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Considerations for Chucking System for Internally Turned Components

إعتبارات بنظم قمط الاجزاء المخروطة داخليا

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ملخص: لقد كان للتطور العلمى فى العصر الحديث لماكينات القطع والتشغيل والذى كان من نتائجه ظهور ماكينات القطع والتشغيل ذات التحكم الرقمى أثره فى ضرورة توافر إحتياجات جديدة فى هذه الماكينات تتواكب مع هذا التطور. وتعتبر نظم قمط المشغولات على المخارط من أهم هذه الإحتياجات التى حدث بها تغيير فى طريقة التشغيل والعمل حتى تتناسب مع سرعات القطع العالية المستخدمة فى هذه الماكينات للحصول على دقة الشكل المطلوبة. فى الآونة الأخيرة لاقت هذه النظم إهتماما فى مجالات البحوث وظهرت أهميتها المؤثرة على دقة الشكل المخروط وتركزت معظم البحوث فى هذا المجال على المشغولات المخروطة خارجيا. يتعرض هذا البحث لبعض الإعتبارات الواجب مراعاتها فى نظم قمط المشغولات المخروطة داخليا كما تناول البحث دراسة تأثير بعض المتغيرات بهذه النظم على دقة الشكل النهائى الناتج من عمليات الخراطة الداخلية وتمت الدراسة بإستخدام الظرف ثلاثى الفكوك. ولقد أثبت تأثر دقة الشكل الناتج من الخراطة الداخلية بعملية قمط المشغولات والمتغيرات الخاصة بها تأثيرا قويا قد يؤدى إلى نتائج مؤثرة على دقة الشكل المخروط. أظهر البحث نقاط جديدة لدراسات مستقبلية فى هذا المجال تشجع الباحثين على التركيز والإهتمام بهذا الموضوع.

ABSTRACT

The development in machine tools and its elements to suite the today's requirements for the NC & CNC systems have considerably increased. One of the main requirements for these new systems is the possibility of having wide range of rpm to cover the latter tendency by the introduction of tool materials.
However, this development spells considerably higher stresses for the turned components clamping devices. The working accuracy is affected by the kinematic and dynamic relationship between the machine-workpart and the tool. The chucking system for the turned components was some what neglected, but recently it has proved to be the decisive link of the form accuracy of the turned components.
The effect of the chucking system using 3-jaws chucks on the form accuracy for internally turned components is rarely investigated. The aim of this work is to invesigate some factors affecting the deformation in the geometrical form of internally turned components due to the chucking system. The study proved the importance of the chucking system on the form accuracy of internally turned components.

INTRODUCTION

3-Jaw chucks, particularly scroll chucks are most frequently employed for clamping ring - shaped and cylindrical workpieces. This leads to some deviations in shape in the turned components, this deviation is affected with many parameters, such as, gripping forces (clamping Torque), centrifugal forces of the rotated Jaws; specially at high r.p.m. values, types of contact between Jaw faces and the workpiece, stiffness variation of the workpiece; chuck and spindle, see Figure (1).

Some of the mentioned parameters were investigated before in many works [1,6,12], but only for solid cylindrical turned components.

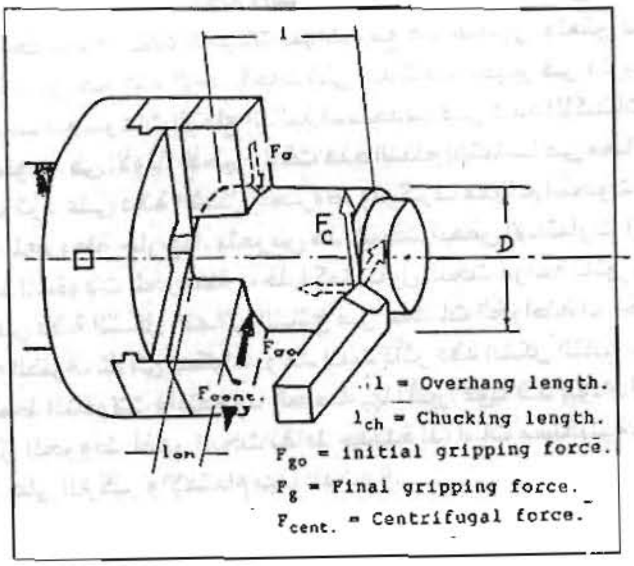


Figure (1) Acting Forces during clamping

The shape of a cylindrical workpiece machined in a lathe is dependent on the type of clamping, specially for manually operated chucks [3,5,9]. The causes of the deviation in shape have been described by many authors [1-9] , but only for solid cylindrical component.

