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Virtual Learning Environments Practices, in the students of System Engineering of the Tecnologico Nacional de Mexico, Campus Mexicali

Jesus Francisco Gutierrez Ocampo

Corina Araceli Ortiz Perez

M.C. Jose Antonio Camaño Quevedo

Abstract.

The virtual learning environment is not just about taking a course and placing it on a computer, it deals with a combination of resources, interactivity, support and activities of structured learning. To carry out this process it is necessary to know the possibilities and limitations that the computer support or virtual platform offers us, so that the students achieve their study objective more adequately, for that reason its use is studied in the students of computer systems engineering career of the Tecnologico Nacional de Mexico, Campus Mexicali.

Keywords: Virtual Learning Environments, TECNM, Ingenieria de sistemas.

Introduction

This 2018 participates in the entrance exam to the Tecnologico Nacional de Mexico, Mexicali campus, and as a tutor I have to deliver the results of this to a group of students of the Systems Engineering Career of this school, this process is not New, but increasingly it is more important for the results offered by this test to the student and the teacher, to be delivering the results to students, I realized that I was missing information on virtual learning environments, because they are currently used in the vast majority of educational institutions, and I took on the task of researching on this topic that I consider that boosts the competitiveness of the institutions that use them.

Methodology

explaining how this research was carried out, based on the conception of the idea, and its problematic, we defined the objectives and formulated the questions, then we defined the study population, indicating the main factors for which it has been delimited, including the formula statistics used to determine the sample, the instrument used for compiling the information was designed, which forms the sample, basically focusing on the survey. And, finally, we will detail the assumptions used in the investigation, as well as the statistical results.

n = 75

N = 417

Zα = 1.96

p = .17

q = .17

e = .17

$$n = \frac{417\,(3.8416)\,(0.5)\,(0.5)}{(417-1)(0.0025)+(3.8416)(0.17)(0.17)} = 75$$

Survey:

1. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students.

2. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, is useful for the student.

3. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, is used regularly in classes.

4. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students, will be recommended to other students.

5. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students, considers them necessary for a better learning.

6. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students, Apart from the use in class you have seen them being used in some other career.

7. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students, In the last 12 months you have used them.

8. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students, If you had the opportunity to use this technology you would use it.

9. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students, considers them reliable for use in the classroom.

10. The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali, are known by students, You consider yourself an enthusiast of the virtual learning environment.

With the following multiple choice answers:

a) Strongly Disagree

b) Disagree

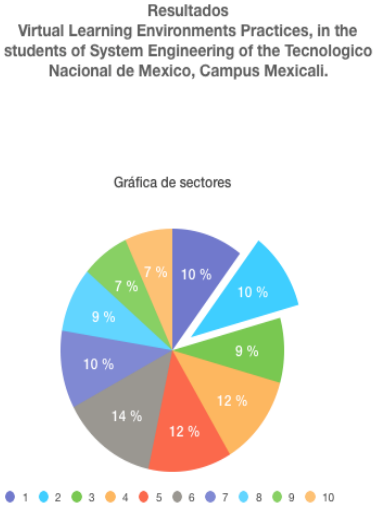
c) I slightly disagree

d) A little agreement

e) Agree

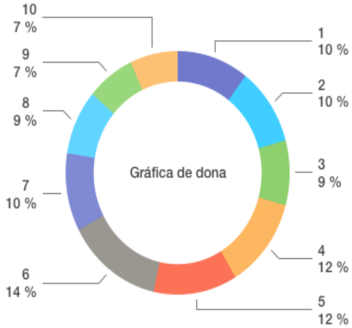
f) Totally agree

Result:



Resultados

CUESTION	ANSWER 1	ANSWER 2	ANSWER 3	ANSWER 4	ANSWER 5	ANSWER 6
1	6	4	5	4	5	7
2	6	7	7	4	7	7
3	5	6	6	3	6	8
4	7	5	7	5	7	8
5	7	5	7	5	7	6
6	8	8	4	6	8	7
7	6	7	3	6	8	7
8	5	4	5	6	5	7
9	4	5	6	7	5	6
10	4	4	4	5	4	6



Conclusion

The virtual learning environment, which is used in the subjects of the career of Computer Systems Engineering at the TECNM Campus Mexicali on the answers obtained it is known by the students, besides being considered useful, and is used regularly in classes, and students recommend it to other students, and consider them necessary for a good learning, it was detected that not all the students use the virtual learning environment.

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The Principles of Energy Efficient Microclimate Provision in the Skyscraper "Biotecton" of 1 km Height

Krivenko O.

PhD, associate professor, Department of Architectural Constructions
Kyiv National University of Construction and Architecture, Kyiv, Ukraine

Mileikovskyi V.

PhD, associate professor, Department of Heat Gas Supply and Ventilation
Kyiv National University of Construction and Architecture, Kyiv, Ukraine

Tkachenko T.

PhD, associate professor, Department of Labor Protection and Environment
Kyiv National University of Construction and Architecture, Kyiv, Ukraine

Abstract

The article deals with the formation of a healthy human living environment in superstructure buildings with the requirements of indoor air quality, environmental and constructive safety. The results of the development of "Biotecton" - an ultra-high-rise multi-functional building (the height is 1000 m) are presented. In order to effectively overcome the wind and seismic loads, the principles of the structure of the natural form (Gramineae stems, Triticale) are used. It is a multi-tiered spatial structure, in the nodes of which there are dampers for limiting oscillatory movements. For solving the problems of increasing the energy efficiency of ventilation and air conditioning, the use of air from height 1000 m with the minimum of anthropogenic pollution is investigated. Two mechanisms of the movement of air in a superstructure were investigated: natural impulses (under the action of gravitational pressure and wind) and mechanical (fans). It is shown that the natural pressure is insufficient for air movement. The mechanical impulse is necessary, but its energy requirement can be compensated by a renewable energy source - wind turbines with a total capacity of 5.3 MW. For high air quality, the use of "oxygen gardens" in green areas, which are evenly spaced along the entire height of the building, is explored. The study proposed a list of plants that effectively clean air from pollution, sequestrate excess CO_2, enrich the air with oxygen and release phytoncides that effectively fight against pathogenic microorganisms.

Keywords: superstructure building, skyscraper, indoor air quality, ventilation, oxygen gardens

1. Introduction

In connection with the consolidation of the development of cities-metropolises throughout the world, the active implementation of the "fabric" of the city is not only high-rise buildings but also tall buildings (above 75 m). Every year, the number of high-rise buildings in the world is growing, which is due to the demand for such types of objects and the development of the latest architectural, engineering, engineering and design solutions.

Skyscrapers bring people very high above the surface of the earth, which separates them from the natural environment. There is a need for an artificial microclimate of skyscraper premises with the requirements of temperature, humidity, gas composition of air, environmental safety of premises, intellectualizing of the building, etc. The energy component of the maintenance of a skyscraper is growing, which complicates the balance of the relations of natural and artificially created environment.

The task of creating vertical spatial structures based on natural forms capable of interacting with the environment to ensure their viability was the basis for the development of the skyscraper "Biotecton", capable of overcoming the height of 1000 m, conducted by scientists and students of the Kyiv National University of Construction and Architecture since 2015. As a basis, the stem of cereals has been taken as a shape-forming architectural and constructive element. The constructive shape of the *Gramineae* stems has the same effects of natural influences and mechanical forces as acting on the skyscraper. Stems of cereals with an average diameter of the base of 3 mm can reach a height of 1500 mm. When the coefficient of harmony is 1:500, the rye stem carries a spike, which is 1.5 times heavier than the weight of the stem itself.

2. Previous studies

Previous anatomical studies conducted by scientist Alexey Lazarev (*Lazarev A, 1985*) confirmed that the internal structure and relationships between the structural elements of stems can effectively bear the loads on the vertical spatial structure (Fig. 1).

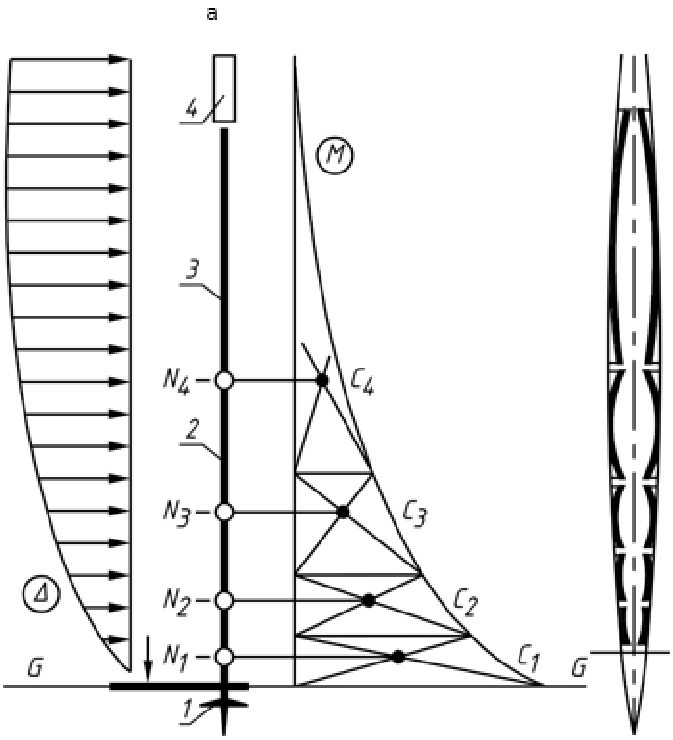

Figure 1 Features of the structure of the stem of wheat:
a – scheme of static work of the wheat stem by the architect A. Lazarev and the engineer G. Sarkisian;
b – structure of the stem of wheat:
1 – root; 2 – internode; 3 – stem; 4 – spike; N_1 ... N_4 – stem nodes; G – G – the ground level C_1...C_4 – centres of equal planes on the diagram M of bending moments; Δ – the displacement diagram

As a result of anatomical studies of *Gramineae* stems, *Triticale*, the following features of the shape of its structure were determined:

- a stem of cereals is a multi-tier structure, which is divided into a number of internodes, which reduce the force of wind pressure and the load;
- internodes of stems have a spindle-like shape, which reduces the deflection;
- at the nodes of the stem there are dampers – elastic hinges that form a dynamic damping system to limit the oscillatory movements of the stem;
- additional stability is provided by a mutual arrangement in the stem of firm and soft tissues, their ability to work both on compression, and on stretching;

- the cereal root system is a strong complex system, which consists of the main vertical root, lateral roots, more roots developing in different directions.

3. The basis of the "Biotecton" structure

The three-dimensional shape of the ultra-high-rise building "Biotecton" of height 1000 m is based on the tectonic structure of rye, which is musty-tier and multi-functional structure. The effectiveness and efficiency of the bearing system of "Biotecton" are achieved by separating the structure of the building by three dampers, spindle-like shape with minimal reliance area, the system of braces, stiffening core and root-like foundations to ensure effective mounting of the structure.

The damper is a dynamic shock absorber system, which allows fading of the amplitude of oscillation and increasing of seismic resistance. The model of the damping system (Fig. 2) of "Biotecton" is based on the results of anatomical studies and experimental tests on the vibrating bench in the laboratory of aerodynamics. The damping effect (quenching) fluctuations in the model "Biotecton" has been confirmed using devices Bruhl and Kyer (Denmark).

