STAMPING WITH UDDEHOLM VANCRON 40

TOOLING APPLICATION | COLD WORK

UDDEHOLM

This information is based on our present state of knowledge and is intended to provide general notes on our products and their uses. It should not therefore be construed as a warranty of specific properties of the products described or a warranty for fitness for a particular purpose.

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For further information see our "Material Safety Data Sheets".

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Selecting a tool steel supplier is a key decision for all parties, including the tool maker, the tool user and the end user. Thanks to superior material properties, Uddeholm's customers get reliable tools and components. Our products are always state-of-the-art. Consequently, we have built a reputation as the most innovative tool steel producer in the world.

Uddeholm produce and deliver high quality Swedish tool steel to more than 100,000 customers in over 100 countries. Some markets are served by ASSAB, our wholly-owned and exclusive sales channel in the Asia Pacific area. Together we secure our position as a world-leading supplier of tool steel.

Wherever you are in the manufacturing chain, trust Uddeholm to be your number one partner and tool steel provider for optimal tooling and production economy.

Quite simply, it pays to go for a better steel.

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Stamping with Uddeholm Vancron 40

Uddeholm Vancron 40 is an advanced cold-work tool steel with unique tribological properties involving high resistance against galling. It is the ideal tool material for long series stamping. It can be used without surface coating in many forming operations where previously the only solution was a coated tool. Significant improvement in tool economy has been achieved in many applications, such as the one shown in the figure below. This brochure is intended to supply some guidelines regarding stamping with Uddeholm Vancron 40.

The most important recommendations are summarised below. More details are added in subsequent sections.

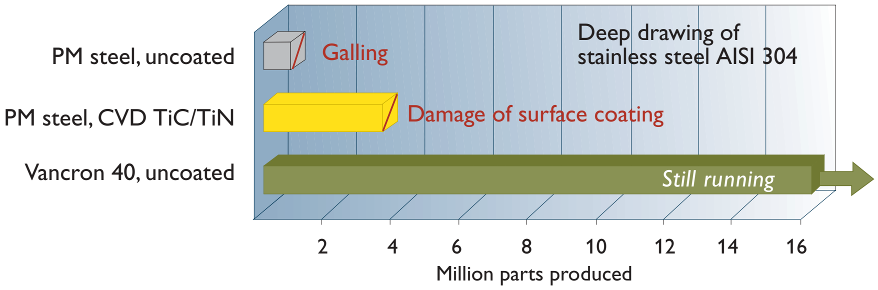


Figure 1. Tool lives with different coated and uncoated tool steels in an industrial deep drawing application with AISI 304 stainless steel. Uddeholm Vancron 40 is still running after 16 million parts. More information can be found on page 23.

Summary of guidelines for stamping with Uddeholm Vancron 40

- For best economy in long series production of material prone to galling: use uncoated Uddeholm Vancron 40.
- For best anti-galling performance in very difficult cases: use coated Uddeholm Vancron 40.
- Always prepare active tool surfaces with low surface roughness. Recommendations include R_a below 0.1 µm and polishing of dies for forming of carbon steels.
- Avoid using uncoated Uddeholm Vancron 40 in very difficult applications. The most difficult cases include:
  – ironing with thickness reduction above 20%
  – deep drawing with a combination of thick sheet, small die radius and large drawing depth.
  – U-bending of thick sheet with small tool radii.
- Aim for tool design that avoids buckling. Use a blank holder in drawing operations.
- Always use a lubricant. Sometimes lubrication can be reduced but lubrication is always recommended. Even a minimum of lubrication improves tool life significantly. Delivery oil on the sheets often provides enough lubrication.

Properties of Uddeholm Vancron 40

The efforts to find the optimum tool material for an application should be focussed on the failure mechanism that causes the worst damage on the economy of the process. In stamping the worst failure mechanism is often galling.

Galling is a type of adhesive wear involving cold welding of sheet material fragments to the die. After severe galling the tool surface will cause scratches or scoring on the blanks and finally the tool must be reconditioned or scrapped. Galling can occur both for hard and soft work materials. An example of galling is shown below.

Figure 2. Galling on a punch.

In terms of galling resistance Uddeholm Vancron 40 performs significantly better than other tool steel grades and often similarly to coated powder metallurgical (PM) tool steels. However, the galling protection of a coated steel is reduced if the coating is damaged. Uddeholm Vancron 40 on the other hand can maintain its galling protection even if the surface becomes slightly worn. In the event of galling appearing after long service, the surface of a Uddeholm Vancron 40 tool can easily be restored by light polishing. Restoring the surface of a coated tool requires re-coating, which is not only time consuming and costly but also limits the life of the tool, since the tool can only be re-coated a limited number of times.

The unique anti-galling properties of Uddeholm Vancron 40 are the result of alloying with nitrogen. In the production process the nitrogen reacts with other alloying elements and forms small and hard particles, nitrides, throughout the material. On the surface they contribute to reduce the friction and to protect against galling.

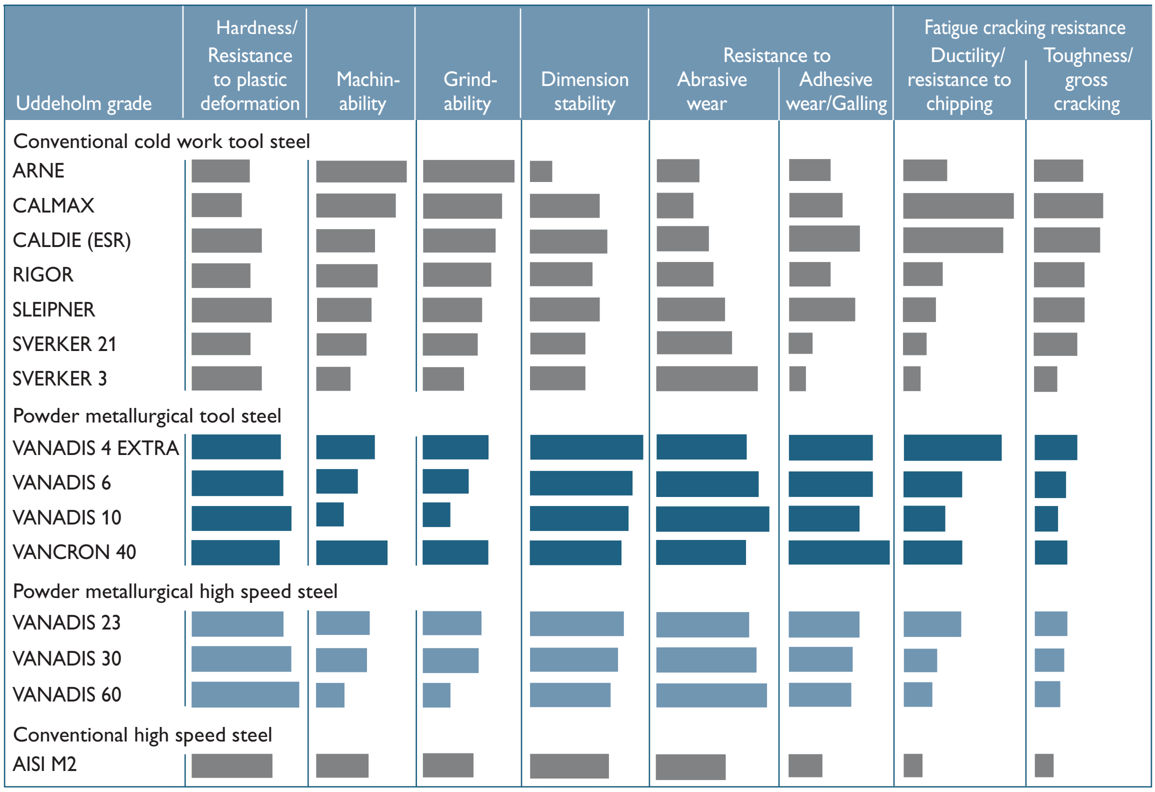
Although Uddeholm Vancron 40 was developed as a low-friction and high-galling-resistance material, other properties are on the high end as well. The excellent properties are much a result of the PM production route. Thus if the tool life depends on galling, it is unlikely that switching to Uddeholm Vancron 40 would reduce the tool life because of other failure mechanisms.

The properties of Uddeholm Vancron 40 can be summarised with the following list.

- Very high resistance to adhesive wear and galling.
- Low friction in sliding contact.
- Simple maintenance and low reconditioning cost.
- Good resistance to abrasive wear.
- Good chipping and cracking resistance.
- High compressive strength.
- Good through-hardening properties.
- Good dimensional stability in hardening.
- Very good resistance to tempering back.
- Good EDM properties.
- Good machinability.
- Excellent hard machinability
- Suitable for surface coating if extreme galling resistance is required.
- Wide hardness range. Result of standard heat treatment is 60–62 HRC but 57–65 HRC can be achieved by varying the hardening temperature.
- Not suitable for welding.

Table 1 on next page, shows a comparison between properties of different cold work tool steels.

TABLE 1. UDDEHOLM VANCRON 40 PROPERTIES IN RELATION TO OTHER TOOL STEEL.



When can the advantage of Uddeholm Vancron 40 best be exploited?

In some cases the benefits of Uddeholm Vancron 40 are particularly great. The following list shows some of those situations.

- For forming operations ranging from average to difficult, where a coated tool steel is the alternative.
- For long series production.
- For production with hard sheet materials, which would cause considerable wear and reduced life of the coated steels.
- When costs for tool maintenance and resulting downtime are high.

Applications also exist where the superior properties of Uddeholm Vancron 40 cannot be fully utilised. In those situations Uddeholm Vancron 40 can still be used but other tool materials may be more cost-effective. The following list shows some of them.

