THE INTERNATIONAL CONFERENCE OF THE CARPATHIAN EURO-REGION SPECIALISTS IN INDUSTRIAL SYSTEM
6th edition

CONSTRUCTIVE DESIGN PRINCIPLES APPLIED TO ENHANCE SUPPORT EQUIPMENT QUALITY

Nicolae Iliaş[1], Iosif Andras[2], Attila Kovacs[3], Andrei Andras[4], Emanoil Venescu[5] Livia Iliaş[6]
[1,2]Prof. Eng. Ph.D., [3,4]Eng.Ph.D., [5,6]Eng., University of Petrosani, str.Universitatii, nr.20

Abstract: *The present paper examines practical application of the principles of constructive design in order to increase the quality of supporting equipment for mining industry.*
Key words*: Quality, TQM, longwall mining, support shield*

Quality is the aptitude of making a product or offering a service capable of complying with the users' and communities' requirements and demands, all along the lives of the formers, without a significant alteration of the characteristics, which made the difference when choosing them. This definition is accepted by all industrialized states, and is the principle on which quality approach is based.
Quality approach gives adequate answers to the rapid modifications of the more and more complex social and economic circumstances all over the world, providing economic agents international chances of survival.
Quality assurance of a product should be assumed in any stage of its lifecycle. In the design stage, application of constructive principles provides an effective instrument of quality assurance for power supports (stepping sections, articulated beams, hydraulic and cylindrical power props).

1.Constructive Design

Constructive design is that part of the design process where technical and economic structure of the product is calculated without ambiguity and completely, starting from the principle solution.
Constructive design requires a large number of correction stages as well, where analysis and synthesis alternate, and which makes quality elements turn into quantity elements, that is, general constructive design into detailed one. A particularity of constructive design is the assessment and searching procedure, supported by complying with directives including principal characteristics of constructive design, as it is shown in Table 1.

Table 1 Characteristics and directives regarding constructive design

Main characteristics	**Examples of directives**
-function	Is the planned function met? What secondary functions are required?
-effective principles	Do selected effective principles have the desired effect? What functioning errors are expected to happen?
-design	Does the chosen material, the designed shapes and sizes warrant along the pre-established life of the product, in planned conditions, an acceptable durability, admitted shape modifications, sufficient stability, avoiding resonance, non-dangerous dilatation, an adequate behavior to corrosion and wear?
-safety	Are factors influencing the safety of components, functions, operation and environment considered?
-ergonomics	Are man – machine relationships considered? Are overstrains and damages avoided? Was an adequate design followed?
-manufacture	Are manufacturing aspects considered along with technical and economic ones?
-control	Are required controls possible and admissible? Were stand trials planned ?
-assembly	Can all assembling processes be simply and clearly ensured at the manufacturer and at the beneficiary?
-transportation	Are transportation conditions and risks at the surface and underground considered and verified?
-exploitation	Are events occurring during use, operation and maneuver considered?
-maintenance	Are maintenance, inspection and repair measures possible and easily followed?
-recycling	Would reuse or revaluation be possible?
-costs	Could planned cost limits be met? Do additional, secondary or operation costs increase?

2. Basics of Constructive Design

A brief review of principles and rules to be kept in mind in constructive design follows, since its correct application can provide a basis in quality assurance in the design stage.

2.1.Basic rule of constructive design

"Clearly, simply and reliably" is a primordial instruction for the designer and arises from the general objective.

"Clarity" means that the designer should state his action and behavior in a clear manner to accomplish the technical function of the product.

"Simplicity" resides in the combination of certain clearly defined shapes in the accomplishment of constructive shapes and provides lower manufacturing costs.

"Reliability" involves necessity of stating life duration, reliability, safety and environment protection (safety for man and environment).

Application of this rule, corroborated with the directives stated in the table, will lead to a series of questions and answers, in the sense that no important factor had been overlooked and the newly designed product will be truly a quality product.

2.2 Principles of constructive design

These principles involve specific product strategies and are not all applicable in general to all products. In this sense, only principles applicable to power supports are analyzed.

2.2.1 Principle of task separation

Practical selection and giving functional elements for functions to be accomplished lea to the following questions:

- which sub-functions can be accomplished together, only using a single element?
- Which sub-functions must be accomplished using separate functional elements.

In general, the aim is to accomplish a large number of functions with less functional elements. Analysis of operation or searching weak parts and defects can show that restrictions, difficulties or interruptions might come up.

The principle of task separation leads to better levels of employment, due to removing ambiguities, higher performances by reaching specific upper limits, clear behavior in operation (accomplishing characteristic function, life duration), and a better manufacturing, assembling, maintenance and repair cycle.