Multi-tiered, multifunctional structure "Biotecton" has free spaces, allowing their free use while ensuring efficiency and economy.

4. The grounding of air exchange principles

4.1. Main principles

An important principle of designing "Biotecton" was the creation of a comfortable environment for people. One of the main factors of comfort is the provision of air exchange for the organization of a healthy microclimate in premises with suitable heat-humidity conditions.

A significant part of the glazing of the facades and the impossibility of traditional ventilation of the premises through open windows leads to a significant increase in power demand for air conditioning. These and other factors cause special design of air exchange in "Biotecton" and require researches of energy-efficient solutions. At the level of 1 km, there is fresh, cool and clean air independently of artificial pollutions at the Earth's surface. Therefore, it is a good idea to take the air from the upper levels of "Biotecton". The air will move down (Fig. 3) by a duct in the inner stiffening core and after that will be distributed by premises. At the altitude of 1 km, the air temperature during the warm period of the year is lower (ICAO, 1993) than on the surface of the Earth by 6.49 °C/km (averaged value), which reduces the energy consumption for air cooling.

In this great building, there is a necessity for high air exchange amount. For energy efficiency, we need to search for ways of reducing the air demand, decreasing the energy for air movement and treatment.

4.2. The grounding of the air movement motive

Two options for air movement motive are used in ventilation and air conditioning: natural (under the action of gravitational pressure and wind) and mechanical (fans). If the temperature of the external air near to the ground level is 32 °C (305.15 К), the temperature of the intake air at the level of 1 km will be t_{ext} = 32 – 6.49 = 25.51 °C or T_{ext} = 298.66 К. The density of this air coerced to the standard atmospheric pressure is (Mileikovskyi & Klymenko, 2016) ρ_{ext} = 353 / 298,66 = 1,1819 kg/m³. Comfortable air temperature during a warm period of a year for the design of buildings and microclimate systems (EN 15251:2011 (2011) in residential buildings, office space, conference halls, classrooms, restaurants is t_{wz} = 26 °C. (T_{wz} = 299.15 K) The corresponding air density is ρ_{wz} = 353 / 299.15 = 1.1800 kg/m³. Gravitational pressure on the ground floor (height between the air intake and the premises is about H = 1000 m) at gravitational acceleration g = 9,80665 m/s² is $\Delta P_{gr} = (\rho_{wz} - \rho_{in})\, g\, H$ = = (1,1819 – 1,1800)·9,80665·1000 = 19 Pa, which is not enough for a kilometre network of air ducts. Another negative aspect of the use of gravitational pressure was studied by the authors in the paper (Mileikovskyi & Klymenko, 2016): natural ventilation has low energy efficiency. Energy (heat) of exhaust air (total energy) is [W]

$$E_{tot} = \Delta Q = c_p\, \rho_\ell\, L\, (T_\ell - T_{ext}), \qquad (1)$$

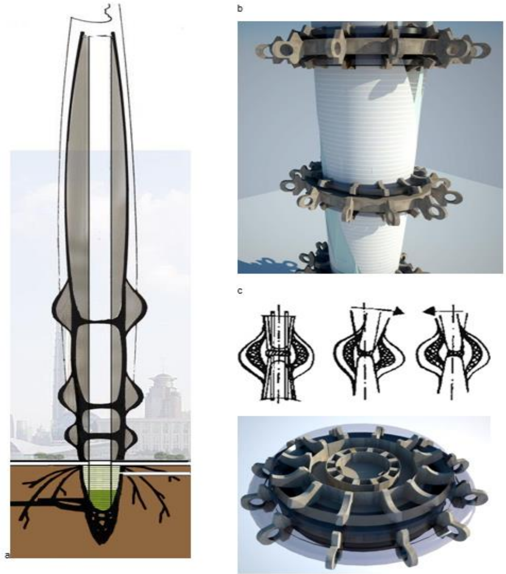

Figure 2

Demonstration system "Biotecton":

a – sketch of placement, b – general view of the damping system, c – wheat stem damper, d – an element of the damper

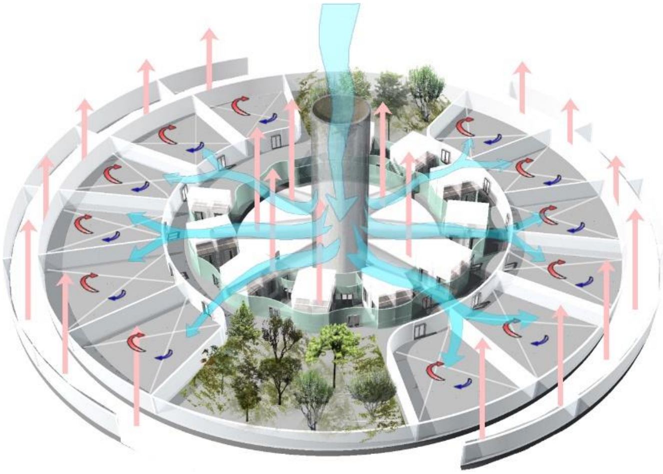

Figure 3 Spatial scheme of the ventilation system in "Bietekoton"

where c_p = 1006 J/(kg·K) – isobar heat capacity of air (Mileikovskyi & Klymenko, 2016); L – volume flow rate of air, m^3/s. For simplicity, sensible heat is used, which leads to a certain underestimation of the heat supply and an overestimation of the efficiency of the system. Useful energy is the energy that is used for the movement of air through the air ducts (with pressure losses equal to the gravitational pressure [Pa]) [W]:

$E_{usef} = \Delta P L.$ (2)

The effectiveness $\eta_{v,g}$ of the natural ventilation is determined (Fig. 4) as the ratio of the useful energy E_{usef} [W] to the total E_{tot} [W] taking into account the formulas (1...3):

$\eta_{v,g} = E_{usef} / E_{tot} = g H / (c_p T_{ext}) = 9{,}75 \cdot 10^{-3} H / T_{ext}.$ (3)

By Fig. 4 the effectiveness of natural ventilation in the cold period of the year is only 3.5%. Therefore, the mechanical ventilation with the heat (cold) utilization from exhaust air should be preferred. For this purpose, it is proposed to use mechanical combined extract and input ventilation units with heat pumps located in technical spaces. They take air from the duct, located on the axis of the building. For disposing the exhaust air, other airline in the stiffening core can also be used. Air release can be carried out under the facade glazing to transport it to the top of the building. The condition of using this space is to prevent the condensation of moisture on the glass in the cold season for these climatic conditions. Condensation worsens the operating conditions of the enclosing structures and distorts the view from the windows.

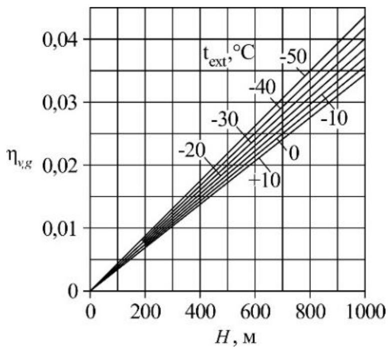

Fig. 4. Schedule of the coefficient of efficiency of natural ventilation

(Mileikovskyi & Klymenko, 2016), extended to 1 km

Typically, the pressure of embedded fans in the standard combined ventilation units is not sufficient to provide the movement of air by kilometre air ducts. Therefore, we should install an additional fan or fans that will create sufficient pressure and air flow in the air ducts. At the top of the buildings, we should use wind turbines to utilize the energy of winds, which are significant at such level. According to preliminary data of mathematical modelling, the wind turbines provide 5.3 MW of energy, which at properly designed airlines and air ducts should be sufficient for air movement.

4.3. Biotechnical method of improving air quality

To improve the quality of the internal air, green zones (Fig. 5) are designed in "Biotecton", which can be used for ventilation on each floor. Interior landscaping of skyscrapers provides an opportunity for improvement of ecological and psychological comfort of a person. Landscaping zones in the vertical spatial structure of "Biotecton" make it possible to give access to the natural environment. In "Biotecton", planting is the basis of the architectural and planning decision. The green interior band may spirally wrap the building. Green areas of common use in "Bietecton" are located one per five floors. The proposed solution gives an opportunity to provide 30 % landscaped volume of the skyscraper and to ensure its even placement in the height of "Biotecton". In fact, thanks to the projected planting system in Bietekoton, a person has access to the natural environment on every floor of the building.

In order to improve the air exchange in the premises of "Biotecton", it is proposed to use "oxygen gardens", which are envisaged by the project in "green zones". Most "oxygen gardens" are above the cloud level. Therefore, they are under the constant influence of solar radiation, which allows obtaining a stable photosynthesis during the year. There are two options for using "oxygen gardens":

1. The inflow air with the flow rate G_{ext} [kg/s] and the concentration of CO_2 q_{ext} [ppm] is fed to oxygen gardens, where it is further enriched with oxygen, and after that, the air

will be supplied to other premises. This solution allows getting the best conditions for people to rest in the "oxygen gardens";

2. Some part of the exhaust air with flow rate G_R [kg/s], and CO_2 concentration q_ℓ [ppm] from the premises without the possibility of release of harmful and odoriferous substances is recirculated to oxygen gardens, which, through sequestration of CO_2 will be enriched with oxygen and becomes re-usable. Due to the increased concentration of CO_2 in the exhaust air, plant growth improves.

Figure 5 A three-dimensional planning solution of the biotecton planting system: a – general view of "Biotecton", b – floors with greening; c – section of greening; d – general view of "green zones"; e – turn of greening zones on different floors

For the accepted assortment of plants, it is possible to calculate the total sequestration of CO_2 ΔS [mg/s]. Then the decrease in the concentration of CO_2 [ppm] in the air passing through an "oxygen garden" with the flow rate G [kg/s] is [ppm]

$$\Delta q = 1000\ \Delta S / G. \qquad (4)$$

Air and CO_2 balance in the "oxygen garden" [kg/s, mg/s]

$G_{ext} + G_R = G_{in}$. (5)

$G_{ext}\, q_{ext} + G_R\, q_\ell - \Delta S = G_{in}\, q_{in}$. (6)

Required flow rate by of external and recirculated air in the "oxygen garden" using equations (5) and (6)

$G_{ext} = G_{in}\,(q_\ell - q_{in}) \,/\, (q_\ell - q_{ext})$; (7)

$G_R = G_{in}\,(q_{in} - q_{ext}) \,/\, (q_\ell - q_{ext})$. (8)

If recirculation is not used, the reducing of the standard sanitary norm G_{norm} [kg/s] of external air can be achieved up to [kg/s]:

$G_{ext} = G_{norm}\,(q_{ext} - \Delta q) \,/\, q_{ext}$. (9)

Thus, "oxygen gardens" reduce the need for outdoor air, and thus increase the energy efficiency of ventilation and air conditioning. They are a biotechnical method for energy-efficient indoor air quality achievement.

4.4. Plant assortment for air quality control

Although plants have no specialized respiratory organs, they are actively taking part in gas exchange. This phenomenon is based on two of the most important physiological processes: photosynthesis and breathing. For photosynthesis, plants absorb CO_2 from the ambient air. One of the final products of photosynthesis is oxygen, without which the existence of all living things on our planet would be impossible. The process of respiration of plants in many respects is the opposite to photosynthesis.

