REVIEW ON ADVANCES IN VIBRATION MEASURING INSTRUMENTS-LASER DOPPLER VIBROMETER

Sayli M. Jadhav[1], Nilesha U. Patil[2] , Aaditi A.Patankar [3], Neeta B. Phatak[4]

***Abstract*:**
In this recent testing and measurement trends devices which monitor a parameter of a system without disturbing working parameters of a machine is required. In mechanical structural products research, design, production and maintenance the Vibration measurement is becoming so much important. Laser Doppler Vibrometer is very important to control and in reduction of the noise levels in different fields of the engineering application. In the automotive industry, in reducing noise from engines, tyres, covers either to optimize vehicle cabin acoustics. In this paper, the basic working principle of of Laser Doppler Vibrometer, with the area of the structural acoustic analysis is described. Laser Doppler Vibrometer has large capability in experimental vibration testing in various industrial and research fields. It provides more advantages over traditional vibration measurements. The detailed review of the research work in various fields of Laser Doppler Vibrometry is discussed in this paper.

Keywords: Vibration Measurement, Laser Doppler Vibrometry, Automotive Industry, Mechanical Structures

I. PRINCIPLES OF LASER DOPPLER VIBROMETRY

A laser Doppler vibrometer is becoming so much valuable and flexible instrument for measuring structural vibration response. There are various differences in the design but, basically, a coherent laser beam is directed at the point whose motion is to be measured and the back-scattered light is compared with the incident light in an interferometer [1]. The Doppler shifted wavelength is then measured and processed to give the surface velocity in the direction of the incident laser beam. Typical performances are a bandwidth up to 1 MHz, a velocity range of ±10 m/s, a resolution of about 8 nm in displacement and 0.5 μm/s in velocity. The calibration accuracy is nearby ±1.5% of RMS value. Deflecting mirrors can be provided to direct the laser beam at the desired point on the surface under test, providing a scanning capability. The scanning of the laser beamcan be performed by this Scanning Laser Doppler Vibrometer (SLDV) quickly and precisely on the structure under test, which can allow the analysis of large surface with high spatial resolution and short testing time. This particular capability, together with the noncontact nature, makes the SLDV technology suited for situations where the use of accelerometers is not possible, that is in the case of hot, light and rotating surfaces. Besides, if a high number of measurements have to be taken over different points, it might be essential to arrange an array of these transducers, that is time consuming and costly. Electronic Speckle Pattern Interferometry (ESPI) and double-pulse laser holography, provide only spatial information and not any means to control the time dependence. The outstanding capabilities outlined are certainly important to extend limits of experimental vibration and acoustical testing. Actually , the possibility of performing accurate vibration measurements provides a reliable database to be used in a large number of applications in vibro-acoustic analysis.

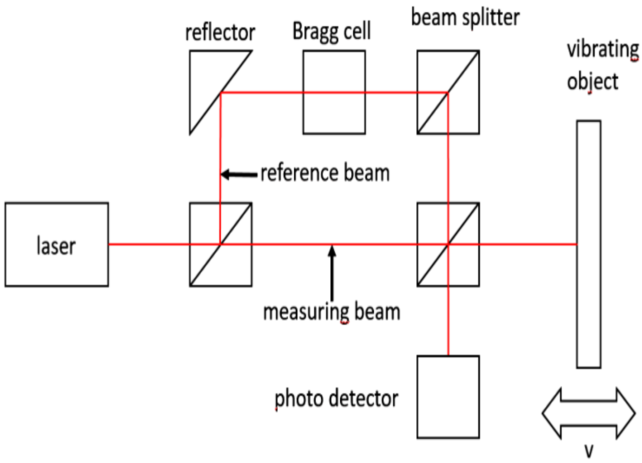

Fig.1 Working principle of laser vibrometry

The different authors had studied the use of laser Doppler vibrometer for different applications has discussed as follows.

II REVIEW ON USE OF LASER DOPPLER VIBROMETER FOR MEASURMENTS IN VARIOUS FIELDS

. In this paper Aida, Tsutomu; Yamazaki, Ai; et.al [2] The vibration of a vibrating tube densimeter can be measured by A laser-Doppler vibrometer for measuring P-V-T data at high temperatures and pressures. The apparatus developed allowed the control of the residence time of the sample so that decomposition at high temperatures could be minimized. To excite the U-shaped tube, Function and piezoelectric crystal was used in one of its normal modes of vibration. Densities of methanol-water mixtures are reported for at 673K and 40MPa with an uncertainty of 0.009g /cm3.

In this paper, Halkon, Ben J.; Rothberg, Steve J[3]. - The sensitivity of instrument vibration is confirmed to enable correction of measurements for arbitrary instrument vibration before development theoretically and experimentally of a practical scheme. A Pair of correction sensors is required by the scheme with appropriate orientation and relative location. It can be done while using frequency domain processing to accommodate inter-channel time delay and signal integrations. Error reductions in excess of 30 dB are delivered in laboratory tests with simultaneous instrument and target vibration over a broad frequency range. Ultimately, application to measurement on a vehicle simulator experiencing high levels of vibration demonstrates the practical nature of the correction technique and its robustness in a challenging measurement environment.

