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DUAL CONTACT TOOL HOLDING TECHNOLOGY ANALYSIS

DIVU KONTAKTVIRMU INSTRUMENTU TURĒTĀJU ANALĪZE

OSKARS LINIŅŠ, DR.SC.ING.
RIGA TECHNICAL UNIVERSITY, MECHANICAL ENGINEERING INSTITUTE
ADDRESS: EZERMALAS STR.6, LV-1006, RIGA, LATVIA
PHONE: +371 67089701, FAX: +371 67089739

ANDRIS KAMOLS, DR.SC.ING.
RIGA TECHNICAL UNIVERSITY, MECHANICAL ENGINEERING INSTITUTE
ADDRESS: EZERMALAS STR.6, LV-1006, RIGA, LATVIA
PHONE: +371 67089701, FAX: +371 67089739

MĀRIS BALODIS, M.SC.ING.
RIGA TECHNICAL UNIVERSITY, MECHANICAL ENGINEERING INSTITUTE
ADDRESS: EZERMALAS STR.6, LV-1006, RIGA, LATVIA
PHONE: +371 26462882
E-MAIL: MARISBALODIS@APOLLO.LV

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Abstract: This research describes dual contact tool holder's analysis and its influence on the machining accuracy. Today in the multi-functional and milling centres are used many different rotating tool holding systems, for example, BT, SK, HSK, CAPTO and many others. Only few of these tool holding systems can ensure simultaneous dual contact along the tool holders taper and flange surface. Due to this fact research article includes calculations to prove the facility of dual contact along the machine spindle and tool holder's taper and flange caused by elastic deformations. This larger contact area results in remarkable improvement to machining rigidity, performance and most important to machining accuracy and repeatability.

Introduction

Today we are living in a world which can not be imagined without different technologies. These are technologies and achievements created by human beings. It has taken many hundreds of years and efforts invested in order to build up the world we are living today. People day by day have been thinking of innovations to make environment around us more comfortable by adopting different technologies for daily use. Any innovation, achievement, new product, new technology is designed and produced by engineers, the people who are mostly involved in mechanical engineering sector in general. Therefore we can say that mechanical engineering sector, as provider of enabling technology to all other sectors of the economy, provides the fundamental industrial infrastructure for almost all economies and its sub-sectors. Mechanical engineering is a strategic industry: it is a high added-value, knowledge-intensive sector which supplies all other sectors of the economy with the machines, production systems, components and associated services, as well as technology and knowledge they need. It is also considered an important contribution to sustainable development because it can result in more efficient production and, in this way, in the decoupling of resource use from economic growth. Mechanical engineering is not a homogeneous but a very diversified industry which covers a wide range of sub-sectors, including: lifting and handling equipment; machine tools; woodworking machinery; non-domestic cooling and ventilation equipment; pumps and compressors; machinery for mining, quarrying and construction; bearings, gears, gearing and driving elements; taps and valves, engines and turbines; agricultural and forestry machinery; machinery for textile, apparel and leather production; machinery for food, beverage and tobacco processing; agricultural equipment; machinery for paper and paperboard production; industrial furnaces and furnace burners; machinery for metallurgy, etc. To produce all the products mentioned above industry needs machine tools which can produce all of these products in efficient, cost effective and safe way. Nowadays production processes are becoming more and more automated where peoples' factor in terms of quantity is getting less but in terms of skills - more. To solve manufacturing tasks people have invented and implemented in production different type of machine tools to satisfy many industry needs – one of the most popular processes within general metal working has been and still is machining process that includes turning and milling. These processes are used to machine different metals by removing chip. By considering this process importance through many centuries and years I have drawn the particular attention to this process in general and in details.

Research topic

Analysis of the dual contact tool holder system influence on the machining process quality, productivity and cost effectiveness. Application of the dual contact tool holder systems in manufacturing plants around the Europe is very small. "Why does it happen so? Why dual contact tool holders in milling and multitasking machine tools are having very poor application among European producers?" First of all I would like to explain what the dual contact tool holder is. Most of the tool holders used nowadays is having only taper contact with spindle, respectively, contact between machine rotating spindle and tool holder is ensured only through one surface which is tool holder's taper surface and not flange contact in addition. Therefore such tool holders are easier and cheaper to produce. From one side it sounds good to have tool holder for a reasonable price and save the production costs, but let us look from the other side and answer to the following question: "Do we increase the productivity and quality with the same machining parameters?", "Does more expensive and precise tool holder can give us higher productivity and cost savings compared with one surface contact tool holders etc." There are many questions we should answer in order to make right decision what to choose for any individual application and situation. Therefore I see a vital need of practical tests and analysis of the dual contact tool holders and its influence on machining quality in order to understand the right application and usage of it compared to other tool holder systems used today.

