

## Speeding Up During Global Slowdown

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### Introduction

The competitiveness among companies in the highly automated metal fabrication industry is tough in these days of global economical slowdown. Efficient production along with a high output of the line(s) is crucial for the plants. Plants with low productivity will quickly disappear from the map.



In many cases metal fabrication involves a process of station-to-station handling of oily/slippery metal sheets or blanks. The most common method of handling such sheets is by using suction cups connected to a vacuum source that is either centralized or decentralized. Suction cups have been the mainstay in the press room for a number of years. The cups are easy to apply to the parts being handled and they are very compliant to the automation and evolution of the forming process in a line of dies. There are productivity challenges however! One is to prevent the cups from slipping out of position or even dropping the part being handled due to oil or die lubrication used in the forming operation. If the cups slip out of position, the sheets will be placed incorrectly in the next station, resulting in a production stop to manually reset the sheets. A dropped part can lead to even more disastrous consequences such as scratched parts, line stoppage and time required by personnel to reset. Another challenge is the continued technical developments and speeds of automation combined with the higher speed capabilities of the metal fabrication machines, leading to the realization of 20 strokes per minute in a press line in the not too distant future, something which causes

enormous demands on the suction cups. This is a factor many tend to forget, that the material handling system with suction cups needs to cope with the new demands. If this factor is not considered, it will not be possible to take full advantage of the machines' capabilities. A synchronized cross-bar press handling large body side appitures, for example, can be accelerated up to  $30 \text{ m/s}^2$  ( $> 3g$ ). These same appitures must be de-accelerated nearly as fast to be placed in the next station. An emergency stop can cause even higher stress on the ability of the suction cup to hold.

This paper will take a look at the problem of slipping suction cups on oily metal sheets and the best methods to manage and avoid design mistakes.

### Theoretical analysis

A suction cup will lose position if the holding force/grip is lower than the sum of all counteracting forces. In very "slow" handling applications the "dimensioning" force is the force created by the weight of the object handled (and gravity). In faster applications, and especially in applications with rapid acceleration and/or de-acceleration/braking, there are other important forces to take into consideration when dimensioning, and that is the force which gives the mass, "m", of the object and the acceleration/de-acceleration/braking, "a".

Newton's second law says:  $F_{\text{acceleration/brake}} \text{ (N)} = M \times A.$

Where:

M = Weight of the object (kg)

A = Acceleration/de-acceleration ( $\text{m/s}^2$ )

Suction cups generate a normal (vertical) lifting/holding force ( $F_n$ ). They also generate and a parallel friction force ( $F_{fr}$ ). The level of the friction force depends on the friction coefficient ( $\mu$ ).

$$F_{fr} = (F_n) \times \mu$$

$F_n$  = Vertical force created by the cup

$\mu$  = Friction coefficient between the materials in contact

The table below shows approximate and general values of the friction coefficient between the material combination of rubber and metal.

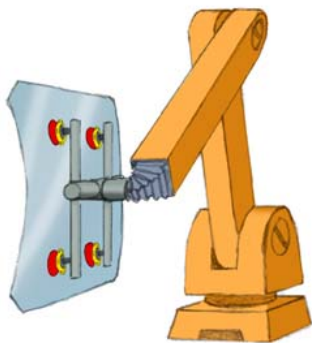
$\mu_{\text{rest}}$		$\mu_{\text{motion}}$	
Dry surface	Oily surface	Dry surface	Oily surface
0.5	0.2	0.3	0.1

The frictions coefficient is higher at rest ( $\mu_{\text{rest}}$ ) compared to motion ( $\mu_{\text{motion}}$ ), i.e., higher force is needed to start the motion than to maintain it. If cups start to slide due to an applied force, there is a great risk that they slide much more when the motion is started.

### An example – handling an automobile hood in a stamping line

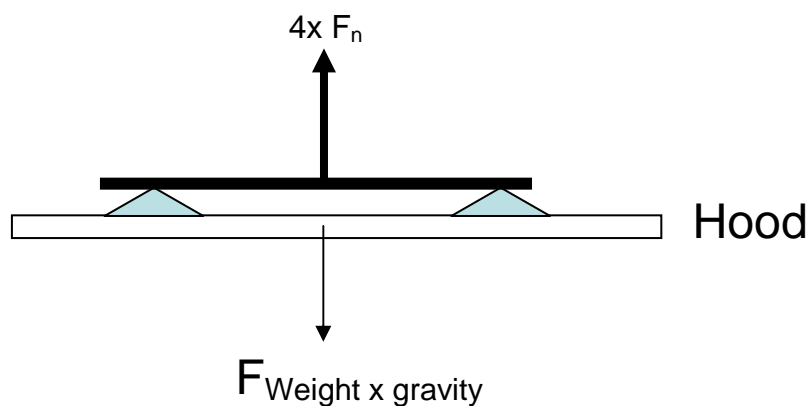
An automobile hood is to be formed in a press line under the following conditions.