- If galling or coating failure does not have a significant influence on tool economy for other materials.
- If sliding contact occurs under extreme contact pressure. Under such conditions galling is likely to occur for all tool materials. An example of a difficult case is ironing with large thickness reduction.
- For simple cases where uncoated grades perform well enough.
- For prototyping.
- When sheet materials are zinc coated. The soft coating will have a tendency to stick to most tool materials. On the other hand there will be less damage on the tool from a soft zinc coating than from a harder work material. As a result the use of Uddeholm Vancron 40 with zinc coated sheet materials may give limited advantage over other tool steels. However, the result depends on the application and there still may be cases with coated sheet where the performance of Uddeholm Vancron 40 is significantly better than for other tooling materials.

Recommendations for sheet metal forming

The present section includes some recommendations and rules of thumb for sheet metal forming with dies of Uddeholm Vancron 40. The recommendations are based both on results from tests with Uddeholm Vancron 40 and knowledge applicable to most tool materials.

Please note that the recommendations given in this brochure are oriented to the tool performance and mainly with respect to galling. It is also essential to ensure that the deformation of the blank is within the formability limits of the sheet material. For instance, the maximum bending radius with respect to sheet failure will usually differ from the maximum bending radius to avoid galling.

Sheet material

The tendency for galling depends in several ways on the sheet material.

Surfaces of stainless steels and aluminium that are exposed to air become covered by a protecting oxide. The oxide film will usually be broken during the forming, exposing fresh bulk material with high adhesion to the dies. Furthermore, oxides from the sheet surface may be abrasive. Scratches on the tool from oxides may be initiation points for galling. Thus, for these materials lubrication is more important than for carbon steels.

Increasing strength of the sheet material does allow higher contact pressure but that change is compensated by the higher contact pressure required for the forming. Still the softest and the hardest work materials are often the most difficult materials to form in terms of galling.

Typical for soft materials and for materials with good formability such as stainless steels is a high work hardening rate. This may increase the tendency to galling because the work hardening causes an increase in contact pressure. Furthermore, galling involves a transfer of highly deformed sheet material fragments to the die surface. A higher work hardening rate will make the galling fragments harder and more harmful.

To some extent the experience that materials with high formability can have a greater tendency to galling can be the fact that the formability is actually utilized. Thus forming of stainless steels often involves large deformation and long sliding distances which contribute to create galling.

The work hardening rate is often expressed as the n-value. A high value of n in particular improves the formability in stretch forming, but as mentioned above may increase the tendency for galling.

Another parameter, the normal anisotropy or the R-value, should also be high in order to improve the formability in drawing. A high value of this parameter means that the stress is reduced for the typical deformation at the flank. That should lower the total forming force and reduce the contact pressure. Accordingly it should contribute to reduce galling.

High strength sheet materials or materials that cause abrasive wear on the dies may also be a problem because they may damage the surface of the tool, creating initiation points for galling. High strength materials also produce more heat during forming, which may increase the tendency for galling.

Figure 9, page 17, does not reveal the fact that tendency to cause galling is higher for austenitic stainless than for carbon steels. It might have been visible in the diagram if all applications had been run with similar type of lubrication. Here the applications with carbon steels were run with delivery oil while the stainless steels were lubricated more carefully. Secondly the high work hardening rate of stainless steel gives a rapid increase in forming load and contact pressure. This increases the tendency for galling even if the critical pressure for galling is not changed.

Surface finish

MINIMUM DEMANDS

In order to make full use of Uddeholm Vancron 40 it is important that the active tool surface is smooth. As a rule of thumb the same demands should apply to the surface of a Uddeholm Vancron 40 tool as to the surface of a tool to be coated. The recommended maximum R_a value is 0.1 µm. The galling resistance will continue to increase with further reduction in roughness at least to an R_a value of 0.05 µm for dies to be used with carbon steel sheets. Stainless steels require better lubrication and in order to maintain enough lubricant for those steels the optimum surface roughness for the die is about 0.06 µm. Using the material with a surface roughness above recommendations can be considered a waste of performance.

This means that in order to best use the potential to create high galling resistance of a tool for carbon steel, the surface should generally be polished.

In fact, R_a does not provide full information of the surface integrity with respect to galling. Single deep scratches can act as initiations for galling even on a surface of low R_a. A high value of R_y, R_z or R_{max} may indicate the presence of deep scratches.

Uddeholm Vanron 40 tool for powder compacting.

GRINDING AND POLISHING

In order to polish a Uddeholm Vancron 40 tool for high surface finish to an R_a value of 0.05 µm, it is necessary to perform grinding in several steps

- use wet grinding paper from 180 mesh
- continue in steps down to 800, 1000 or 1500 mesh.
- use diamond paste starting from 15 µm and step down to 1 µm until the aimed surface finish has been achieved.

This sequence will avoid remaining scratches which might appear if switching over to diamond paste too soon, after grinding only to say 180 or 220 mesh.

In case of tools for forming of stainless steel, do not use finer grinding paper than 1000 mesh and do not polish. On a very fine machined surface it may be enough to start at 500 mesh and subsequently go to 800 and finally 1000 mesh.

Surface coating

Uddeholm Vancron 40 was developed to be used uncoated. In this condition the potential for the total economy is the greatest, mainly through reduced maintenance and down time costs and increased tool life.

Yet, coating of Uddeholm Vancron 40 is fully possible and experience shows that coating increases its galling resistance further, producing extreme galling protection.

It has been reported that the coating on a Uddeholm Vancron 40 tool has very good adhesion to the base material. Furthermore, a small damage of the coating would be less detrimental on a Uddeholm Vancron 40 tool than on tools where the base material is less galling resistant.

For different steel grades with the same coating the galling resistance is of similar magnitude if we only take work material pick-up on the tool surface into account. If we instead compare typical total tool lives there is a bigger difference since tool life of coated tools is also limited by damage of coatings, Figure 3.

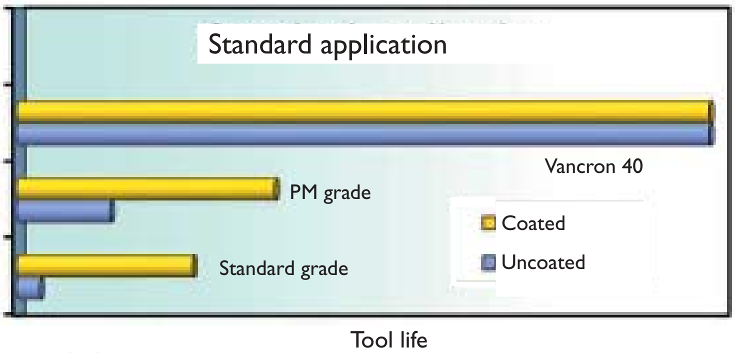


Figure 3 a)

Figure 3. Principal influence of tool steel grade and surface coating on tool life controlled by galling and coating damage in a) a standard application and b) a difficult application. All variants behave worse with increasing difficulty but coated Uddeholm Vancron 40 has a better resistance to extreme contact pressure.

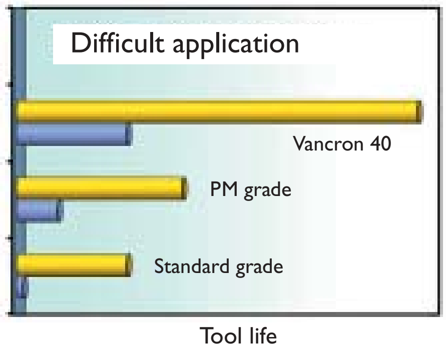


Figure 3 b).

The difference in tool life between coated and uncoated Uddeholm Vancron 40 depends on the magnitude of the surface loads in the application. The coating mainly prolongs the tool life in difficult cases. For standard cases there is no reason to coat the tool. There is also a strong influence of the type of coating that is used.

The possibility to coat means that a second chance exists if Uddeholm Vancron 40 does not perform satisfactorily when it is first tried without a coating in a difficult application. The further improvement of the galling resistance by coating may be sufficient to solve the problem.

As long as the process temperature is below the tempering temperature, the process will not influence the bulk properties of the steel.

Uddeholm Vancron 40 can be nitrided or coated with CVD or PVD. The most recommended coating is PVD with Ti(C, N) or TiAlN.

Lubrication

Lubrication is one of the most effective ways to reduce friction and avoid galling. This is true for Uddeholm Vancron 40 as well as for other tool materials. There is even a tendency that Uddeholm Vancron 40 can boost the positive effects of lubrication. On a well polished surface the low friction nitride particles form rounded peaks surrounded by valleys that can act as reservoirs for lubricant.

However, for environmental and economical reasons the best possible lubricants in terms of galling protection cannot always be selected.

Many sheet materials are delivered with a small amount of corrosion protection oil on the surface. This delivery oil can often provide sufficient lubrication for carbon steels. Running the application fully dry by removing the delivery oil is not recommended.

Stainless steel and aluminium often require more galling protection. Oil addition may be necessary for these materials.

Geometry and type of forming

The type of forming may significantly influence contact pressures and sliding distances and accordingly the tendency for galling. In stretch forming operations the sliding against the die is limited while in deep drawing it is significantly longer.

The contact pressure is influenced by various geometry parameters. Some of them are listed in Table 2. Increasing sheet thickness or reduced die radius can significantly increase the contact pressure and accordingly the tendency for galling.

In cylindrical deep drawing the drawing ratio, which is the blank diameter to punch diameter ratio, influences the amount of deformation of the flank. Increasing the drawing ratio also increases the contact pressure. In other forming operations where bending takes place on a straight edge the blank size should not influence the contact pressure. In the general case where the die opening consists of both curved and straight sections, the size and shape of the blank will influence the contact pressure. Optimizing the blank shape may reduce the risk of galling.