The disadvantage of applying the principle lies in higher costs and difficulty of comparing economic efficiency and safety.

In power supports, the principle is largely applied in design, due to reasons of safety and reliability, as well as to technical limitations, such as the necessity of exerting spatially oriented forces working on several active elements (beam, foot, shield, flitting rod, extensible lateral part, face gripper etc.), and the direction of application of cylinder and prop forces strictly depends on their orientation (active forces in the piston rod and cylinder are exclusively axial). This involved designing specialized elements, even if the technical solutions were complex and costly (for example, square equi-distancing mechanisms).

2.2.2. Principle of self-protection

Meaning that the system should support itself, so that its functions would be accomplished more efficiently and to avoid damages in overload situations. The general effect required in this principle comes from a basic effect and an auxiliary one. This project can be self-protective or self-damaging, as the case may be.

In practice, self-protective solutions are devised, acting as self-strengthening or self-compensation.

In power supports, if we analyze the hydraulic circuit and the machinery as a whole, both self-protective variants are seen to be applied.

For instance, in bearing props, which are pre-tensioned at a certain strain after stepping, as an effect of rock pressure, self-strengthening occurs(the pressure in the prop increases up the nominal value), then a self-compensation occurs (when the safety valve opens once the pressure for which it had been adjusted is reached, hydraulic agent is released from the prop, it glides, forces working on the support are redistributed, prop pressure implicitly decreasing).

2.2.3. Principles of force and energy transmission

Energy transfer, by transmission of forces and moments which lead to deformations, is characteristic to any technical product (system). In case of power supports, the value and duration of active forces, and especially reaction ones, involve additional constructive measures provided in design stage.

2.2.4.Constructive design and force flow

Forces and moments transmitted through component sections can be perceived as a force flow. Special requirements result for a constructive solution including the concept of force flow. Force flow should always be closed (action = reaction). Sudden deviations in force flow and sudden changes in transversal section ought to be avoided.

Principle of equal resistance. Equal distribution of resistance is achieved by an adequate choice of materials and shape.

Principle of minimum force transmission path. Forces and moments should be transmitted with minimum costs for materials. Reduced deformation requires minimum length paths and only strains with stretch and compression components. High elastic deformation requires a long path of force transmission and preferably bending or torsion strains. In power supports reduced deformation is applied first of all (in metal construction elements), and the second only for hydraulic part (in sealing elements and hoses).

Principle of harmonized deformation. The components should be designed so that a proportional adaptation to stress should take place, providing an equal deformation and a minimum relative deformation.

The aim is to avoid or reduce strain in excess and wear of surfaces due to friction and to avoid tear due to deformations.

Harmonization can be accomplished by adjusting position, shape, or size, or by choosing a suitable material (elasticity module).

Principle of force compensation suggests compensation elements for medium forces and symmetrical distribution for relatively high forces.

In shield type power supports, corner cylinders were provided to play the role of a compensation element, and in most of power supports, props are positioned in pairs (one or several roes), with symmetrical arrangement as to the longitudinal axis of the support, perpendicular to face line.

2.2.5. Principles of safety and reliability

Literature distinguishes between direct, indirect and inferred safety principles. Direct safety principles inherently and intrinsically ensure that no danger situation might occur. Indirect safety involve protective systems and devices. Inferred safety principles only alert on the danger or show danger areas, without solving any safety issues.

Safe-Life principle mean that all components and their links would resist during the pre-established time of use in all possible and probable conditions, without defects or destruction.

Fail-Safe principle means controlled deterioration (fall and/or break), avoiding serious consequences.

2.2.6.Principle of multiple or redundant structure

It means an increased safety, since one faulty system element does not an intrinsic danger, and system elements in series or in parallel take over the disturbed function, or at least part thereof.

In case of active redundancy, all system elements play an active part, in passive redundancy they are stand-by elements and their activity needs commutation. System elements should correspond to one of the before mentioned principles.

Indirect safety includes protective systems and devices. The latter protect dangerous points (linings, covers, protectors) in an ergonomics' context. In danger situations, protective elements can automatically shut down a system or a machine (shut down power, material flow, or can prevent starting).

2.3.Specifications for constructive design

Specifications for constructive design come from general and special constraints for a product, but also from nature's and probability laws regarding machine parts design.

2.3.1 Design for resistance

The principles of material resistance theories and force transmission principles should be considered.

