the development of internal thread processing towards high performance, low cost and low energy consumption. It has vast application foreground in the field of aviation, spaceflight, high speed train and etc. The internal thread processing and anti-fatigue manufacture technology are summarized. In terms of the perspective of processing quality and fatigue serving life, the advantages and disadvantages of the processing methods from are compared. The internal thread cold-extrusion processing technology is investigated for the purpose of improving the anti-fatigue serving life of internal thread. The superiorities of the plastic deformation law and surface integrity of the metal layer in the course of cold extrusion for improving its stability and economy are summed up. The proposed research forecasts the development tendency of the internal thread anti-fatigue manufacturing technology.

CONTENTS

Vol. 30, No. 2, 2017

ORIGINAL ARTICLES

Advanced Manufacturing

DOI 10.1007/s10033-017-0074-8

Abstract: Due to the influence of magnetic hysteresis and energy loss inherent in giant magnetostrictive materials(GMM), output displacement accuracy of giant magnetostrictive actuator(GMA) can not meet the precision and ultra precision machining. Using a GMM rod as the core driving element, a GMA which may be used in the field of precision and ultra precision drive engineering is designed through modular design method. Based on the Armstrong theory and elastic Gibbs free energy theory, a nonlinear magnetostriction model which considers magnetic hysteresis and energy loss characteristics is established. Moreover, the mechanical system differential equation model for GMA is established by utilizing D'Alembert's principle. Experimental results show that the model can preferably predict magnetization property, magnetic potential orientation, energy loss for GMM. It is also able to describe magnetostrictive elongation and output displacement of GMA. Research results will provide a theoretical basis for solving the dynamic magnetic hysteresis, energy loss and working precision for GMA fundamentally.

DOI 10.1007/s10033-017-0092-6

Abstract: The progressive cutting based on auxiliary paths is an effective machining method for the material accumulating region inside the mould pocket. But the method is commonly based on the radial depth of cut as the control parameter, further more there is no more appropriate adjustment and control approach. The end-users often fail to set the parameter correctly, which leads to excessive tool load in the process of actual machining. In order to make more reasonable control of the machining load and tool-path, an engagement angle modeling method for multiple-circle continuous machining is presented. The distribution mode of multiple circles, dynamic changing process of engagement angle, extreme and average value of engagement angle are carefully considered. Based on the engagement angle model, numerous application techniques for mould pocket machining are presented, involving the calculation of the milling force in multiple-circle continuous machining, and rough and finish machining path planning and load control for the material accumulating region inside the pocket, and other aspects. Simulation and actual machining experiments show that the engagement angle modeling method for multiple-circle continuous machining is correct and reliable, and the related numerous application techniques for pocket machining are feasible and effective. The proposed research contributes to the analysis and control tool load effectively and tool-path planning reasonably for the material accumulating region inside the mould pocket.

DOI 10.1007/s10033-017-0077-5

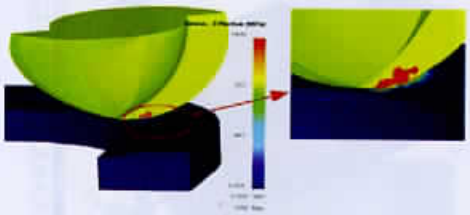
Abstract: Synchronization errors directly deteriorate the machining accuracy of metal parts and the existed method cannot keep high synchronization precision because of external disturbances. A new double position servo synchronous driving scheme based on semi-closed-loop cross-coupling integrated feedforward control is proposed. The scheme comprises a position error cross-coupling feedforward control and a load torque identification with feedforward control. A digital integrated simulation system for the dual servo synchronous drive system is established. Using a 20 t servo broacher, performance analysis of the scheme is conducted based on this simulation system and the simulation results show that systems with traditional parallel or single control have problems when the worktable works with an unbalanced load. However, the system with proposed scheme shows good synchronous performance and positional accuracy. Broaching tests are performed and the experimental results show that the maximum dual axis synchronization error of the system is only 8 μm during acceleration and deceleration processes and the error between the actual running position and the given position is almost zero. A double position servo synchronous driving scheme is presented based on cross-coupled integrated feedforward compensation control, which can improve the synchronization precision.