Application:	First press stages
Blank size:	1000 x 1500 x 1 mm
Oil on blank:	2 g/m <sup>2</sup>
Blank weight:	12 kg
Suction cup:	75 mm diameter
Cup lifting force:	150N @ -60 kPa (Normal, vertical force)
Max parallel acceleration:	20 m/s <sup>2</sup>
Emergency stop:	-30 m/s <sup>2</sup>
Max speed:	12 m/s
Press speed:	12 strokes per min (720 parts per hour)



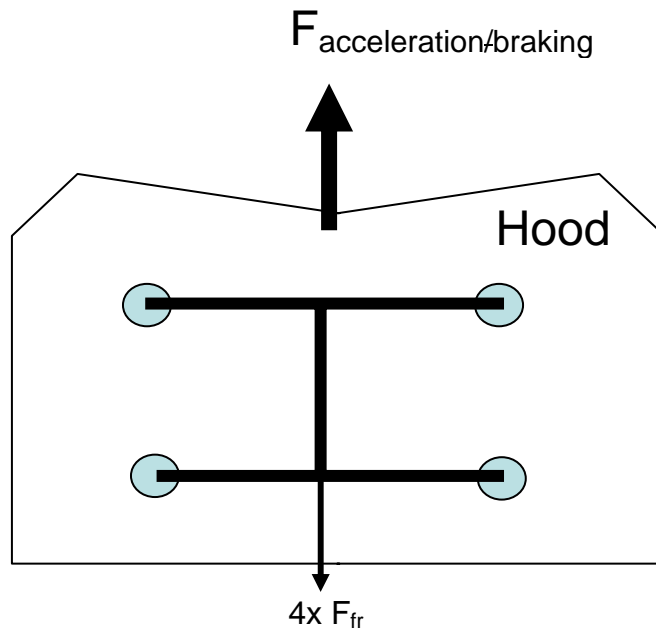
Let's take a look at three approaches, step-by-step.

**Step 1.** Let's start by just dimensioning by looking at the weight of the blank/sheet and use a safety factor, a normal procedure for inexperienced designers. Typically, a safety factor of 2-4 will be used, and in this case we specify a minimum of safety factor of 4.  
(i.e.  $4 \times F_n \times \text{“safety factor”} > F_{\text{weight} \times \text{gravity}}$ )



The weight of the blank is 12 kg, so the designer calculates that he/she will need 4 pieces of cups that are 75 mm in diameter, which gives a safety factor of approximately 5. Is this enough to handle the acceleration/braking force?

$4x F_{fr}$  must be  $> F_{\text{acceleration/braking}}$



It seems that four 75 mm cups will be enough to handle an oily blank with a weight of 12 kg, including a safety margin of “5”, but is it enough to handle the acceleration and braking forces?

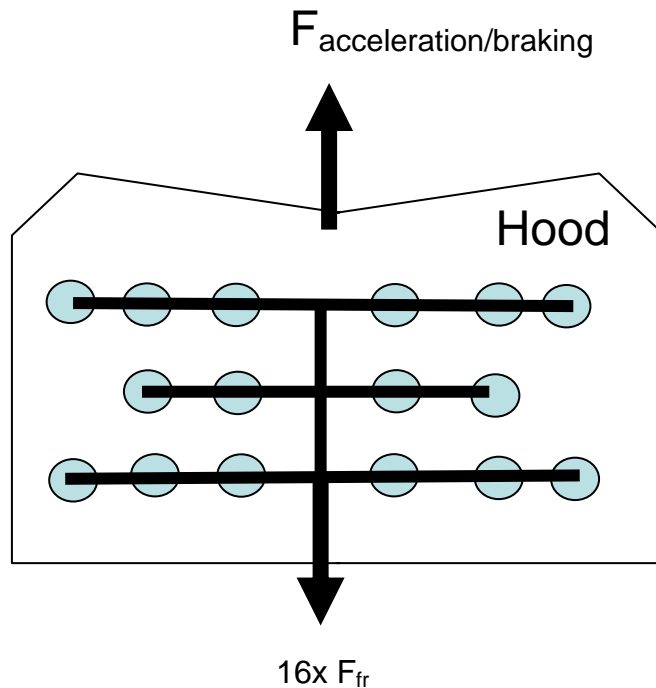
Let's check this in the next step.

