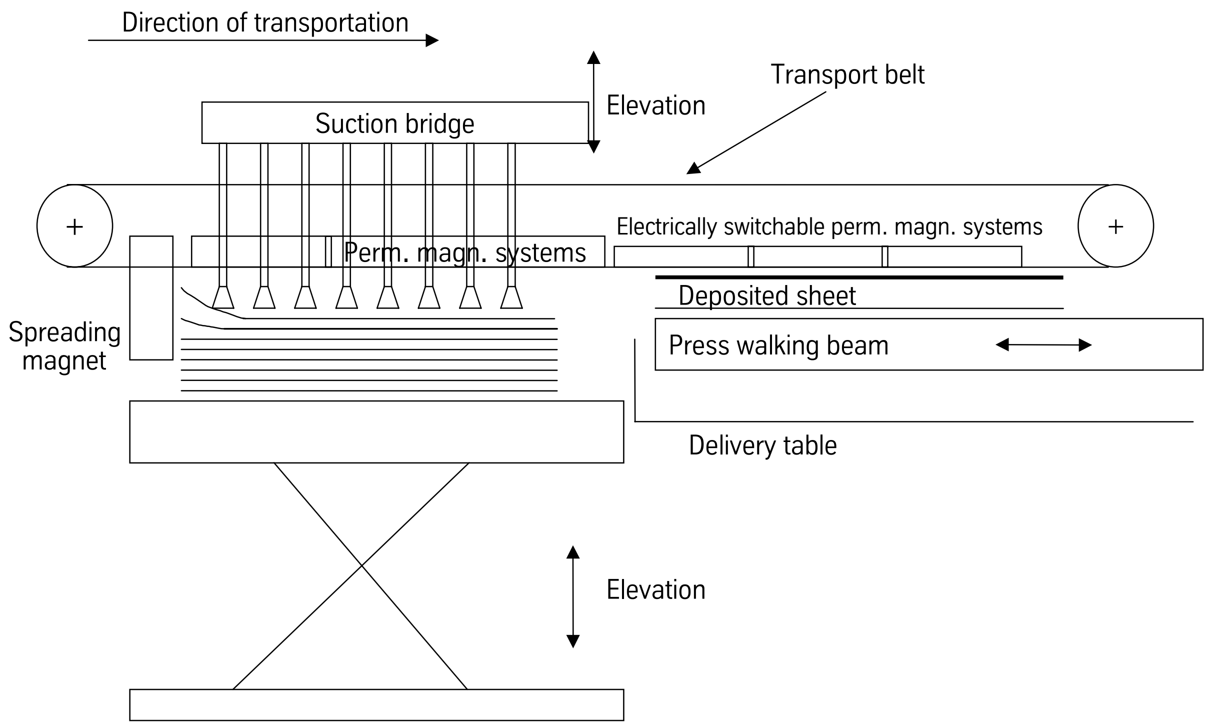
The use of magnets in the destacking process

The typical procedure will be shown using an example from the automotive industry.

The items of sheet metal are first cut from a coil using a press or shears, and a stacking system is used to stack the packs of sheet metal. These packs of sheet metal are then transported to a pressing line, in which the parts of an automobile, such as doors, roofs or the side component of an automobile, come into being from the individual items of sheet metal. Before, however, the sheet arrives at the press, it must be separated by a so-called "sheet loader", i.e. removed from the stack of sheet metal and transported to the press. This example was chosen because several types of magnet systems - switchable and non-switchable - can be explained using this one case.

The stack of sheet metal is properly fed into the correct destacking position by means of conveyor vehicles, chain conveyors and finally an elevating platform, which ensures the correct working height. The items of sheet metal are usually in thicknesses of 0.5 to 3.0 mm and have areas of 200 mm x 200 mm to 2,000 mm x 2,000 mm.

Representation of the principle of a sheet loader



The centrepiece of a sheet loader is the removal unit and the destacking. This process is usefully supported by spreading magnets [2].