Unlike many animals, plants do not have adaptations that would provide an active flow of gases. They penetrate into plants solely by osmosis, that is through passive diffusion along the formed gradients of concentration. The gases contained in the tissues of a leaf, in a cortex, in a stalk and in a root, are also passively moved by the special intercellular moves. These "gas pipelines" are combined with ambient air with the help of stomata that are located on the surface of leaf plates. Plant cells can be considered as tiny water containers. Many gases are well soluble in the aqueous phase. Thanks to this, the absorption of gases by plants is very fast. It is known that many harmful substances cause plants to intensify the processes of respiration. Consequently, plants react actively to them. It is logical to assume that in the process of the long evolution in plants, they implemented protective mechanisms that allow neutralizing harmful substances and gases entering the tissue together with carbon dioxide. This assumption is confirmed in (*Yan Van der Neer (2005)*. Specialists of NASA have derived a generalized coefficient of air purification efficiency of plants (Table 1). It was calculated taking into account the degree of danger of absorbed gases, the breadth of their spectrum, and the rate of their absorption. This coefficient is expressed in terms of units and is located on a numerical axis in the range from 0 to 10.

For qualitative air, it is also recommended to use phytoncide plants, through which the air of the premises is restored. For "oxygen gardens" it is recommended to additionally use plants with CAM-metabolism, which contributes to limiting the loss of moisture during nights. As a result, in these plants, stomata are opened at night to absorb CO_2 and store it in the form of organic acid in vacuoles of cells. At day, the stomata are closed. The organic acid decarboxylates again to CO_2. Such plants include, for example, species of the genus *Sedum*, which may be promising for the "green vertical" walls in the rooms.

Thus, "oxygen gardens" reduce the need for outdoor air, and increase the energy efficiency of ventilation and air conditioning.

Conclusions

For the provision of a stable and healthy operation of skyscrapers, it is possible to use natural shapes. "Biotecton" - a building with high of 1 km – is stable and can provide high indoor air environment quality due to use of the shape of rye. The calculations presented have shown that natural ventilation is not able to provide normative air exchange in the premises of "Biotecton" during the warm period of the year due to low natural pressure – less than 20 Pa.

Table 1. Absorption by plants of poisonous substances

Appointment	Absorbed substance	Cleaning quality	Recommended use for premises
Aglaonema	Benzene, toluene	6,8 P	with artificial carpeting
Azalea	Formaldehyde	6,3	in rooms of any type
Aloe	Formaldehyde, tobacco smoke	6,5	in recently built or renovated
Anturium	Formaldehyde, ammonia, toluene	7,2	of any type
Araucaria	Various impurities	7,0 P	offices and halls
Musa	Formaldehyde	6,8	greenhouses and winter gardens
Begonia	Volatile chemical compounds	6,9	of any type
Guzmania	Formaldehyde, toluene	6,0	of any type
Dendrobium	Methanol, acetone, formaldehyde, ammonia, toluene	6,0	offices
Dieffenbachia	Formaldehyde	7,3	of any type, except children's
Dracaena	Formaldehyde, benzene, trichlorethylene	7,8	of any type
Kalanchoe	Formaldehyde	6,2 P	of any type
Calathea	Formaldehyde	7,1	selectively in offices and

			rooms
Codiaeum	Volatile chemical compounds	7,0	selectively in offices and rooms
Maranta	Various impurities	6,6	in the winter gardens; in largely backlit aquariums
Neoregelia	Toluene, various impurities	6,4	of any type
Nephrolepis	Formaldehyde	7,5	in the dark with high air humidity
Peperomia	Formaldehyde	6,2	of any type
Hedera	Formaldehyde, trichlorethylene, benzene	7,8	of any type
Sansevieria	Formaldehyde, trichlorethylene, benzene	6,8	of any type
Syngonium	Formaldehyde	7,0	of any type
Spathiphyllum	Formaldehyde, acetone, trichlorethylene, benzene	7,5	of any type
Scindapsus	Formaldehyde, benzene	7,5	of any type
Tradescantia	Formaldehyde	7,8	of any type
Phalaenopsis	Formaldehyde, toluene	6,3	of any type
Ficus	Formaldehyde, trichlorethylene, benzene	8,0 P	of any type
Philodendron	Formaldehyde	7,0	of any type
Phoenix	Toluene	7,8	of any type
Chlorophytum	Formaldehyde, carbon monoxide, tobacco smoke	7,8 P	of any type
Chrysalidocarpus	Formaldehyde, trichlorethylene, benzene	8,5	with high air humidity
Cyclamen	Летючі органічні сполуки	6,0	with high air humidity
Cissus	Volatile Organic Compounds	7,5	in semi-oiled spaces of any type
Schefflera	Formaldehyde, benzene, toluene	8,0	in rooms of any type
Schlumbergera	Volatile chemical compounds	5,6	in well-lit rooms any type
Aechmea	Formaldehyde, volatile organic compounds	6,8	in rooms of any type

Remark. P - phytoncides emissive plant

In the cold season, natural ventilation has a low efficiency of 3.5%. Therefore, the advantage must be given to mechanical ventilation with the utilization of heat (cold) of exhaust air. At the same time, it is recommended to use a renewable energy source – wind turbines with a total capacity of 5.3 MW. It is expedient to remove air from the upper part of the building through clean air and more moderate parameters than in the surface layer. It is a good idea to use "oxygen gardens" with plants that clean air from pollution, to sequester excess CO_2, enrich the air with oxygen, and release phytoncides that effectively fight against pathogenic microorganisms, in order to decrease the necessary airflow.

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Study on Urban Sustainable Restructuring of Leinefelde, Germany and Revealing the Important Strategies for Environmental Well-Being for Shrinking Cities

Sri Charan P

Assistant Professor, Faculty of Architecture,
Manipal Academy of higher education, India

Abstract

Why habitat Mars when you can make earth livable. Demographic change led to the shrinking of the city and also aging native population were big problems in leinefelde. Sustainable urban structures, housing affordability and availability was a big criteria. The political and economic change in the eastern Germany after reunification in 1989, anticipated and intensified the problems. By 1993 municipality realized that it should develop strategies and policies to stop the breakdown of economic and political breakdown of the city. As a result of the actions taken, leinefelde has become successful transformation of shrinking cities in the world. This research paper finds the problems led to shrinking of the city and then focuses on the different parameters and strategies like project context, social aspects, environmental aspects, economic aspects, organizational aspects, sustainable aspects that were carried out in order to have a successful transformation of leinefelde. And finally list down the key indicator for project being successful as a conclusion.

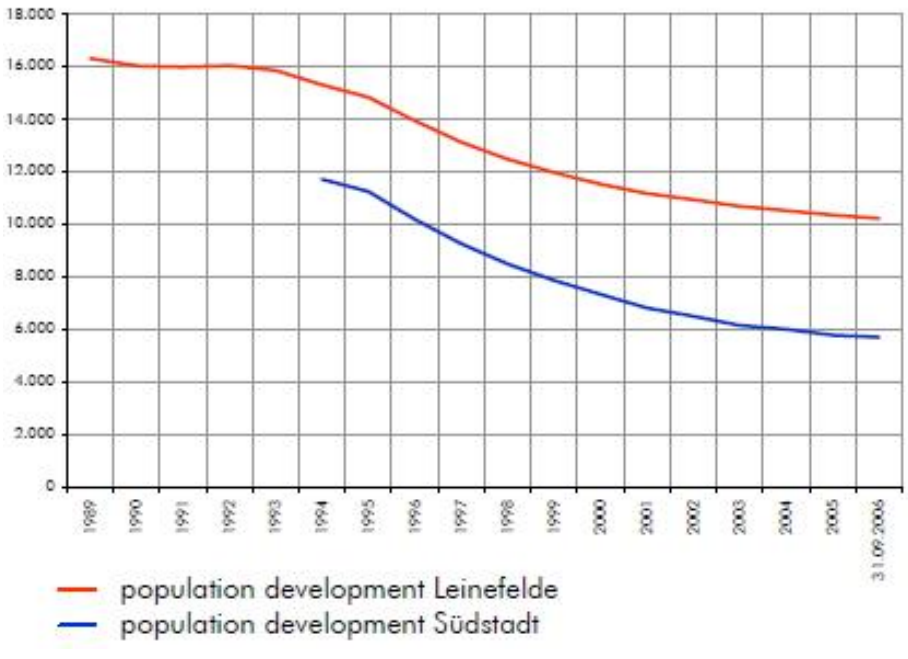
Keywords: Restructuring, project context, social characteristics, environmental features, economic aspects, organizational aspects, sustainable and innovation.

Introduction

Until 1960s leinefelde was a small village in the rural eichsfeld region. The division after World War II led the village separated from its traditional markets and West Germany economy. Subsequently, in 1960 East Germany government began a large industrialization for the region "Eichsfeld Plan". Which led to the village from 2500 habitants to 16500 modern industrial town. In corresponding to the construction of textile industries in leinefelde, a new town was developed – Sudstadt. Sudstadt town was designed to the predominant ideal socialist town: blocks of pre-fabricated flats set in a green landscape, sports fields and infrastructure facilities. In 1969, Leinefelde was given an eminence of an urban municipality, with responsibilities and rights of East Germany's

German democratic republic (GDR). After twenty years, the reunification of Germany gave leinefelde status as urban municipality and in 1990 municipal council and mayor were elected in the first free vote after the world war[1].

In 1993, lot of local population was leaving leinefelde to find the fortune somewhere else. The main reason is because of the reunification of Germany led to change from an organized to a market economy, this in general has changed the value system and socialist housing policy. The main reason is the lack of sustainability, soon it became evident and downfall of textile branch after reunification destroyed the economics of the town. This led to the growing unemployment rates in the city and many people left to the most prosperous regions in Germany which led to the vacant flats. And in the competitive housing market, standardized pre-fabricated units with low quality were rejected which were the major housing units. People who are better off moved out from the apartments and owned their new houses. This directed to the depopulation of leinefelde and sudstadt, native population is decreasing and aging population added more to collapse of the city.



Graph 1: Depopulation in leinefelde and sudstadt

By analyzing the graph it is evident that the demand for rental property in the city was decreased by 50 percent.

But 1993, Mayor and administration took the following first steps towards sustainable urban development of the city:

- Subsidy program run cooperatively by the German federal government and the state of Thuringia.
- Authorizing an urban development master-plan in order to explore the potentials of the sudstadt district.
- Implementing an initial pilot project "the refurbishment of boniftius square"- Public open square.
- Municipality with its responsibility for urban and social enhancements had been involved in number of actions, Such as:
- Establishing a participative development process.
- Encouraging economic development.
- Public subsidies for transformation processes.
- Commencing quality and quarter management.
- Renewing flats.
- Renovating all social and technical infrastructures under public responsibilities.

Main Aims and Strategies of the Project:[1][2]

- Maintaining balance between employment capacities, number of habitants, urban structures and housing volumes.
- Improving surroundings, environment and living conditions.
- Promote affordable and attractive housing.
- Progress social, economic and community life in the city.

