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EFFECT OF MACHINE TOOL LEVELLING AND FIXATION ON THE MACHINE BEHAVIOURS

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تأثير إستواء وتثبيت ماكينة الورش على سلوكيات الماكينة

خلاصة: عند تركيب ماكينة ورش ما فإنه يراعى استوائها ثم تثبيتها بقاعدتها الخرسانية. ومع استمرار التشغيل يجب أن تحافظ الماكينة على استوائها وتثبيتها. في هذا البحث، عند حدوث اى فقد للاستواء أو التثبيت، يتم دراسة تأثيرهما على السلوك الاستاتيكى والديناميكى وعلى أداء القطع لهذه الماكينة. ولإجراء هذه الدراسة تم أختيار ماكينة خراطة وتم تثبيت مشغولة على هيئة كابولى فى ظرف ذو ثلاثة فكوك لايضاح السلوكيات الاستاتيكية والديناميكية، وكذا القطع تحت هذه الظروف.

ABSTRACT: *Once a machine tool has been installed, it is levelled and then fixed to its concrete foundation. During running, the machine tool should maintain its levelling and fixation. This paper investigates the case when a machine tool loosen its levelling and/or fixation, showing their effects on the static, dynamic and cutting behaviours of such machine tool. During this study an engine lathe with three-jaw overhang chucked workpiece has been experimentally investigated, to clarify the static, dynamic and cutting behaviours under such conditions.*

INTRODUCTION:

Building a machine tool requires the careful assembly of structural elements onto main base, the levelled objective system is then located and fixed to a concrete foundation. To do so, the need for different types of joints are present, as an essential part of the functional requirements to enable the operational movements and manufacturing requirements to be fulfilled [1]. In that case, these joints form a link or a number of links in the chain of elements closing the flow of the resultant cutting forces. Therefore, the machine tool joints, which are in direct relation to the levelling and fixation of the machine tool, should be regarded as important as other structural elements.

On the other hand, machine tools are used in varying configuration and, correspondingly, with varying dynamics between tool and workpiece leading to varying conditions for the limit of the machine tool static and dynamic stability [2]. Therefore, there is always the dynamics of the machine tool combined with the dynamics of the tool-workpiece system.

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Statistical enquires [3] show that about 75% of all machined wo pieces, which are round and symmetrical in shape, have a ratio of length diameter equal or less than three. Workpieces of this proportional a normally overhung clamped and machined in three-jaw chucks. In t regard, numerous research works have been carried out to clarify t static, dynamic and cutting behaviours due the effects of types of ch [4,5], chucking method and cutting stability [3,6,7,10], stiffn variation of the chucked workpiece [7,8,10], types of contact area betw workpiece and jaw faces [8,9]. However, the effects due to lack levelling and/or fixation on the machine tool behaviour have not clarif yet.

In this paper, therefore, the effects of the levelling and fixation an engine lathe on the static, dynamic and cutting behaviours, of overhung three-jaw chucked workpiece, have been clarified experimentally some extent.

EXPERIMENTAL PROCEDURE:

To clarify the static, dynamic and cutting behaviours of the mach tool-workpiece-tool system under the effects of levelling and fixation, engine lathe with conventional three-jaw scroll chuck of 250 mm in diame was employed. The engine lathe first has been put randomly unlevelle then it has been levelled along its bed and guideways by means of spir level with sensitivity of 0.05 mm/m. For both the unlevelled and level conditions, the bed of the lathe was free or fixed to its foundati according to the experimental requirements.

It is well known that, among the components of the resulting cutt forces, the radial force component has the greatest effect on t geometrical accuracy of the chucked workpiece [3,4,7]. Also, the lo deflection behaviour of the workpiece due to this radial component consis of those of the machine spindle, chuck, workpiece and their interfaces.