The following facilities are possible for removing items of sheet metal:

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

1. Use of pneumatic suction equipment

This requires an appropriate conditioning system for the air, suction bellows and a quite complicated suction adjustment system. The sheets which are to be destacked may have almost any geometry as well as having punchouts. Pneumatic suction units therefore involve specific setting of the suction equipment in terms of the sheet geometry. It must be possible to switch on and off each item of suction equipment individually, and each item of suction equipment has a valve of its own for the elevation movement and for the vacuum. Because the elevating platform performs follow-on cycles, the upper edge of the stack can be maintained almost always at the same level, making it possible for the elevation of the suction unit to remain largely constant. This solution for destacking has frequently proven itself in the past and represents the state of the art. This configuration will therefore be used as a reference in the following comparison of the systems, and all statements will be made relative to it.

The expensive conditioning system for the air, the wear and tear of the suction bellows and the outlay in controlling the individual suction units are disadvantages. Also, the air and vacuum feed systems must be designed so as to be variable because the entire suction unit is elevated. The major advantage in this solution is that force is exerted specifically onto the uppermost sheet; i.e. no force is exerted on the sheets which are located below it. About 20 sheets per minute may be destacked using a unit of this kind.

Advantages:

- only the first sheet on the stack is subjected to the exertion of force
- switching off the holding force in the top position is possible without any difficulties;
- the sheet metal is not scratched, since soft suction cups are used.

Disadvantages:

- it is necessary to condition the air
- complicated control system for selecting and controlling the individual suction units
- wear and tear of the suction bellows
- an elevating movement is necessary
- relatively large weight of the suction unit which carries out the elevating movement
- the pneumatic connections must also be moved in the elevating movement.

2. Use of holding magnets

Permanent magnets which are similar in size (approx. 30 mm x 50 mm) now appear instead of the individual suction units. They have the disadvantage that they do not achieve as great an adhesive power as the pneumatic suction units. There is also the risk that the outer skin of the sheet metal will be damaged and will be scratched if the magnets are not equipped with an additional polyurethane coating. This coating gives rise, however, to an air gap, which further reduces the adhesive power of the holding magnets. If the holding magnets are too powerful, two thin sheets may be removed at once. It is absolutely essential to avoid this. The pole pitch of the holding magnet may result in the depth at action being affected, because the more poles that there are per magnet area, the greater is the adhesive power in the case of thin items of sheet metal and the smaller is the deep action. So as to hold a 0.5 mm thick item of sheet metal, the pole pitch would have to be small, the magnet thus having many poles, resulting in a small deep action. This is also desired in the case of such thin items of sheet metal, since only one sheet, and not two, must be removed. It must not be allowed that the magnetic field be penetrated.

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

Air gaps between sheet metal and magnet are, however, to be avoided in the case of a configuration of this kind, since the small deep action would cause the holding power to be greatly reduced.

The advantage of holding magnets in comparison with suction units is that there is no need to generate a vacuum and no electric lines have to track the elevation of the suction unit. There is the disadvantage, however, that the sheet must be torn from the holding magnet at the uppermost position of the magnetic suction unit. This does not, however, generally represent a serious disadvantage. So as largely to avoid a complicated adjustment of the individual magnets and to achieve a greater insensitivity in respect of the sheet geometry, the magnet area must be markedly greater.

Advantages:

- simple control, since permanent magnets are used
- no moving connections involved in the elevating movement
- lower weight of the magnetic suction unit in the elevating movement
- minimum wear and tear.

Disadvantages:

- an elevating movement is necessary
- sheets may be scratched
- holding power cannot be switched off in the upper position
- provision of the holding power is a function of the system design
- complicated adjustment of the individual holding magnets.

3. Permanent magnetic strips

Having a width of about 50 mm and a length of 500 mm, these magnet systems are significantly larger than those previously mentioned. As many magnet systems are configured longitudinally until even the longest sheet is completely held. The largest sheet can be removed securely from the stack when there are five to seven magnetic tracks next to one another. Even punchouts no longer have any part to play, since there is still a sufficient area of sheet metal held. The sheet now has no direct contact with the system since the magnet system is equipped with either a stainless steel or a brass sheet, thus avoiding any damage to the sheet metal. These systems have also been used successfully and have a greater insensitivity to the geometry of the sheets, since even very small and very large items of sheet metal can be removed without any adjustments being made. However, at the end of the elevation, the sheet is still necessarily torn away from the magnet system. In particular the use of magnetic materials of the rare earth group allows the weight of the magnets to be kept low. This is why a higher removal speed is possible even in this case.

Advantages:

- simple control, since permanent magnets are used
- no moving connections involved in the elevating movement
- lower weight of the magnetic suction unit in the elevating movement
- minimum wear and tear.
- there is no complicated adjustment of the magnetic lines.