In this study, the different parameters affecting the final shape for internally turned components will be analyzed. A general analysis of the problem has been carried out to predict the shape and amount of deviation.

For internally turned components, measuring the geometrical accuracy is very essential in the evaluation of the product and the machine itself.

However the scatter of results obtained for the same product from the same machine are so wide that those standardization may be considered to be quite far from perfection, because they failed to consider some important points in the chucking conditions, e.g. the chucking force, the chucking length (1), the types of contact between the Jaws surface and the workpiece, the number of Jaws in the chuck as investigated for solid cylind. components [4 , 5].

The problem occurs specially when clamping thin walled components which require exact control on the gripping force within a narrow band for securely clamping and to avoid any undesired deformation in the form of the clamped components.

GRIPPING FORCES

The gripping forces in 3-Jaw chucks are proposed to be constant during the cutting action. The required gripping force depends on the type of the workpiece to be performed and on the working conditions.

During the cutting action and due to the rotational speed of the chuck and its elements (Jaws), a centrifugal force is generated acting on the Jaws in the shown direction in Figure (1), which affects the total gripping force.

During cutting, the chuck and the turned component are subjected to centrifugal forces due to the masses of the three jaws and their location to the center line of rotation. This force will relief the workpiece i.e. the gripping force will decrease by a certain amount. The variation in the gripping force will be affected by the variation of the spindle rotational speed.
Progress in machining technique has made it necessary for safety reasons not only to determine the necessary gripping force but also to know and consider its change with the increasing in the rotational speed.

The forces and moments generated by the machining operation must be properly absorbed and transmitted by the chuck. The chuck accomplishes this task mainly by producing a gripping force. The gripping force (F_g) is the arithmetic sum of the radial forces (FC, cutting force and $F_{cent.}$, centrifugal force) exerted on the workpiece by the jaws. The initial gripping force (Fgo) produced when the chuck is stationary, and it is controllable.

$Fgo = Fg \pm Fcent.$

- for external clamping.

+ for internal clamping

The feed force and the passive components are not included in the description.

At high speeds, the gripping force of the rotating chuck is generally influenced by the centrifugal forces of the Jaws. These forces must be considered in the determination of the initial gripping force [12].

The shown Figure (2) illustrates the variation in the gripping force due to the effect of the centrifugal force of the rotated jaws against the rotational speed of the chuck.
The gripping force decreases with the increase in the rotational speed for external clamping within a range for a minimum and a maximum centrifugal force. The gripping forces shows an incremental performance for internal clamping.

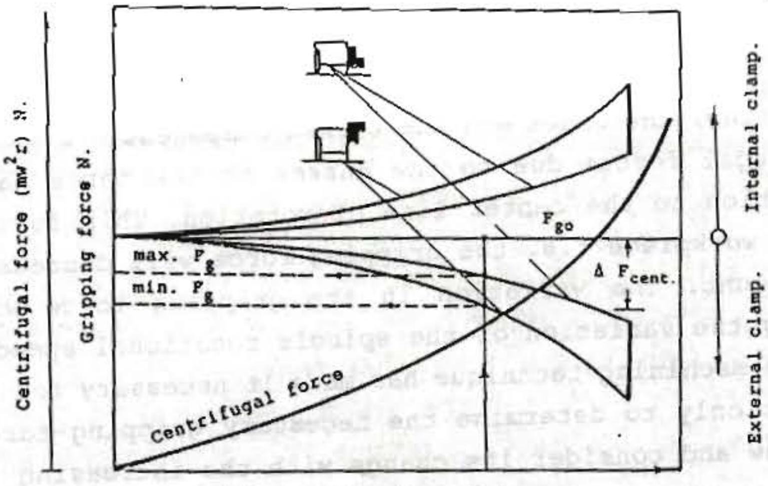


Figure (2) Influence of the centrifugal force on the gripping force.