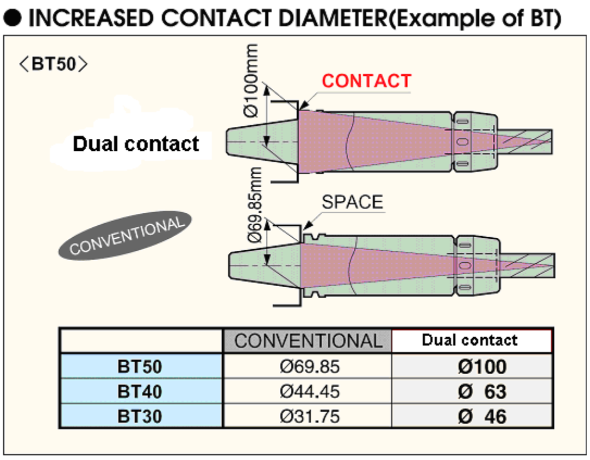

Fig.1. Contact diameter comparison between conventional and dual contact system

Basic concept

Dual contact is achieved with the Spindle System by eliminating the gap or space which generally exists between the machine spindle face and the tool holder flange face. For example, in the case of BT30 and BT40 taper machines, this gap is approximately 2.0mm, and in the case of BT50 taper machines, this gap is approximately 3.0mm (see Fig.1).

Calculation of toolholder's taper surface contact micro deformation potential

First of all we should make the elastic deformation calculations to find out the potential of the spindle and tool holder surface behavior when clamping force is applied in order to find out tool holder's axial movement into the spindle which is the most important parameter that can ensure spindle and tool holder's face contact (See Fig.2)

Please follow the elastic deformation calculations below that partly confirm tool holder axial movement due to elastic deformation caused by clamping force.

Calculation of the nominal FORCE applied on toolholder's taper surface 1mm^2

F=800kg - pulling force
Nominal force

$$Fn=\sin\cdot(8.33°)\cdot F \tag{1}$$

Fn=115,899kg

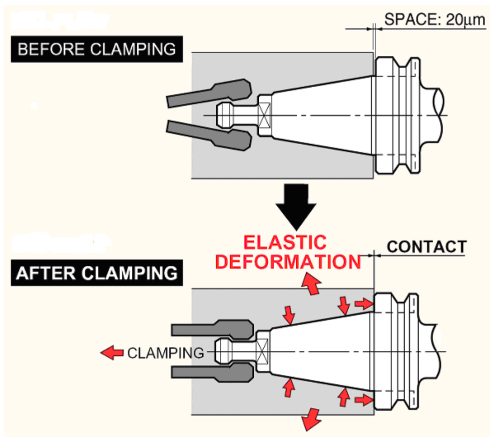

Fig.2. Elastic deformation of the spindle after clamping by ensuring tool holder dual contact

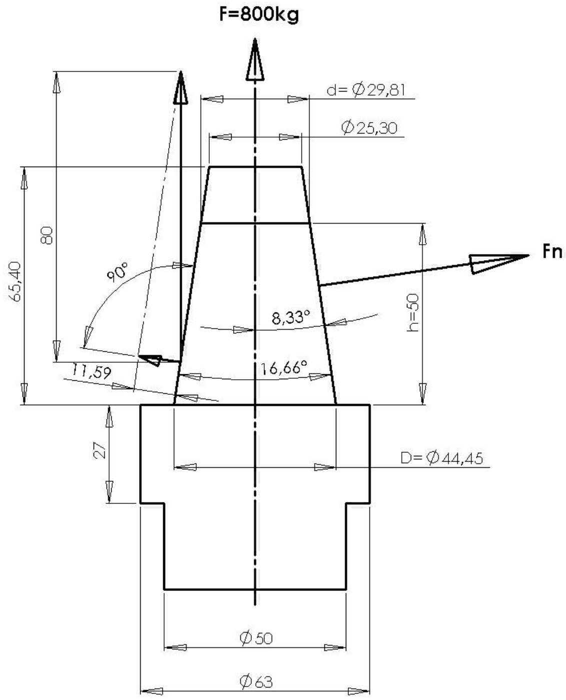

Fig.3. Tool holder's working principle diagram for calculations

h=50mm - effective contact height of the toolholder's taper surface
D=44.45mm - taper diameter at the bottom
d=29.81mm - taper diameter at the top
Calculation of the taper height

