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KNOWLEDGE AND SUBCONSCIOUS ACTIVITY AT THE CONCEPTUAL STAGE OF DESIGN

M. Szafarczyk

Warsaw University of Technology

e-mail: m.szafarczyk@cim.pw.edu.pl

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Abstract: *The conceptual stage of a quite new design has a crucial influence on the success of the whole project. At this stage of design heuristic approach prevails, supported sometimes by computer aided evaluation of created variants. Some design concepts are created in subconscious of the designer and the subconscious works in its own way. The paper presents personal attitudes of the author to the new designs illustrated by machine tool projects based on screw mechanisms.*

1. INTRODUCTION

A design task may have quite different character. In most cases it is continuation or similarity attitude which prevails. In hardware the designed machine is going to be a new member of the family already in production or it is going to fight on the market being similar to a successful design of the competitor. In software the designed program is going to realize similar tasks as other programs already known. Following already known patterns it is much easier to fulfil many constraints and additional requirements that are common in every, even relatively simple, design.

Another strong factor, which makes the design similar one to another and restricts creativity, is modular design. Ready to use and already proved modules are, in hardware and software designs, fully justified solutions both from economical and reliability points of view. But a design from ready-made blocks seams to be a less creative task. Perhaps the most creative attitude is now possible in a design process of modules themselves?

Nevertheless creativity is still needed, especially at the conceptual stage of new designs. It seams that, till now, a human mind is the best tool for creation a new solution. Computers are very important tools for designers but even with "artificial intelligence" they may only support a designer at this stage of his (or her) activity. The first of all they may help in evaluation, according to the established axioms and rules, the solutions generated by the designer. In axiomatic theory of design, for example, it is the independence of functional requirements and the minimization of information content which decide about value of the design concept [1,2].

The work of human mind is outside technical knowledge so fare, especially when it generates new ideas. There are also considerable differences between human minds. Nevertheless it may be not bad to present some remarks on an experience gained when using a human subconscious during a work on a new solution. Perhaps it will help somebody.

2. THE USE OF SUBCONSCIOUS

It seems that subconscious has a crucial role in generation of new solutions. It is important to use it, but it works according to its own rules. The rules should be known and followed when the full potential of subconscious is to be exploited.

Certainly a designer should, first of all, formulate the task and think about it for some time, trying to solve the problem "himself". Then the problem should be left for the designer's subconscious to work on. Unfortunately it is not possible to predict the time of the solution, if any solution will be generated by the subconscious. The designer should "keep contact with his/her subconscious" returning to the problem consciously from time to time. Any solution generated by the designer's subconscious should be evaluated at once and a new formulation of the task should be made if needed.

When the action is fruitful and some solutions have been created it may help when the designer will build some kind of their classification making "the order in the family".

3. CLUSTER THINKING

It looks that a subconscious uses some kind of fuzzy thinking with many different associations. It is probably a good attitude for creativity action of the subconscious and we should not fight with it. But because of that it works "in clusters" and many "by-product ideas" are created. They may occur quite valuable by themselves but are not solutions to this particular design task. The cluster of ideas is of course limited to the area of knowledge and experience of the designer. The byproduct ideas may be worth remembering and developing, but for other products or processes. Again it is up to the designer to evaluate the ideas and to decide what to do with them. Sometimes it occurs that byproducts become more valuable than the solution of the primarily formulated task.

Unfortunately such procedure is not in accordance with the organization of modern industry, with strong specialization and as short "time-to-market" as possible.

In bigger enterprises there are development units with people having enough time for the use of subconscious but their minds may be barren by only one attitude – improvement of the enterprise products. They must think only about it and kill all other ideas, which do not feet to the main task.

4. A CLUSTER OF SCREW DRIVES

Some two years ago I started thinking on development of an electrical drive for turning chuck which would be competitive to a typical hydraulic one. The hydraulic solution has several drawbacks. The main ones are:

- there is always some danger of opening the chuck during rotation of the spindle as a result of unpredictable drop of the oil pressure,
- there are leaks and loss of energy when supplying oil to the rotating spindle, especially now, with tendency of increasing the speed of spindle rotation,
- use of oil is always no good from environmental point of view.

A screw mechanism with a spring seemed to be the best solution. It allowed replacing a hydraulic cylinder at the rear end of the spindle by a screw with a spring; with changing neither the machine tool nor the chuck itself. The screw mechanism was needed for changing rotation movement to linear one and keeping the position because of self-locking ability. The spring was used for accumulating energy and for the relatively simple measuring of the force gripping the workpiece in the chuck. Such solution was proposed as a result of logical conscious thinking.