**Step 2.** In this step we also take into consideration the maximum acceleration/braking force which the “friction force” of all the cups must withstand.

By using Newton's 2 law, the maximum acceleration of the machine will give a force of  $12 \times 20 = 240$  N. However, an emergency stop at maximum speed will give a force of  $12 \times 30 = 360$  N.

To manage the worst case, an emergency stop at maximum speed, suction cups with a total friction force of 360 N are needed. The conventional cups we have in possession are without any friction pattern. A handbook will show that the friction coefficient ( $\mu_{\text{rest}}$ ) is approximately 0.2 between rubber and oily metal.

The calculation results in  $360 / (150 \times 0.2) = 12$  cups, i.e., a minimum of 12 conventional cups must be used to handle the emergency stop braking force. To have a good safety factor, 16 cups would be recommended.



*Sixteen conventional suction cups of 75 mm in diameter are needed to handle the emergency stop braking force.*

#### Conclusions after step 1 and step 2:

As step 2 shows, the calculated 4 cups in step 1 were far too few. The sheets would have slid even by the acceleration force. The option, instead of increasing to 16 cups, which costs a lot in rebuilding the end-of-arm tool, would have been to slow down the speed of the press-line. Maybe it would be possible to add a few cups to the existing end-of-arm-tool.

The maximum speed, 12 m/s, generates emergency stop braking of  $-30 \text{ m/s}^2$ . To brake, the 12 kg hood will create 360N in braking force.

Let's assume that we (realistically) can add 4 more cups to the existing end-of-arm tool in step 1. We will have 8 conventional cups with a total friction force of  $150 \times 0.2 \times 8 = 240 \text{ N}$ .

The emergency stop de-acceleration/braking (A) can also be determined by:

$$A = (V_f - V_i) / t$$

$V_f$  = Final speed

$V_i$  = Initial speed

t = Time

$$A = -30 \text{ m/s}^2 \text{ (machine specification)}$$

$$V_f = 0 \text{ (full braking)}$$

$$V_i = 12 \text{ m/s (machine specification)}$$

$$\Rightarrow t = -12/-30 = 0.4 \text{ sec (time needed at maximum speed to brake completely)}$$

How fast can we run the machine if the 8 cups can handle just 240N (and not 360N)?

First; how powerful "emergency stop" braking can we manage with 8 conventional cups?

$$240\text{N}/12\text{kg} \Rightarrow -20 \text{ m/s}^2$$

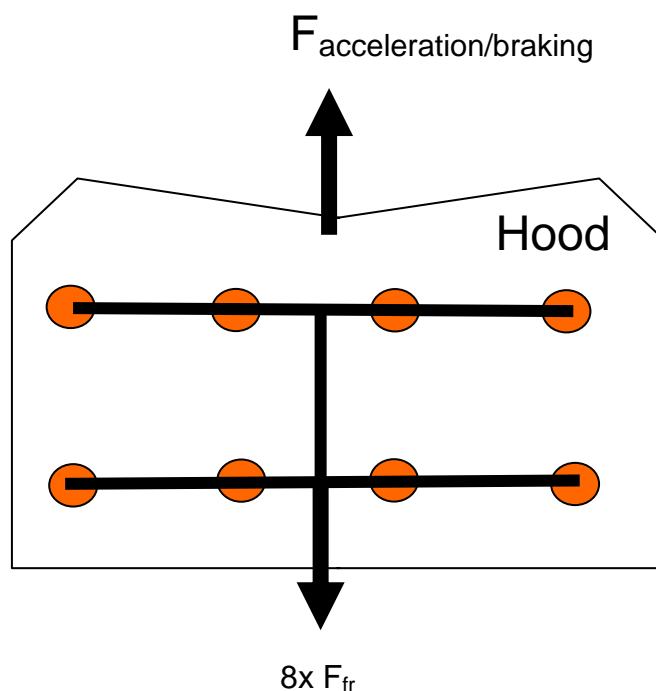
If we assume that the time (t) to achieve complete emergency stop braking is constant (0.4 seconds), this tells us that the maximum allowed speed ( $V_i$ ) will be:  $0.4 \times 20 = \mathbf{8 \text{ m/s}}$ .