$$hs := \sqrt{h^2 + \left[\frac{(D-d)}{2}\right]^2} \tag{2}$$

$$hs = 50.533 \quad mm$$

Taper contact area

$$Ac := \frac{(\pi \cdot hs)\cdot(D+d)}{2} \tag{3}$$

$$Ac = 5894.538 \quad mm^2$$

Contact force on $1mm^2$

$$F1mm2 := \frac{Fn}{Ac} \tag{4}$$

$$F1mm2 = 0.02 \quad \frac{kg}{mm2}$$

Calculation of Elastic deformation

Factor Q of material elasticity

μ_1=0.3 Puason factor of the spindel material
μ_2=0.3 Puason factor of the toolholder's material
$E_1=2.1\cdot10^4$ kg/mm^2 Elastic modulus of the spindel material
$E_1=2.1\cdot10^4$ kg/mm^2 Elastic modulus of the toolholder material

$$Q := \frac{\left[1-(\mu_1)^2\right]}{\pi\cdot E_1} + \frac{\left[1-(\mu_2)^2\right]}{\pi\cdot E_2} \tag{5}$$

$$Q = 0.0000275869 \quad \frac{mm2}{kg}$$

Roughness pitch along the middle line
Sm1=0.072 mm
Correction factor of effective contact surface
Ky=0.2
Toolholder taper surface roughness Ra=0,000506 according to practical measuring tests

Function of LAPLAS
Function of LAPLAS is used to calculate elastic deformation of the contact surfaces between tool holders and spindle taper.

$$F1y := \frac{(F1mm2Q\cdot Sm1)}{Ky\cdot Ra} \tag{6}$$

$$F1y = 0.0001543639$$

Approximation for elastic contact deformation
Values are taken from the book „Microgeometry and operation characteristics of machinery"; Riga - 1979
γ=3.2 elastic deformation after clamping force has been applied
γ_0=3.5 elastic deformation before clamping force has been applied
Calculation of elastic deformation

$$a := \sqrt{\frac{\pi}{2}}\cdot(\gamma o - \gamma)\cdot Ra \tag{7}$$

$$a = 0.0000317088$$

$$a\mu := a\cdot 1000 \tag{8}$$

$$a\mu = 0.032 \quad \mu m$$

Practical tests of elastic deformation due to centrifugal forces

There has been made experiments of toolholder movement along the Z axis caused by centrifugal forces of spidel rotation. We can see in Table 1, that toolholder moves into the spindle 6μm when the speed of 15000 min-1 is reached. Main elastic

Table 1

Toolholder movement along the Z axis
depending od spindle speed

Spindle rotation [min-1]	Tool length [mm]
0	150,099
5000	150,098
8000	150,097
12000	150,095
15000	150,093

deformation of toolholder is caused by centrafugal forces.

Summary of calculations

Total movement of toolholder into the spindle along the z axis is sum of centrifugal force and elastic deformation which results in ~ 6-7 µm. By having all tolerances strictly controlled by high tolerance gauges and measuring equipment, simultaneous dual contact of the face and taper is thus assured. This approves that practically machine tool spindle and tool holder considering its manufacturing tolerances can be assembled or clamped ensuring dual contact. This might seem impossible considering the steel properties, but this very small elastic deformation is enough to ensure dual contact. This larger contact area results in remarkable improvement to machining rigidity and performance which is proven by practical tests below.

Advantages that improves machining accuracy

Perfect interchangeability with existing machines and toolholders.

Dual contact holders can be used on existing standard machine spindles. Existing standard tool holders can also be used on Dual contact spindles. In this case, simultaneous contact can not be attained. In order to achieve excellent performance of simultaneous contact, Dual contact holders should be used on Dual contact spindles. To benefit from all the technical advantages which the Dual contact Spindle System offers, both a Dual contact HOLDER and a Dual contact Spindle are required.

Minimized vibration prevents fretting corrosion.

One of the problems in heavy machining and high speed machining is the tarnishing in the taper portion of both the machine spindle and toolholder, which is called fretting corrosion. Fretting corrosion is a friction oxidation that develops when two contacting pieces of metal have movement as a result of machining vibration. Dual contact protects the toolholders from this oxidation by reducing the machining vibration with the higher rigidity achieved by its dual contact method. This results in greatly extending the life of both the machine spindle and the toolholder.

Elimination of Z-axial movement

At high rotational spindle speeds, the mouth of the machine spindle can expand slightly due to centrifugal force. As the machine spindle expands, the conventional toolholder, which is under constant draw bar pulling pressure, moves further into the spindle. On high tolerance applications, this slight pull back of the cutter can affect dimensional accuracy of the Z-axis (see Fig.4). Pull back can also cause the toolholder to get locked into the machine spindle taper. The face contact provided by the Dual contact Spindle System prevents the toolholder from being drawn back into the machine spindle.