CONTENTS

Vol. 30, No. 2, 2017

DOI 10.1007/s10033-017-0088-2

Abstract: To optimize milling force and machining accuracy quality in corner milling process, the changing law of milling force is revealed by Finite Element Method(FEM). Based on DEFORM software a serial of 3D FEM models for corner milling process are devloped. Tool curved trajectory is achieved by establishing accurate relationship of tool location with milling time. Adaptive remeshing technique and iterative algorithm are adopted to ensure convergence of FEM model. Component force characteristics are revealed by analyzing FEM simulation results. It indicates that the milling force in Y direction becomes negative comparing with forces in X and Z direction. Magnitude of forces in three directions decreases with increase of spindle speed, while it increases with increase of milling feedrate. The simulation results for cutting force are in good agreement with those obtained from experiment. The FEM simulation model is first successfully established for corner milling process in this study, and the results provide a guide for optimizing cutting parameters in cutting process.

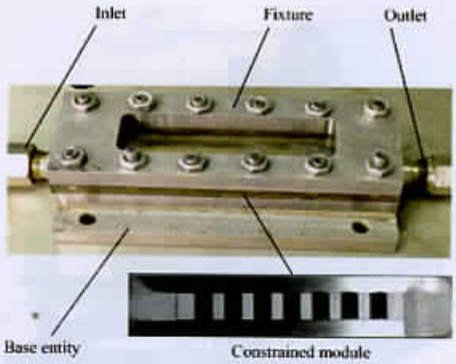


DOI 10.1007/s10033-017-0078-4

Abstract: In traditional electroforming process for revolving parts with complex profiles, the drawbacks on surface of deposits, such as pinholes and nodules, will lead to varying physical and mechanical properties on different parts of electroformed components. To solve the problem, compositely moving cathode is employed in abrasive-assisted electroforming of revolving parts with complicated profiles. The cathode translates and rotates simultaneously to achieve uniform friction effect on deposits without drawbacks. The influences of current density and translation speed on the microstructure and properties of the electroformed nickel layers are investigated. It is found that abrasive-assisted electroforming with compound cathode motion can effectively remove the pinholes and nodules, positively affect the crystal nucleation, and refine the grains of layer. The increase of current density will lead to coarse microstructure and lower micro hardness, from 325 HV down to 189 HV. While, faster translational linear speed produces better surface quality and higher micro hardness, from 236 HV up to 283 HV. The weld-ability of the electroformed layers are also studied through the metallurgical analysis of welded joints between nickel layer and 304 stainless steel. The electrodeposited nickel layer shows fine performance in welding. The novel compound motion of cathode promotes the mechanical properties and refines the microstructure of deposited layer.

DOI 10.1007/s10033-017-0071-y

Abstract: Soft abrasive flow(SAF) finishing can process the irregular geometric surfaces, but with the matter of low processing efficiency. To address the issue, an improved SAF finishing method based on turbulent kinetic energy enhancing is proposed. A constrained flow passage with serration cross-section is constructed to increase the turbulence intensity. Taking the constrained flow passage as the objective, a two-phase fluid dynamic model is set up by using particle trajectory model and standard k-ε turbulence model, and the flow field characteristics of the flow passage are acquired. The numerical results show that the serration flow passage can enhance the turbulence intensity, uniform the particles distribution, and increase the particle concentration near the bottom wall. The observation results by particle image velocimetry(PIV) show that the internal vortex structures are formed in flow passage, and the abrasive flow takes on turbulence concentrating phenomenon in near-wall region. The finishing experiments prove that the proposed method can obtain better surface uniformity, and the processing efficiency can be improved more 35%. This research provides an abrasive flow modeling method to reveal the particle motion regulars, and can offer references to the technical optimization of fluid-based precision processing.