In this paer Pfister, Thorsten et.al[4]-This research work presented novel laser Doppler techniques, which allow simultaneous measurement of radial position and tangential velocity and, thus, determination of the shape of rotating objects with one single sensor. Conventional laser Doppler velocitymeters measure only velocities. A concurrent position measurement can be realized by generating two fan-like interference fringe systems with contrary fringe spacing gradients and evaluating the quotient of the two resulting Doppler frequencies. Alternatively, two tilted fringe systems in combination would be employed with phase evaluation. It is shown that the position uncertainty of this sensor is not only independent of the surface roughness but, most notably, that it is in principle independent of the object velocity. Thus, the novel laser Doppler position sensor offers high temporal resolution. The automatic 3D shape measurements of turning parts and to monitor the rotor unbalance and dynamic deformations, sensor was applied. Furthermore, in situ measurements of tip clearance and rotor vibrations at turbo machines for up to 600 m/s blade tip velocity are reported. The results were in excellent agreement with those of triangulation and capacitive probes, respectively.

In this paper Chen, Da-Ming; Zhu, W. D.[5] –A scanning laser Doppler vibrometer (SLDV) has been widely used in non-contact vibration measurement. This paper presents a novel investigation of three-dimensional (3D) vibration measurement by a single SLDV sequentially placed at three different positions, where 3D vibration is defined as three vibration components along axes of a specified measurement coordinate system (MCS), which can give more precise knowledge of structural dynamic characteristics. A geometric model of the SLDV is proposed and a vibrometer coordinate system (VCS) based on the geometric model is defined and fixed on the SLDV. The pose of a SLDV with respect to a MCS is expressed in the form of a translation vector and a direction cosine matrix from the VCS to the MCS, which can be calculated by four or more target points with known coordinates in both the MCS and the VCS. An improved method based on the least squares method and singular value decomposition is proposed to obtain the pose of the SLDV. Compared with an inverse method, the proposed method can yield an orthogonal direction cosine matrix and be applicable to a two-dimensional structure. Effects of the number of target points on the accuracy and stability of the proposed method are investigated. With three direction cosine matrices of three different positions obtained by the proposed method, measured vibration velocities along laser line-of-sight directions can be transformed to vibration components along axes of the MCS. An experiment was conducted to measure 3D vibration of a target point on a beam under sinusoidal excitation by a single SLDV sequentially placed at three different positions. Vibration components along axes of the MCS obtained by the single SLDV were in good agreement with those from a commercial Polytec 3D scanning laser vibrometer PSV-500-3D.

In this paper Wei, J.; Liu, Chi-Him et al.[6] -They studied, vehicle surfaces' vibrations caused by operating engines measured by Laser Doppler Vibrometer (LDV) have been effectively exploited in order to classify vehicles of different types, e.g., vans, 2-door sedans, 4-door sedans, trucks, and buses, as well as different types of engines, such as Inline-four engines, V-6 engines, 1-axle diesel engines, and 2-axle diesel engines. The results are achieved by employing methods based on an array of machine learning classifiers such as AdaBoost, random forests, neural network, and support vector machines. To achieve effective classification performance, They seek to find a more reliable approach to pick authentic vibrations of vehicle engines from a trustworthy surface. Compared with vibrations directly taken from the uncooperative vehicle surfaces that are rigidly connected to the engines, these vibrations are much weaker in magnitudes. In this work we conducted a systematic study on different types of objects. We tested different types of engines ranging from electric shavers, electric fans, and coffee machines among different surfaces such as a white board, cement wall, and steel case to investigate the characteristics of the LDV signals of these surfaces, in both the time and spectral domains. Preliminary results in engine classification using several machine learning algorithms point to the right direction on the choice of type of object surfaces to be planted for LDV measurements.

It this paper Halkon, B. J.; Rothberg, S. J [7] readily accepted that a laser vibrometer measures target velocity in the direction of the incident laser beam, but this measured velocity must be considered in terms of the various components of the target velocity. This paper begins with a review of the theoretical description of the velocity sensed by a single laser beam incident in an arbitrary direction on a rotating target undergoing arbitrary vibration. The measured velocity is presented as the sum of six terms, each the product of a combination of geometric parameters, relating to the laser beam orientation, and a combination of motion parameters - the 'vibration sets'. This totally general velocity sensitivity model can be applied to any measurement configuration on any target. The model is also sufficiently versatile to incorporate time-dependent beam orientation and this is described in this paper, with reference to continuous scanning laser Doppler vibrometry. For continuous scanning applications, the velocity sensitivity model is shown formulated in two useful ways. The first is in terms of the laser beam orientation angles, developing the original model to include time dependency in the angles, whilst the second is an entirely new development in which the model is written in terms of the mirror scan angles, since it is these which the operator would seek to control in practice. In the original derivation, the illuminated section of the rotating target was assumed to be of rigid cross section but, since continuous scanning measurements are employed on targets with flexible cross sections, such as beams, panels and thin or bladed discs, the theory is developed in this paper for the first time to include provision for such flexibility.