There is also a strong influence on the contact pressure from the die clearance, i. e the clearance between the punch and the die at the die opening. If this parameter is less than the sheet thickness, ironing will take place producing a high contact pressure. If ironing is a part of the forming it is recommended to perfom this in a separate step or in several separate steps if the reduction is high. The influence of the wall reduction on the contact pressure is very strong. There is still a strong influence of the die clearance even when the clearance is above the sheet thickness at least up 1.2 times the sheet thickness. With further increasing clearance the contact pressure continues to fall but at lower rate.

CONTACT PRESSURE AND GALLING RISK

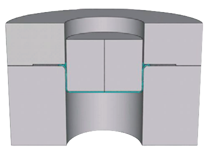
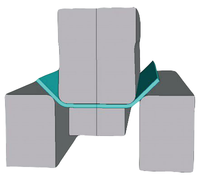
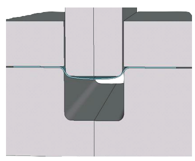
FORMING OPERATION	 Axi-summetric deep drawing	 U-bending	 2D-draw-bending
PARAMETER CHANGE INCREASING SHEET THICKNESS	Strong increase	Strong increase	Strong increase
INCREASING RATIO, BLANK SIZE/PUNCH SIZE	Increase	No effect	No effect
DECREASING DIE RADIUS	Strong increase	Increase	Strong increase
DECREASING PUNCH RADIUS	Negligible effect	Increase	Negligible effect
DECREASING DIE CLEARANCE	Strong increase at small clearance	Strong increase at small clearance	Strong increase at small clearance

Table 2. Influence of change in a geometry factor on the contact pressure and galling tendency in three variants of sheet metal forming. The effects listed here can be observed using the V40Guide spreadsheet.

Ironing is an especially difficult type of forming since the high contact pressure is usually combined with a long sliding distance and an increase in surface area of the sheet. The newly expanded surface may be more adhesive than the initial surface. In such difficult operations it may be hard to avoid galling even with Uddeholm Vancron 40, especially at high thickness reductions. In a laboratory test on a flat specimen of austenitic stainless steel sheet the limit for an Uddeholm Vancron 40 tool was approximately 30 per cent reduction. For carbon steels higher reductions could be accepted. In actual applications galling may probably appear even for smaller reductions, hence for ironing above 20 per cent wall reduction, Uddeholm Vancron 40 is recommended only in combination with one of the earlier mentioned coatings.

Optimum ironing die shape with respect to the maximum contact pressure and the galling tendency appears to be a large and constant die radius. A radius of 10 to 20 times the sheet thickness gave the lowest contact pressure at 20 per cent reduction in a numerical study.

Blank holders and draw beads

If deep drawing is performed with a low blank holder force or even without a blank holder, as in a crash forming operation, wrinkling or buckling is likely to occur. One result of wrinkling is a concentration of contact loads to the ridges of the wrinkled sheet and the maximum contact pressure will increase. As a consequence galling may appear.

A blank holder, possibly with draw beads, will restrain the motion of the sheet and accordingly it will usually increase the forming force and the total load distributed over the die surface. Still, the load may be more uniformly distributed over a larger area. If the blank holder force is moderate this will usually result in a reduced contact pressure, in particular if buckling can be avoided. With increasing blank holder force the maximum contact pressure will decrease up to the point where the growth in contact area can no longer compensate for the increasing load. At even higher blank holder force the contact pressure will increase.

This means that a high blank holder force or the presence of draw beads may also increase the amount of galling.

Optimization of the blank holder force usually involves a balance between the risk of wrinkling at too low blank holder force and the risk of fracture if the blank is too strongly constrained. It is not evident that this optimization produces exactly the optimum blank holder force in terms of contact stress. In cases with low tendency to buckling, the optimum blank holder load to avoid galling might be somewhat higher than the lowest blank holder force to avoid buckling. On the other hand if the buckling tendency is high, some wrinkling may occur at the blank holder force that minimises galling.

Press speed

The forming speed influences the amount of heat generated by deformation and friction. Reducing the speed or increasing the press cycle time lowers the temperature at the contact points and will thus lower the risk of galling. No general recommendation of forming speed can be given since the temperature depends on too many other conditions as well. However, if nothing else can be done to avoid severe galling, reducing the press speed might help.

Recommendations for punching and blanking

The anti-galling properties of Uddeholm Vancron 40 can also be used to advantage in punching and blanking operations. Galling typically occurs when the cutting clearance is small or when the work material has a tendency for galling. Typical work materials with galling tendency when punching are austenitic stainless steel and aluminium.

Uddeholm Vancron 40 is also suitable for punching high strength steel sheets that have a tendency to give a combination of abrasive wear and galling.

One type is micro alloyed sheet materials which have a tendency to give both abrasive wear and galling.

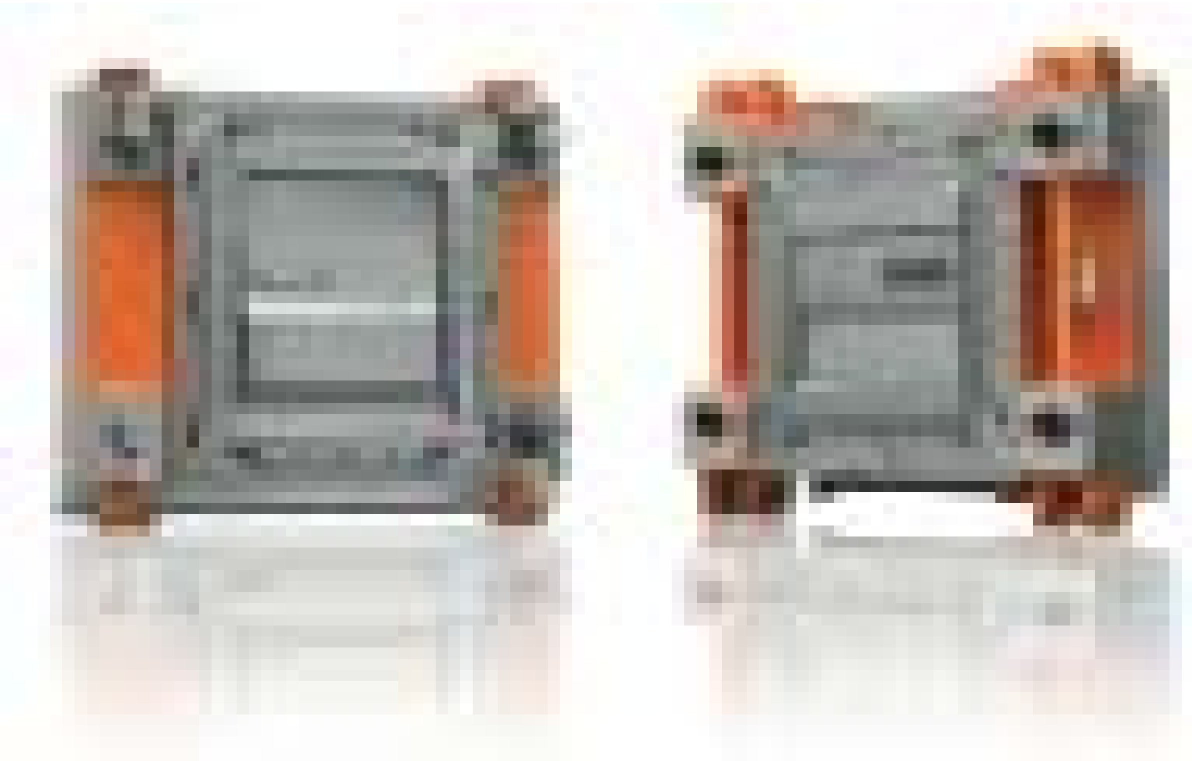
Another type is the dual phase sheet steels. Those sheet steels contain soft ferrite phase that has a tendency for galling together with the hard martensite phase that causes abrasive wear. Applications involving punching or blanking of nickel and copper base alloys have also been successful.

Other anti-galling tool materials

Most tool materials require a surface coating in order to provide good anti-galling properties. Among the few exceptions to this rule are Uddeholm Vancron 40, speciality bronzes and copper alloys and cemented carbides.

A few variants of the speciality bronzes and copper alloy materials exist. The bulk of these materials exhibit similar galling resistance to Uddeholm Vancron 40. However, the maximum hardness of the hardest variant is about 47 HRC whilst Uddeholm Vancron 40 can reach a hardness of 65 HRC. This means that in many applications both materials can resist galling but Uddeholm Vancron 40 outperforms the speciality bronzes and copper alloy materials because of its resistance to other wear mechanisms and plastic deformation. Compared with Uddeholm Vancron 40 cemented carbides are considerably harder and more wear resistant. On the other hand they are more brittle and more difficult to machine and grind.

Accordingly, on a property scale, Uddeholm Vancron 40 positions itself between the other two types of materials.



Tool of solid Uddeholm Vancron 40 for production of dishwashers.

Recommendations for tool making

Machining and grinding

Many toolmakers have reported that the machinability and grindability of Uddeholm Vancron 40 is excellent. In fact, cases exist where the machinability may be the main reason why Uddeholm Vancron 40 outperforms other tool steels from a total tooling economy point of view. One typical area is when milling has to be done in hardened condition, see Figure 4. This is a critical and costly machining operation where the machining properties are especially important.