In power supports, where most of the reference points are subject to relatively high strain and for a long time, this is a significant specification. The choice of quality materials, rigorous sizing and applying safety coefficients are essential.

Stand trials are mandatory both for new projects and for each prototype.

2.3.2 .Design for controlled deformation

In modern power supports, their evolve kinematics allow a gradual, controlled deformation of support structure, so that material deformation of subassemblies should not reach values that might generate defects or destruction thereof, all these being possible along with all the range of projected working heights.

2.3.3 Stability design avoiding resonance

Stability involves both rigidity and turnover risk, and buckling and crushing risks, but also includes possibility of stable operation of the machinery.

Unstable behavior should not enhance or amplify phenomena so that they would become uncontrollable. Power supports frequently work on longitudinal or transversal face inclination or uneven floors; all these should be considered during design.

2.3.4 Design for thermal dilatation

In case of normal use of power supports, thermal dilatation is not an issue, their operation being in a relatively limited temperature range, specific to mining, and during operation they do not generate a significant temperature increase (such as electrical or thermal motors). There are cases, however, when temperature at the workplace is considerably higher (endogenous mine fires), which should not seriously impair their operation. A possible case is also when the hydraulic part does not handle hydraulic agent at the pre-established temperature, but at a higher temperature. In this case hydraulic agent losses might occur and implicitly pressure drops in the cylinders, their dilatation reducing sealing capacity.

The designer should consider dilatations to which materials are subject during processing (flame cutting, welding, cutting at high speed), remnant deformations and inside stresses occurring(mainly with welding). Ambient temperature of assembling sites of points of reference or supports should also be considered in setting margins and adjustments.

2.3.5 Design for corrosion

Corrosion can sooner be reduced than avoided, since it is about implacable chemical and electro-chemical phenomena. Practical and economical reasons prevent the use of non-corrosive materials or the use of equipment in non-corrosive environment.

Constructive design should still propose adequate measures in this sense.

Common corrosion occurs due to the presence of humidity and simultaneous presence of local or atmosphere oxygen, especially for temperatures lower than mist point.

The main result of this phenomenon is surface corrosion (approximately 0,1 mm/year in case of steel). Remedies are thicker walls, material modification, priming, painting or other way of directing corrosion process. The designer should plan smooth surfaces an maximum volume/area ratios, avoiding humidity collecting points.

Localized corrosion is a particular hazard since it generate a significant and hardly foreseeable notch effect.

Types of corrosion that might occur: Fissure corrosion; Contact corrosion; Fatigue fissure corrosion; Strain corrosion

Constructive design should provide as long and even operation life as possible for all components, even if they are affected by corrosion.

Since mine air is more humid and acid (regulations admit 1% Co_2), power supports are subject to a highly corrosive environment. Water spraying for dust removal , sealing problems with hydraulic system increase humidity and accelerate corrosion.
Large surfaces coming in direct contact with rocks and frictions cause by moving lead to rapid degradation of protective paint coatings, which only can be mended when supports are taken out to the surface for general repair. Meanwhile metal surfaces are deteriorated during work due to rock abrasion, superficial or deep scratches being caused, favoring corrosion. A series of measures should be thus taken by the designer regarding the choice of suitable materials, thermal and thermo-chemical treatment to strengthen exposed surfaces, to increase resistance to corrosive agents, considering that reconditioning at a later date is costly and difficult.
Protecting smooth surfaces, such as piston rods and inside cylinder surfaces is especially important, since their degradation inevitably leads to defects. While the problem is relatively simple for cylinders, the presence of hydraulic oil in the agent at required quantity and quality being sufficient, cleaning systems and protectors are necessary for the piston rods plus periodic cleaning – maintenance provided by the staff in charge.

2.3.6 Design for wear

Specific kinematics of power supports and the impossibility of checking on the condition of surfaces (such as inside cylinders, bolts) during work or general servicing, make the designer take adequate measures against adhesive and abrasive wear.

2.3.7 Design for ergonomics and safety of user

Safety of users. Romanian laws for health and safety at work make the designer to work in a responsible way. The safety of people and environment is an essential requirement for any technical equipment. Subjective aspects should also be considered, such as lack of understanding regarding proper use, fatigue, so that in the event of an incorrect handling the designed equipment should not generate accidents.
Ergonomics. The designer should consider easy handling, illumination and ventilation of workspaces, possibility of equipment functioning parameters surveillance, noise, dust, etc.