The performance of the gripping force is determined experimentally by the manufactures of machine tool elements for each chucking system. This leads to the importance of considering the maximum permissible rotational speed for each chuck [2,10,12].

The gripping forces must be determined for any clamped component considering the effect of many parameters, such as, material dimensions, working condition and the clamping conditions.

Aluminum Test specimens were clamped in 3-Jaws and 4-Jaws chucks under different clamping torques to predict their deformation in shape under these clamping torques. The results for internally turned components are illustrated in Figure (3a-3b).

The performance of the deformation has two clear zones; the elastic zone in which the deformation in the clamped component increases linearly against the clamping torque, this deformation could be released by taking up the clamping torque depending on the stiffness of the component, the second zone is the plastic zone in which the characteristic performance of the deformation is non linear depending also on the stiffness of the components. The hole deformations in the geometrical shape of the test components under different clamping torque in the elastic and plastic zones (without releasing the clamping) are shown in Figure (3a-3b) to ensure the importance of clamping force determination.

For Brass internally turned component of 50 mm diameter (D), wall thickness (t) 3 mm and total length of 35 mm, the variation in the geometrical form of the Brass test piece due to the variation in the clamping torque is presented in Figure (4).

The different clamping possibilities for internally turned components and the effect of these possibilities on the geometrical form of the clamped components should be separately investigated to predict the deformation, stress and strain distribution on the clamped components and the clamping devices. A pilot test was carried using F.E. analysis for 3,4,6 points of clamping and collet clamping system for hollowed components to predict the geometrical deformation as well as the stress and strain distribution on the test component as shown in Figure (5). The obtained results prove the expected importance for such study.