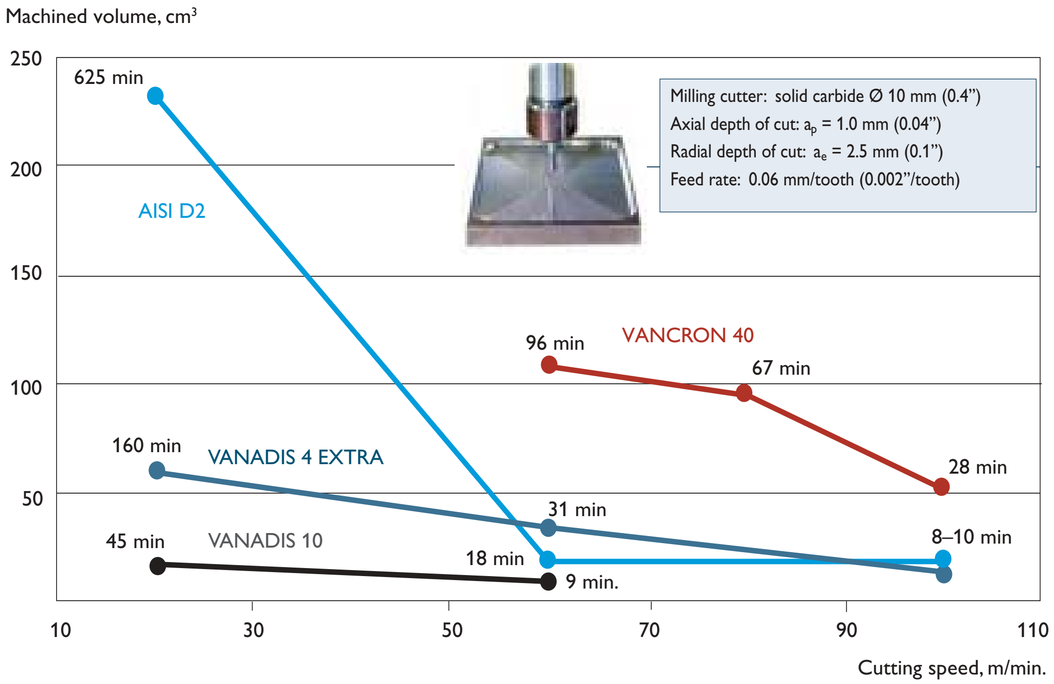


Figure 4. Milling tool life at work material hardness 60–62 HRC. Cutting tool life in removed material volume and milling time.

The main contributions to the beneficial machining and grinding properties of Uddeholm Vancron 40 are the non-sticking behaviour and the small size of the hard phase. Due to the non-sticking behaviour, problems such as built up edge (BUE) formation are rare and surface finish is often better than for other tool steels, as can be seen in Figure 5 and Figure 6. The small size of the hard phase will also reduce the abrasive wear on the cutting edge or the grinding wheel compared to other PM tool steels with similar amount of hard phase.

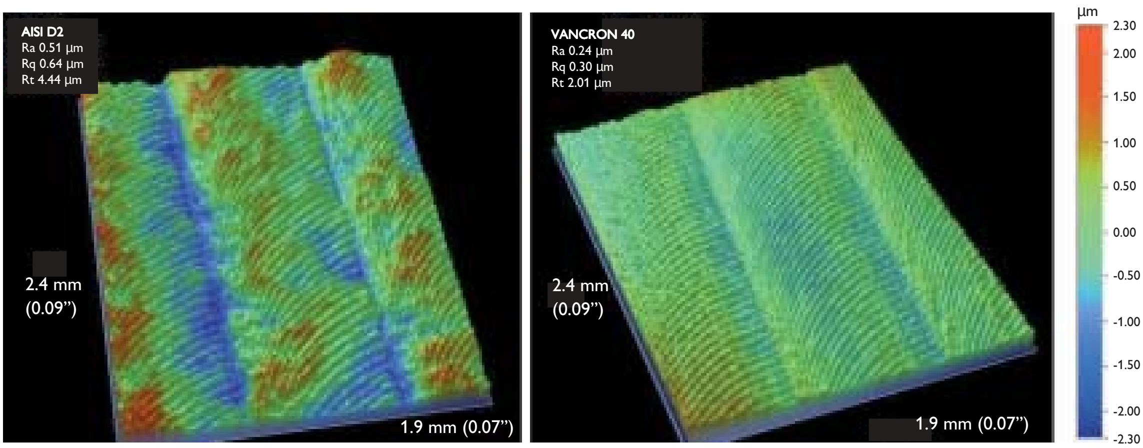


Figure 5. Surface finish after end milling of AISI D2 and Uddeholm Vancron 40, hardened to 60 HRC under the same conditions.

VANCRON 40	AISI D2	PM 23
R_a= 0.05 µm	R_a= 0.06 µm	R_a= 0.10 µm

Figure 6. Surface finish after grinding of rolls with WA400 grinding wheel

EDM

Tools of Uddeholm Vancron 40 can be produced with Electrical Discharge Machining (EDM) as long as the EDM layer is carefully removed. Fine grinding and polishing is recommended. Due to the high nitrogen content, the procedure is somewhat different compared to other steels.

POWER SETTINGS

A coarse pass with high power can result in release of nitrogen from the steel causing pitting. As a general rule of thumb the EDM'ing of Uddeholm Vancron 40 should be done with medium or fine passes using lower power setting.

FLUSHING

N-alloyed PM steels put higher demands on the flushing conditions. The On/Off time ratio should be low, i.e. shorter On time and longer Off time. A general rule of thumb is that Off time should be twice the On time. When possible, use flushing through the electrode or through holes in the work piece. Higher viscosity of the dielectric liquid is also preferable due to better transportation of removed particles (can also give shorter EDM time and better surface finish).

ELECTRODES

For rough EDM operations graphite electrodes are recommended, preferably of high quality (small grain size, and/or Cu impregnated). A switched polarity might reduce sticking on electrode if that happens. For fine EDM use Cu or W/Cu electrodes. When Graphite electrodes must be used in fine EDM, high quality is recommended.

Heat treatment

SOFT ANNEALING

During soft annealing the steel should be protected against decarburization and oxidation. The heat treatment includes through-heating to 900°C (1650°F) followed by cooling in the furnace at 10°C/h (20°F/h) to 650°C (1200°F) and finally free cooling in air.

STRESS RELIEVING

After rough machining the tool should be stress relieved. The heat treatment includes through-heating to 600–700°C (1110–1290°F), holding for 2 hours, slow cooling to 500°C (930°F) and finally free cooling in air.

HARDENING

Uddeholm Vancron 40 has good through-hardening properties at quenching in salt bath or with gas in a vacuum furnace. Pre-heating should be performed in two stages, at 600–650°C (1110–1200°F) and at 850–900°C (1560–1650°F).

To achieve a hardness between 58 and 65 HRC the austenitizing temperature can be varied in the range 950–1150°C (1740–2100°F). Austenitizing is normally performed at 1020°C (1870°F) and seldom below 1000°C (1830°F). Recommended holding time is 30 minutes at normal austenitizing temperature but should be reduced to 10 minutes at 1100°C (2010°F) and above. After austenitizing, the tool is quenched and normally tempered three times, each for one hour at 560°C (1040°F).

The tool should be protected against decarburization and oxidation during hardening. In some cases denitriding should also be considered. To avoid loss of nitrogen, which may lower the surface hardness, a minimum of 10 and up to 3–400 mbar overpressure is recommended. Alternatively the machining allowance could be increased.

The normal austenitizing temperature of 1020°C (1865°F) results in a hardness of 60–62 HRC. This hardness is usually enough even for stamping of high strength sheet materials. For sheet steel with very high tensile strength, exceeding 800 MPa, the hardness can be increased above the standard level if some toughness can be sacrificed. On the other hand, if high toughness is required and the work material has a tensile strength below 600 MPa, it may be enough to stay at the lower range in tool hardness.

Increasing tool hardness helps to resist galling, for hard work materials in particular. So in order to maximize the galling resistance, the hardness should be as high as possible. However, increasing the hardness from a high to an even higher level may cause marginal improvement in galling resistance for soft work materials. In order to maintain the toughness of the tool it is usually wise to stay a little below maximum hardness.

Modelling to assist galling prevention in sheet metal forming

Modelling and numerical simulation was used in order to create some of the guidelines of the present handbook. The theory behind these guidelines is given in the present chapter.

Galling limit for contact pressure

Galling may occur in sliding contact if the contact pressure is high. What should be considered as high pressure depends on the tooling material and to an even higher degree on the softest material in the contact, which is the sheet material. Galling requires plastic deformation, which means that galling is unlikely if the contact pressure is below the yield strength of the work material. A tool material with high galling resistance can resist contact pressures significantly above the yield strength of the sheet.

The influence of contact pressure on the tool life, expressed as accumulated sliding distance until severe galling occurs, typically has the appearance shown in Figure 7. In order to achieve an acceptable tool life the contact pressure should be kept below a critical level, Pcrit. This level depends on several factors. Figure 7 shows two of them, the length of the tool life that we find acceptable and the tool material that we use.

A simple approach is to assume that the critical contact pressure is proportional to the yield strength $Rp0.2$ of the sheet material. This can be expressed as:

$$p_{crit} = C \cdot Rp0.2$$

where C is a constant depending on many factors including those illustrated by Figure 7, the tool material and the limit for tool life that is considered acceptable. There may also be an influence of the type of sheet material, the tool surface roughness, the lubrication and the temperature.

The tool life also depends on the amount of galling damage that can be accepted in various applications. In the application tests performed by Uddeholm we have simply allowed the customer to decide whether the test was successful. This means that Pcrit becomes a critical value for customer satisfaction.