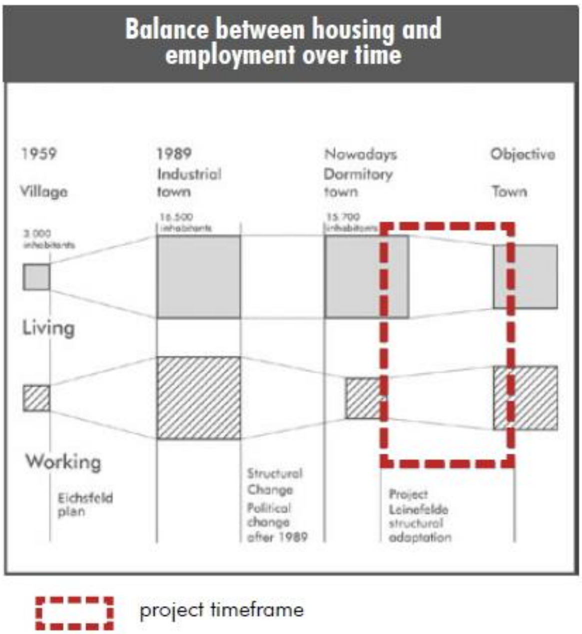


Fig 1: Balance between housing and employment over time.

The above mentioned aims were achieved by following strategies:

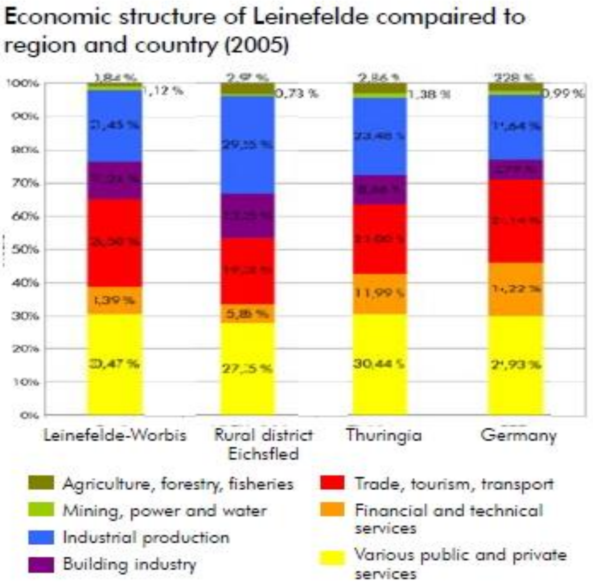
- Sustainability through contribution.
- Sustainability from employment and a diversified economy.
- Sustainability through energy conservation and recycling of building materials.
- The master plan as an apparatus of direction.
- High excellence public amenities and infrastructure to make town attractive.
- Demolition of empty apartment building to offer new urban potentials and market steadiness.
- Improvement of the housing surroundings.
- Making difference between private and public space to have "ownership".
- Different housing typologies as a means of social amalgamation.

2.1 Sustainability through contribution

Photo 1: Communal participation in the project

Main idea for all the activities to be based on coordination between stakeholders and the target groups in order to promote ownership. Active local participatory is important for establishing sustainable investment in housing renovation.

2.2 Sustainability from employment and a diversified economy



Graph 2: Economic structure of Leinefelde

The reason for unemployment and migration in the city was because due to one-dimensional structure of the economy. To solve this, the municipality promoted the establishment of new enterprises with a different range of activities. Empty textile factory was converted into accommodation facilities, newly designed industrial area and trading estates provided complementary opportunities.

2.3 Sustainability through energy conservation and recycling of building materials

Photo 2: Recycling and reuse.

The demolition and the dismantling of prefabricated concrete slab construction from housing units helped to procure the transformation process with raw materials which are reused both in construction and landscaping. As a result, it reduced transportation and dumping cost. Interesting landscaped almost free of cost.

2.4 The master plan as an apparatus of direction

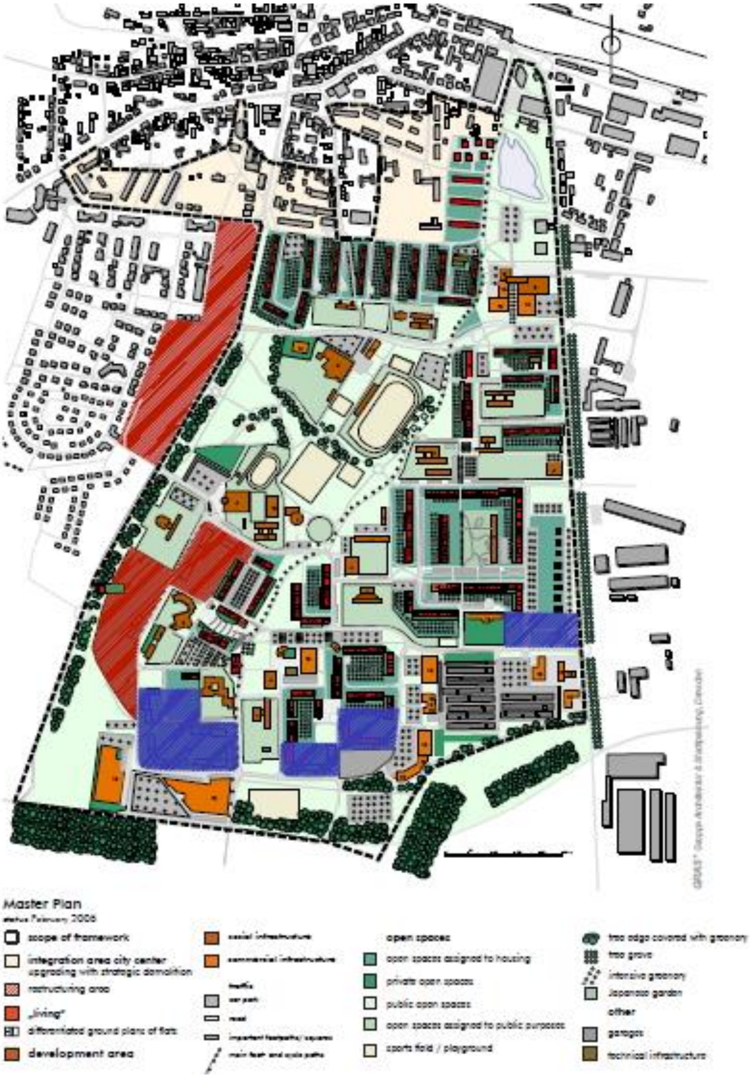


Photo 3: Master plan of leinefelde

First stage of the project included master plan drawn and agreed in 1995. It basically established guidelines for renewal and in particular to the core area. Master plan is a result of discussion between stakeholders.

2.5 High excellence public amenities and infrastructure to make town attractive

Photo 4: New swimming pool

To stop the outward migration, municipality with partners offered high quality facilities and infrastructure like new swimming pool, kindergartens and public transport system. Public investment is for communal good and also provide sustainable private investment in the city.

2.6 Demolition of empty apartment building to offer new urban potentials and market steadiness [3]

Photo 5: Dismantling of prefabricated houses.

It was decided that 50% of the existing housing will be demolished and the remaining renovated in order to improve urban quality and to have healthy housing market. Reducing density, improving and opening urban spaces will revitalize the core area.

2.7 Improvement of the housing surroundings

The project ensured different types of open spaces for private, semi private and public use. Variety of flora and fauna in open spaces improve the ecology of the surroundings. Parking, courtyards and accessibility were designed for easement.

Photo 6: Urban landscape near housing.

2.8 Making difference between private and public space to have "ownership"

Photo 7: Private, semi private and public space.

A very clear divisions were made between private, semi private and public spaces. Giving spatial transition when accessing different spaces. Special importance to the public squares as it is more intensifies public life and civic individuality.

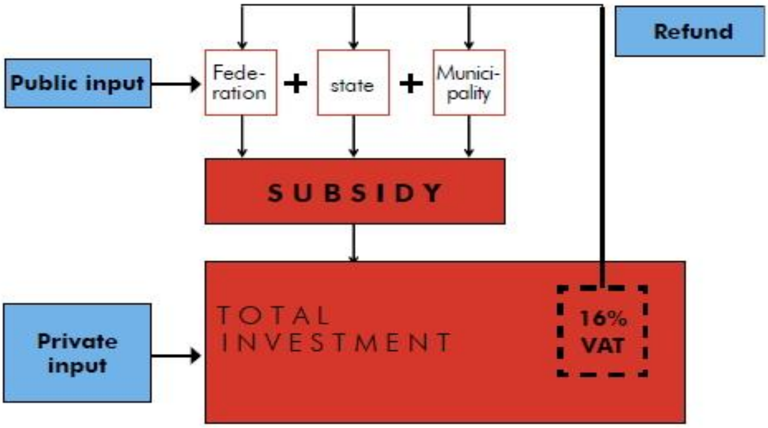
2.9 Different housing typologies as a means of social amalgamation

City had different social categories with a features in socialist housing schemes. To preserve the mixture in a market economy, a variety of housing typologies were designed and constructed. Renovation projects aimed at individualize flats, building and housing area.

Photo 8: Successful reconstruction of apartments.

Photo 9: Successful renovation of apartments.

3 Financial Aspect



Flow Chart 1: All the aspects of finances for the project. [1]

The project financed according to the renovation and renewal of the following facilities:

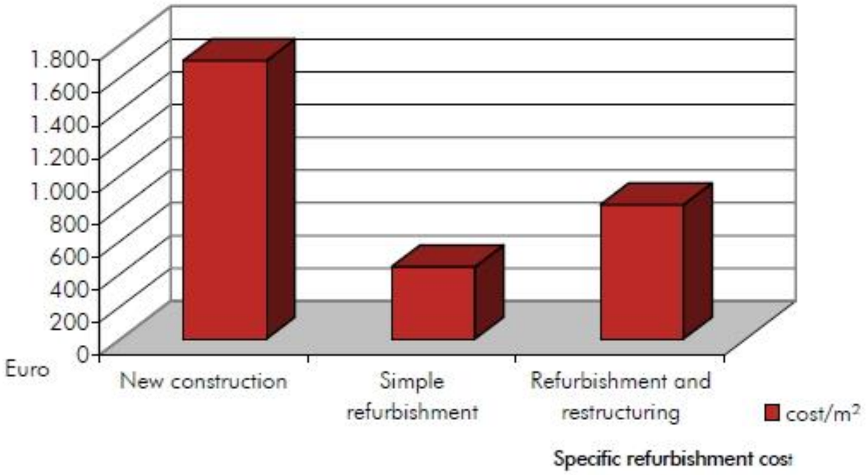
Housing renovation generally offer finance with interest rates to cover nonprofit yielding expenditure.

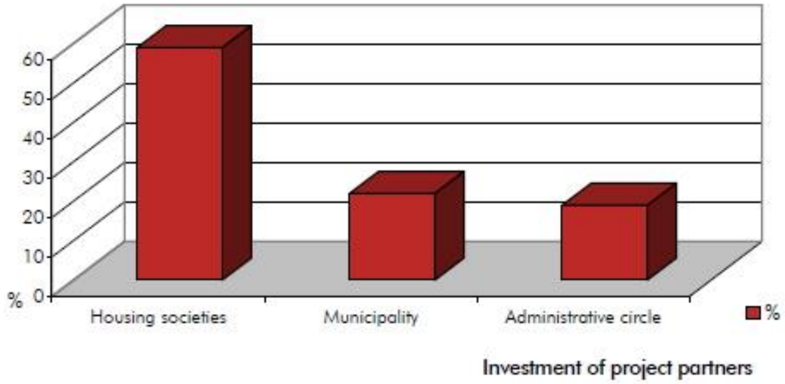
Urban renewal is mainly to target public facilities. The municipality bears almost 25 to 30% of the cost.