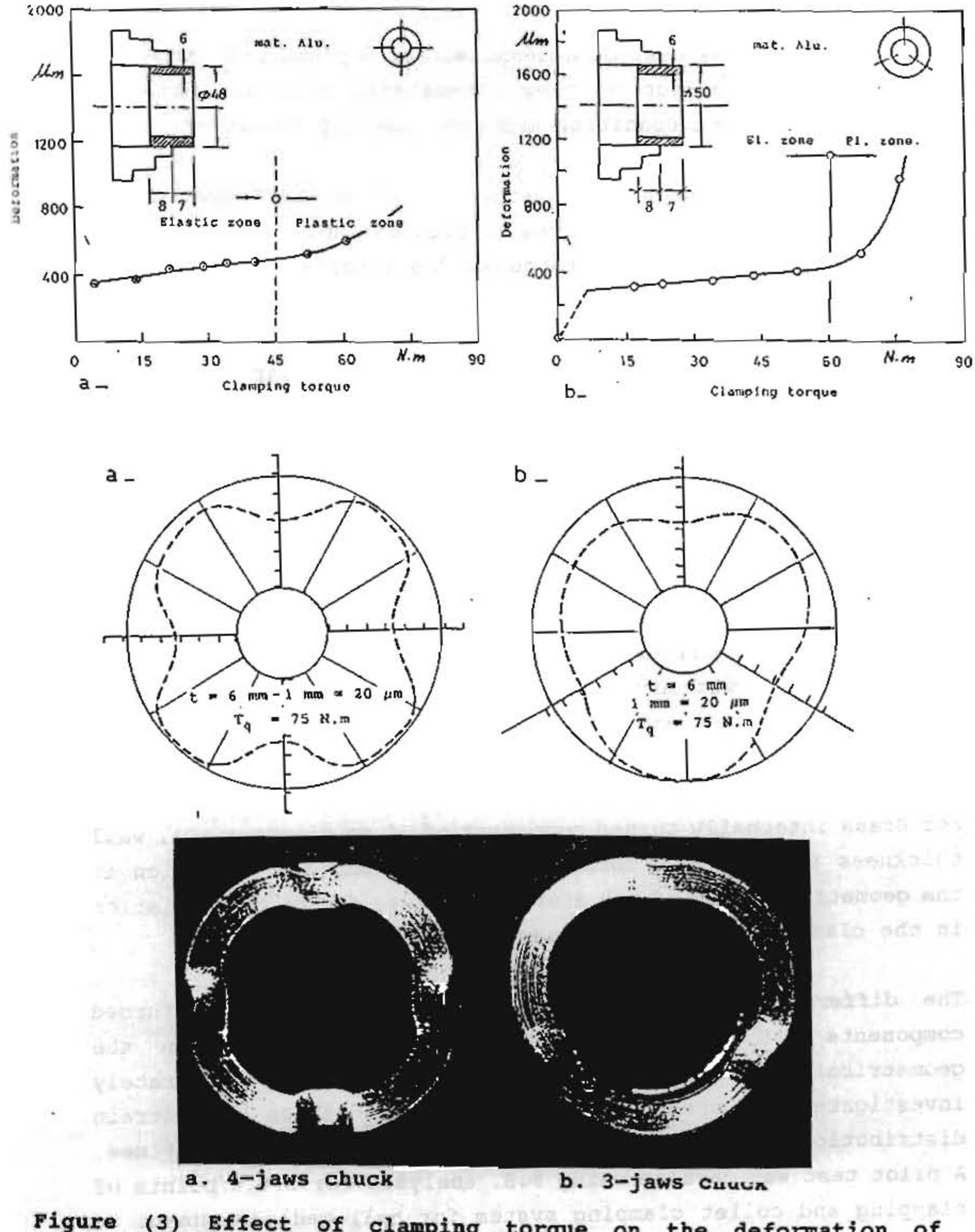
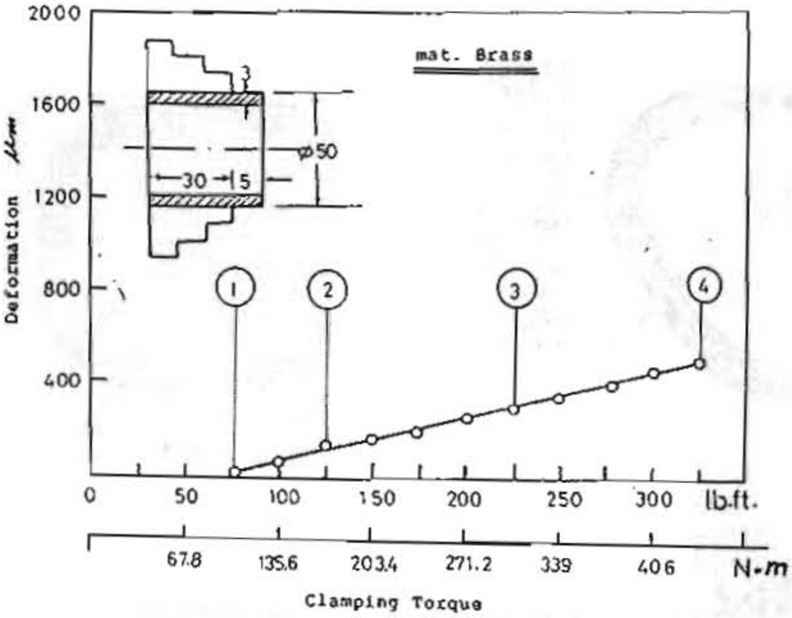


Figure (3) Effect of clamping torque on the deformation of internally turned components.



