A lifetime model of industrial cutters informed by Laser Doppler Vibrometry Impact of vibration velocity or displacement on the accuracy of cutting tools in industries

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Abstract— **This study addresses the operation of Laser Doppler Vibrometry (LDV) and industrial cutters for identifying the aspects of vibration velocity or displacement. This has been indicated in terms of the accuracy of cutting tools within industries and the positive influence of LDV in enhancing the accuracy of cutting tools. The study has analysed industrial cutters with respect to the factors of LDV by indicating stability cutting parameters, cutting accuracy and automation with LDV. In addition, LDV and measurements, and the operation of LDV itself has also been discussed. Investigating for an optimum process for reducing vibrations during the process of machining is essential in order to have efficiency throughout the procedure and better results. By identifying the mentioned aspects and the associated literature of the research, the study has further suggested that LDV is a relevant technique in order to eliminate the vibrational factor and improving the accuracy of the cutting tools.**

Index Terms— **Accuracy, Cutting Tools, Doppler Effect, Laser Cutting, Laser Doppler Vibrometry (LDV)**

I. INTRODUCTION

Laser Doppler Vibrometers (LDV) have been utilised in terms of noncontact and nonreactive evaluations. Several applications such as optimising acoustic characteristics towards a new product, active noise compensation, measurement of hearing aids, are based on the concept of Laser Doppler Vibrometry. Out of such applications, measurements regarding the cutting procedures, in developing ultrasound tools for instance, are involved as well. This study would analyse industrial cutters with respect to the Laser Doppler Vibrometry and address the impact of vibration velocity or displacement on the accuracy of cutting tools in industries [1].

II. LITERATURE REVIEW

The process of cutting tools contributes in presenting several types of associated products that are presented for quality and rapid functioning [2]. Studies have indicated that current cutting tools would be beneficial in terms of accuracy and cleanliness in cutting procedures. This means that identifying processes that are associated with the cutting tools for presenting quality outcomes is essential [3]

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A. *Stability Cutting Parameters*

In a related study [4] in terms of depicting the stability cutting parameters in terms of LDV, it highlighted that high-speed milling functioning of thin walls could be restricted by the regenerative effect, causing poor finishing of the surface. For the optimisation of the cutting procedure with respect to productivity and quality surface, measuring the frequency response function (FRF) of the walls have been identified in the discussed study. This would identify modal characteristics that contribute in acquiring stability lobes in order to indicate the parameter values of the optimal system as a necessity for stable cutting situations [5].

The mentioned research was directed towards indicating the variation of FRF measurements that were obtained through the LDV instrument and accelerometer sensors. This was done throughout the milling operation, involving the work-piece of thin-walled aluminium (1 mm thickness and 30 mm height). The study depicted that variations on the FRF values had a strong impact on stable cutting bounds. Their results also identified that high quality and suitable surface finish was obtained in this way [6].

B. *Cutting Accuracy and Automation with LDV*

In another study [7] regarding continuous processing accuracy and productivity from LDV, this aspect has been addressed in terms of adaptive laser cutting (ALC) system. It utilises a dynamic feedback system for analysing and regulating the laser power, course of cutting, and optimisation of cutting parameters automatically and maintaining consistent accuracy as well.

The study further states that this system is specifically functional in operating thicker steels through automation because machine speed is usually at a particular level and is responsible for variations in the properties of the focused material. The study depicts that ALC contributes in the cutting process by automatic adjustments with respect to the changed conditions, operating at the maximum speed and optimum efficiency. This helps in avoiding the necessity to monitor the cutting speed and further contributes in more productivity [8].

C. *LDV and Measurements*

Gatzwiller et al. [9] have identified that LDV presents accuracy and diverse noncontact vibration transduction for situations where mounting the vibration transducer on a vibrating object is difficult. Such conditions are for applications that are associated with vibration measurements for rotating surfaces, structures that are light weighted, objects targeted in water, objects behind glass layers, and remote targets. Utilising LDV for such applications has the need for focusing practical problems, because their elimination would provide better outcomes.

The discussed study has addressed these issues and depicted how to operate them so that measurement precision, accuracy, and reliability could be achieved at a maximum level. These issues were the high temperature surfaces, noise floor encountered when measuring processes are conducted on rotating targets, glass layers, speckle noise, operating with mirrors, and mass loading with an LDV [10].

The study further states that another factor should be identified, which is the cutting accuracy, regarding the associated tools and vibrations of the related machines could present displacements. These are usually not focused during the course, which automatically indicates the inaccuracy of the used cutting tool. As most machineries are open towards worn and torn, aspects related with predisposition should be analysed. In this context, LDV helps in detecting vibrational structure damages, also involving cutting machines [11].

III. Measurement Tool operation

Analysing the operation of the LDV instrument and the aspect of industrial laser cutting would contribute in understanding the influence of vibration velocity on the accuracy of cutting tools within industries [12].

A. Laser Doppler Vibrometry

LDV is used to conduct noncontact vibration measurements, in which the laser from this scientific instrument is transmitted towards the targeted surface, and then the vibration amplitude and frequency can be observed with respect to the Doppler shift from the reflected beam frequency, which is based on the movement of the concerned surface. The output of this instrument is usually an analogue voltage in a continuous manner [13].

LDV is relevant when it comes to targeting factors that cannot easily be directed. In this context, the mentioned continuous voltage is directly proportional to the concerned velocity factor, which is present along the pathway of the directed laser beam. A vibrometer in general, comprises of a two-beam laser interferometer, which is projected towards the measurement of a frequency or phase difference in terms of an internal reference beam and the beam that is being tested [14].