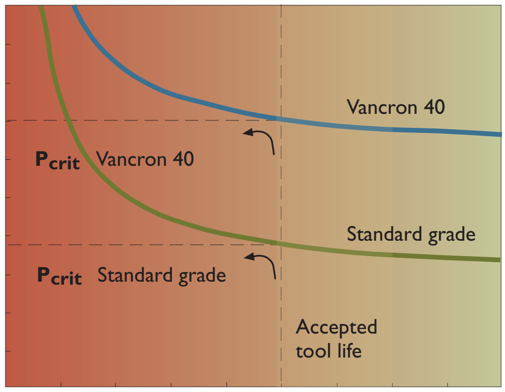


Figure 7. Typical appearance of tool life vs. contact pressure for Uddeholm Vancron 40 and a standard grade. A given application corresponds to a certain maximum contact pressure. The contact pressure and the tool material both have a strong influence on the tool life. The dashed lines indicate how the critical pressure P_{crit} depends on the tool material and the limit for accepted tool life.

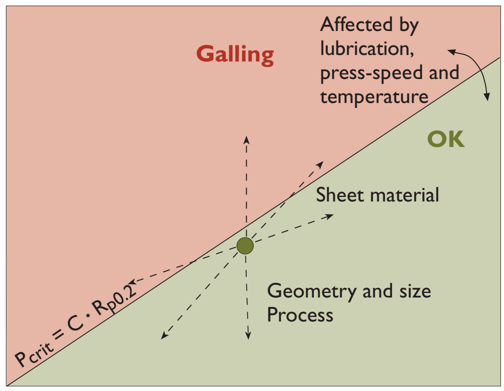


Figure 8. Graphical illustration of the galling limit, where an application would be represented by a point in the diagram.

The equation can be illustrated graphically as in Figure 8, where an application would be represented by a point in the diagram. The position of the point is given by the sheet material and the contact pressure required for the forming. A successful forming could be expected if the point is in the green area. The arrows show how a point in the diagram can move from the red to the green area or vice versa if the sheet material is changed or if the geometry of the tool and/or the produced part is modified. The slope C of the limiting line between success and failure can also be influenced by for instance improving the lubrication, press speed or temperature. That will expand the green area, possibly enough to move an application from the red galling zone into the nongalling green area.

For a number of application tests the contact pressure has been computed with numerical simulation. From these results the constant *C* was estimated to be about 2.6 for Uddeholm Vancron 40. Each application test represents a point in Figure 9.

From laboratory tests performed with AISI D2 tool steel a significantly lower critical pressure for galling was found.

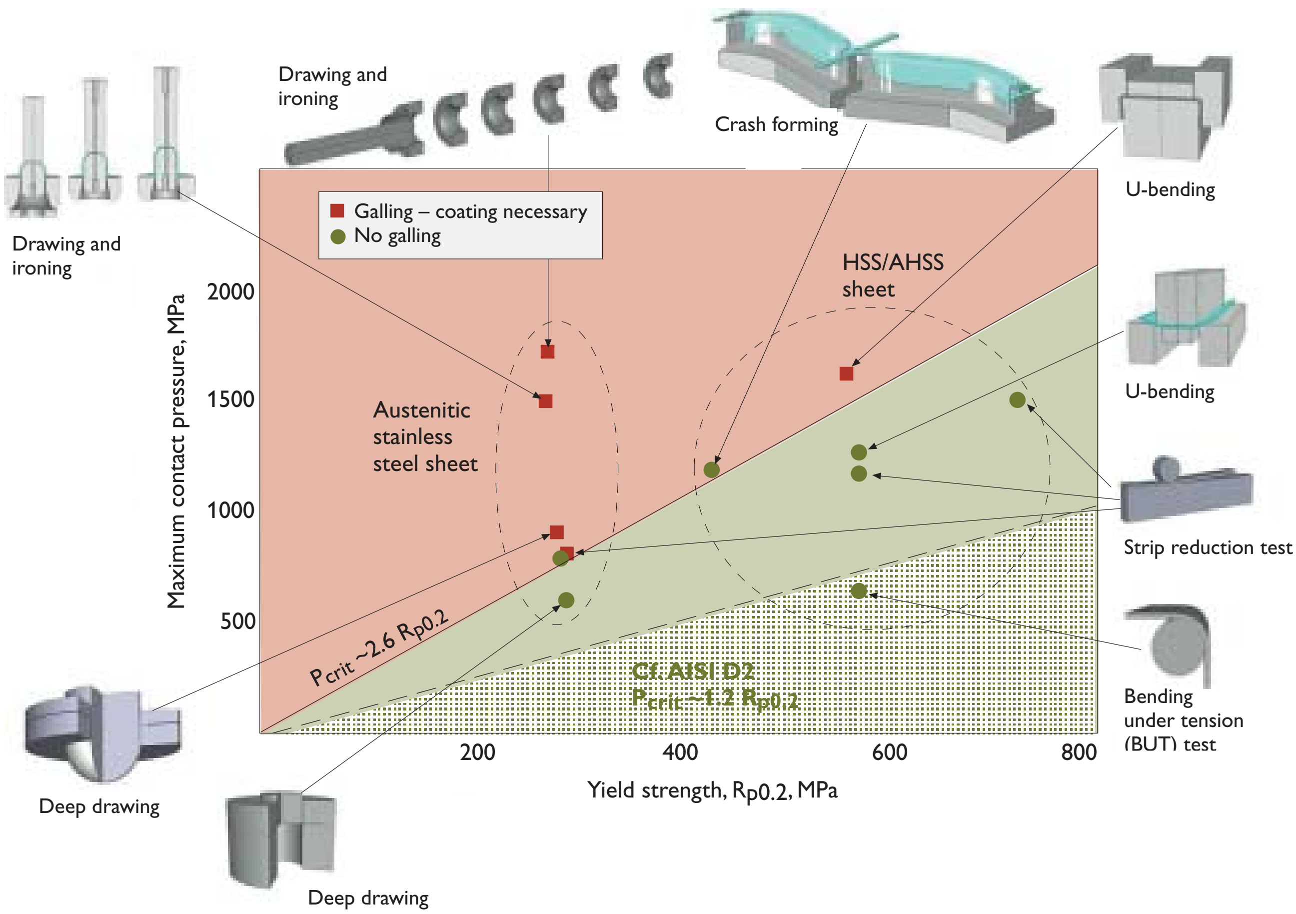


Figure 9. Successful (green circles) and failed (red squares) application tests with Uddeholm Vancron 40. The position of the spot represents the computed maximum contact pressure versus the yield strength of the formed sheet material. The galling limit of Uddeholm Vancron 40 is represented by the limiting line between the green and the red areas. The approximate galling limit of AISI D2 is also indicated.

Prediction of galling in an application

With a calibrated expression for the critical pressure with Uddeholm Vancron 40 it is possible to estimate the difficulty to perform a new application. This requires a computation of the maximum contact pressure. If the computation indicates that the contact pressure is below the limit, i. e. in the green area of Figure 9, page 17, there is a good chance that the application will be successful.

Mainly two ways are used to estimate the contact pressure. The most accurate computation is to simulate the forming using a numerical method, the Finite Element Method. Such simulations can be performed at Uddeholm. However, the simulations can be quite complicated and time consuming to run. They can presently only be run for forming but not for blanking or punching. The most important input to the simulation is the geometry of all active tool surfaces and the blank.

A simpler method to predict whether galling will be a problem or not is to use an Excel spreadsheet called V40Guide, developed by Uddeholm. It includes a few simple variants of sheet metal forming, where geometric data and sheet materials can be modified. The contact pressure is computed using analytical models. This tool is simple to use but less flexible and less accurate than finite element analysis.
A screenshot of the spreadsheet is shown in Figure 10. Running a test involves selection of type of forming and sheet material together with a few other parameters. The spreadsheet immediately responds by estimating the contact pressure and comparing it to the galling limit. If the contact pressure is low enough a green square with the text “Safe” will be displayed. If the estimated contact pressure is above the galling limit the colour will change to red and the text will change to “Exceeding galling limit!”.

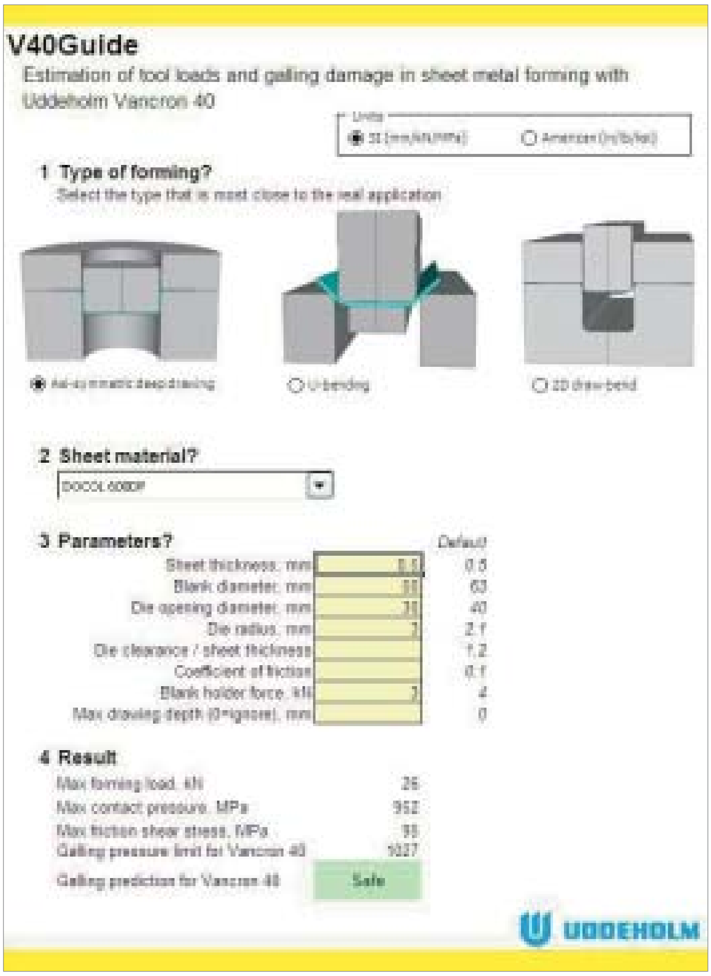


Figure 10. Screenshot of the V40Guide spread sheet. In this example the spread sheet predicts a safe deep drawing of a cup in 0.5 mm DP600 sheet.