So the actual conclusion is that the machine can be run only at a maximum speed of 8 m/s and not the specified 12 m/s, if we are supposed to manage a complete emergency stop without sliding cups. It would require 16 conventional cups and rebuilding the end-of-arm tool to do that.

A 33% slower speed during the vacuum handling cycle will definitely lead to a reduced total cycle time by probably 20-25%. The machine capacity, 12 strokes/min, will not be reached, probably only 9-10 strokes/min. Instead of 720 part produced/hour we would be lucky if we could achieve 600 parts produced/hour. We will get a “gross margin loss” of approximately 120 parts/hour.

A press line usually runs 20-24 hours per day. That means that we are produce approximately 2,400 fewer parts per day than what is possible at 10 strokes/min vs. 12 strokes/min, due to the chosen vacuum/cup solution. If each stamped hood has a gross margin value of 2 €, the gross margin loss will be €4800 per day!

**Step 3.** After carrying out market research we learned about tailor-made **friction suction cups** for oily sheets/blanks. A state-of-the-art tailor-made friction cup can increase the friction coefficient ( $\mu_{\text{rest}}$ ) from approximately 0.2 to nearly 0.4-0.5, i.e., almost the same as on a dry metal sheet. Using the same calculations (with  $\mu_{\text{rest}} = 0.45$ ) as in step 2, the result will be that only 6-8 friction cups are needed, including a safety margin to manage the 360 N in emergency stop braking force.



*Tailor-made friction cups for oily sheets can more than double the grip. 6-8 cup will do the same job as 16 conventional cups.*

#### Conclusions after step 3:

The end-of-arm tooling can remain the same (no re-tooling/building) and production can run at the maximum speed of the machine, 12 strokes per minute. An emergency stop will not make the sheets/blanks slide.

*Note! In this simplified example we have just looked at a parallel motion with acceleration and braking. A vertical or angled motion with acceleration/braking will add even more to the*

*needed friction force of the cups due to gravity. We have assumed a decentralized vacuum system. The vacuum pump/generator solution can also affect speed. A decentralized system is faster in most cases.*

### **Friction cups - crucial components in high speed sheet metal fabrication**

The constant development for higher speeds and output in metal fabrication has led to a situation where the material handling system (in most cases a vacuum system) has become the bottleneck. Until recently, there have not been good enough friction cups in the market. Many users and machine builders are not aware of the friction cups either, and continue to use conventional suction cups without a friction pattern. Sometimes, the bottle neck can be solved by adding more or larger cups but in most situations there is no room for more or larger cups because of the shape of the sheet/blank. The final stations of press lines are good examples of this.

As we have shown previously, well designed friction cups can more than double the shear force/friction grip on an oily metal sheet. Fewer cups can be used to manage the specifications of the machine (acceleration and braking). The possibility to run the machine at maximum speeds is more likely. More parts per minute can be produced!

### **Different friction cups – pay attention and chose the right brand**

The market offers friction cups from a handful of suction cup suppliers. Most of the suppliers have developed an internal friction surface in the cup with a high density of pattern (knobs, oil channels, etc.). These cups show a good friction force/grip initially, however, the wear on the cups from normal usage will very soon “eat up” the friction pattern and the cups will soon have more or less the same performance as conventional cups. The user has to frequently change the cups in order to maintain the performance of the machine.

DURAFLEX® Friction Cups are of a suction cup brand with a special “friction pattern design” that resembles the one which can be found on (stud-free) winter/snow tires for vehicles. The sharp and finely grooved lamellar structure is one of the important parameters to get a super grip.



*“Slick tire” – excellent performance on dry surfaces*



*“Friction tire” – excellent performance on ice and snowy surfaces*



*DURAFLEX® Friction Cup, excellent performance on oily surfaces.*

The big benefit with this design is that the friction performance will be maintained during the entire life. As a matter of fact, the initial wear will improve the friction grip slightly.

*The table below compares the initial friction force/grip performance and also how the performances varies and degrade over time.*