The name itself indicates the use of Doppler effect in order to obtain the vibration velocities. The operation involves inducing a Doppler frequency shift on the imposed laser based [15]. The linear relation can be analysed between the velocity component and the direction of the laser beam as it is developed based on the Doppler shift among the mentioned two aspects. In turn, this indicates the linear relation between velocities and the frequency variations of the laser beam. Doppler shifts are generally small relatively to the laser fundamental frequency and for analysing such small values requires the use of interferometry. This concept contributes in combining the high frequency oscillations and further reducing them to lower values for better understanding [16].

The following figure depicts the operation of the LDV. Light coming from the laser block enters the beam splitter mentioned as BS1 and is split into two pathways of the reference beam and an object beam. The object beam is transferred from BS3 and then focused on a particular point on the sample vibrating object through the lens. The operation involves the diversion of the backscattered light from BS3 and then transmitted towards BS2 [17].

Now, the backscatter combines with the frequency of the shifted reference beam. This interference occurs at BS2 and based on the Doppler effect, it identifies any frequency difference present between the sample object and reference beam at the BS2, in terms of an intensity modulation. Vibrometers generally utilise He-Ne, which initiates the Doppler frequency shift of almost 3.16 kHz. The photo-detectors identified as PD1 and PD2 in the figure, they convert the optical signal into an electrical signal and also contributes in decreasing noise and drift [18].

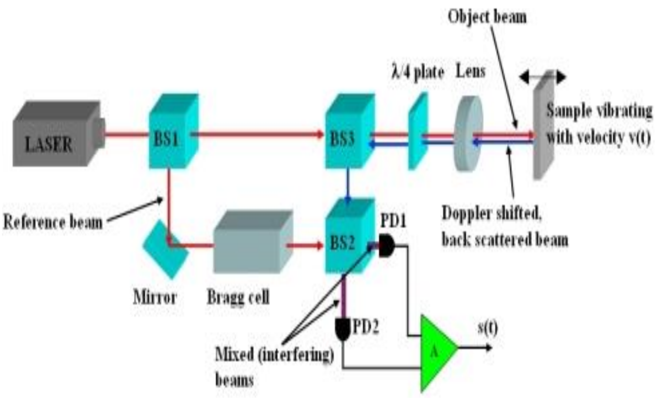

Fig. 1 Laser Doppler Vibrometry Operation

B. Industrial Cutters

In terms of industrial cutters, the LDV technology can be applied by implementing laser for cutting materials and for processing industrial manufacturing applications. The focused laser beam from the LDV instrument is targeted towards the concerned material, and based on the laser cutting aspect, it would either burn, melt, vaporise, or blown up, and an edge, comprising of good-quality surface finishing is left. Industrial cutters are associated with cutting flat-sheet material, and structuring and piping them [19].

IV. Discussion

LDV is a technique, in which a surface beam is presented onto a particular surface and from the Doppler shift; extraction of the amplitude and frequency of the produced vibration is conducted. The mentioned technique is utilised in several industries that are based on current technology in this sector as this process has been efficiently proven in comparison with other methods. The literature section has identified the process of milling. Milling itself is an essential process for cutting machines and the vibration velocity components that are involved. These contribute in utilising the milling vibration tool measurement throughout the course of cutting from LDV [20].

This indicates that searching for an optimum procedure for avoiding vibrations throughout the machining process is essential. This is in particular to the required high accuracy and efficient productivity needs in manufacturing of parts. Analysing cutting forces in the spindle structure by using displacement sensors has been reported as a significant approach. Even so, analysing quality on a long-term basis is an issue because the sensor signal could include offset drift that is a major contribution in terms of producing displacement within the spindle.

In the above sections, for having accurate predictions regarding the dynamic model properties within a machining system, LDV is utilised. This is because this technique serves as a noncontact method in order to measure the vibrations for the rotating spindle. This identifies the importance of those vibrations and the velocity and displacement factor involved in vibration measurements. Before the implementation of LDV, accuracy of cutting tools had not been imposed at a higher level in different industries because of the influence of vibration velocity.

In terms of rotary mechanisms, they have bearings for supporting the rotating parts, their weights, and the forces that are related to the rotary motion and vibration. Large forces are present in this context, which could damage the machinery and hence have an impact on cutting tools when they interact with the torn down machine. Vibration is based on the mass, stiffness, and damping factor of the object, and the machine that needs to be operated.

This is the reason that studies have suggested to minimise the tendencies of vibrations in the machining process. Forced vibrations that are based on periodic forces provided by the system are also responsible for damaging it. This includes unbalanced rotating masses and the engaging of multitooth cutters. The machine tool would oscillate based on the force frequency and if the frequency is associated with the structure, the machine would then resonate in the natural manner of the vibration.

This identifies the importance of limiting vibrations within the tool structure of the machine because the outcomes are poor surface finishing, damages to the cutting edge and irritating noises as well. In order to enhance the current capability of cutting edges, the accessible cutting tool materials, high stable and power machine related tools and strong cutting tools are needed.

V. CONCLUSION

This study has addressed the concept of Laser Doppler Vibrometry (LDV) and industrial cutters. The study has identified the impact of vibration velocity on the accuracy of cutting tools within industries and the importance of the cutting tools in the related sectors as well. The study suggests that based on the discussed literature LDV is an appropriate technique in this context for elimination the vibrational factor and enhancing the accuracy of cutting tools.

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