When it was left to the subconscious to work on the original solution has been created: to use the main drive of the spindle for clamping and unclamping the workpiece in the chuck [3]. Modern turning machines have possibility of slow controlled rotation of the spindle with a considerable torque to be applied. About one turn of the spindle can be enough for clamping or unclamping the workpiece. The solution may be especially useful in turning from a bar when rotating during clamping is not important. The concept of design is presented in fig.1.

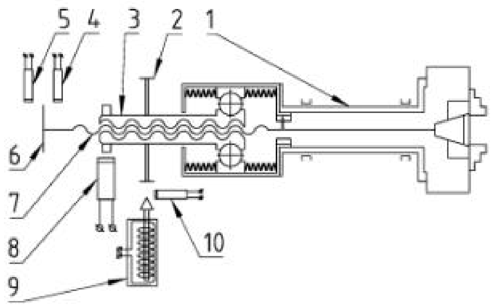

Figure 1. Schematic view of the electric drive of turning chuck.

At the rear end of the spindle 1 there is a designed screw drive. It rotates with the spindle. The force driving the chuck is transmitted by an element 7 which in real design is a tube allowing for machining from bars. On the outer surface of the tube 7 there is a thread and its nut 3 is connected with springs through a ball bearing. A bolt 9 may lock the disk 2, attached to the nut and then it is possible to move the tube 3 axially by slow rotation of the spindle. It causes movements of the chuck jaws and when the jaws touch the workpiece the springs are compressed applying a clamping force. An analog sensor 8 measures the clamping force (the springs' deflection). Unclamping is possible by the rotation of spindle in opposite direction. Choosing the direction of rotation it is also possible clamping by outside or by inside surface of the workpiece. Triggers 4, 5 signal the extreme positions of the chuck jaws. A trigger 10 informs that the bolt is extracted and the spindle can not be used for machining.

Because of "cluster thinking" the subconscious started work on other possibilities of using screw mechanisms in machine tools. The idea was to use screw mechanisms with switchable transmission ratio. It seemed especially useful when a machine tool element should be moved quickly and then it should apply a rather big force. The typical example is a tailstock. When a workpiece is going to be clamped between centers in a lathe the tailstock spindle or the whole tailstock is quickly moved to the workpiece and then the tailstock center is pressed to the workpiece center hole with a considerable force. A hydraulic cylinder is typically used for the purpose. A screw with two threads could replace it as it was shown in fig. 2.

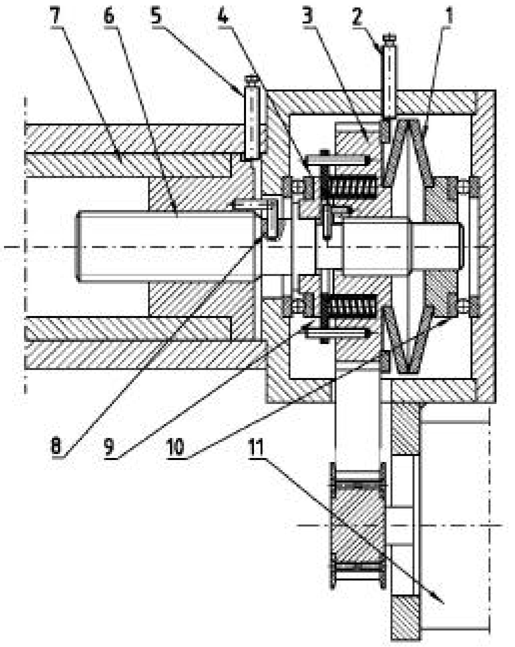

Figure 2. Screw mechanism for movements of a tailstock spindle.

A relatively small electric motor 11 rotates through a belt transmission a nut 3 of a thread with the smaller lead. A torque needed for rotating the nut 3 relative to the screw 6 may be increased by a brake 9. The torque is bigger than a torque needed for rotating the whole screw 6. Rotation of the screw relative to the nut in the tailstock spindle causes movement of the spindle with high speed. When the tailstock center touches the workpiece center hole resistance to the movement becomes much bigger. The rotation of the screw stops and the nut 3 starts rotation relative to the screw 6. Because of the smaller lead of the thread the speed of the spindle movement is smaller but the applied force may be bigger. The nut 3 moves backward deflecting a main spring 1. An analog sensor 2 measures the deflection corresponding to the force clamping the workpiece between centers. When the motor rotates in opposite direction the tailstock spindle 7 and the nut 3 return to their starting positions established by stops 4 and 8. A trigger 5 signals return of the spindle to the starting position.

In another step of "cluster thinking" it occurred that it is possible to obtain much bigger change of a rate of transmission by moving to differential screw drive. It can be achieved quite simply by the use of a driven screw with two threads of the different leads. The idea is shown in fig. 3.