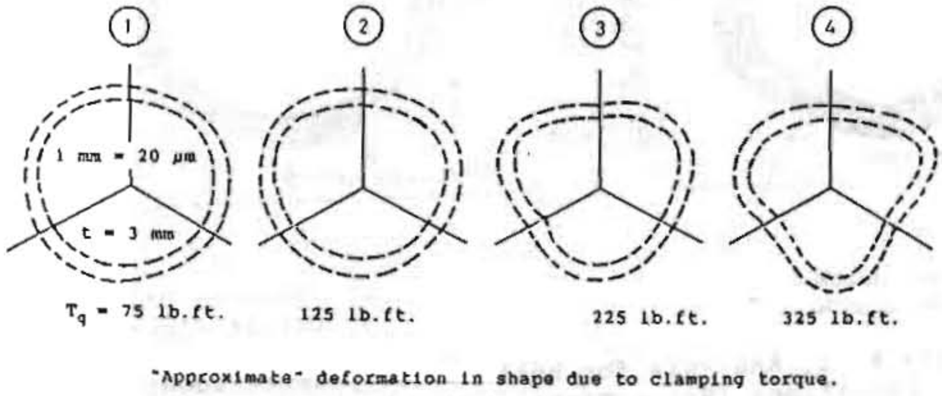
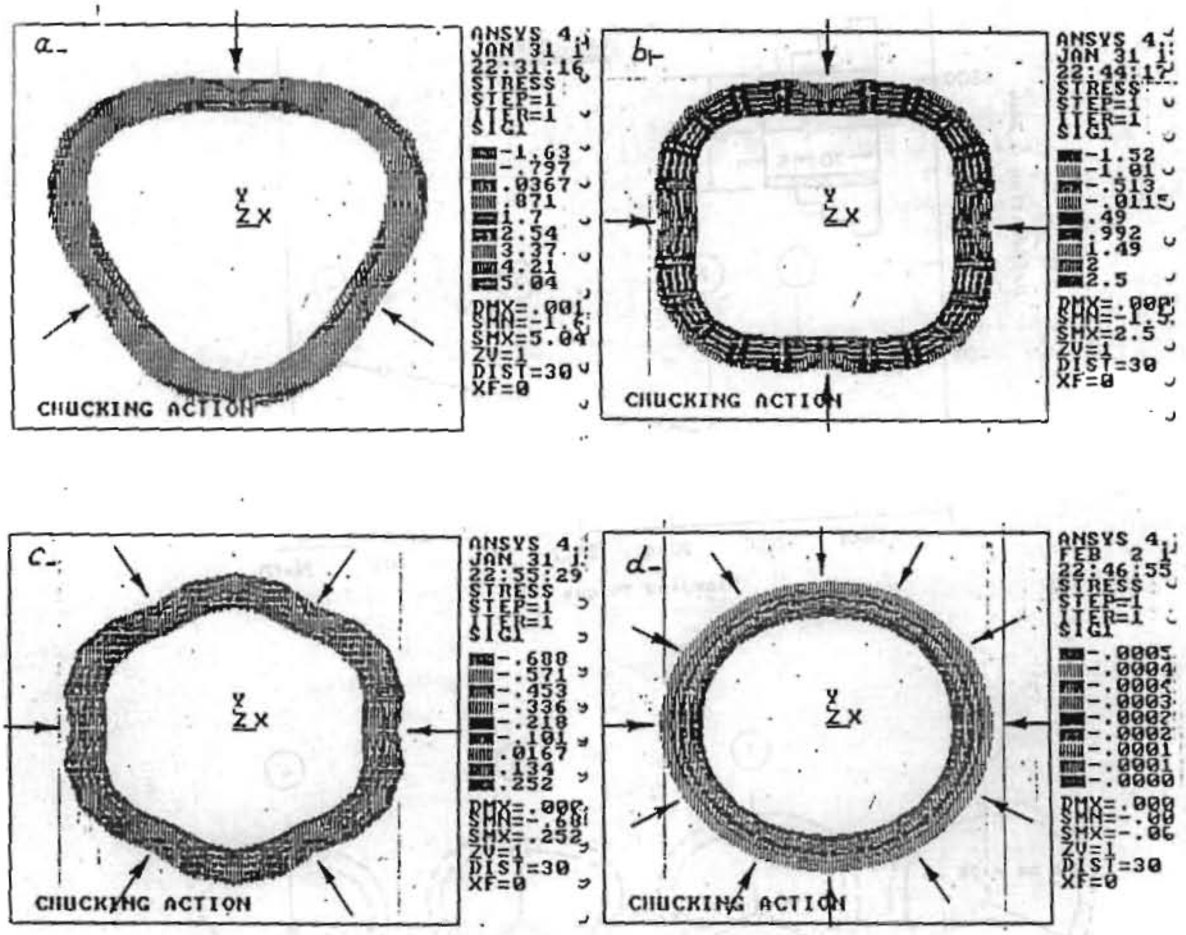