CONTENTS

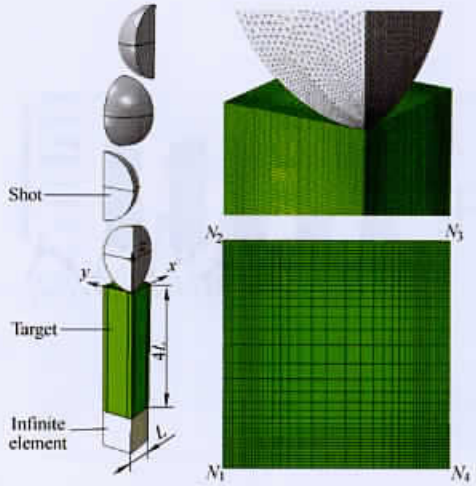
Vol. 30, No. 2, 2017

CONTENTS

Vol. 30, No. 2, 2017

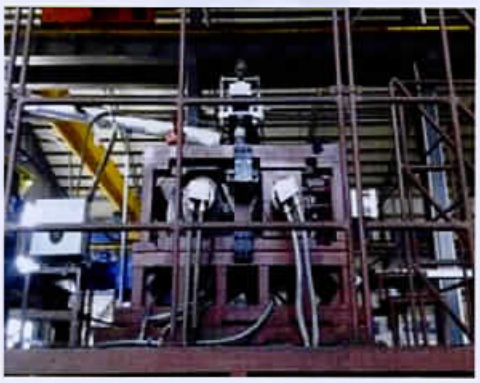
DOI 10.1007/s10033-017-0084-6

Abstract: The symmetrical cell model is widely used to study the residual stress induced by shot peening. However, the correlation between the predicted residual stresses and the shot peening coverage, which is a big challenge for the researchers of the symmetrical cell model, is still not established. Based on the dynamic stresses and the residual stresses outputted from the symmetrical cell model, the residual stresses corresponding to full coverage are evaluated by normal distribution analysis. The predicted nodal dynamic stresses with respect to four corner points indicate that the equi-biaxial stress state exists only for the first shot impact. Along with the increase of shot number, the interactions of multiple shot impacts make the fluctuation of the nodal dynamic stresses about an almost identical value more and more obvious. The mean values and standard deviations of the residual stresses gradually tend to be stable with the increase of the number of shot peening series. The mean values at each corner point are almost the same after the third peening series, which means that an equi-biaxial stress state corresponding to the full coverage of shot peening is achieved. Therefore, the mean values of the nodal residual stresses with respect to a specific transverse cross-section below the peened surface can be used to correlate the measured data by X-ray. The predicted residual stress profile agrees with the experimental results very well under 200% peening coverage. An effective correlation method is proposed for the nodal residual stresses predicted by the symmetrical cell model and the shot peening coverage.



DOI 10.1007/s10033-017-0085-5

Abstract: The thermodynamic behavior of twin-roll casting(TRC) lead alloy strip process directly affects the forming of the lead strip, the quality of the lead strip and the production efficiency. However, there is little research on the thermodynamics of lead alloy strip at home and abroad. The TRC lead process is studied in four parameters: the pouring temperature of molten lead, the depth of molten pool, the roll casting speed, and the rolling thickness of continuous casting. Firstly, the thermodynamic model for TRC lead process is built. Secondly, the thermodynamic behavior of the TRC process is simulated with the use of Fluent. Through the thermodynamics research and analysis, the process parameters of cast rolling lead strip can be obtained: the pouring temperature of molten lead: 360–400 ℃, the depth of molten pool: 250–300 mm, the roll casting speed: 2.5–3 m/min, the rolling thickness: 8–9 mm. Based on the above process parameters, the optimal parameters(the pouring temperature of molten lead: 375–390 ℃, the depth of molten pool: 285–300 mm, the roll casting speed: 2.75–3 m/min, the rolling thickness: 8.5–9 mm) can be gained with the use of the orthogonal experiment. Finally, the engineering test of TRC lead alloy strip is carried out and the test proves the thermodynamic model is scientific, necessary and correct. In this paper, a detailed study on the thermodynamic behavior of lead alloy strip is carried out and the process parameters of lead strip forming are obtained through the research, which provide an effective theoretical guide for TRC lead alloy strip process.