In 2002, a new program was offered that aims to associate market by financing the demolition of vacant flats. 100% subsidy in case of simple demolition.

Since 1993, a total of 140 million euros has been invested in refurbishment, new construction and private green space.

Average investment for renovation varies from 470 euro/meter square to 820 euros, which is still less than the half of the construction of new building.





Graph 3: Cost per square meter and investment of project partners.

4 Social Aspects [1][6]

The integrated approach helped develop employment opportunities and town with great levels of urban quality. This allowed inhabitants to develop social and physical environment. The following have proven for encouraging social sustainability and community empowerment:

Discussions between municipality, landlords and tenants.

Survey on residents for their current state and their hopes and expectations.

A regular newspaper for the updates.

Workshops for particular project for tenants and stake holders.

Social service center offers assistance to problem groups.

Different standards of renovation: no exclusion for low or high income group.

5 Environmental aspects [1]

To improve environmental quality is important factor for sustainability and helped in the transformation process in leinefelde and the principles followed are as follows:

Diversity and intensity by planting different local species of trees and vegetation.

Established biological links and micro climatic exchanges in landscape areas.

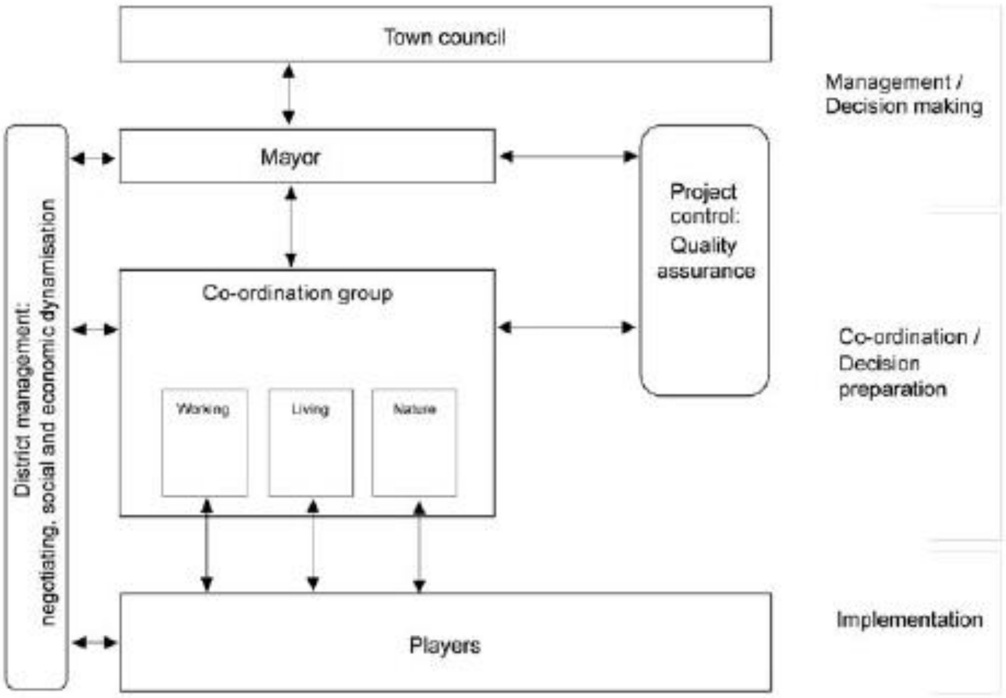
Improvement of the energy efficiency of buildings by modern heating, technologies and renewable fuel.

The reuse of concrete slabs and pieces for landscape architecture and allow of entire concrete slabs for the construction of detached houses.

Reconstitution of ground water is important for sustainable bio diversity.

Improving pedestrian areas and cycle paths.

6 Organizational aspects



Flow Chart 2: Organizational chart for entire project

Organizational setup of the project places all the different stakeholders under common leader. The key factor is the balance between individuals, common interests and project decisions.

Regular meetings, guarantee coordination and quality management is necessary for the whole transformation process. District management provides link between habitats and the project. It collects and distributes information both direction. It works actively to improve social situations of long term unemployment, lack of qualification and family troubles. From the start, municipality engaged an external consultant for strategic planning, coordination and quality management. The consultant closely works with mayor and head of the urban development.

7 Monitoring and evaluating [5]

The project was regularly monitored using global indicators: demographic data, urban development, housing supply & demand and the financial & economic situation. These data could be used for the adjustments of the master plan. Two surveys (1994 and 2001) analyzed inhabitant's responses to the project. It confirmed the fundamental change in social attitude, perception of quality.

Conclusion

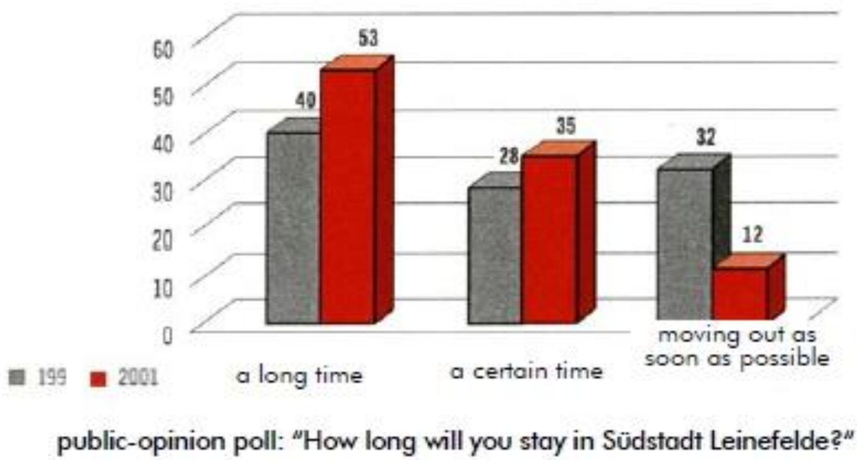
Key indicators of the projects success are conclusion and are as follows [7]:

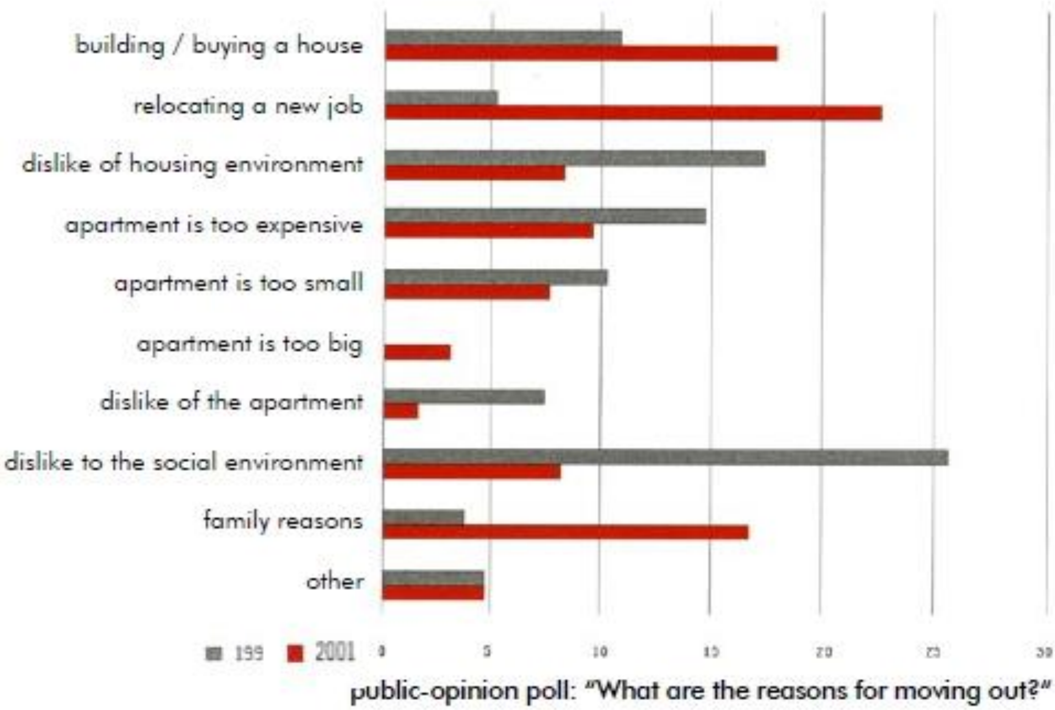
Demographic and social development: demographic erosion has been slowed and 150 inhabitants are lost per year.

Urban development: 1764 apartments have been demolished, 4 years ahead of the project initial schedule, thus anticipating the future reduction in subsides.

Economic development: There are currently 1200 businesses in the city and the regional unemployment rate in 2005 was 15% significantly lower than the state of Thuringia average of 18%.1300 people commute to city for employment opportunities.

Financial situation of municipality: Leinefeldes's municipality debt is 650 euros per inhabitant despite its below average per capita tax income, which is lower than the average in state of Thuringia i.e. 960 euros per inhabitant.





Graph 4: Comparison of parameters of 1991 and 2001

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Analysis of Dimensional Variations of Precision Gear Forging Die Geometry Due to Shrink Fit

Prof. Dr. Omer Eyercioglu

Gaziantep University, Faculty of Engineering,
Mech. Eng. Dept., Gaziantep, Turkey

Abstract

The usual way to shrink fit design for precision forging dies are made by thick wall cylinder approach; i.e., taking the pitch diameter of the gear as bore diameter of the die insert without considering gear tooth shape. However, the compressive pre-stress due to the shrink fitting causes dimensional variations on the gear profile of the die insert. The dimensional accuracy of the final product is dependent on the accuracy of the gear die. Therefore, the dimensional variations due to shrink fit must be pre-determined and the gear tooth profile on the die insert modified accordingly. In this study, the dimensional variations of the precision spur gear forging die because of shrink fitting are analyzed by finite element method and the results are compared with the experimental ones. The results show that the FE model is successful to simulate the cylindrical die and agree well with thick wall cylinder approach and the experimental measurements. However, both the experimental measurements and the finite element results of gear die predict much higher radial displacements than the results of cylindrical die. Therefore, the determination of shape change of the gear die profile is beyond the capability of the thick wall cylindrical approach.

Keywords: Precision Gear Forging, Die Design, Shrink Fit, Finite Element

Introduction

The technology of precision forging has attained great commercial success in recent years. The major application is the forging of gears for high volume commercial sectors such as automobile and truck transmissions (Behrens BA, 2007). The process has been successively applied for straight and spiral bevel gears at first then spur and helical gears have been forged with functional surfaces which can be finished in one operation (Eyercioglu O, 1996, Dean TA, 2000). The current studies are focused on increasing the quality of the precision forged gears for high quality gear transmission applications such as turboprop gearboxes (Eyercioglu, O, 2018). One of the important problems in precision gear forging is the dimensional change of the die components during forging. They subjected to high loads in a very short period of time and should withstand to high static and impact pressures, friction forces between surfaces, and both mechanical and thermal fatigue (Yilmaz. NF and Eyercioglu O, 2018).