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

Disadvantages:

- an elevating movement is necessary
- holding power cannot be switched off in the upper position
- provision of the holding power is a function of the system design

4. Permanent magnetic walking beams

These are even wider than the magnetic strips (about 120 mm), making them heavier also. It is here possible to maintain the elevation of the magnetic beam constant. This is done in a simple way by means of a crank gear. The elevating platform now takes over alone the task of performing follow-on cycles, with the result that the uppermost sheet on the stack is always at about the same height. Three to five magnetic beams of this kind, extending over the entire length of the sheets, are sufficient for secure destacking of the usual dimensions. As a result of the now very large magnet area, small air gaps no longer have any part to play, and complete independence from the sheet metal geometry is achieved. The simplicity of control and the fact that adjustment work is no longer necessary are major plus points for this solution. In addition, it is sufficient to effect the elevating movement on one side, by only the front part of the magnetic walking beam being lowered onto the sheet. Supported by electromagnetic spreading magnets, the sheet is usually peeled off from the stack and drawn to the walking beam, thus largely eliminating the risk of removing two sheets. It is also possible to equip the walking beam with a transportation belt (toothed belt) so that no separate transportation unit is necessary. Simple elevation actuation allows a greater removal speed in this case also.

Advantages:

- simple control, since permanent magnets are used
- no moving connections involved in the elevating movement
- constant elevating movement of the magnetic suction unit only on one side
- minimum wear and tear.
- combination of the walking beam with a transportation belt is possible
- no conditioning of the air.

Disadvantages:

- an elevating movement is necessary
- provision of the holding power is dependent on the design of the system.

All these magnet solutions still have, however, one disadvantage. Their holding power is largely constant, since it is specified by the permanent magnets and it cannot therefore be ideally matched to the various thicknesses of the sheets. Since the thickness of the sheet metal varies between 0.5 mm to 3.0 mm, this means that the holding power also ought to be variable by a factor of 6. A suitable field-numerical magnet system design, i.e. optimization of the number of poles of the magnet system, its width (deep action) and the choice of the correct magnetic material allows a practical compromise to be found which is sufficient for a certain range of the thicknesses of sheet metal.

Nevertheless, there is the problem that the holding power cannot be set. If the magnet systems are designed to the max. holding power in the case of 3 mm sheets, it is possible to be certain that, given 0.5 mm thick sheets, at least 2 sheets will be removed from the stack at the same time. A compromise must thus be found which satisfies the entire range. The magnet solutions which have been described so far are appropriate in all cases, provided that the thicknesses of sheet metal do not vary so greatly. A facility for setting the holding power has been developed so as to provide a solution for all cases.

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

5. Electrically settable permanent magnets

This solution is related to Points 2 and 3. Monostable magnet systems which can be set in terms of holding power are used instead of the permanent holding magnets (1). They have an adhesion area of 30 mm x 90 mm, and they will be described at this point in somewhat greater detail because they can be used universally.

The operation is based on the principle of field displacement, i.e. when the current is flowing, the magnetic field of the permanent magnet is switched off, thus contrary to the operation of electromagnets. The use of modern magnet materials allows small dimensions to be realized. This system was optimized in respect of a high level of holding power, a small deep action and a low compensation current. Since the sheets are often suspended directly (without an air gap) from the system, very effective compensation must be ensured, i.e. the residual adhesive power must be eliminated. This demand can be achieved only with a current stabilization regulation system which makes up for the heating of the coils. The choice of the magnet material is also geared to this demand. The magnet system comprises a permanent magnet of the rare earth group and a coil. This coil allows the permanent magnetic field to be reduced as far as complete compensation. The principle of the design of the magnet system is presented in **Fig. 2.**