DOI 10.1007/s10033-017-0044-1

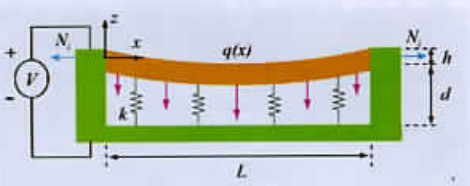
Abstract: Load behavior is one of the most critical factors affecting mills' energy consumption and grinding efficiency, and is greatly affected by the liner profiles. Generally, as liner profiles vary, the ball mill performances are extremely different. In order to study the performance of the ball mill with regular polygon angle-spiral liners(RPASLs), experimental and numerical studies on three types of RPASLs, including regular quadrilateral, pentagonal and hexagonal, are carried out. For the fine product of desired size, two critical parameters are analyzed: the energy input to the mill per unit mass of the fine product, E^*, and the rate of production of the fine product, F^*. Results show that the optimal structure of RPASLs is Quadrilateral ASL with an assembled angle of 50°. Under this condition, the specific energy consumption E^* has the minimum value of 303 J per fine product and the production rate F^* has the maximum value of 0.323. The production rate F^* in the experimental result is consistent with the specific collision energy intensity to total collision energy intensity ratio E_s/E_t in the simulation. The relations between the production rate F^* and the specific energy consumption E^* with collision energy intensity E_s and E_t are obtained. The simulation result reveals the essential reason for the experimental phenomenon and correlates the mill performance parameter to the collision energy between balls, which could guide the practical application for Quadrilateral ASL.

CONTENTS

Vol. 30, No. 2, 2017

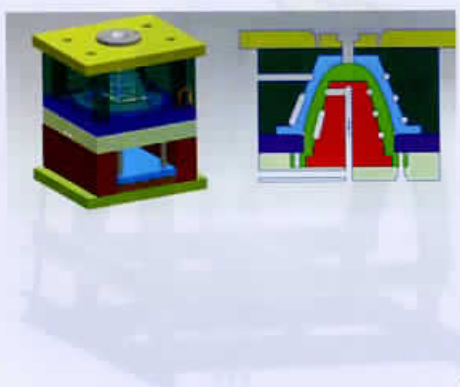
DOI 10.1007/s10033-017-0083-7

Abstract: For the car sequencing(CS) problem, the drawbacks of the "sliding windows" technique used in the objective function have not been rectified, and no high quality initial solution has been acquired to accelerate the improvement of the solution quality. Firstly, the objective function is improved to solve the double and bias counting of violations broadly discussed. Then, a new method combining heuristic with constraint propagation is proposed which constructs initial solutions under a parallel framework. Based on constraint propagation, three filtering rules are designed to intersecting with three greedy functions, so the variable domain is narrowed in the process of the construction. The parallel framework is served to show its robustness in terms of the quality of the solution since it greatly increases the performance of obtaining the best solution. In the computational experiments, 109 instances of 3 sets from the CSPLib's benchmarks are used to test the performance of the proposed method. Experiment results show that the proposed method outperforms others in acquiring the best-known results for 85 best-known results of 109 are obtained with only one construction. The proposed research provides an avenue to remedy the deficiencies of "sliding windows" technique and construct high quality initial solutions.



DOI 10.1007/s10033-017-0079-3

Abstract: This paper provides the static and dynamic pull-in behavior of nano-beams resting on the elastic foundation based on the nonlocal theory which is able to capture the size effects for structures in micron and sub-micron scales. For this purpose, the governing equation of motion and the boundary conditions are driven using a variational approach. The formulation includes the influences of fringing field and intermolecular forces, such as Casimir and van der Waals forces. The differential quadrature (DQ) method is employed as a high-order approximation to discretize the governing nonlinear differential equation, yielding more accurate results with a considerably smaller number of grid points. In addition, a powerful analytical method called parameter expansion method (PEM) is utilized to compute the dynamic solutionand frequency-amplitude relationship. It is illustrated that the first two terms in series expansions are sufficient to produce an acceptable solution of the mentioned structure. Finally, the effects of basic parameters on static and dynamic pull-in instability and natural frequency are studied.