In the static experiments, therefore, the load-deflection behaviour of the chucked workpiece (as shown in Fig.1), as well as the bending stiffness were investigated with the bending load of up to 2.0 KN, which was applied to the free end of the workpiece by means of the load cell. The due deflections were measured by means of dial gauge with sensitivity of 2.0 μm. These experiments were repeated three times, while the average values were used to clarify the load-deflection behaviour, and to calculate the corresponding bending stiffness.

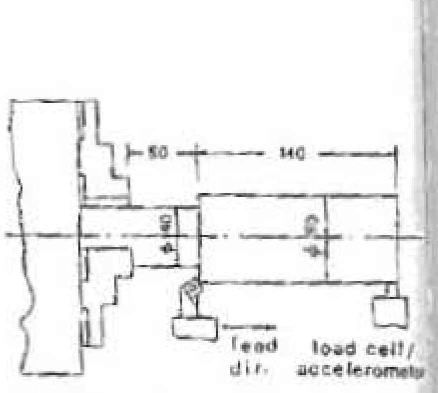

Fig.1 Experimental Set-up.

In the dynamic experiments, the impulsive excitation technique was employed by means of an impact hammer at the free end of the workpiece. The resultant vibration signals were detected by an accelerometer fixed opposite to the excitation point. Then the dynamic characteristics were analyzed using the spectrum analyzer.

The cutting experiments were carried out in the form of longitudinal turning operation, i.e. the bending mode, while the left-hand cutting has been employed to avoid the deflection owing to chatter in the beginning of the cutting operation. During these experiments each tip was used once only, while three workpieces were cut for each levelling and fixing condition. Then the surface roughness 'Ra' was measured at five tracing positions along the machined surface; 10 mm after the beginning of the cut, 10 mm before the free end of the workpiece, and three positions in between with distance of 30 mm apart. In this respect, due to the effect of the directional orientation of the chuck-jaw position relative to the radial cutting component, the surface roughness of each tracing position was, therefore, measured at six points; three at the jaws position and another three points in between each two jaws.

In addition, through all the static, dynamic and cutting experiments, to assure sufficient chucking stiffness of the workpiece, the chucking torque and chucking length of the workpiece were 125 N.m and 50 mm in constant. Also, the chucked length was ground, to an average value of 0.5 µm Ra, to ensure high contact rigidity.

EXPERIMENTAL RESULTS AND CONSIDERATIONS:

a) *STATIC BEHAVIOUR*:

In the case of conventional chuck, chucking condition, rigidity of spindle-chuck system, and directional orientation of the jaw position in respect to the radial component, are the main factors affecting the overall deflection of the workpiece. All these factors have been fixed, leaving the levelling and/or fixation effects being the main factors to affect the overall load-deflection behaviour of the objective system.

Regarding such suggestions, Fig.2 shows the effects of levelling and fixation of the lathe on the overall radial deflection, at the free end of the chucked workpiece. The loading-unloading curve for each case implies the plastic deformation after a loading-unloading cycle (measured at zero load), and the total deflection to the corresponding applied radial load.

From this figure, it is clearly observed that both levelling and fixation have great effects on the overall deflections. Also, it is remarkable to point out that the resultant plastic deformations are in direct relation to the fixing condition and not related to the levelling action. The interface between the machine bed-foundation base has the major role in determining the plastic deformation of the chucked workpiece system. In addition, the case of levelled-fixed condition is showing the lowest overall radial deflections of the workpiece. The scatter of the obtained resultant deflections, is due to the directional stiffness orientation of the jaws position relative to the applied radial load, which has no great effect on the load-deflection behaviour.

Figure 3 shows the calculated bending stiffness of the concerned experiments. From which it can be envisaged that the fixation of the machine base to its foundation claimed more stability to the bending stiffness of the objective system, also showing higher values compared with the free-levelled and unlevelled conditions.