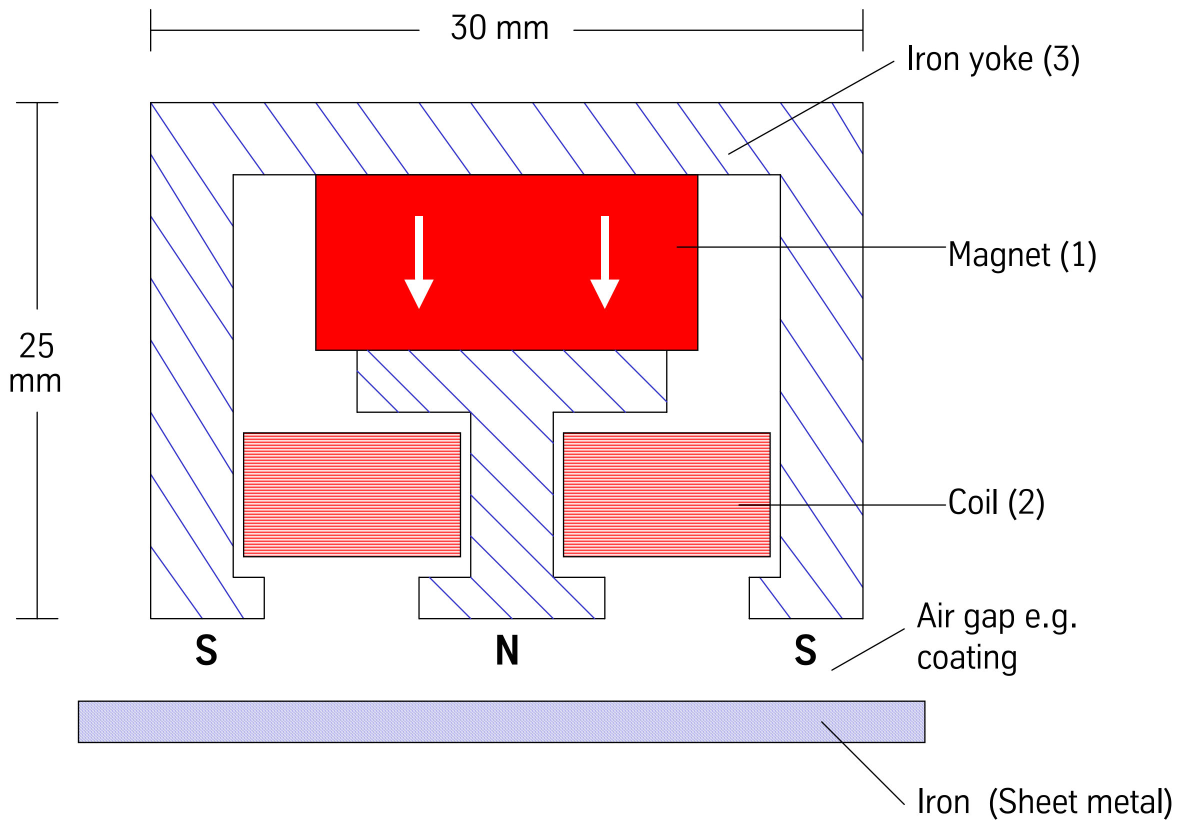


Fig. 2: Monostable displacement system with 1 - magnet, 2 coil and 3 - iron items

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

The following problem underlies removal from the stack of sheets. Spreading magnets generally ensure a spreading of the upper sheets, so that only the uppermost sheet of a stack is held by the magnet systems. It is absolutely essential to avoid removing two sheets at once. For this purpose, it is necessary to achieve a settable adhesive power and thus deep action. The adhesive power should again be compensated for deposition. The range of sheets usually extends from 0.5 mm to 3 mm thick metal sheets, the system then having to meet the following contradictory demand:

a) it is not permissible to remove two 0.5 mm thick sheets;
b) a 3 mm thick sheet must be removed securely.

It must then be possible to set the system in wide limits so as to meet these demands in one system. For this purpose, the system is dimensioned in such a way that, when there is no current, only one 0.5 mm thick sheet is removed with the appropriate degree of security. The current is made to flow in the supporting direction for greater thicknesses of sheet metal so that the adhesive power is doubled in the case of a current which corresponds to half the compensation current. A current of the same magnitude as the compensation current, but in a different direction, would approximately quadruple the adhesive power.

This version too has already been used successfully. It has the advantage that it can be switched off at the upper end of the elevating movement so that it is possible to avoid the sheet tearing off from the magnet systems, thus enabling a cleaner transfer to the longitudinal conveyor. Since this configuration does not involve a vacuum being generated or released, a somewhat greater removal speed is also possible here.