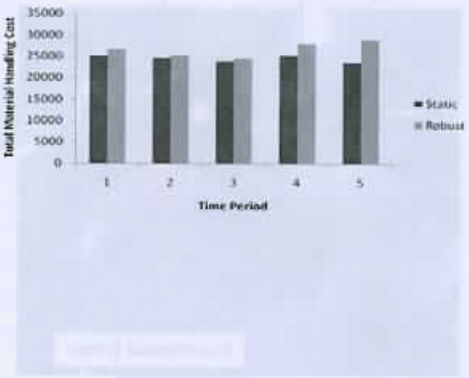
DOI 10.1007/s10033-017-0081-9

Abstract: The use of plastic-based products is continuously increasing. The increasing demands for thinner products, lower production costs, yet higher product quality has triggered an increase in the number of research projects on plastic molding processes. An important branch of such research is focused on mold cooling system. Conventional cooling systems are most widely used because they are easy to make by using conventional machining processes. However, the non-uniform cooling processes are considered as one of their weaknesses. Apart from the conventional systems, there are also conformal cooling systems that are designed for faster and more uniform plastic mold cooling. In this study, the conformal cooling system is applied for the production of bowl-shaped product made of PP AZ564. Optimization is conducted to initiate machine setup parameters, namely, the melting temperature, injection pressure, holding pressure and holding time. The genetic algorithm method and Moldflow were used to optimize the injection process parameters at a minimum cycle time. It is found that, an optimum injection molding processes could be obtained by setting the parameters to the following values: T_M=180 °C; P_{inj} = 20 MPa; P_{hold} = 16 MPa and t_{hold} = 8 s, with a cycle time of 14.11 s. Experiments using the conformal cooling system yielded an average cycle time of 14.19 s. The studied conformal cooling system yielded a volumetric shrinkage of 5.61% and the wall shear stress was found at 0.17 MPa. The difference between the cycle time obtained through simulations and experiments using the conformal cooling system was insignificant (below 1%). Thus, combining process parameters optimization and simulations by using genetic algorithm method with Moldflow can be considered as valid.

CONTENTS

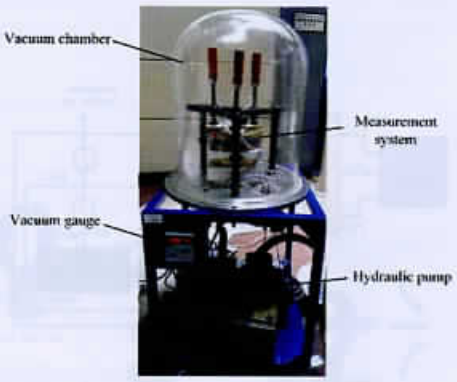
Vol. 30, No. 2, 2017

Abstract: Design of a robust production facility layout with minimum handling cost (MHC) presents an appropriate approach to tackle facility layout problems in a dynamic volatile environment, in which product demands randomly change in each planning period. The objective of the design is to find the robust facility layout with minimum total material handling cost over the entire multi-period planning horizon. This paper proposes a new mathematical model for designing robust machine layout in the stochastic dynamic environment of manufacturing systems using quadratic assignment problem (QAP) formulation. In this investigation, product demands are assumed to be normally distributed random variables with known expected value, variance, and covariance that randomly change from period to period. The proposed model was verified and validated using randomly generated numerical data and benchmark examples. The effect of dependent product demands and varying interest rate on the total cost function of the proposed model has also been investigated. Sensitivity analysis on the proposed model has been performed. Dynamic programming and simulated annealing optimization algorithms were used in solving the modeled example problems.

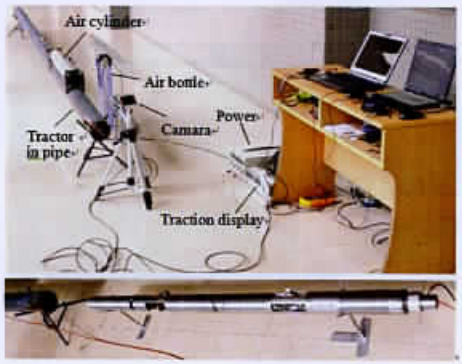


Robotics

Abstract: The efficiency and precision of parameter calibration in discrete element method (DEM) are not satisfactory, and parameter calibration for granular heat transfer is rarely involved. Accordingly, parameter calibration for granular heat transfer with the DEM is studied. The heat transfer in granular assemblies is simulated with DEM, and the effective thermal conductivity(ETC) of these granular assemblies is measured with the transient method in simulations. The measurement testbed is designed to test the ETC of the granular assemblies under normal pressure and a vacuum based on the steady method. Central composite design(CCD) is used to simulate the impact of the DEM parameters on the ETC of granular assemblies, and the heat transfer parameters are calibrated and compared with experimental data. The results show that, within the scope of the considered parameters, the ETC of the granular assemblies increases with an increasing particle thermal conductivity and decreases with an increasing particle shear modulus and particle diameter. The particle thermal conductivity has the greatest impact on the ETC of granular assemblies followed by the particle shear modulus and then the particle diameter. The calibration results show good agreement with the experimental results. The error is less than 4%, which is within a reasonable range for the scope of the CCD parameters. The proposed research provides high efficiency and high accuracy parameter calibration for granular heat transfer in DEM.