These results can be such interpreted as follows:

1) In respect to the machine tool joints, it is important to prevent any separation of the joint surfaces. Of those, the machine-foundation interface play the important role in determining the load-deflection behaviour, as well as the bending stiffness of the chucked workpiece.
2) The performance of the machine tool- workpiece system and their interfaces has significant effects on the overall behaviour of the concerned machine tool. Deviations in alignment, due to lack of levelling between the chuck-workpiece and the machine tool base, is one major factor causing dimensional instability due to lack of the machine spindle-chuck-workpiece overall stiffness.

b) *DYNAMIC BEHAVIOUR:*

To clarify the dynamic behaviour, the vibration responses of the tested system in the time-domain and the frequency-domain have been analyzed. From which the

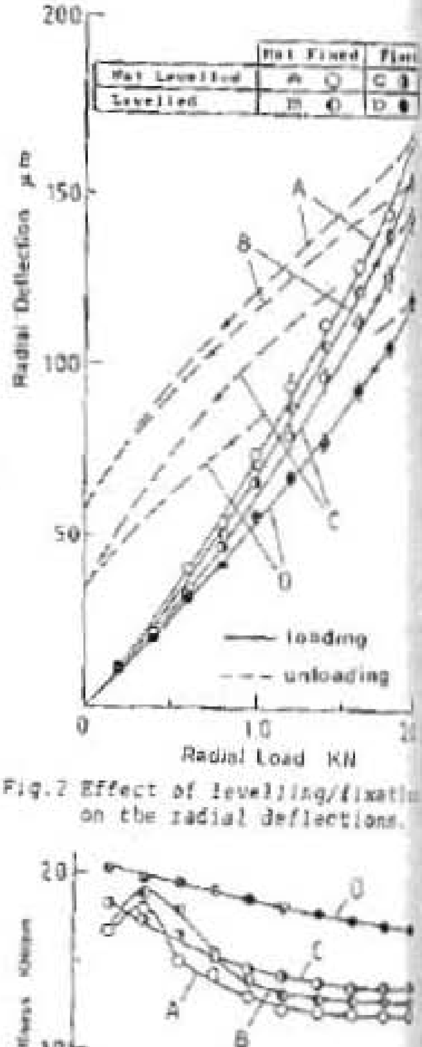

Fig.2 Effect of levelling/fixatio
on the radial deflections.

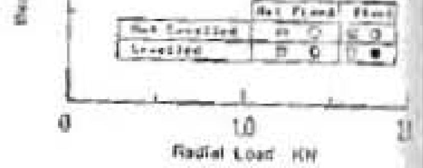

Fig.3 Effect of levelling/fixatio
on the bending stiffness.

natural frequencies 'f' were found from the major peak of the frequency response analysis, while the damping capacities have been calculated by either the band-width method (Frequency-domain) or the logarithmic damping decrement 'Δ' (time-domain) [11].

Figure 4 shows the obtained vibration responses for the different experimental conditions. From Fig.4 (c and d), it is clear that the vibration responses in the time-domain of the machine without fixation (levelled or not levelled), are showing unsmooth wave forms with other superimposed harmonic waves, compared with those of the machine with fixation (levelled or not levelled), which are showing clear and smooth wave forms, as shown in Fig.4 (a and b).

On the other hand, the frequency spectrum forms are showing a single major peak with fixed machine (levelled or not levelled). In the case of machine without fixation their are multi peaks and difficult to be separated, however having a dominating peak from which the natural frequency has been found. Also, the damping capacity of the machine without fixation was impossible to be deduced from both the wave and the frequency response forms, i.e., due to the irregularities in the wave form, and the existance of other peaks close to the dominating peak in the frequency response forms. In addition, the machine tool levelling has but small effect on the dynamic behavior; it reduces slightly the natural frequency and showing no significant effect on the damping capacity.

These results confirm the obtained ones of the static behaviour, showing that fixation and levelling of the machine tool have significant effects on the machine tool rigidity, which in turn has a great effect on the machine tool dynamic stability.

c) CUTTING BEHAVIOUR:

The basic function of a machine tool is to produce a workpiece of the required geometric form with an acceptable surface finish. Also, in the case of three-jaw chuck, the overhang length of the workpiece expected to have a significant influences on the geometrical accuracy and surface finish of the due product [7]. Therefore, to clarify the feasibility of the static and dynamic behaviours, some cutting tests were carried out under the same aforementioned experimental conditions, with the cutting conditions shown in Table 1.