Advantages:

- the holding power can be set to a certain thickness of sheet metal
- the holding power can be switched off at the upper position without difficulty
- no scratching of the sheet metal, since coated systems are used
- relatively light weight of the elevating unit

Disadvantages:

- an elevating movement is necessary
- electrical connections for the elevating movement
- involved adjustment and electrical control of the individual magnets.

In the case of all the above-mentioned solutions, there is, however, the disadvantage that a quite complicated elevation unit must be created for the magnet systems. It is thus clear to dispense with the elevating movement and to use an electromagnet system to make the items of sheet metal jump and solely the elevating platform on which the pack of sheet metal is located perform the follow-on cycle, so that the upper edge of the pack has always a defined distance from the electromagnets. If the sheet metal is located at the magnet system, it may be further transported in a suspended position and fed to the press.

6. Special magnet system for close and remote action

This magnet system will be discussed in greater detail in the following, since it combines several functions. This system is a special design for destacking ferromagnetic items of sheet metal and is advantageously supported in its action by electrically controllable spreading magnets (3). The purpose of this magnet system is to elevate ferromagnetic plates without contact from as large a distance as possible and then to hold them securely. The magnet systems are here located directly above a pack of sheet metal comprising individual sheets. So as to meet

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

www.thyssenkrupp-magnettechnik.com

this demand ideally, the magnet system comprises a permanent magnetic and electromagnet part. The electromagnet part is activated for „sucking" the sheet, the permanent magnet part is activated for securely holding and further transporting the sheet. This combination has the advantage that a brief current surge is required only at a quite specific time (namely, during the suction). Since the time of the current flow can remain brief, allowing the switch-on period of the electro magnetically operating part also to be brief, the switch-on period in normal cases is less than 20%. This allows very high current densities to be achieved, which make themselves felt for a brief period by a very powerful magnetic suction action. This causes the sheet to be elevated from the stack and to jump to the magnet system, at which it is then held by permanent magnets. This magnet system can, of course, be used everywhere that a very high level of adhesive power is required over brief periods.

6.1 Functional principle

The principle of the design of the system is presented in **Fig. 3**. The special configuration of the 4 permanent magnets and the coil can be seen. The permanent magnets conduct the magnetic flux through the iron pieces in such a way that this flow is obstructed at the system ground plate. This leads to almost no scatter flux being generated, resulting in the entire flux leaving the permanent magnets having to leave the magnet system and thus contributing to the sheet which is located under it being securely held. The magnet volume is here ideally implemented in terms of adhesive effect. In addition, this special configuration of the magnets has the advantage that only one pole pitch which corresponds to the magnet thickness has an effect and not the one which corresponds to the system width.