In this paper Sci T Pfister, Thorsten; Guenther, Philipp; et.al[8] they studied Monitoring rotor deformations and vibrations dynamically is an important task for improving the safety and the lifetime as well as the energy efficiency of motors and turbo machines. However, due to the high rotor speed encountered in particular at turbo machines, this requires concurrently a high measurement rate and high accuracy, which cannot be fulfilled by most commercially available sensors. To solve this problem, we developed a non-incremental laser Doppler distance sensor (LDDS), which is able to measure simultaneously the in-plane velocity and the out-of-plane position of moving rough solid objects with micrometer precision. In addition, this sensor concurrently offers a high temporal resolution in the microsecond range, because its position uncertainty is in principle independent of the object velocity in contrast to conventional distance sensors, which is a unique feature of the LDDS. Consequently, this novel sensor enables precise and dynamic in-process deformation and vibration measurements on rotating objects, such as turbo machine rotors, even at very high speed. In order to evidence the capability of the LDDS, measurements of rotor deformations (radial expansion), vibrations and wobbling motions are presented at up to 50,000 rpm rotor speed.

II. CONCLUSION

The main conclusions of the study is the laser Doppler vibrometer has large potential in vibration measurement in all the fields. This review shows wide application of laser Doppler vibrometer in various field with comparison with mathematical models.

REFERENCES

1. Application of Laser Doppler Vibrometry to the Vibroacoustic Analysis in the Industrial FieldE.P. Tomasini Department of Mechanics, University of Ancona, 60131 Ancona, Italy
2. L.E. Drain, The Laser Doppler Technique, New York, J. Wiley and sons, 1980.
3. P. Castellini, G.M. Revel and E.P. Tomasini, The Shock and Vibration Digest 30, 443-456 (1998).
4. Laser-Doppler vibrating tube densimeter for measurements at high temperatures and pressures NASA Astrophysics Data System (ADS) Aida, Tsutomu; Yamazaki, Ai; Akutsu, Makoto; Ono, Takumi; Kanno, Akihiro; Hoshina, Taka-aki; Ota, Masaki; Watanabe, Masaru; Sato, Yoshiyuki; Smith, Richard L.; Inomata, Hiroshi 2007-11-01
5. Taking laser Doppler vibrometry off the tripod: correction of measurements affected by instrument vibration NASA Astrophysics Data System (ADS) Halkon, Ben J.; Rothberg, Steve J. 2017-04-01
6. Shape and vibration measurement of fast rotating objects employing novel laser Doppler techniques NASA Astrophysics Data System (ADS) Pfister, Thorsten; GÃ¼nther, Philipp; BÃ¼ttner, Lars; Czarske, JÃ¼rgen 2007-06-01
7. Investigation of three-dimensional vibration measurement by a single scanning laser Doppler vibrometer NASA Astrophysics Data System (ADS) Chen, Da-Ming; Zhu, W. D. 2017-01-01
8. Engine classification using vibrations measured by Laser Doppler Vibrometer on different surfaces-NASA Astrophysics Data System (ADS) Wei, J.; Liu, Chi-Him; Zhu, Zhigang; Vongsy, Karmon; Mendoza-Schrock, Olga 2015-05-01
9. Vibration measurements using continuous scanning laser Doppler vibrometry: theoretical velocity sensitivity analysis with applications-NASA Astrophysics Data System (ADS) Halkon, B. J.; Rothberg, S. J. 2003-03-01
10. Dynamic Rotor Deformation and Vibration Monitoring Using a Non-Incremental Laser Doppler Distance Sensor Sci T Pfister, Thorsten; Guenther, Philipp; Dreier, Florian; Czarske, Juergen 2010-05-28

AUTHORS PROFILE

of

Sayli M. Jadhav Asst. Professor in Mechanical Engineering Dept. K.B.P. College Engg. Satara .M.E. (Design) -5 yrs Teaching Experience. 3 International Research Publications. 2 National Research Publications.

Nilesha U. Patil, Asst. Professor in Mechanical Engineering Dept. SKNCOE,Vadgaon,Pune,. M.E. (Design) -7 yrs Teaching Experience. 4International Research Publications. 4 National Research Publications.

Aditi Amit Patankar Lecturer Govt.Polytechnic miraj

Neeta B. Phatak, Lecture in Mechanical Engg. Dept. of Yashaswi Institute of Technology, Pune. M.E. (CAD/CAM & Robotics) – 8 yrs Teaching Experience. 2 National Research Publications.