As an engineering practice, the die insert is shrunk fit into one or more shrink rings in order to increase the resistance of the die insert against forging pressure. A compressive hoop (tangential) pre-stress on the die insert is created by interference between mating diameters of adjacent rings. The compressive hoop stress imposed by shrink ring has a cumulative effect at the bore of the die insert. Consequently resultant tensile hoop stress on the bore, caused by the forging loads can be substantially reduced. The usual way to calculate the interference allowance between the die insert and the shrink ring is to use thick wall cylinder approach (Parsons and Cole, 1968). The approach is given in detail by Lame (1852). This approach is also used for design of precision spur gear forging dies (Eyercioglu O and Dean TA, 1997) by considering the die assembly as a short cylinder if the facewidth of the gear is not too long. In this case, the die is considered as a cylinder with an inside (bore) diameter equal to the pitch circle of the gear and the actual gear tooth shape is neglected.

However, the compressive pre-stress due to the shrink fitting causes dimensional variations on the gear profile of the die insert. The dimensional accuracy of the final product is dependent on the accuracy of the gear die. Therefore, the dimensional variations due to shrink fit must be pre-determined and the gear tooth profile on the die insert modified accordingly. For this purpose many researcher have been worked on the dimensional accuracy of the gear forging dies (Eyercioglu O 1994, Sadeghi MH 2003, Yilmaz NF, 2009, Eyercioglu, O. 2009). Pederson (2006) suggest two methods (classical plane analysis and a super element technique) to obtain a direct solution without iteration to determine the shape of a shrink fit surface result in a prescribed distribution of contact pressure due to the shrink fit. A theoretical model is presented for predicting involute profile deflection in hot precision forging of gears was presented by Zuo (2017).

In this study, the dimensional variations of the precision spur gear forging die because of shrink fitting are analyzed by finite element (FE) method and the results are compared with the experimental ones. The FE model is verified with thick wall cylinder approach and the experimental results for cylindrical die.

Shrink Fit Design

The thick wall cylinder equations formulated by Lame (1852) are generally used in most shrink fit applications. The interference pressure (p) between die and the ring due to shrink fitting in terms of radial interference, (z), is given as:

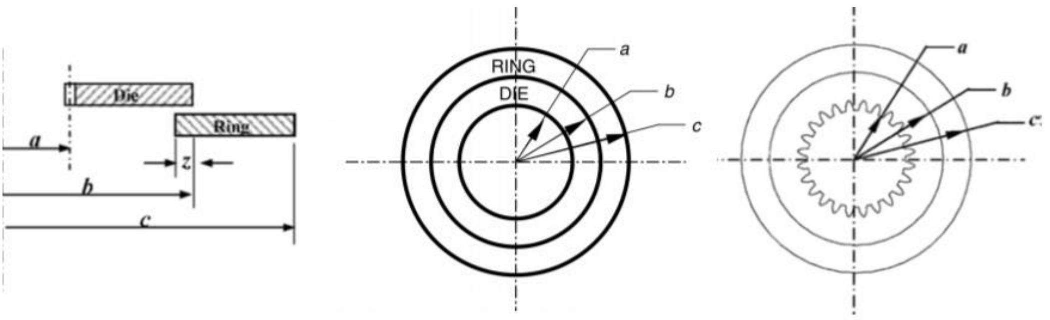


Figure 1. Shrink fit models for cylindrical and gear dies

$$p = \frac{Ez(b^2 - a^2)(c^2 - b^2)}{2b^3(c^2\text{-}a^2)} \quad (1)$$

where (E) Young's Modulus, (a) and (b) are the inner and outer diameter of the die insert, respectively. The die insert that is shrink fitted by the ring, seen in figure 1, is exposed to an external pressure p due to the shrink-fit between die and ring. The tangential (hoop) (σ_t) and radial stresses (σ_r) on the die insert can be calculates as:

$$\sigma_t = -\frac{pb^2}{b^2 \text{ - } a^2}\left(1 + \frac{a^2}{r^2}\right) \quad (2)$$

$$\sigma_r = -\frac{pb^2}{b^2 \text{ - } a^2}\left(1 - \frac{a^2}{r^2}\right) \quad (3)$$

and the radial displacement (u_d) is given as:

$$u_d = -\frac{pb^2}{E(b^2 - a^2)}\left[(1-v)r + (1+v)\frac{a^2}{r}\right] \quad (4)$$

here the variable r varies between limits a and b, and(v) is Poisson's ratio.

Similar equations can be used for the ring can be for the stresses and the radial deflections (u_r) of the ring are written as: (where r varies now between b and c)

$$\sigma_t = \frac{pb^2}{c^2 - b^2}\left(1 + \frac{c^2}{r^2}\right)$$

(5)

$$\sigma_r = \frac{pb^2}{c^2 - b^2}\left(1 - \frac{c^2}{r^2}\right)$$

(6)

$$u_r = \frac{pb^2}{E(c^2 - b^2)}\left[(1-v)r + (1+v)\frac{c^2}{r}\right]$$

(7)

The optimised values of (*b, c, z*) are determined based on the procedures given in Handbook of Metal Forming (Lange K, 1985). For a known die inner radius *a*, radial interference *z*, die outside radius *b* and ring outside radius *c* are given as:

$$z = \frac{b.S_y}{\mathrm{E}}\left(\frac{1}{K_1} - Q_1^2\right)$$

(8)

$b = a/Q_1$ (9)

$c = a/Q$

(10)

where;

$$Q_1 = \sqrt{\frac{1}{2}\left(1 + \frac{1}{K_1}\right) - p'}$$

(11)

$Q_2 = Q_1 \sqrt{K_1}$

(12)

$Q = Q_1 \, Q_2$

(13)

$p' = p_i / S_y$

(14)

$K_1 = S_{y(ring)} / S_{y(die)}$

(15)

here (Sy) is the yield strength.

In the case of gear forging die, the shrink fitting is designed based thick wall cylindrical approach by considering the pitch diameter of the gear is the inner diameter of the die insert. Therefore, the Equations 8-15 are used however, it may be expected that the profile of the gear tooth may cause stress concentrations on the inside surface of the die.

Experimental Procedure

Forging Gear Die

The gear in the study is a 3 mm module (m), 28 teeth (N) and 20^{o} pressure angle standard spur gear (i. e. addendum is equal to module and the dedendum is 1.25 times module). The corresponding pitch diameter is equal to 84 mm (a=42 mm). The height of the inner die and the outer ring is selected as 50 mm. The internal pressure encountered during precision forging of the gear used in this study was taken as 620 MPa from the previous study of the author (Eyercioglu O, 2018). The corresponding die geometry parameters (b, c and z) were calculated by using Equations 8-15 and shown in Table 1. For validating the analytical, simulation (FEM) and experimental results a cylindrical die having 42 mm bore radius was also manufactured. The gear die assembly is given in figure 2.

Table 1. The die geometry parameters

m (mm)	N	E (GPa)	Sy (MPa)	v	p (MPa)	a (mm)	b (mm)	c (mm)	z (mm)
3	28	210	1030	0.3	133	42	66.42	105.05	0.2

Figure 2. The gear die assembly

Die Material, Manufacturing and Shrink Fitting

AISI H13 hot work tool steel was used for inner die and the outer ring materials. The die components are hardened and tempered to obtain 52-55 HRC. The cylindrical inner die and the outer rings for cylindrical and gear dies are machined to required diameters using a CNC lathe and grinding machine in the accuracy of ±0.01 mm. The gear tooth profile was cut by using wire electro discharge machine (WEDM). The inner die and the outer ring were shrunk by cooling the inner die in liquid nitrogen and heating the outer ring to a temperature of about 200° C.

Profile Measurements

The dimensions of the die components and the gear profile before and after shrink fitting were measured by Kemco 3D Coordinate Measuring Machine (CMM) using a 1 mm ruby touch probe of Renishaw. The measurements repeated at least three times to ensure the results.

Finite Element Modeling

For the gear die, a 3D single tooth a model was created in SolidWorks and exported to Simufact Forming FE package. The generated mesh type and the number of elements were tetrahedral and 180000, respectively. Symmetry plane boundary condition applied to the both side of the model. A uniform friction (0.2) and interference z=0.2 mm was applied between the die and the ring. The cylindrical die model was created similarly. The 3D FE models of the gear and cylindrical dies are shown figure 3.

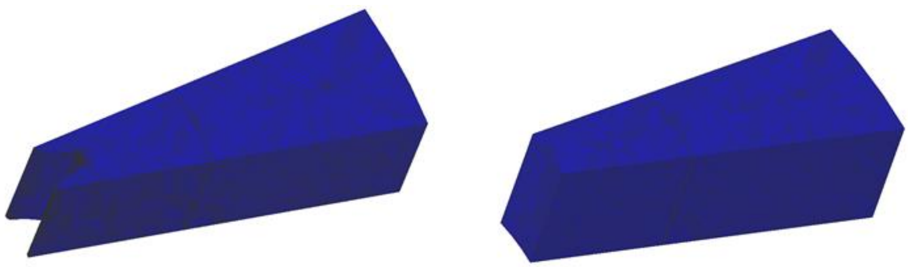


Figure 3. 3D FE models of the gear and cylindrical dies.

Results and Discussion

The Cylindrical Die

The radial displacement (contraction) of the inner die bore radius is calculated as -0.0886 mm by using equation 4. The finite element results (see figure 4) and the 3D CMM measurements given in Table 2 are in well agreement with the analytical one. The 3D CMM measurements of the inner die radius is scattering between 41.909 mm to 41.914 mm, the corresponding radial displacement is in between -0.091 to -0.086 mm. The FE results show a uniform distribution over inner surface with a radial displacement value of -0.0879 mm. The slight differences among analytical, CMM and FEM are coming from the nature of the measurement and truncated values during re-meshing. These results show that the FE model is successful to simulate the thick wall cylinder approach and it is validated with the experimental ones (CMM).

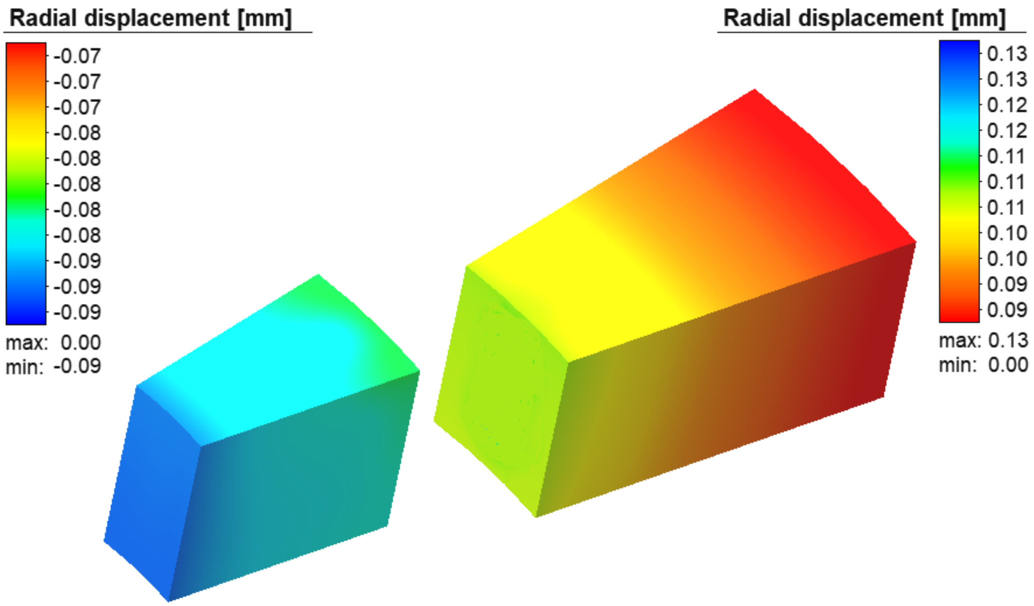


Figure 4. FE results of cylindrical die.