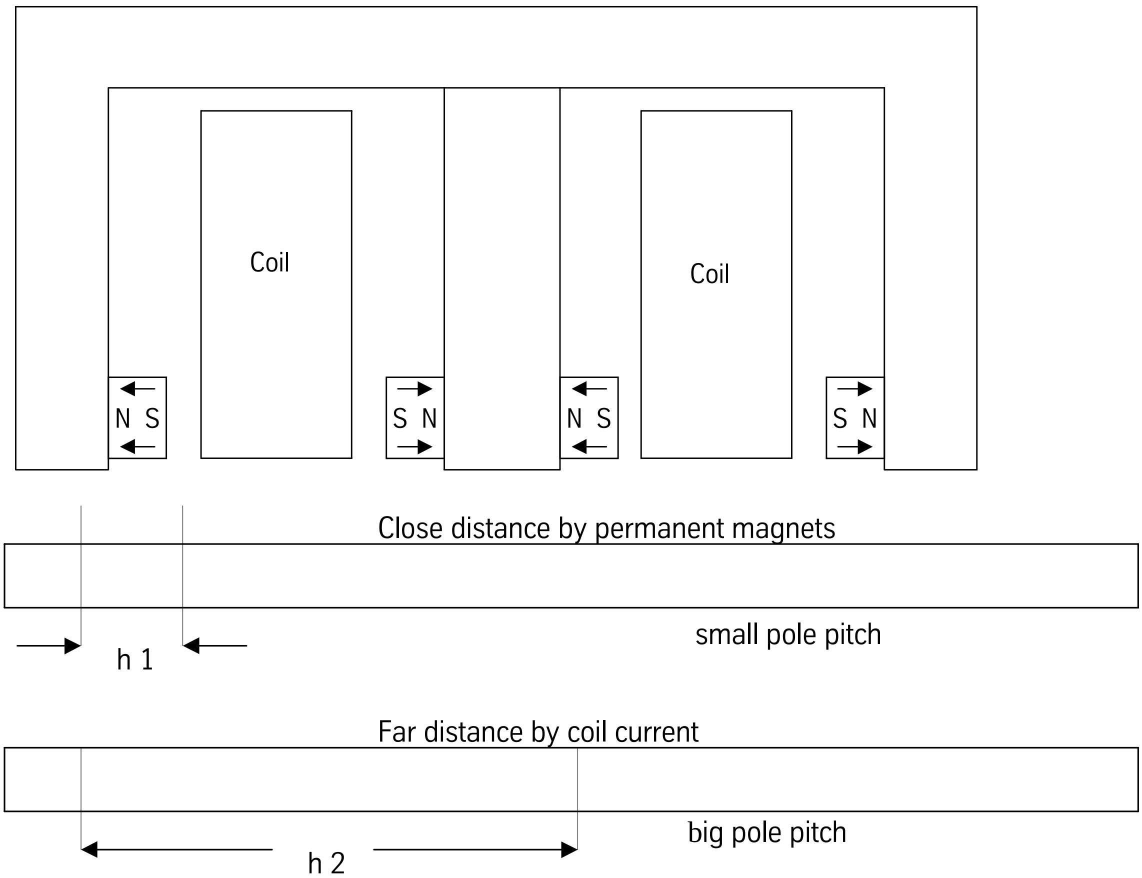


Fig. 3: Representation of the two pole pitches in one system

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

Permanent magnetic part

Since the pole pitch is a measure of the deep action of the magnet system, this means that the permanent magnet part of the system has only a small range, but it has a high adhesive power even in the case of thin sheets. This is because, as a result of iron saturation, the adhesive power/area can be increased in the case of thin sheets only by means of a greater number of magnetic poles, and precisely this fact then leads to the fine pole pitch. The fine pole pitch has only a small deep action. This corresponds also to the application in a sheet loader, because the item of sheet metal which has just been elevated must be further transported and fed to a press. This means that there is a state in which no sheet is located under the permanent magnet system, but there is still a supply of sheets as a pack of sheet metal directly under the system. Too great a range of the permanent magnetic system part would result in it being possible to take a sheet from the stack at such a moment without it being under control, leading then to a fault in the system. The permanent magnet part of the system must thus have a short range (small pole pitch) and a high adhesive power.

Electromagnetic part

This part of the system has the task of taking a sheet specifically from the stack (magnetic suction). It can be seen from the foregoing that a large pole pitch should now be present so as to obtain a large magnetic range. This is ideally achieved by the coil which is located above the permanent magnetic circuit and generates for its part a pole pitch which corresponds to half the system width and thus, depending on the form of the design, is 6 times larger than the pole pitch which is brought about by the permanent magnet part. The magnet system thus corresponds to a magnet system with two pole pitches, which can be used depending on the application, the small range corresponding to the permanent magnet part and the large range to the electromagnet part. This special system configuration has been registered for patent with the number PS 38 22 842 [4]

6.2 Transfer behaviour

The decisive parameters for the transfer behaviour are:

- transfer height
- sheet thickness
- sheet geometry
- the homogenous distribution of mass in respect of the magnet systems
- the rake of the sheet surface in respect of the magnet systems
- the bonding effects
- the dynamics of the sheet metal.

Since there is a dynamic process during suction, all the above-mentioned parameters should also be regarded with a view to their dynamic behaviour and not only statically, although definitive statements in respect of the individual parameters can be made only statically. For example, **Fig. 4** represents the transfer height as a function of the sheet thickness, an area take-up of 36% being taken as a basis. The transfer height should be understood to be the distance at which the sheet metal just jumps to the magnet system in opposition to gravity. This applies only to the static case with the indicated area take-up and for a single sheet without additional support coming from spreading magnets. The current strength should be dimensioned in such a way that a switch-on period of 20% can be ensured, resulting in the transfer height also being increased.

