CALCULATING THE CLAMPING FORCE FOR MACHINING

How much clamping force do I need to hold this part?

Regrettably, accurately determining the answer to this question is often "glossed over" during the design phase of clamping fixtures. Rather than evaluating the actual forces generated during machining and selecting clamps accordingly, clamping devices are more commonly sized using a seat-of-the-pants approach or other mystical methods.

Clamping fixtures designed without first performing some simple clamping force calculations typically result in one of two possible outcomes, both undesirable. The first possibility is that the clamping devices selected are too small, not providing enough force for the particular machining application. This results in the need for fixture rework after trial machining demonstrates the inadequacy of the initial approach. The second and more common possibility is that of selecting clamping devices that are substantially larger than the application requires. Those oversized devices will securely hold the part, but hog valuable fixture space and add cost to the finished fixture. Rather than pursuing fixture design in a haphazard fashion, one should take the few minutes required to study the machining operations being performed and determine through a series of simple calculations the actual forces acting on the work piece while it is being machined.

Where does one go to find the information needed to perform such calculations; the formulas, charts and tables? One good source for this type of information is the "Machinability Data Handbook" published by *Metcut Research Associates* of Cincinnati, Ohio. Chapter 17 of the Handbook, found in Volume Two, contains the formulas and data needed to perform machining force calculations for a wide variety of materials and manufacturing processes. The data in the Handbook, while extensive, is not the only source one must consult though. For the remaining information needed to complete machining force calculations, the manufacturing process plan for the particular work piece should be consulted. The process plan for the particular work piece should be consulted. The process plan is where the specific tools that will be used during machining should be defined. (If no formal plan exists, one must still know what tools will be used to perform each machining operation). Another excellent source of information is your tool supplier who can offer specific recommendations on feeds and speeds to use with the tools that he provides.

Armed with all this data, one need only "crunch a few numbers" to arrive at the desired solution.

To illustrate the simplicity of cutting force calculations, assume that the most significant cut to be made in a particular work piece involves boring a 3 inch diameter hole. The work piece material is aluminum alloy 6061, heat-treated and aged. The boring bar itself uses an indexable carbide insert. Referring to Chapter One of the Handbook, one will find general recommendations for the speed, feed

and depth of cut to use for this operation. For this example assume the bar will feed at .010 inch per revolution, with the tool turning at 1500 surface feet per minute (the max our spindle can handle) and with a .060 radial depth of cut. Referring to Chapter 17 of the Handbook, one will find both the formulas and empirical data needed to calculate the resultant cutter forces.

Start by retrieving the value for unit power required for this application. Unit power is defined as the horsepower required to remove one cubic inch of material in one minute. From table 17.2-3 of the Handbook one finds two values for the estimated unit power (P) required when turning (boring) aluminum. One value is for sharp tools, the other for dull tools. Using the worst case condition of a dull tool, the value obtained from the table is .3 hp/cu.in./minute.

The required calculations are then:

Metal Removal Rate = d x Fr x Vc x 12 (in./ft.)

(Q) (cu.in./min.)

Where d = Depth of Cut (in.)

Fr = Feed Rate (in.)

Vc = Cutting Speed (sfm)

or Q = .060 in. x .010 in. x 1500 ft/min x 12 in./ft

= 10.8 cu. in./min

Horsepower required = metal removal rate x unit power

(Hp) (Q) (P)

or Hp = 10.8 (cu. in./min) x (Hp/cu.in/min)

= 3.24 Hp

Resultant cutter force = Hp x 33000 / cutter speed (sfm)

(Fc) (ft-lbs/min/Hp)(Vc)

or Fc = (3.24 x 33000) / 1500 sfm

= 72 pounds

If swing clamps are used to hold the work piece the radial cutter forces acting on the part must be resisted by the vertical squeezing forces applied by the swing clamps. The magnitude of vertical (squeezing) force required to counteract the radial (horizontal) cutting force is a function of the friction between the work piece and fixture. Assuming a coefficient of friction of .15, then the minimum swing clamp force required to resist the 72 pounds of cutter force would be:

Clamping Force =
72lbs/.15
= 480 lbs

The calculated value is the minimum amount of force needed to exactly offset the cutter forces generated. To provide an adequate margin of safety for the clamping system, this value should be increased by a factor between two and four to provide a reasonable safety factor. If a safety factor of three is used in this case, then the total force required from the three clamps is 1440 pounds (480 x 3) or about 500 pounds per clamp. After going through all these calculations why allow so much for a safety factor? Because we both know that as soon as the fixture hits the shop floor, someone will try to cut the cycle time by increasing the speed, feed or both. Maybe that's why so many tools end up being over designed in the first place.

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