Estimated safe range of parameters to avoid galling with Uddeholm Vancron 40

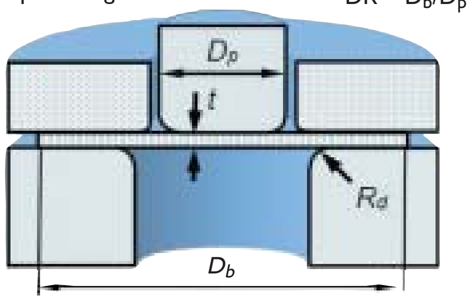
The present chapter includes a few charts that can be used to predict the safe range with respect to galling using Uddeholm Vancron 40. Predictions are presented for parameter combinations in simple deep drawing and U-bending applications. The results are based on computation of the contact pressure using the V40Guide spreadsheet. It cannot provide definite answers but may be used as a guideline. The charts show the limits for DP 600 and AISI 304. These materials can be regarded as representative of carbon steels and austenitic stainless steels, respectively. The parameters are listed below.

PARAMETERS
t = Sheet thickness
D_p = Punch diameter
D_b = Blank diameter
DR = Drawing ratio
R_p = Punch (nose) radius
R_d = Die (edge) radius

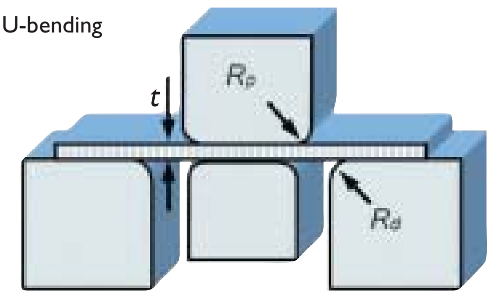
A typical appearance of the charts is sketched below. Here the horizontal and vertical axes represent the sheet thickness and the die radius, respectively, and the drawing ratio is the third parameter. The safe area for any combination of the two parameters on the diagram axes is limited by a line that corresponds to a fixed value of the third parameter. The safe area for a specific value of the third parameter is here marked with green. In the actual charts there is no such green field but the limiting line is double with its green part towards the safe area.

Deep drawing

DR = D_b/D_p



U-bending



Die radius, R_d

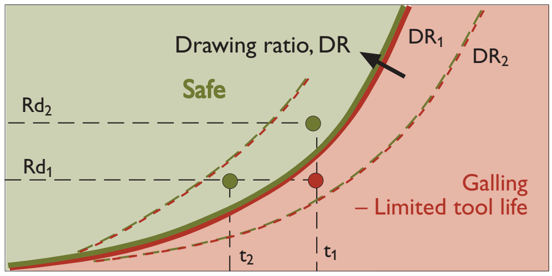
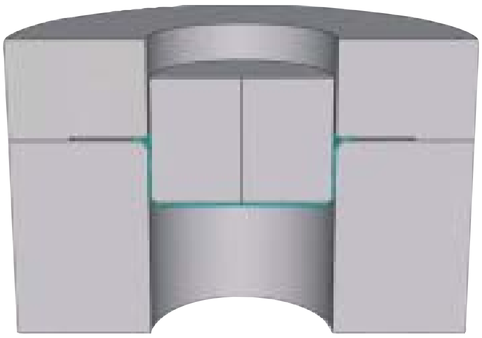


Figure 11.

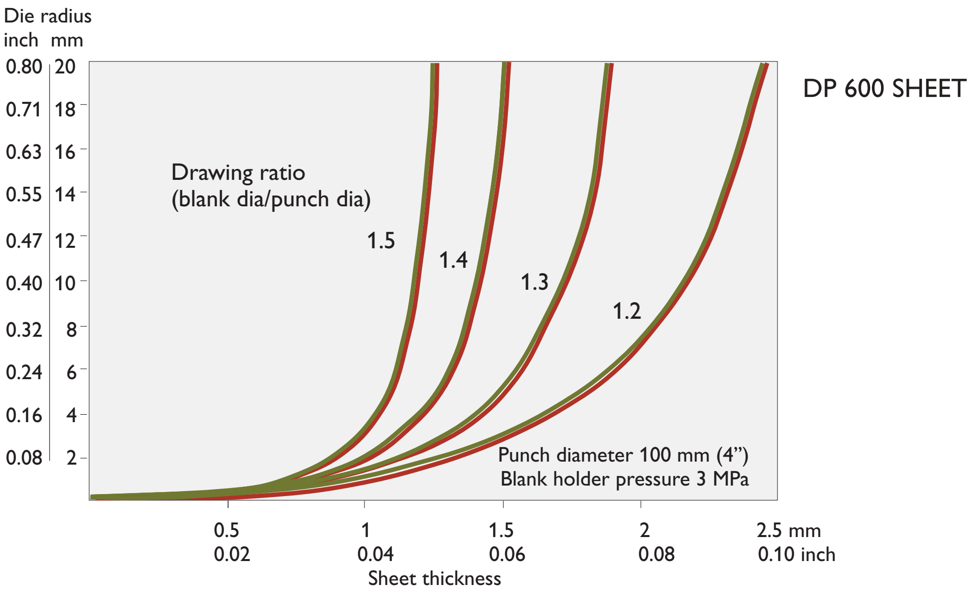
Sheet thickness, t

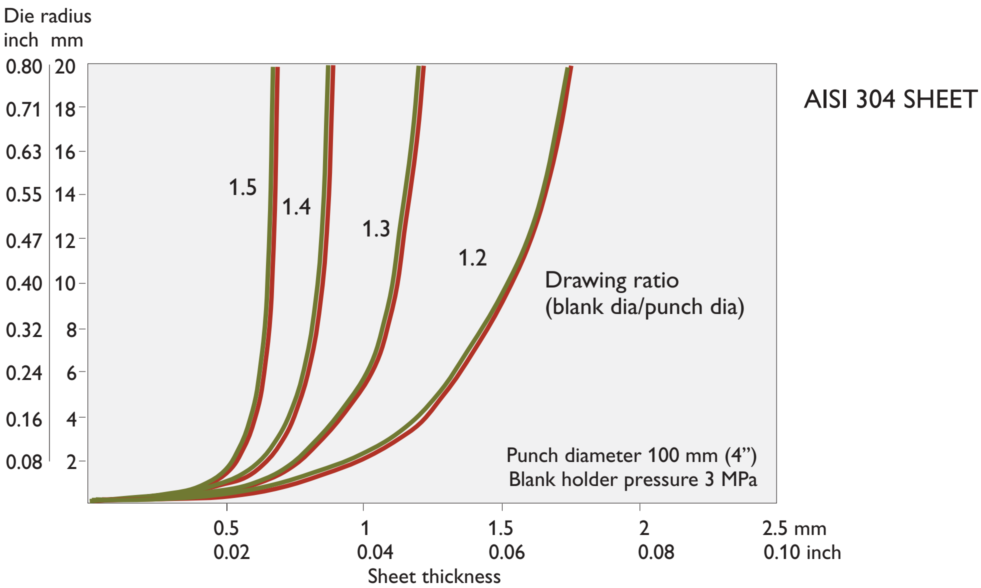
In this example, galling problems are predicted with the parameter combination of thickness t_1, die radius R_{d1} and drawing ratio D_{R1}. Alternatively, reducing the sheet thickness from t1 to t_2, increasing the die radius from R_{d1} to Rd2 or reducing the drawing ratio from D_{R1} to D_{R2} would change the predicted result to safe.