Table 1 Cutting Conditions

LATHE	Swing over bed : 500 mm Center distance : 1000 mm Motor power : 7.5 KW	
WORKPIECE	Mild steel	
TOOL	Cemented Carbide (25x25mm) (9,13,8,6,60,57,0.8mm)	
CHUCKING CONDITION	Chucking torque : 125 N.m Chucking length : 50 mm	
CUTTING MODE	Left - hand longitudinal cutting	
Cutting speed	Feed rate	Depth of cut
100 m/min	0.3 mm/rev	1.5 mm/dia

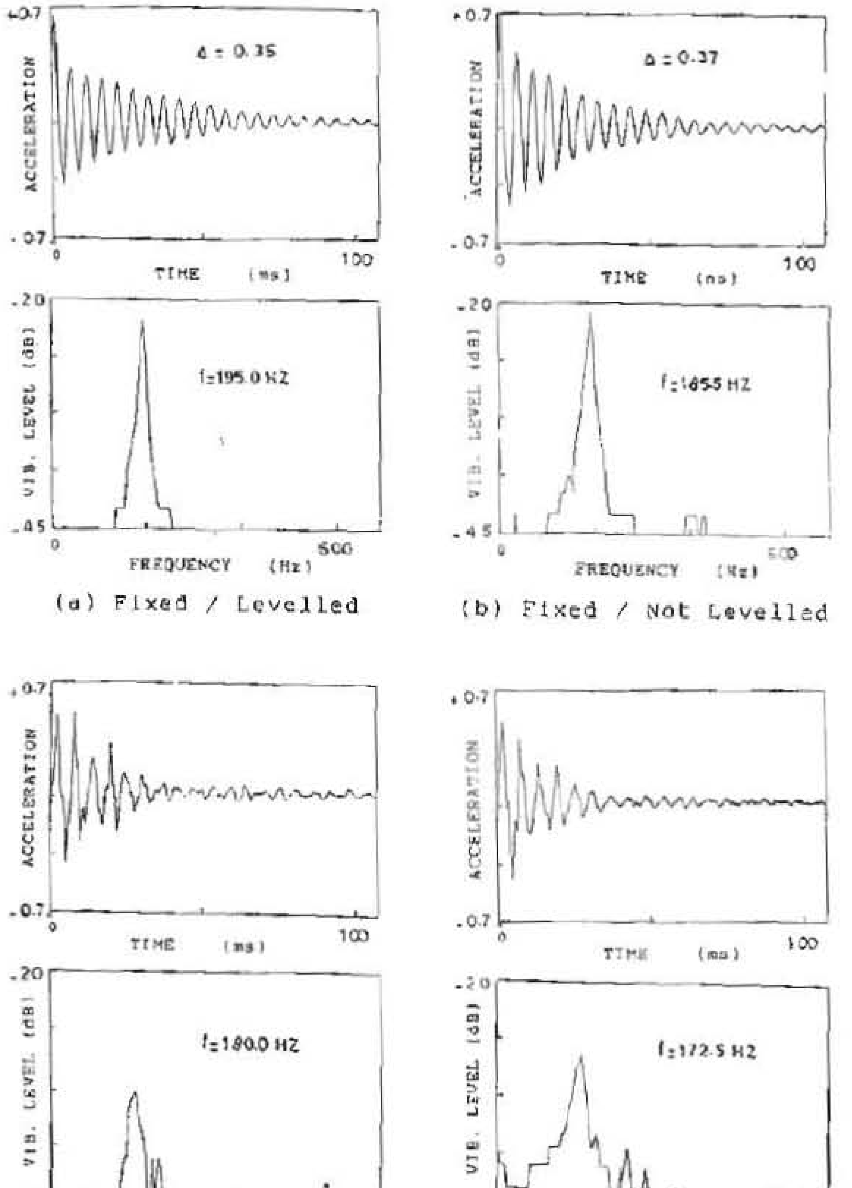

Fig. 4 Effect of levelling/fixation on the machine tool vibration response.