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

„Area take-up“ should be understood to be the ratio of the active area of the magnet system to the sheet area. An area take-up of 50% means that the sheet area is twice as large as that of the magnet system. **Fig. 4** also presents the transfer height of that part of the system which operates purely by permanent magnets. The range of secure destacking can be seen from the difference between the two pertinent curves for the same thickness of sheet metal. This range should be as large as possible, so as not to have constantly to optimize the height of the elevating platform which is performing follow-up cycles from below; this would involve rapid wear. This range should also be sufficiently great in the case of various thicknesses of sheet metal so that the elevating platform - when changing the thickness of the sheet metal - does not have to make any other settings.

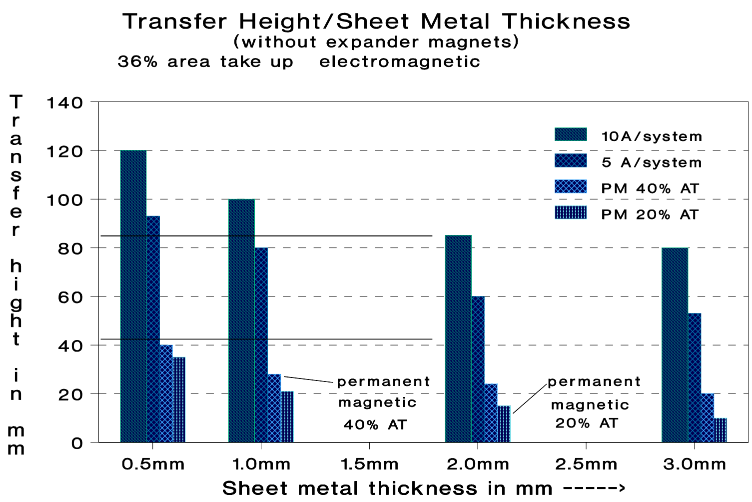


Fig. 4: Transfer heights of the electromagnetic system part in comparison with the permanent magnetic system part

The sheet geometry and thus the mass distribution also have a major role in the transfer behaviour. The magnet system cannot act homogeneously over the mass of the sheets, since the entire suction unit comprises several individual systems, which should, however, be configured as uniformly as possible over the sheet geometry. Cutouts and holes in the sheets make the mass distribution non-homogeneous, and the magnet system can be effective only at those places where there is ferromagnetic material. A magnet system directly above a large sheet cutout thus does not make any contribution to the suction action. This results in the possibility of non-uniform suction of the sheets and of non-alignment. There is also the risk of non-alignment if, for example, the surface of the pack of sheet metal is not in parallel with the area of the magnet systems as a result of the formation of burrs, because the sheet will always make first contact with the system with the part which is located nearest to the magnet system area, and the remainder of the sheet will orient itself accordingly as a result of the friction.

In addition, bonding effects of the lubricated sheets may also lead to non-alignment. The sheets are generally in the store for quite a long time where they are stacked and lubricated one on top of another in a pack of sheet metal until they are further processed.

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

www.thyssenkrupp-magnettechnik.com

The weight of the sheets presses some of the oil out of the stack again, and the remaining film of oil can turn to resin in time under the pressure. Two sheets then sometimes bond tightly together. It is easy to see how this bonding effect can also lead to non-alignment, even if the edges of the sheets are bent up by spreading magnets. The dynamic of the sheet metal is improved by using electrically controllable spreading magnets which support the suction action by their expander effect [(2)].

The indicated parameters make clear that it is not possible to provide any generally valid information on the suction effect of these special magnet systems, since the suction height is, in practice, affected by many dynamic factors which cannot be recorded in reproducible form. It is thus possible to make statements only on individual cases, so as to be able to provide an overview in this overall context.

7. Support by means of spreading magnets

As already mentioned above, various factors affect the suction effect. So as to improve this and thus to minimize the unwanted side-effects, an electrically controllable spreading magnet system is required in addition to the „suction system“ so as to be able to switch off the adhesive action. This is because the expander effect is also combined with an adhesive action. An additional reason can be seen in spontaneous action. The expansion of the pack of sheet metal results in the uppermost sheet being elevated to some extent in the direction of the suction systems. Expander and suction action thus support each other. However, this positive action of the spreading magnets comes to an immediate end when the sheet has reached the upper edge of the spreading magnet. Reluctance now takes effect here, and it tries to keep the sheet fixed in place. That is why it is absolutely necessary to switch off the spreading magnet at this moment, so that the suction system alone is now effective. Optimization of the time behaviour between spreading magnets and suction systems makes both effects work usefully together.

There is thus quite a similar effect such as in the application of magnetic walking beams, namely a peeling off of the upper sheet from the stack below.