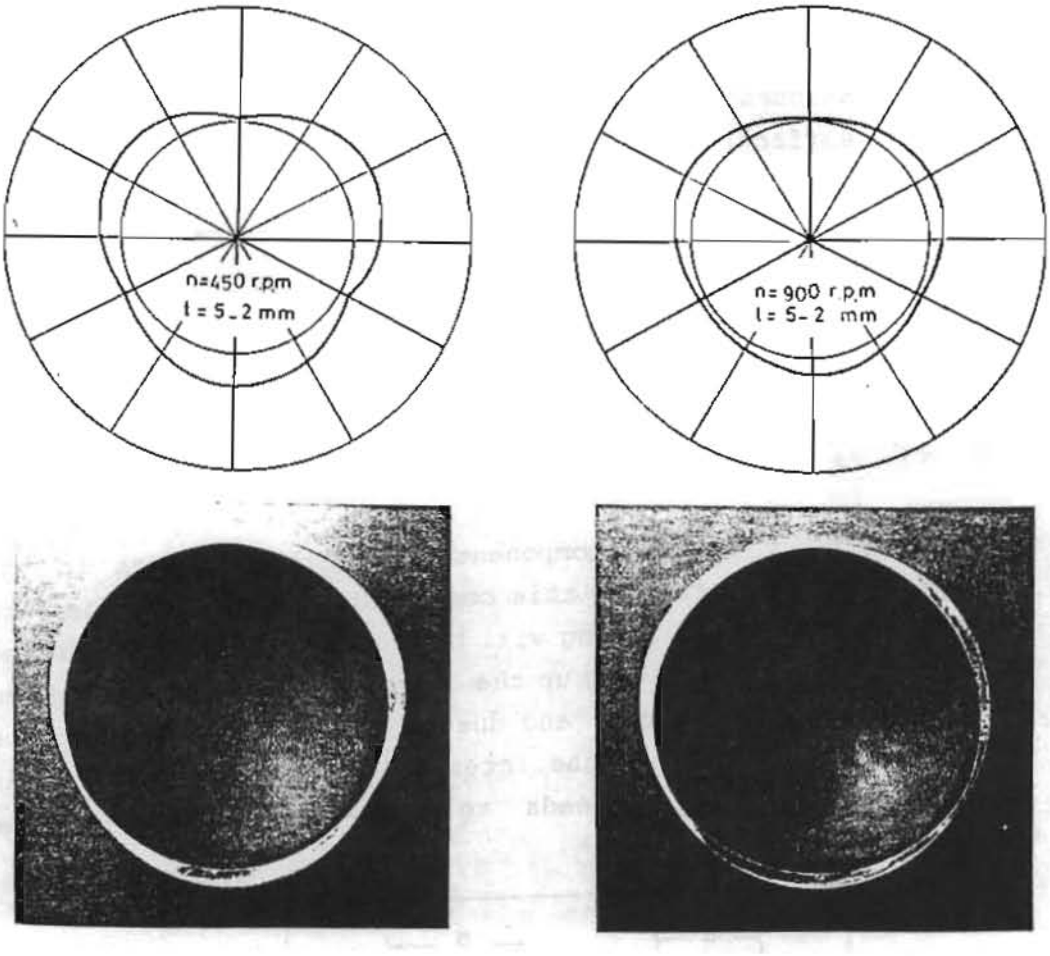
Figure (4) Effect of the incremental variation in the clamping torque on the deformation of internally turned specimen.



a. 3-jaws chuck
b. 4-jaws chuck
c. 6-points of clamping
d. Collet clamping

Figure (5) F. E. Analysis for hollowed components under different clamping conditions (Pilot test).

max. deviation = 1.91 mm   max. deviation = 1.12 mm



Working conditions:

D = 50 mm
t = 5 - 2 mm
L/D = 0.7

Chuck length = 15 mm
Overhang = 20 mm
Clamp. torque = 200 N.m

Figure (6) Effect of rotational speed on shape during turning under constant clamping torque.