Figure 5 shows the measured surface roughness 'Ra' along the machined surface of the workpiece, due to the effects of the machine levelling and fixation cases. The scattered results at each tracing position were including the measured surface roughness of the three machined workpieces, corresponding to each experimental case, the six points at each tracing position, as well as their average values. From this figure, it is clearly observed that the obtained results obey the ones of the static and dynamic experiments. The higher the static bending stiffness (levelled-fixed case), the lower the surface roughness of the workpiece has been obtained. Also, the surface roughness values increase when the measured tracing position goes toward the free end of the chucked workpiece.

Figure 6 shows the effect of the chuck-jaw directional orientation on the surface roughness. In this figure, the two extreme experimental conditions, i.e unlevelled-free case and levelled-fixed case, have been considered. From this figure, it is clear that the directional orientation has no significant influence on the surface roughness when the tracing position was near to the workpiece chucked portion, while it is significant near to the free end of the workpiece. These results also ascertain the importance of the machine tool levelleing, fixing, and workpiece overhung length in eliminating the effects of the chuck-jaw directional orientation on the surface roughness

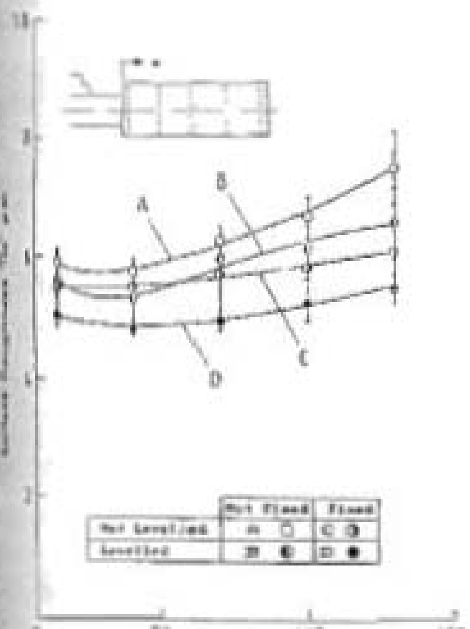

Fig.5 Effect of levelling/fixation on the surface roughness.

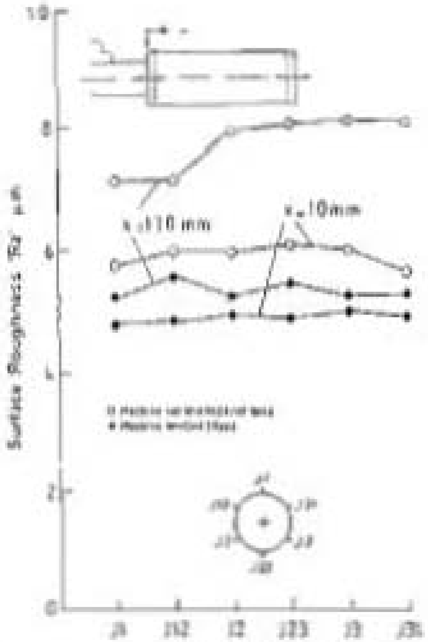

Fig.6 Effect of jaw position on the surface roughness.

CONCLUSIONS:

In this study the static, dynamic and cutting behaviours of a overhung chucked workpiece, due to the effects of levelling and fixation of an engine lathe, have been investigated experimentally. From the obtained results, it can be pointed out that both levelleing and fixation of machine tool have great effects on the overall behaviour of such machine tool.

It is, however, important to point out that the machine tool fixation is the key role in determining the static, dynamic and cutting behaviour of the tested system. In addition, the chuck-jaw directional orientation has slight influences on the cutting behaviour with three-jaw chucked workpiece. However, the special attention should essentially be paid to the fixation and levelling of the machine tool.

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