In case of power supports, the main health and safety requirements are related to the following:

- avoid fall of rocks at the face;
- provide working and travel space;
- avoid staff being bruised in the area of support;
- exclude faulty operations (inter-blocking, labels with instructions etc.);
- adequate illumination and visibility;
- good handling possibility of subassemblies and support as a whole in assembling, transport;
- possibility of electricity cut off and insulation from the hydraulic circuit;
- keeping pressure in props in case of inadvertent or planned electricity shutdown or in case of defects of elements along the hydraulic circuit;
- stability;
- risk of breaking of mechanical or hydraulic subassemblies;
- risks generate by sharp edges and corners;
- explosion risks (air with methane + coal dust);
- avoiding dust generation during handling.

2.3.8 Design for aesthetics

Refers to permanent analysis regarding shape, color and graphics.

2.3.9 Design for ease of manufacturing and inspection

Refers to component structure to allow simple manufacturing, quality control and inspection.
In this sense the designer should be familiarized with the technical level and technological possibilities of the manufacturer, he should adapt the project to the latter's possibilities of making the product so that the required qualities would not be impaired.

The project will be thus influenced regarding shape, size, surface quality, assembling margins and adjustments, manufacturing procedures, tools and quality control.
The objective is to reduce costs and improve quality, taking into consideration various manufacturing procedures and individual stages thereof.

2.3.10 Design for adapted assembling

Assembling surfaces and order of parts will be considered in constructive design. Solutions are applied that would need minimum simple assembling operations, parallel assembling of modules, automation possibilities for operations.
Operations specific to assembling will be considered: storage, handling of parts, positioning, assembling adjusting, ensuring, assembly control.
Since supports have large and heavy, transported in underground in subassemblies, (larger modules) and are equipped in underground, this specification becomes very important.

2.3.11 Design for capacity of operation and maintenance

Constructive maintenance should allow for operation and maintenance. Maintenance includes up keeping, inspection and repair.
Commissioning and use will be reliable and simple.
Operation results should be clearly perceived, so that inspectors could see during inspections if the equipment operates correctly, according to the requirements, or a critical situation came up that requires repair.
Repairs should be done, if possible, with a minimum number of disassembling – assembling operations, at the very site of operation. This specification is especially important in the design of power support, since taking it out for repair would involve stopping work at face, removing equipment, which would entail heavy costs, due to production losses and high transportation costs from underground to surface and back again.

2.3.12 Design for easing recycling

Any product has a well-determined lifecycle. Design should have in mind economical recycling when the product is decommissioned.
Saving and using raw materials, including recyclable materials is beneficial both from economic point of view and for the environment.
Economical disassembling, ease of material separation, selection and adequate marking of recyclable material will be considered in design stage already.

References

1. ZAMFIR,V., ILIAŞ,N., and ANDRAS, I. – *Susţineri mecanizate miniere*, Ed. Tehnică, Bucureşti, 1993
2. ILIAŞ,N, ANDRAS, I, SERAFINCEANU, A., GRUNEANŢU, I., and RADU, S. – *Noutăţi în susţinerea abatajelor*, Ed. Universitas, 2001
3. DUBBEL – *Manualul inginerului mecanic*, Fundamente, Ed. Tehnică, Bucureşti, 1998
4. KORONKA, F. – *Exploatarea, întreţinerea şi repararea utilajului mecanic minier*, Ed. Tehnică, Bucureşti, 1993
5. MATACĂ, E. – *Tehnologie de mecanizare complexă pentru minele de cărbune*, Ed. Tehnică, Bucureşti, 1993
6. MARIAN,I. – *Mecanizare în minerit,* Ed. Tehnică, Bucureşti, 1977
7. MATACĂ, E. – *Complexe mecanizate din abataj,* Ed. Tehnică, Bucureşti, 1977
8. *** - *Manualul inginerului de mine*, vol ****, Ed. Tehnică, Bucureşti, 1988
9. *** - *Cărţi tehnice ale susţinerilor mecanizate,* SMA-1, SMA-2, SMA-PH1, SMA-PH2, CEPROM, Satu Mare, filiala Petroşani
10. ILIAŞ, N., KOVACS, A. – *Creşterea calităţii susţinerilor mecanizate de abataj prin aplicarea principiilor proiectării constructive. Asigurarea şi promovarea calităţii.* Nr. 2/2002 INID Bucureşti
11. KOVÁCS , A. – *Contribuţii la îmbunătăţirea susţinerii mecanizate în funcţie de utilajele din complex şi de interacţiunea cu rocile înconjurătoare*. Teză de doctorat – 2006
12. ANDRAS, A. – *Studii privind perfecţionarea metodologică de proiectare a echipamentelor pentru industria extractivă* – Teză de doctorat - 2006