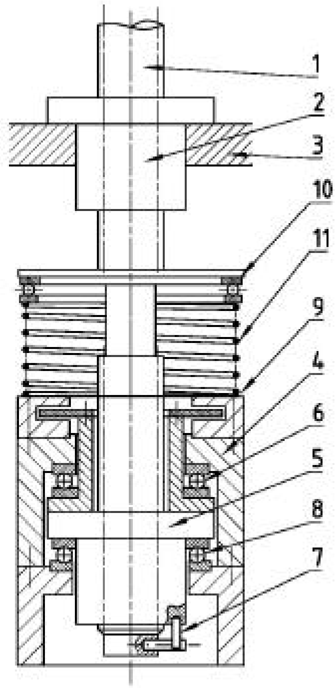

Figure 3. Differential screw drive.

One of the nuts 2 may not rotate but another one, nut 5, may rotate in the bearings. Switching on a brake 9 stops the rotation of the nut 5. When the brake 9 is switched off only nut 2 is active and the nut 5 rotates with the screw 1. When the brake 9 is switched on both nuts are active. Then one rotation of the screw moves one of nuts relative to another by a difference between the leads. The difference between leads may be as small as needed.

There are some difficulties when a differential screw drive is used. One is loss of energy in both nuts working with relatively high speed and big force. Another one is the need of moving the nut with the brake back to the starting position on the screw. Use of a ball screw should diminish the both difficulties, thanks to its high efficiency. The loss of energy in both ball nuts is not high and as a result efficiency of the drive may be around 50%. For the return of the nut a force of spring or a force of gravity may be used because the ball screw is not self-locking.

A main drive of a press may be a typical application of this kind of drive. A press ram should move quickly and at the end of a stroke it should apply a very big force. A solution with a differential screw for a press with a ram moving upward is presented in fig. 4.

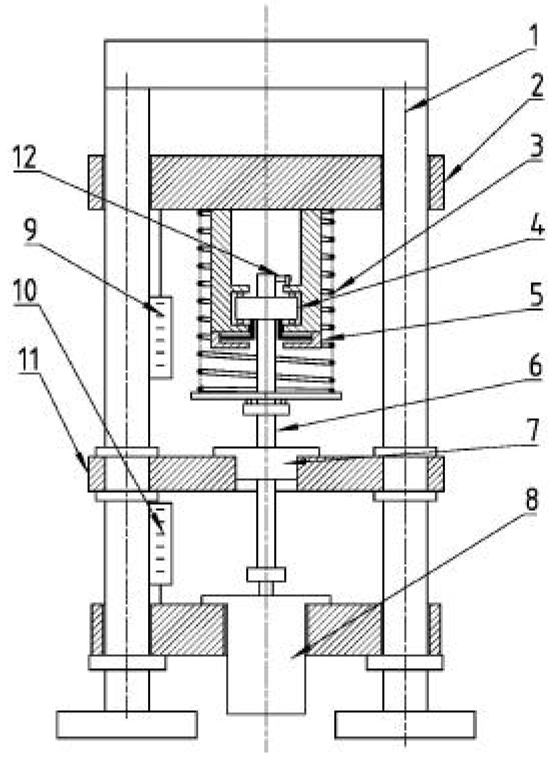

Figure 4. A press with a differential screw drive.

For making design as simple as possible a driving motor 8 is moving together with a screw 6 on pillars 1. During fast movement upward a brake 5 is switched off a ram 2 is moving with them. Only a nut 7, fasten to a shelve 11, is active. A nut 4 rotates with the screw 6. When the brake 5 is switched on the nut 4 stops. It is differential screw drive now - the ram 4 moves by a difference between leads of both threads at every revolution of the screw 6. The rate of transmission may be much higher and the applied force may be much bigger. The motor 8 and the screw 4 are still mowing fast. Digital sensors 9 and 10 measure positions of the ram 4 and the motor 8 respectively.

When the motor 8 is switched off all moving elements go down under the law of gravity. At the same time the spring 3 is moving the ram 2 upward relative to the screw 6, allowing next cycle of movements. The move is limited by a mechanical stop 12.

5. CONCLUSIONS

In new designs it is advisable to use a designer's subconscious at a conceptual stage of the project. Effective use of subconscious needs some time left "free" after formulation of the task.

It is worth remembering that the subconscious uses some kind of cluster thinking. Solutions generated by the subconscious should be analyzed not only from the point of view of the formulated task but more generally. Promising concepts should be registered. Some classification of the concepts may be useful.

In the described example of the task replacing hydraulic linear drive by a screw drive and springs several solutions have been generated. Apart from using a single thread screw the concepts in which a screw has two threads with different leads are described. In presented solutions the screw drive rate of transmission may be switched automatically during operation. Some kind of classification may be proposed. In one solution the threads operate in sequence and in another one they may work together as a differential drive, giving opportunity of a very big rate of transmission.

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