Abstract: During oil-gas well drilling and completion, downhole tools and apparatus should be conveyed to the destination to complete a series of downhole works. Downhole tractors have been used to convey tools in complex wellbores, however a very large tractive force is needed to carry more downhole tools to accomplish works with high efficiency. A novel serial active helical drive downhole tractor which has significantly improved performance compared with previous work is proposed. All previously reported helical drive downhole tractors need stators to balance the torque generated by the rotator. By contrast, the proposed serial downhole tractor does not need a stator; several rotator-driven units should only be connected to one another to achieve a tractive force multifold higher than that was previously reported. As a result, the length of a single unit is shortened, and the motion flexibility of the downhole tractor is increased. The major performance indicators, namely, gear ratio, velocity, and tractive force, are analyzed. Experimental results show that the maximum tractive force of a single-unit prototype with a length of 900 mm is 165.3 kg or 1620 N. The analysis and experimental results show that the proposed design has considerable potential for downhole works.



CONTENTS

Vol. 30, No. 2, 2017

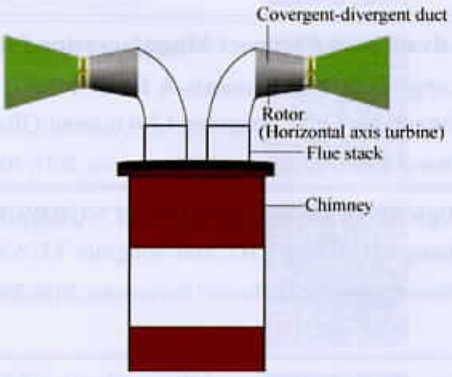
CONTENTS

Vol. 30, No. 2, 2017

Fluid Dynamics

DOI 10.1007/s10033-017-0090-8

Abstract: An innovative idea of extracting kinetic energy from man-made wind resources using ducted turbine system for on-site power generation is introduced in this paper. A horizontal axis ducted turbine is attached to the top of the chimney to harness the kinetic energy of flue gases for producing electricity. The turbine system is positioned beyond the chimney outlet, to avoid any negative impact on the chimney performance. The convergent-divergent duct causes increase in the flue gas velocity and hence enhances the performance of the turbine. It also acts as a safety cover to the energy recovery system. The results from the CFD based simulation analysis indicate that significant power 34 kW can be harnessed from the chimney exhaust. The effect of airfoils NACA4412 and NACA4416 and the diffuser angle on the power extraction by the energy recovery system using a 6-bladed ducted turbine has been studied with the CFD simulation. It is observed that the average flue gas velocity in the duct section at the throat is approximately twice that of the inlet velocity, whereas maximum velocity achieved is 2.6 times the inlet velocity. The simulated results show that about power may be extracted from the chimney flue gases of 660 MW power plant. The system can be retrofitted to existing chimneys of thermal power plants, refineries and other industries.



DOI 10.1007/s10033-017-0089-1

Abstract: Aeroacoustic performance of fans is essential due to their widespread application. Therefore, the original aim of this paper is to evaluate the generated noise owing to different geometric parameters. In current study, effect of five geometric parameters was investigated on well performance of a Bladeless fan. Airflow through this fan was analyzed simulating a Bladeless fan within a 2 m×2 m×4 m room. Analysis of the flow field inside the fan and evaluating its performance were obtained by solving conservations of mass and momentum equations for aerodynamic investigations and FW-H noise equations for aeroacoustic analysis. In order to design Bladeless fan Eppler 473 airfoil profile was used as the cross section of this fan. Five distinct parameters, namely height of cross section of the fan, outlet angle of the flow relative to the fan axis, thickness of airflow outlet slit, hydraulic diameter and aspect ratio for circular and quadratic cross sections were considered. Validating acoustic code results, we compared numerical solution of FW-H noise equations for NACA0012 with experimental results. FW-H model was selected to predict the noise generated by the Bladeless fan as the numerical results indicated a good agreement with experimental ones for NACA0012. To validate 3-D numerical results, the experimental results of a round jet showed good agreement with those simulation data. In order to indicate the effect of each mentioned parameter on the fan performance, SPL and OASPL diagrams were illustrated.