Experience shows that spreading magnets are necessary so as to minimize the bonding effects which occur. Electric switchability is a result of the demand that it must be possible to switch off the attractive forces which occur on leaving the active expander zone. The suction effect can be optimized still further if suitable control electronics are used to ensure that account is taken of the overall dynamics of suction. Since the spreading magnets also have only a brief switch-on period in this case, the current density may be markedly increased with them because a switch-on period of 30% is not usually exceeded here either. Rapid switching of the electromagnetic system parts with time-optimized control thus provides a clear gain in dynamics, making itself felt by an increased transfer height or at least by an increased functional safety. The success of this kind of optimization can be seen in Fig. 8. Here too, there is the requirement for a single sheet in the static case, however, with the support of four electrically controlled spreading magnets which make up an edge take-up of 36% with their areas.

The supporting action of the spreading magnets allows the range of secure destacking to be increased by approx. 30 mm, so that both a 0.5 mm thick item of sheet metal as well as a 3 mm thick item of sheet metal can be removed with one setting of the elevating platform.

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555

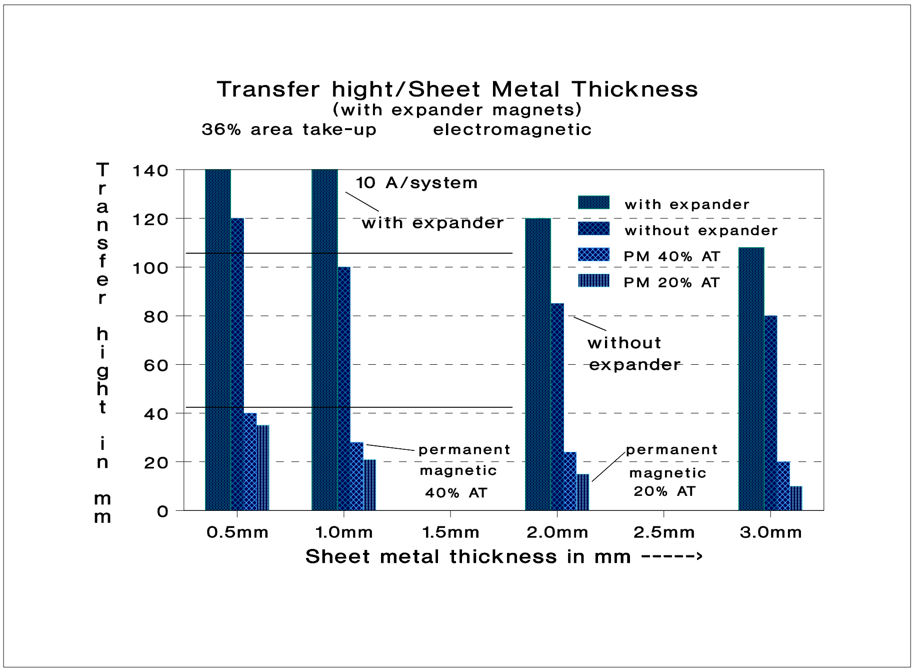


Fig. 5: Representation of the supporting action of the spreading magnets

Advantages:

- the magnetic suction effect can be set to a certain thickness of sheet metal
- no scratching of the items of sheet metal
- no elevating movement of the suction unit necessary
- no conditioning of the air necessary
- large degree of independence from the sheet geometry.

Disadvantages:

- electronic control system of the suction action and time coordination with the spreading magnets are necessary.

LITERATURE:

1) Cassing, W.: Bleche mit schaltbaren Magnetsystemen stapeln. Werkstatt und Betrieb 129 (1996) 4, S. 284ff.

2) Cassing, W.: Spreizmagnete helfen Bleche zu entstapeln. Werkstatt und Betrieb 129 (1996) 10, S.908ff.

3) Hübner, K.-D.: „Elektrospreizmagnetsystem“ Patentschrift PS 36 15 186 vom: 05.05.1986

4) Cassing, W.: „Magnetsystem für Nah- und Fernwirkung“ Patentschrift PS 38 22 842 vom: 06.07.1988

www.thyssenkrupp-magnettechnik.com

Johanniskirchstraße 71
45329 Essen, Germany
Tel. +49 (0)201 946161-0
Fax +49 (0)201 946161-555