COMPONENT DIMENSIONS

The ratio between the diameter and the wall thickness (D/t) plays an important role in the final shape of the deformed components. The stiffness of the solid turned components affects the final geometrical form of the product as previously investigated [5,6,8], therefore this factor must be considered for internally turned components, in which its stiffness is mainly affected by the ratio between the diameter and the thickness (D/t). For the same test piece, which was clamped in the elastic zone, the decrement in the wall thickness (t) due to internal turning process leads the components to lie in the plastic zone, causing a permanent undesired deformations, which remain permanently on the outer surface.

Figure (6) shows the deformation in the geometrical form due to the variation in the thickness (t) from 5mm to 2mm under the shown working conditions.

Due to this plastic deformation, the outer surface keeps the plastic deformation, but the internal surface will be free of this deformation due to the internal turning process.

When clamping a certain components using 3-Jaw chuck in the elastic zone, after turning this components internally, the form deviation due to the clamping will be compensated as illustrated in Figure (7a), after taking up the clamping force (releasing the components from the chuck); and due to the spring action of the components, the outer and the internal surfaces will deform as in Figure (7b), which leads to undesired errors in the geometrical form.

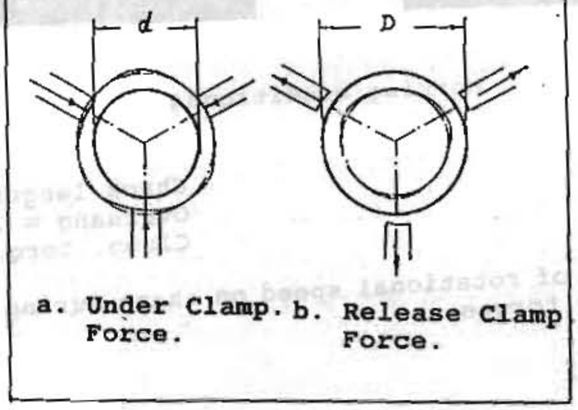


Figure (7) Elastic deformation in shape due to gripping force.

SPINDLE ROTATIONAL SPEED

Progress in machining techniques has made it necessary to know and consider the change in the rotational speed and its effect on the gripping forces not only for safety reasons, but also to determine the necessary gripping forces and eliminate the effect of the rotational speed on the variation of the gripping forces during any cutting process as mentioned before and shown in Figure (2).

Manufacturers of machine tools considered this point for the different ranges and types of chucks i.e. a performance curve as in Figure (2) for each chuck must be available for the proper selection of the gripping forces under different cutting conditions.

A brass components were internally turned under different working conditions shown in Figure (6) to predict the effect of the rotational speed on the geometrical form. It was clear that the variation in shape was affected mainly with the rotational speed, it decreases with the increase in the rotational speed, this decrement is due to the effect of the centrifugal forces which leads to decrease the gripping forces at high speeds, this suits the expected decrement in the gripping force to compensate the effect of wall thickness variation under cutting action.

CONCLUDING REMARKS

In this study a generalized analysis of the problem has been carried out to predict the shape and amount of deviation for internally turned components affected with the clamping conditions. From the investigation carried out in this work, it may be considered that the tested conditions are not sufficient to cover the hole concept, but the importance of clamping internally turned components is now under spotlights.

It may be suggested here that the following considerations are necessary:

-The gripping force must be constant during the cutting process and be within the elastic zone of the turned components to eliminate the form errors in the geometrical form.

-The D/t ratio and its variation during the turning process affect the periodical variation in the stiffness which could lead to undesirable results concerning the geometrical form.

-Any hollowed components must be safety clamped within the elastic zone to prevent its entrance in the plastic zone due to the decrement in the wall thickness (t) during the turning process.

-Considerably max. critical rotational speed for each chuck must be considered to minimize the losses in the gripping forces during the cutting process due to the effect of the centrifugal forces.

It is necessary here to say, that there are some important parameters to be considered in further works, e.g. chucking length, relative shape of the inner face of the jaw with respect to the test piece and the number of jaws and the effect of the machining conditions. A complete F.E. analysis should also be carried out to predict the stress and the strain distributions on the components and on the chucking system as well as the expected geometrical deformation in the components concerning its stiffness characteristics.

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