The Gear Die

The radial distance (r) and the corresponding radial displacement (u_r) of the gear profile are given in Table 2. The radial displacement calculated from 3D CMM measurements is scattering between -0.105 mm to -0.114 mm. The FE result shows a uniform distribution over inner surface with a radial displacement value of -0.110 mm as shown in figure 5 and Table 2. The CMM and FE results are in well agreement. However, both the experimental (CMM) and the finite element results of gear die predict much higher radial displacements than the results of cylindrical die (-0.0886 mm). Therefore, the shape change of the gear die profile is beyond the capability of the thick wall cylindrical approach. The gear profiles measured by CMM before and after shrink fit are shown in figure 6. In the design of gear forging die, the gear tooth profile have to be modified before cutting according to obtain the standard gear after shrink fitting. This can be done by adding radial displacement due to shrink fit on the radial distance of tooth profile ($r + u_r$).

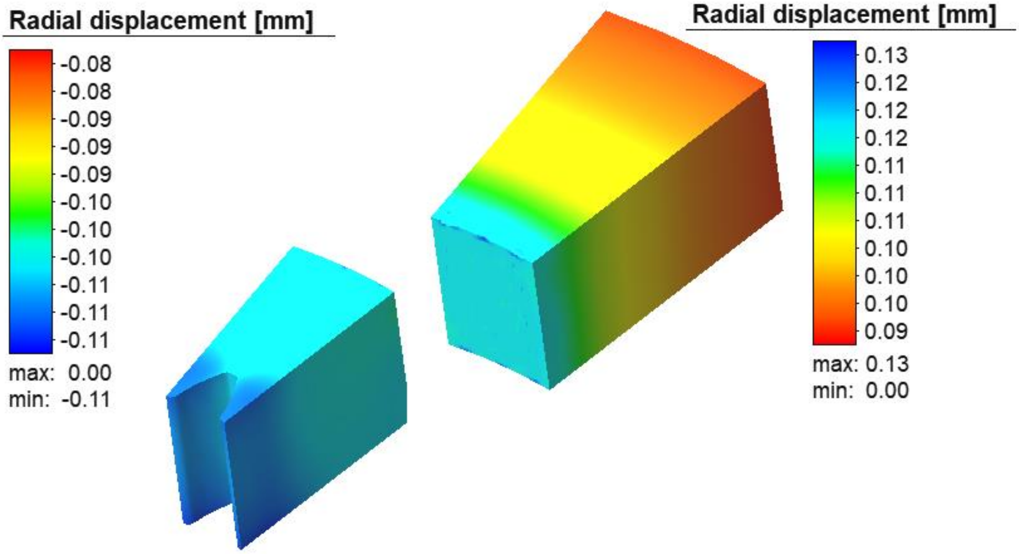


Figure 5. FE results of gear die

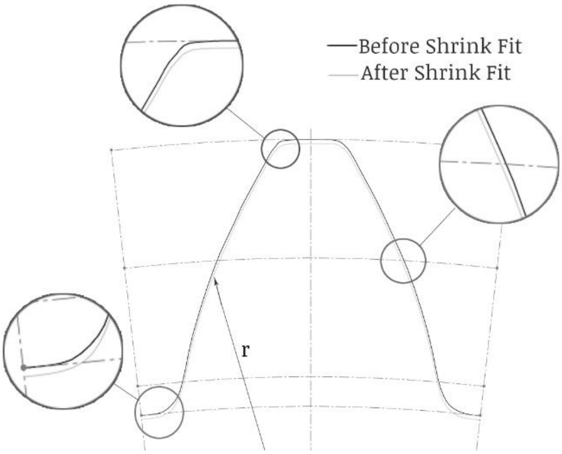


Figure 6. Gear tooth profile before and after shrink fitting.

Table 2. Radial displacement of the inner surfaces

Clylindrical Die			Gear Die		
a CMM (mm)	u_r CMM (mm)	u_r FEM (mm)	r (mm)	u_r CMM (mm)	u_r FEM (mm)
41,912	-0,088	-0,088	38,152	-0,105	-0,110
41,912	-0,088	-0,088	38,158	-0,107	-0,110
41,911	-0,089	-0,088	38,197	-0,108	-0,110

41,914	-0,086	-0,088	38,279	-0,113	-0,110
41,913	-0,087	-0,088	38,487	-0,106	-0,110
41,911	-0,089	-0,088	38,850	-0,107	-0,110
41,911	-0,089	-0,088	39,298	-0,114	-0,110
41,913	-0,087	-0,088	39,780	-0,113	-0,110
41,911	-0,089	-0,088	40,247	-0,108	-0,110
41,914	-0,086	-0,088	40,709	-0,111	-0,110
41,910	-0,09	-0,088	41,160	-0,114	-0,110
41,914	-0,086	-0,088	41,610	-0,113	-0,110
41,911	-0,089	-0,088	42,051	-0,111	-0,110
41,912	-0,088	-0,088	42,474	-0,111	-0,110
41,913	-0,087	-0,088	42,893	-0,106	-0,110
41,910	-0,09	-0,088	43,281	-0,113	-0,110
41,912	-0,088	-0,088	43,639	-0,112	-0,110
41,909	-0,091	-0,088	43,949	-0,108	-0,110
41,913	-0,087	-0,088	44,192	-0,111	-0,110
41,912	-0,088	-0,088	44,409	-0,109	-0,110
41,911	-0,089	-0,088	44,589	-0,105	-0,110
41,912	-0,088	-0,088	44,725	-0,112	-0,110
41,912	-0,088	-0,088	44,834	-0,106	-0,110
41,911	-0,089	-0,088	44,884	-0,109	-0,110
41,912	-0,088	-0,088	44,892	-0,107	-0,110
41,913	-0,087	-0,088	44,893	-0,105	-0,110
41,910	-0,09	-0,088	44,893	-0,104	-0,110

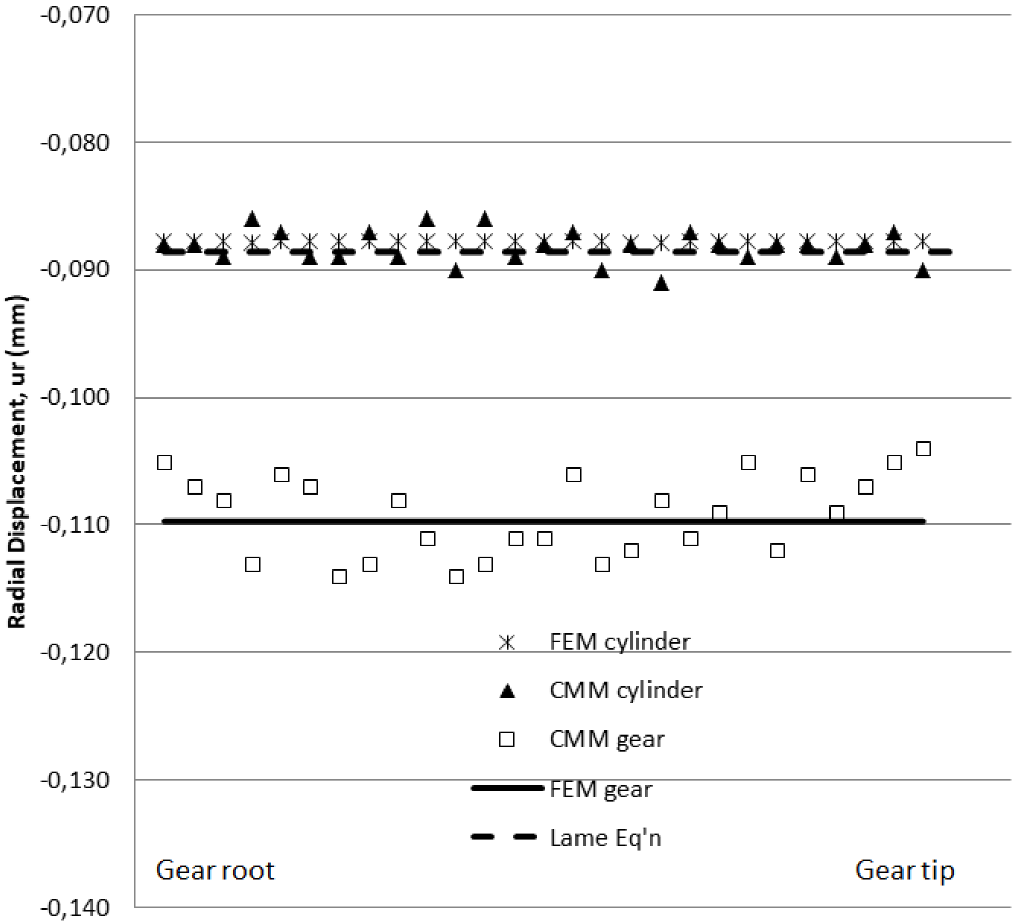
Conclusions

In general practice, shrink fit design for precision forging dies are made by thick wall cylinder approach; i.e., taking the pitch diameter of the gear as bore diameter of the die insert without considering gear tooth shape. However, the compressive pre-stress due to the shrink fitting causes dimensional variations on the gear profile of the die insert. The amount of radial displacement of the gear tooth profile must be predetermined and the profile has to be modified accordingly to manufacture the forged gear in required accuracy. The followings can be concluded from the analytical calculations, experimental work and FE analyses performed in this study:

For cylindrical die insert, the experimental results (CMM measurements) show that the thick wall cylinder approach formulated by Lame well predicts the radial displacement of the inner die radius.

The FE model is successful to simulate the cylindrical die and agree well with thick wall cylinder approach and the experimental ones (CMM).

Both the experimental (CMM) and the finite element results of gear die predict much higher radial displacements than the results of cylindrical die. Therefore, the determination of shape change of the gear die profile is beyond the capability of the thick wall cylindrical approach.



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Inverse Brillouin Function and Demonstration of Its Application

Aleksandr Hayrapetyan

Faculty of Physics, Yerevan State University, Armenia

Abstract

The Brillouin function arises in the quantum theory of paramagnetic materials, where it describes the dependence of the magnetization on the externally applied magnetic field and on the temperature of the system. There is no closed form exact analytical expression for the inverse Brillouin function, however, there have been several approximations proposed. In this work, we first compare relative errors and simplicity of several approximations for the inverse Brillouin function. Next, we demonstrate the application of the inverse Brillouin function by determining the Hamiltonian of the system using the simulation data of the magnetization dependence on the temperature. Then we compare the Hamiltonian that was used to set up the simulation with the Hamiltonian determined from the magnetization temperature dependence and an approximation to the inverse Brillouin function. We found that some of the approximations for the inverse Brillouin function can be used to accurately predict the Hamiltonian of the system given the magnetization dependence on temperature.