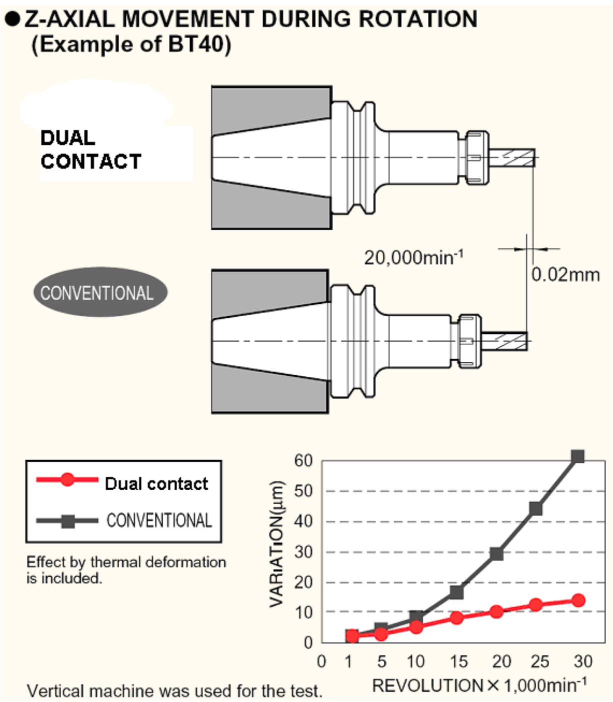

Fig.4. Z-axial movement elimination

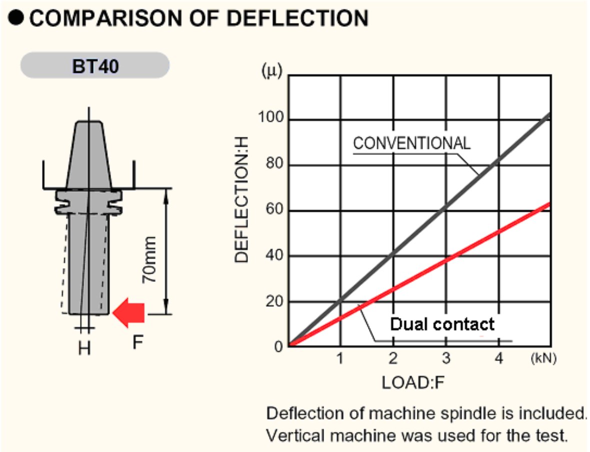

Fig.5. Radial deflection

Minimized deflection for maximum machining accuracy and superior finish

With Dual contact simultaneous contact, machining rigidity is greatly enhanced due to the larger contact diameter of the tool holder flange face. This larger face contact combined with the taper contact works together to resist deflection. With less deflection, greater machining accuracy and superior finish can be achieved see Fig.5.

Conclusions

As a result, there will be axial movement of the tool holder after clamping of the pull stud due to elastic deformation both in tool holder and spindle. The axial movement is different on each model of machine depending on the external diameter, rigidity and clamping mechanism of the machine spindle. To determine the proper spindle nose dimensions and tolerances, the axial movement of the tool holder is very carefully measured. In this way, the dual contact Spindle System skillfully utilizes the elastic deformation (see Fig.2) of the machine spindle to control the gauge line accuracy, which thus insures that dual contact of the face and taper is achieved. This larger contact area results in remarkable improvement to machining rigidity and performance.

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Balodis M., Kamols A., Liniņš O. Divu kontaktvirsmu instrumentu turētāju analīze

Šis raksts ir par divu kontaktvirsmu instrumentu turētāju analīzi un to ietekmi uz apstrādes precizitāti. Šodien metālapstrādē izmanto dažādas rotācijas instrumentu turētāju sistēmas frēzmašīnās un daudzfunkcionālos apstrādes centros, piemēram, BT, SK, HSK, CAPTO un citas, bet tikai dažas instrumentu turētāju sistēmas no visa lielā klāsta nodrošina divu virsmu kontaktu, tas ir, pa instrumenta turētāja konusu un apmali vienlaicīgi. Tāpēc darbā ir veikti aprēķini, lai pierādītu, ka ir iespējams nodrošināt instrumenta turētāja kontaktu ar iekārtas darba vārpstu pa divām virsmām vienlaicīgi, rezultātā ievērojami tiek uzlabota apstrādes precizitāte un atkārtojamība.

Балодис М., Камолс А., Лининс О. Анализ держателей инструментов двух контактных поверхностей

Эта статья об анализе держателей инструментов двух контактных поверхностей и о его влиянии на

точность обработки. Сегодня в металлообработке используются различние системы держателей инструментов как для фрезировочных машин, так и для многофункциональных центров обработки, например BT, SK, HSK, CAPTO и другие. Но только несколько систем держателей инструментов из всего спектра предлагаемых обеспечивают контакт двух поверхностей, а именно одновременно по конусу держателя и по кромке. Поэтому в работе произведены расчёты, с целью доказать, что есть возможность обеспечить контакт с рабочим шпинделем устройства одновременно по двум поверхностям. В результате значительно улучшается точность и воспроизводимость обработки.