Deep drawing of cylindrical cup

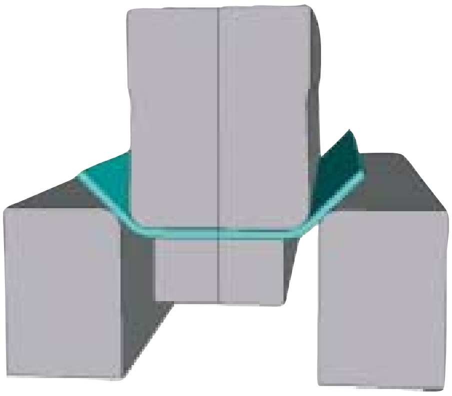


THE MOST IMPORTANT GEOMETRY PARAMETERS IN DEEP DRAWING OF A CYLINDRICAL CUP

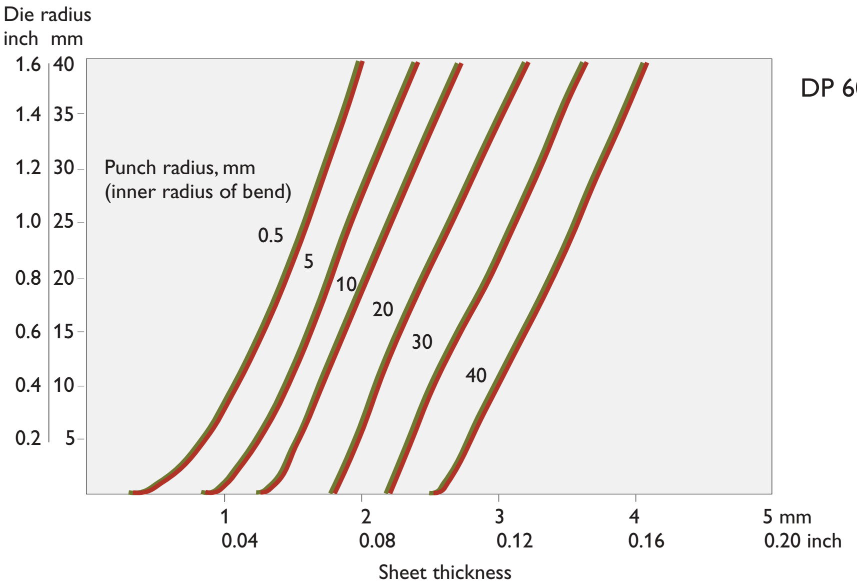




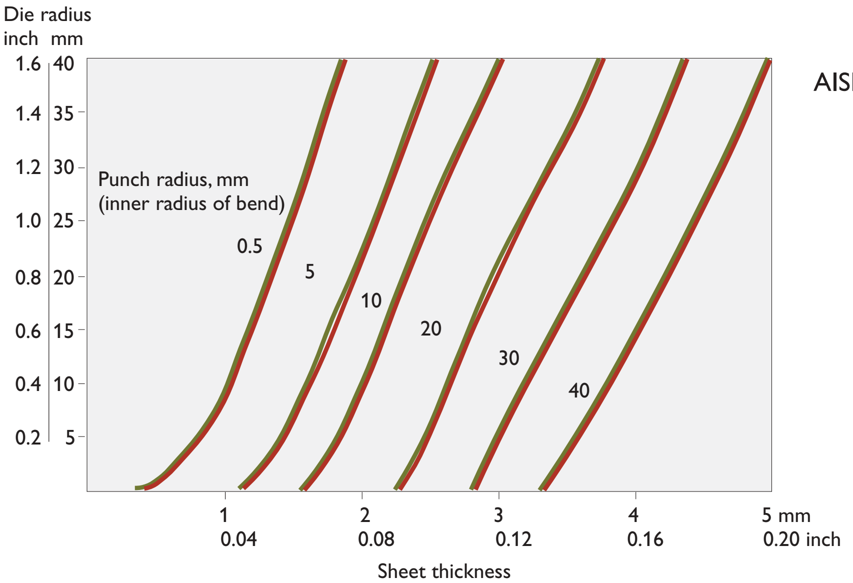
U-bending



THE MOST IMPORTANT GEOMETRY PARAMETERS IN U-BENDING



DP 600 SHEET

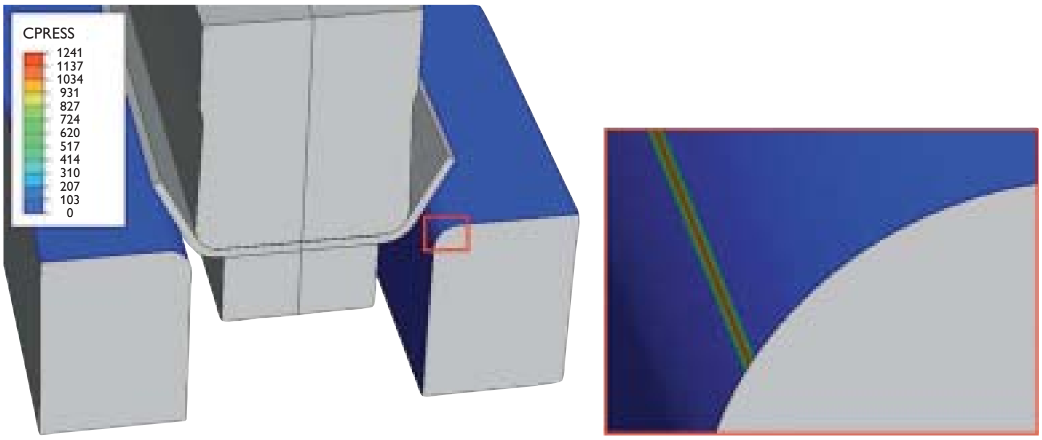


AISI 304 SHEET

Examples of application tests and simulations

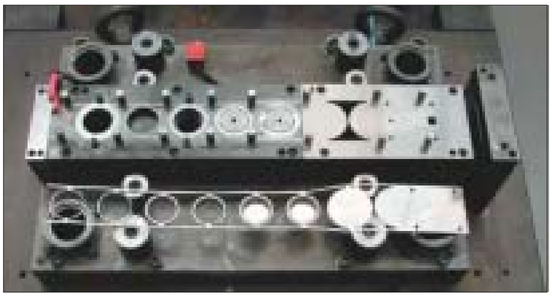
U-BENDING	
Tool	Die
Sheet material	800 DP ($R_{p0.2}$ ~575 MPa)
Sheet thickness	2 mm (0.08 inch)
Die radius	5 mm (0.20 inch)
Punch radius	5 mm (0.20 inch)
Assumed galling limit	2.6 x 575 MPa = 1495 MPa
Computed maximum contact pressure	1241 MPa

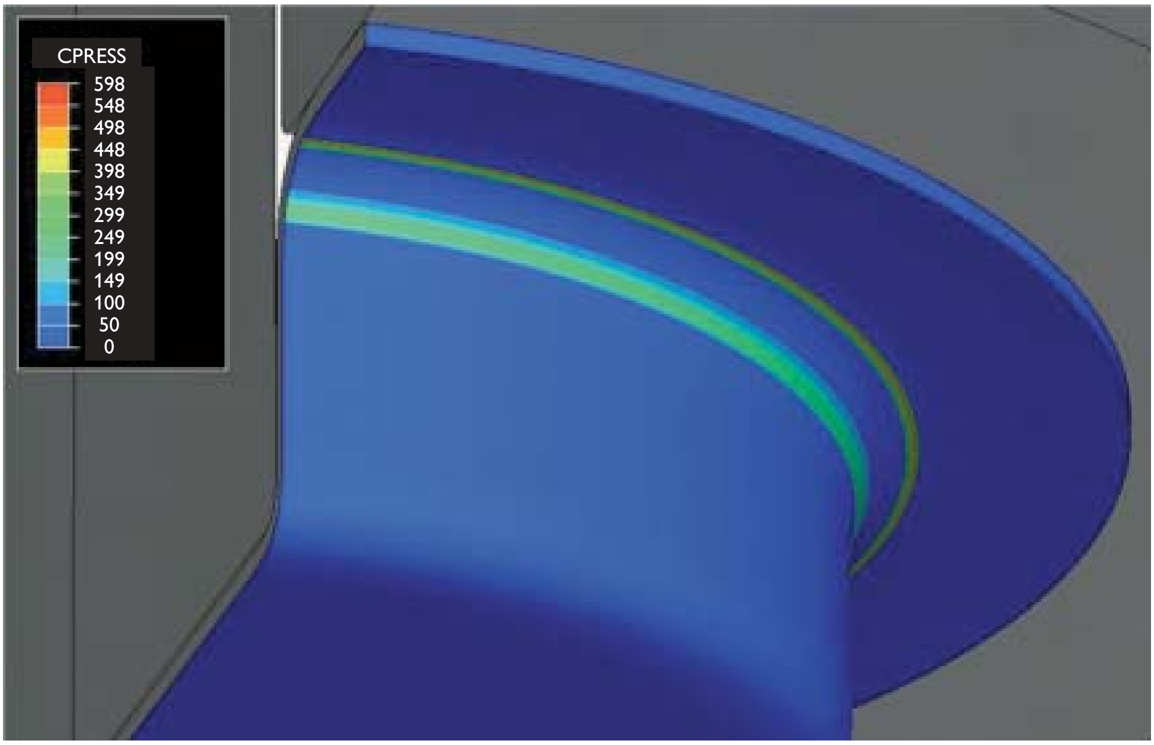
	SLEIPNER CVD-COATED	VANCRON 40 UNCOATED
Parts produced	>480 000	>480 000
Failure type	None	None



DEEP DRAWING	
Tool	Die
Sheet material	AISI 304 ($R_{p0.2}$ ~296 MPa)
Sheet thickness	0.5 mm (0.02 inch)
Die radius	2.1 mm (0.08 inch)
Assumed galling limit	2.6 x 296 MPa = 770 MPa
Computed maximum contact pressure	598 MPa