Keywords: inverse, brillouin, function, demonstration, application

Introduction

To study different paramagnetic phenomena in the classical and quantum theory of paramagnetism, two special functions are used. The first of these is the Langevin function [1]. This function appears when calculating the magnetization if there is a medium in which N atoms is contained in a unit volume. Magnetization takes place in cases where atoms have magnetic moments μ that are oriented to an external magnetic. Several mathematical calculations will be shown in the next section of this paper.

Another special function, which is applied while considering various problems related to the quantum theory of paramagnetism, is the Brillouin function [1]. In the contemporary professional literature not only the direct Brillouin function is used, but also its inverse function. These functions are normally mentioned in the following contexts: polymer science, molecular dynamics modeling, magnetism, rubber theory, etc. But unfortunately, the inverse Brillouin and Langevin functions cannot be calculated analytically, so their approximations are taken, in which the relative error tends to the minimum.

It is noteworthy to mention a few words about paramagnetism, in which we use the above-mentioned special functions. These atoms and molecules have an uncompensated spin magnetic moment. Other examples include free atoms and ions with incomplete inner shells, some molecules with an even number of electrons, lattice defects with an odd number of electrons, metals, other types of atoms and molecules. For the first time, the theory of paramagnetic susceptibility was created by P. Langevin and was used in the above mentioned problem.

In modern literature, one may find the inverse Langevin function, has a wide range of uses. But the quest for the inverse Brillouin function, has not yet been crowned with success. Currently, the existing approximations of the inverse Brillouin function are being improved every day. In the sections below, we consider the Langevin and Brillouin functions, their existing approximations, their negative and positive sides, and their applications.

I would like to mention some works related to the above-mentioned functions, their inverse functions and their areas of application. These topics were discussed in the works of the following authors: A.S. Arrott [2], Martin Kröger [3], M.I. Darby [4], and others whose research we will quote in this paper.

At the end of this paper, a inference will be made about all the above mentioned in very detail, which will allow us to contemplate the indicated functions from new perspectives.

Brillouin and Langevin functions and their applications

Langevin function, it's inverse function and their applications

Let's recall the above mentioned task. Suppose we have an environment that contains N molecules per unit volume. Magnetization arises only when the magnetic moments are oriented under the action of an external field. The energy U, which describes the interaction of magnetic moments (μ) with external field (B), is described by the following scalar product (1):

$$U = -\boldsymbol{\mu} * \boldsymbol{B} \qquad (1)$$

This scalar product can be represented as follows (2):

$$U = -\mu B \cos\theta \qquad (2)$$

where θ is the angle between the moment vector and the direction of the field.

Within this problem, the field magnetization is calculated by the following equation (3)

$$M = N\mu\langle \cos\theta \rangle \qquad (3)$$

where N, as mentioned above, is the concentration, ⟨cosθ⟩ is the average value of cos θ taken from the spatial distribution of magnetic moments in the state of thermal equilibrium.

If in this problem we use the Boltzmann distribution, then we can count the probability that the moment of the molecule is located in an element of a given solid angle $d\Omega$. This probability is proportional to $exp(-U/k_B T)$, and therefore the average value of cosθ (〈cosθ〉) can be calculated by the following equation (4)

$$\langle cos\,\theta\rangle = (\int e^{-\beta U} cos\,\theta\, d\Omega) * (\int e^{-\beta U} d\Omega)^{-1} \qquad (4)$$

here, $\beta \equiv 1/k_B T$ designation is inserted, and $d\Omega = sin\,\theta d\varphi d\theta$. In the above equation, integration is performed over all values of φ and over all values of θ. For all values of φ, we get 2π, a θ varies from 0 to π (5):

$$\langle cos\,\theta\rangle = \frac{\int_0^{\pi} 2\pi\, sin\,\theta\, cos\,\theta\, e^{\beta\mu B cos\theta} d\theta}{\int_0^{\pi} 2\pi\, sin\,\theta\, e^{\beta\mu B cos\theta} d\theta} \qquad (5)$$

For simplicity, let's introduce the following reductions (6)

$$s \equiv cos\,\theta\,,\, x \equiv \frac{\mu B}{k_B T} \qquad (6)$$

and after integration we get the following equation (7)

$$\langle cos\,\theta\rangle = \left(\int_{-1}^{1} exp(sx)\, sds\right) * \left(\int_{-1}^{1} exp(sx)\, ds\right)^{-1} =$$

$$= \frac{d}{dx} ln \int_{-1}^{1} exp(sx)\, ds = \frac{d}{dx} ln(exp(x) - exp(-x)) - \frac{d}{dx} ln(x) = cthx - \frac{1}{x} \equiv L(x) \qquad (7)$$

The resulting function is called the Langevin function. It has the following form (8)

$$L(x) = cth(x) + \frac{1}{x} \qquad (8)$$

The final calculation of the magnetization field is made by the following formula (9)

$$M = N\mu L(x) = N\mu(cth(x) + \frac{1}{x}) \qquad (9)$$

This function can be regarded in two cases. When $\mu B \gg k_B T$ and when $\mu B \ll k_B T$. In the first case, saturation can be found in the graph of the function, and the second case is of great interest for experimenters when calculating various kinds.

Let's look at some approximations of the Langevin function.

If in the Langevin function we expand in the series $cth\,(x)$ then for small values of x we get the following expression (10)

$$cth(x) \approx \frac{1}{x} + \frac{x}{3} - \frac{x^3}{45} + \cdots \qquad (10)$$

Putting this expression into the Langevin function, we obtain the following approximation (11)

$$L(x) \approx \frac{x}{3} \qquad (11)$$

For magnetization, we obtain the following expression (12)

$$M \approx \frac{N\mu^2 B}{3k_B T} = \frac{C}{T}B \qquad (12)$$

Where C stands for Curie (13)

$$C = \frac{N\mu^2}{3k_B} \qquad (13)$$

Let's discuss another approximation of the Langevin function. If we decompose the Langevin function in a Taylor series for small values of x, we get the following result (15)

$$L(x) = \frac{1}{3}x - \frac{1}{45}x^3 + \frac{2}{945}x^5 - \frac{1}{4725}x^7 + \cdots \qquad (14)$$

This approximation method is an alternative approximation of the $cth(x)$ approximation. From the point of view of numerical calculation, both approximations are equivalent to each other and are more demanded than direct evaluation of an analytical expression.

It can be said that the Langevin function has been fully investigated and is widely used in describing various tasks.

Below we will discuss the Brillouin function.

Brillouin function, it's inverse function and their applications

Brillouin function, inverse function and its applications

We shall first and foremost recall the formula (15)

$$B_J(x) = \frac{2J+1}{2J}coth\left(\frac{2J+1}{2J}x\right) - \frac{1}{2J}coth(\frac{1}{2J}x) \qquad (15)$$

In which J is a positive integer or half-integer number,

x stands for the relation of Zeeman energy ratio of the magnetic moment in an internal field to the heat energy. (16)

$$x = \frac{g\mu_B JB}{k_B T} \qquad (16)$$

in which g is factor g, μ_B is Bohr magneton, J is the full angular momentum, B is the applied magnetic field, k_B is Boltzmann constant, and T is the temperature.

Brillouin function changes by taking values from -1 to 1, reaching +1 if $x \to \infty$ and -1 if $x \to \infty$. Brillouin function has a wide range of utilization, but most often it is used for calculating the magnetization of an ideal paramagnet. It describes the dependency of M from the applied magnetic field B and the total angular momentum J. Magnetization is expressed through the formulum (17)

$$M = Ng\mu_B J B_J(x) \quad (17)$$

in which N stands for the quantity of the atoms per unit volume. The Brillouin function turns into that of Langevin in the range of $J \to \infty$ (8). If $x \to \infty$, then $B_J(x) \to 1$. This means that the magnetization gets saturated and the magnetic moments become totally aligned in the direction of the applied field. (18)

$$M = Ng\mu_B J \quad (18)$$

And now we shall talk about how one should find the inverse function of Brillouin. It is impossible to achieve analytically, but one can throw some approximations apropos the $coth(x)$ function and find the Brillouin inverse function with some accuracy. If the error of this accuracy does not exceed the applied limit ($\sim$5%), then the given approximation can be safely used in different calculations.

The first approximation can be done in case if $J = 1/2$, and then $B_J(x) \to tanh(x)$. If we are to take this approximation into account, then we can safely write the following expression (19)

$$B_J(x) \approx tanh(nx) \quad (19)$$

in which n is the coefficient dependent solely on J . The absolute and relative mistakes depend on this coefficient. We shall turn to the works of Jeno Takacs in order to demonstrate the most precise result possible [5]. Here we have a result which is currently seen as the most precise and recent one, and it is presented as follows (20)

$$n \approx \frac{1}{2{,}667J} + 0.2 \quad (20)$$

Given the value of n, the relative miscalculation makes about 4%. If we are to use the given approximation for $B_J(x)$, then we will get the following result for the inverse function [5] (21)

$$B_j(x)^{-1} \approx \frac{axJ^2}{1-bx^2} \quad (21)$$

a and b are the coefficients that have the following form (22)

$$a = \frac{0.5(1+2J)(1-0.055)}{J-0.27} + \frac{0.1}{J^2} \qquad b = 0.8 \quad (22)$$

J changes from 1 to 10 . Model (21) is still relevant outside of these values, but with much less accuracy which means that the error value increases.

Let us discuss yet another version of Brillouin inverse function, and then we shall further discuss its use. This other version of Brillouin inverse function reappears when $J = 1/2$ which resembles the original function by its graph and predicts a quite low range of miscalculation. It is as follows: (23) [6]

$$B_J(x)^{-1} \approx ln(\frac{1+2s}{1-2s}) \quad (23)$$

s stands for magnetization. s changes from 0 to ½ . This function cannot be used for other values, as there is a logarithm in the function: when the numerator has a negative sign, the function loses its physical meaning.

Now let us discuss its use. The Brillouin inverse function is used in non-iterative mean field theory. Thus, the mean field equation for an arbitrary isotropic spin Hamiltonian of infinite range will be as follows (24)

$$s = \sigma B_J(-\beta\sigma\frac{\partial H}{\partial s}); \qquad \beta = \frac{1}{k_B T} \quad (24)$$

The given equation can be rewritten in the wollowing manner (25)

$$kT = -\frac{\frac{\partial H}{\partial s}}{B_J(x)^{-1}} \quad (25)$$

One can calculate the dependence of T from s using this equation.

The magnetic entropy can be presented in the following form using the Brillouin inverse function (26)

$$\Delta S = -k_B \int_0^s B_J(s')^{-1} ds' \quad (26)$$

ΔS is to represent the decrease in entropy relative to the paramagnetic phase.

Conclusion

To sum up, we can claim that the Brillouin inverse function is hard to compute in mathematical calculations. Various approximations are put forward in order to overcome this problem. We have mentioned some of them above. One of these is the approximation $tanh(x)$ (19), and another one is the approximation $ln(x)$ (23). In the approximation $tanh(x)$, the obtained function works with a small admissible error in practice. In the approximation, the obtained function in practice works with a small admissible error. The proof of that is the fact that $B_J(x)$ moves toward $tanh(x)$ when $J = 1/2$.

The analytical form of Brillouin inverse function has not yet been found. The abovementioned approximate Brillouin inverse functions work within the operating limits of the quantum number of angular momentum. The majority of materials have J from 1 to 10 in engineering practice. This is why many approximations of the Brillouin inverse function have a great demand in current studies.

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