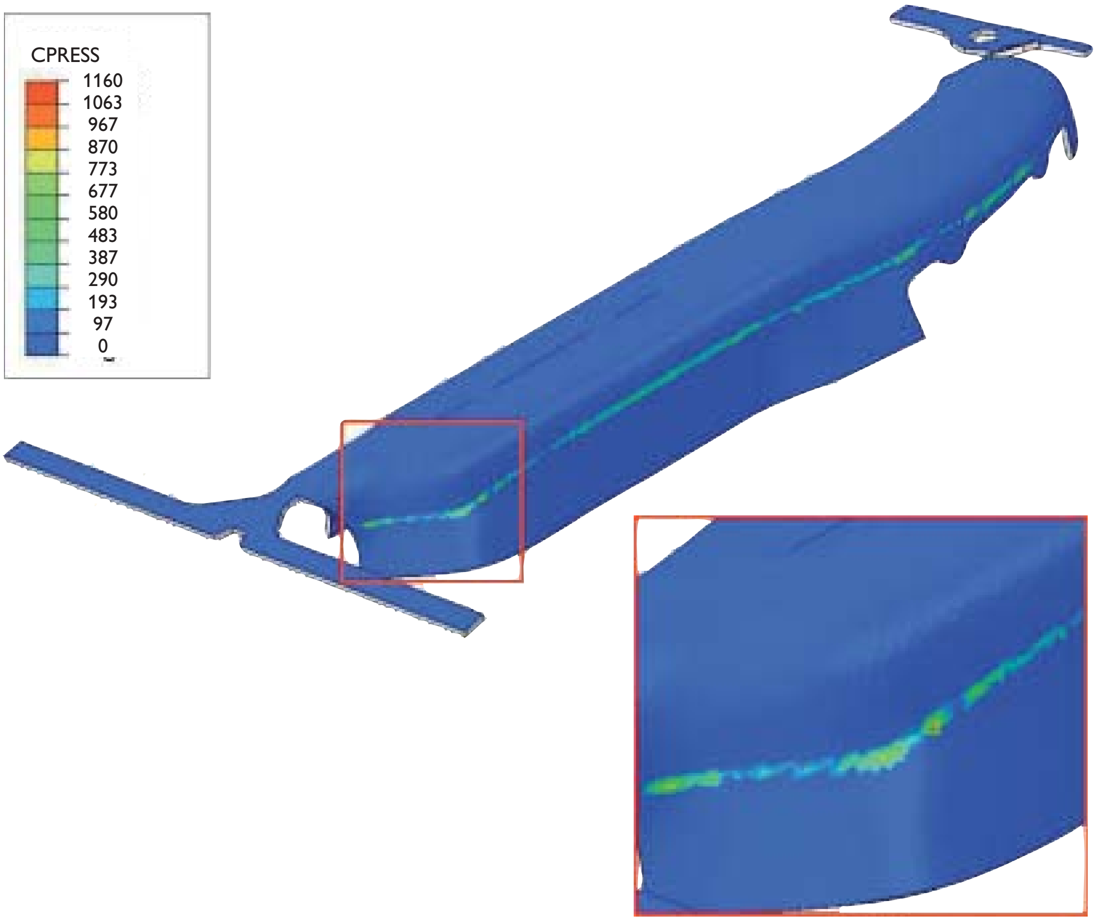
	VANADIS 10	VANCRON 40
Parts produced	1 900 000	>16 000 000
Failure type	Galling	None





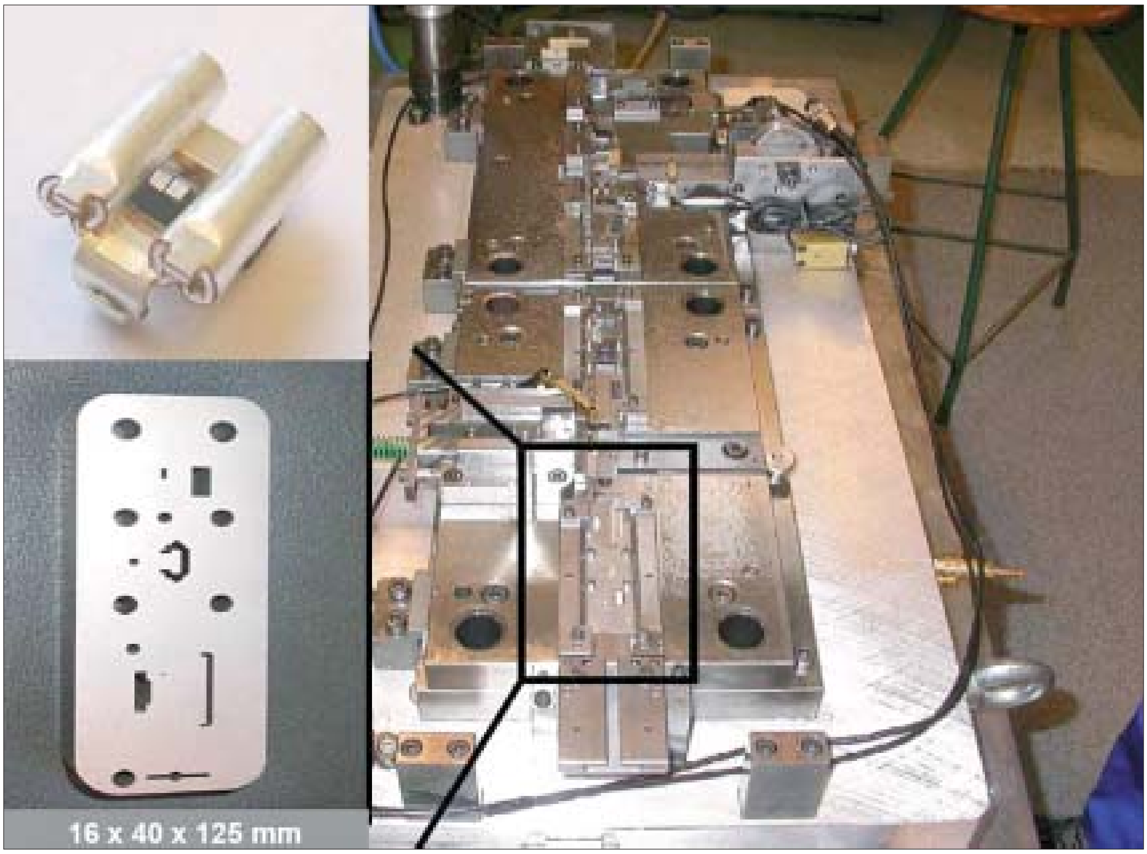
CRASH FORMING	
Tool	Die
Sheet material	HSLA steel ($R_{p0.2}$ ~410 MPa)
Sheet thickness	3.5 mm (0.14 inch)
Die radius	7.6 mm (0.30 inch)
Assumed galling limit	2.6 x 410 MPa = 1066 MPa
Computed maximum contact pressure	1160 MPa

	AISI D2 TD COATED	VANCRON 40 UNCOATED
Parts produced	30 000	>1 100 000
Failure type	Recoating needed	Mild galling



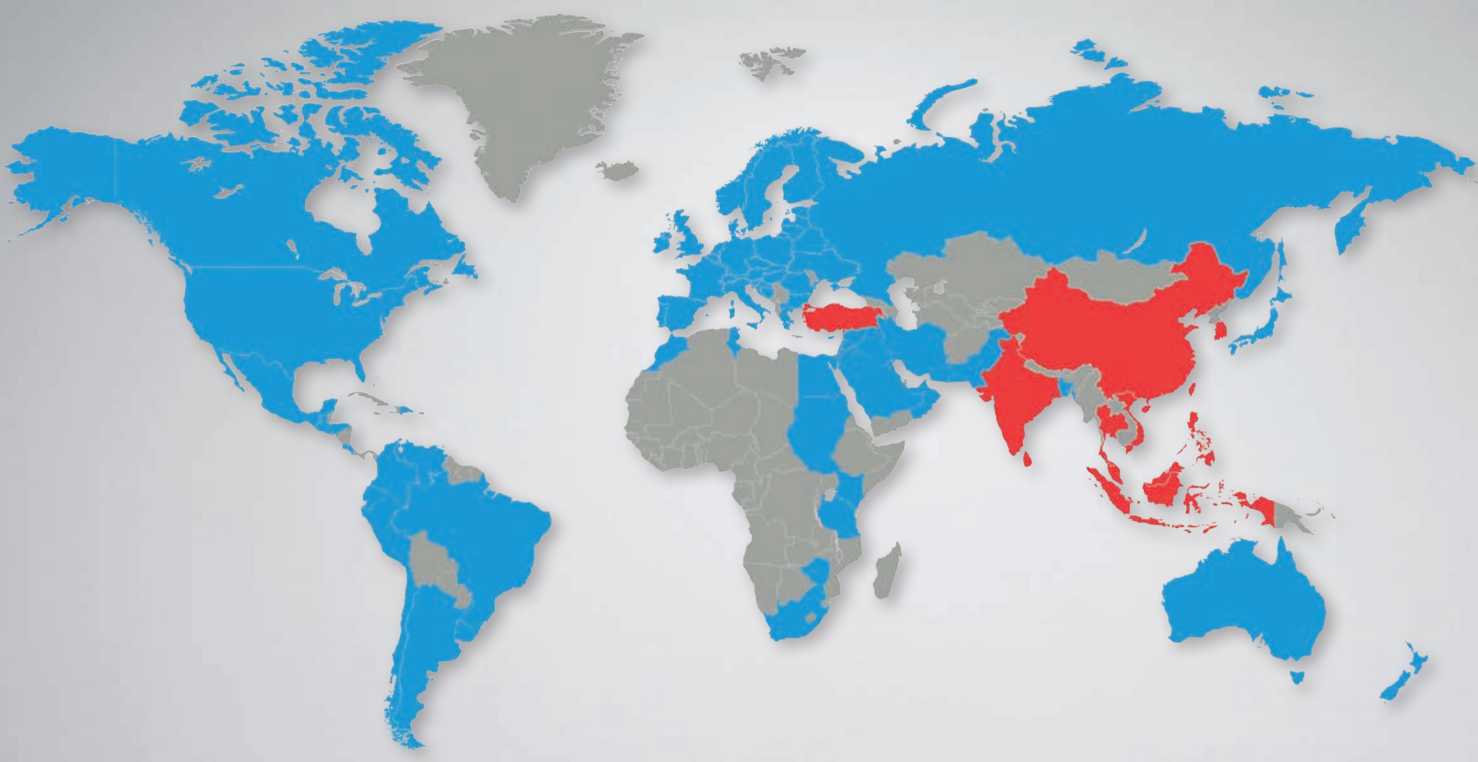
BLANKING	
Sheet material	Cold rolled hard copper-base alloy
Sheet thickness	0.7 mm (0.03 inch)

	VANADIS 10	VANCRON 40
Hardness	62 HRC	62 HRC
Parts produced	600 000	1 200 000
Failure type	Galling/ abrasive wear/chipping	Mild abrasive wear



BLANKING	
Tools	Punch and die
Sheet material	Nickel
Sheet thickness	0.3 mm (0.01 inch)
End product	Contact spring

	VANADIS 10	VANCRON 40
Hardness	62 HRC	63 HRC
Parts produced	60 000	328 000
Failure type	Adhesive wear	None



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